

**INTEGRATING TRADITIONAL TECHNIQUES INTO CONVENTIONAL
PRESERVATION METHODS TO UPGRADE PASTORAL DEEP-FRIED BEEF
PRODUCTS IN KENYA**

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**THESIS SUBMITTED IN FULFILLMENT OF THE REQUIREMENTS FOR THE
DEGREE OF DOCTOR OF PHILOSOPHY IN FOOD SCIENCE AND
TECHNOLOGY OF THE UNIVERSITY OF NAIROBI**

DEPARTMENT OF FOOD SCIENCE, NUTRITION AND TECHNOLOGY

2017

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The student

I hereby declare that this is my original work and that it has not been presented anywhere else apart from the Department of Food Science, Nutrition and Technology, University of Nairobi.



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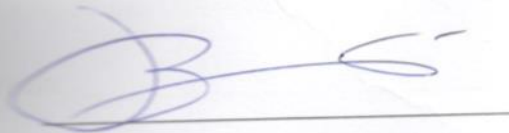
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DEDICATION

I dedicate this PhD to my parents Phares Gichure and Lucy Wanjiku for giving me the wings to fly, to the outstanding role of my wife, Sarah Kangai and daughter Amy Wanjiku for your sacrifices, encouragement and love during my long hours of absence, to my siblings Maina, Wairimu, Njeri and Nyambura, to my nephews Joshua, Jeff and Mwangi and to my niece, Lisa for the patience, love and prayers throughout these years are invaluable. You all drive me to dream, pursue and achieve.

ACKNOWLEDGEMENT

First, I would like to thank the almighty God for good health and the ability to pursue my dreams. Secondly, I pass my gratitude to my supervisors: Dr. Catherine N. Kunyanga and Prof. Jasper K. Imungi for your continuous support and guidance. Sincere thanks also to the Germany Ministry of Education and Research through the RELOAD (Reducing Losses Adding Value in East African Food Value Chains) project for sponsoring my research. I would like to thank the entire RELOAD team and especially the coordinators Prof. Dr. Oliver Hensel and Mr. Michael Hesse and the meat sub-project leader Dr. Kunyanga for giving me an opportunity to be part of the project and for the insightful comments and encouragement. I also acknowledge my fellow PhD students in the RELOAD projects especially those from Kenya (University of Nairobi, Egerton University and ICIPE) for your encouragement, for the difficulties we went through to beat timelines and all the fun we have had. Most importantly to my work-package partner Mr. Pius Mathi who has been very instrumental in ensuring I conducted the research on time. Most important was the time spent in our office, in the field, pilot-plant and laboratories; the fun and the challenges faced will always be remembered. I thank my fellow postgraduate students in the Department of Food Science, Nutrition and Technology at the University of Nairobi for their encouragement, for the difficulties we have been through to beat timelines and all the fun we have had.

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GENERAL ABSTRACT

Indigenous pastoral processing and preservations techniques have not been competitive along the formal meat value chain. Deep-fried products being the main indigenous pastoral products, low engagement in the formal chains and dynamics in their processing and preservation limit their competitiveness. The primary reasons for these include limited knowledge on standard methods of meat processing and preservation; limited access to modern infrastructures; and lack of a standardized processing and preservation technique. There lacks empirical evidence on safety and quality of pastoral deep-fried beef chunks, preserved using spices, herbs, smoke and encapsulation using deep-frying fats. In addition, modern preservation techniques such as curing and modern packaging have failed to find their way in the deep-fried meats.

It is against this background that this project was conceptualized. The main objective was to integrate traditional and conventional meat processing and preservation techniques with view of mainstreaming pastoral deep-fried meat products in the formal markets. In order to accomplish this, the study was designed to collect and authenticate information on the current status of meat preservation technologies among the main pastoral communities in Kenya, and to evaluate the quality of the main deep-fried products. This study also sought to develop a framework for standardizing deep-frying process, and preservation and packaging of deep-fried products.

Structured questionnaires, key informants interviews and focus group discussions were used to collect data from 30 meat processors, 15 county government officials and other experts in livestock sectors and 28 representatives of community groups across three pastoral communities, namely Somali, Maasai and Turkana, in a cross-sectional survey. The researcher also closely observed as the indigenous products were prepared by the focus

groups. Twenty eight samples of deep-fried meat products made by the community groups were then stored in iced cooled boxes and transported to the University of Nairobi, Food Chemistry laboratory for analysis within 72 hours. Based on the information received from the focus groups, similar laboratory-simulated products were prepared using split-plot research design at the University of Nairobi Pilot Plant at the Department of Food Science, Nutrition and Technology. Pre-dried chunks of 15 mm which were most acceptable were then subjected to different processing treatments and packages. Chemical analysis was based on AOAC standard methods while microbial and sensory analysis was based on ISO standard methods.

Nyirinyiri, Enyas, Ng'amorumoru and Olpurda were the main deep-fried beef products identified by the study. Moisture ranged between 8.1% and 28.5%, protein between 42.6% and 46.9%, lipids between 15.4% and 37.9%, fibre between 0.01% and 0.03%, ash between 3.1% and 4.3%, carbohydrates between 3.3% and 9.2% and energy between 424.65 Kcal/100g and 542.24 Kcal/100g. After standardizing the size of chunks and pre-drying time, the products had moisture between 14.1% and 19.4%, protein between 52.1% and 66.5%, lipids between 10.8% and 15.4% and the energy between 329.7Kcal/100g to 404.2 Kcal/100g. There was no significant change in fibre and ash contents. Peroxide values were within acceptable limits and ranged between 0.5 and 3.7 mEq/kg.

Smoking after deep-frying reduced moisture content further to 20.77 ± 0.81 %, decreased free fatty acids to 0.18 ± 0.08 % and increased peroxide values to 1.00 ± 0.05 mEq/kg. Smoking also increased stability against microbial deterioration during storage; minimal increase of total viable count was log 1.56 during 15 days storage time at 20 °C. Curing reduced the rate of increase in free fatty acids (increase of 0.30 %) and peroxide values (increase of 2.32 mEq/kg) at similar storage condition. However, incorporating tripolyphosphate in curing brine

increased water retention with moisture content at 35.90 ± 5.47 in the final products. Cured products performed best with regards to overall sensory acceptability (6.45 ± 0.52 out of 7.00). Submerging chunks in deep-frying media significantly ($p < 0.05$) decreased microbial spoilage (total variable count was log 2.99), but chemical spoilage increased significantly during prolonged storage (peroxide values increased by up to 6.09 mEq/kg while free fatty acids increased by up to 1.27 %). Based on chemical and microbial values, air tight jars increased stability during storage while vacuumed polythene bags allowed in air during storage and therefore would not effectively maintain stability.

Sensory evaluation showed that the 20 mm cuts that had not been pre-dried had significantly the highest scores of colour, appearance, oiliness and size acceptability. On the other hand, the 15 mm cuts that had been pre-dried for 120 minutes had significantly the highest protein (66.5 ± 9.3 %) and energy contents (402.1 ± 29.6 Kcal/100g) and the lowest moisture (14.1 ± 3.6 %), lipids (12.0 ± 1.5 %) and peroxide values (0.5 ± 0.1 mEq/kg). Both treatments had significantly ($P < 0.05$) different scores for colour and appearance; all in all, the values were greater than 4.0 and hence were within the acceptable range.

The study concluded that nutritional quality was enhanced when 15 mm cuts were pre-dried for 120 minutes. Nitrite curing and hot smoking increased the shelf-stability against chemical and microbial spoilage in addition to improving sensory acceptance of the products. The study also found that deep-fried beef products should be hygienically packaged in airtight plastic or glass jars to increase their shelf-life. To mainstream pastoral deep-fried meat into formal value chains, the study recommends sun-drying 15 mm stripes for 120 minutes, and incorporating nitrites and hot smoking to increase shelf-life. Pastoralists are also advised to package deep-fried beef chunks in air-tight plastic or glass jars. Since unsaturated oil was seen to improve nutritional and sensory attributes, the study also concluded that pastoral

communities should shift from animal fat to unsaturated oils and recommends incorporate of antioxidants to prolong shelf stability

CHAPTER ONE: GENERAL INTRODUCTION

1.1 BACKGROUND

Sub-Saharan Africa has an estimated 20 million pastoralists who depend largely on livestock and livestock products for income and food (Wellard-Dyer, 2012). Kenya's estimated livestock worth as at 2008 was US\$ 800 million (Lindqvist and Verba, 2009). Increasing calamities and emergencies have made pastoral communities more food insecure, and in the recent past, reports of huge losses of livestock through droughts, flooding, clashes, among other emergencies. In addition, pastoral communities have been increasingly abandoning their indigenous food preservation technique. Physical remoteness to modern processing and supporting infrastructure such as electricity and the slow rate in adoption of modern preservation techniques such as canning and curing have increased the food insecurity situation amongst pastoralists (Homewood *et al.*, 2012).

The livestock sector accounts for about half of Kenya's agricultural labour force and is the primary source of income for about 6 million pastoralists and agro-pastoralists living in the country's arid and semi-arid lands (ASALs) (Behnke and Muthami, 2011; Otieno *et al.*, 2008). The country has an estimated livestock resource of 14.1 million indigenous cattle and 3.4 million exotic cattle (KNBS, 2009) while beef represented 73 percent of the total meat consumed in Kenya in 2009 (FAOSTAT, 2012). Cattle accounts for approximately 77 percent of Kenya's ruminant off-take for slaughter (Behnke and Muthami, 2011).

Approximately 96 percent of beef cattle in Kenya are in the hands of subsistence farmers and pastoralists distributed based on rainfall patterns. About 70 percent of cattle are from the ASALs

under pastoral production systems, 26 percent from culled dairy cattle and less than four percent from commercial ranches (EPZA, 2005).

Pastoralists and small scale subsistence farmers over time have relied on indigenous knowledge to add value to beef and beef products. Over time, sun-drying, salting, use of herbs and spices, cooling products over deep frying oil and deep frying have been practiced for meat preservation in Kenya's pastoral regions. However, since the livelihoods of pastoral communities are characterized by low incomes and food insecurity, they have not been able to upgrade and standardize their traditional meat products. The situation is worsened by the increasing calamities such as droughts, and floods due to changing weather patterns where animals that would have been slaughtered and their meats preserved are lost (Pavanello, 2010). In addition, the modern meat processing technologies, mainly curing, marinating, canning and low temperature storage have-not being adequately adopted in the pastoral regions (Abegaz, 2009).

Sun-drying is one of the oldest techniques used to preserve meat and by-products (FAO, 1995). Meat is cut to thin slices or stripes and thereafter hanged in direct sunlight to reduce the moisture. Usually, sun-drying takes up-to 5 days and the products have a shelf-life of up-to three months (Ayanwale *et al.*, 2007). The challenge with sun-drying is that the products qualities are dependent on the weather and chances of spoilage by microorganisms are high. In addition, maggots have been reported in sun-dried products due to poor hygiene. To address these challenges, solar-dryers have been developed to shorten the drying time, marinating with spices done to control microorganisms and maggots and handlers taught on hygiene.

The other commonly used meat preservation technique is deep-frying which is basically a heat treatment process where meat chunks are cooked in oil/ fat at a temperature above the boiling

point of water (Hubbard and Farkas, 2000). Under this method, meat is cut into chunks that are pre-dried, boiled, dried on a hot pan and later on deep-fried. The process takes at most three hours and the products have a shelf-life of up-to three months. Slight variations based on time of pre-drying, cut size, deep-frying time, boiling, duration of pounding, use of spices and smoke, selection of meat for processing and the deep-frying media exists among the different communities (Grillo, 2014).

However, urbanization, immigration, population increase, climate change, and other dynamics in pastoral communities have led to gradual reduction in the production of these products and the younger generations are increasingly abandoning the traditions (Teshome and Bayissa, 2014; Olson, 2006). This has resulted to a net increase in meat and slaughter by-products post-harvest losses and overwhelming loss of edible meat during calamities. This has led to realization of the great roles played by the indigenous technologies in enhancing food security. In addition, the rapid urbanization in Africa has increased demand of indigenous food products in the urban centres (Satterthwaite *et al.*, 2010).

1.2 MEAT CONTROL REGULATIONS IN KENYA

In Kenya, the Meat Control (Local Slaughterhouses) Regulations, 2010, CAP 356 is an Act of Parliament that enhances control over meat and meat products intended for human consumption. It covers regulations governing slaughterhouses, abattoirs and other places where meat is processed. For the formal meat value chain, the animals need to be slaughtered in a gazetted slaughterhouse. The first schedule of the act brings out site accessibility and construction, sanitation, hygiene practices, condition and facilities for meat inspection, meat inspection,

disposal of condemned carcasses and parts, marking and labelling of meat and meat containers, and record keeping. The second schedule classifies the slaughterhouses based on infrastructure and the animals slaughtered setting the minimum requirements for each category (Aklilu, 2008).

On the other hand, processing and preservation of meat is under the Food, Drugs and Chemical Substances Act, CAP 254, Regulations, 2012 is An Act of Parliament to enhance prevention of adulteration of food, drugs and chemical substances. In this act, the sub-section on regulations on food labelling, additives and standards, part viii describes meat processing and products. This section brings out the general meaning of “meat products”, permitted preservatives and colours in meat and meat products, general standards for preparing meat, labelling of food consisting of meat products or prepared meat products, preparation of curing brine, packaging of meat products, and declaration of some ingredients added to meat products (Oloo, 2010).

1.3 MEAT PRESERVATION TECHNIQUES AMONG PASTORALISTS

In the pastoral regions of Sub-Saharan Africa, the meat value chain is characterized by huge post-slaughter losses mainly due to inappropriate preservation technologies and lack of proper storage (Rota and Sidahmed, 2010). Despite the fact that there are numerous diverse pastoral communities existing in Kenya’s arid and semi-arid regions, research shows that preservation and processing are almost similar, mainly due to the existence of similar environmental conditions. Pastoral communities have over time relied on moisture reduction, moisture binding and denial of oxygen to stored products as the main preservation techniques (Kisembe *et al.*, 2017; Grillo, 2014). Sun-drying, salting and deep-frying are the main moisture reduction

techniques. Cooling products in deep-frying media and use of spices are the main techniques for denial of oxygen to the stored products.

1.3.1 Sun drying

Sun-drying is a moisture reduction technique used by pastoral communities to preserve meat and slaughter by-products (Ayanwale *et al.*, 2007; FAO, 1995). Meat is cut to thin slices or stripes and thereafter hanged in direct sunlight to reduce the moisture. Usually, sun-drying takes up-to 5 days and the products have a shelf-life of up-to three months (Petit *et al.*, 2014). The challenge with sun-drying is that the products qualities are dependent on the weather and chances of spoilage by microorganisms are high. In addition, maggots have been reported in sun-dried products due to poor hygiene. To address these challenges, solar-dryers have been developed to shorten the drying time and minimize contamination by flies, marinating with spices done to control microorganisms and maggots and handlers taught on hygiene (Janjai and Bala, 2012; Sharma *et al.*, 2009).

1.3.2 Deep Frying

Deep-frying is a relatively cheap and fast method of moisture reduction and normally involves immersion and cooking of meat chunks in hot oil. Heat and mass transfer results from the interactions between the meat chunks and the frying medium. Deep fried meat products form unique desirable crust and the colour, flavour and texture of the products are acceptable. Frying involves dehydration, use of high oil temperature at 160–180°C. There is minimal leaching of water-soluble compounds. Oil uptake by products depends on the continuous fat absorption to replace the moisture lost due to evaporation and the continued absorption after frying (Saguy and Dana, 2003). Some communities pre-dry the meat prior to deep-frying products. Researchers

have shown that this helps reduce moisture absorption, shorten deep-frying time and minimize hydrolysis and peroxidation during the deep-frying process (Shahidi and Wanasundara, 2002).

1.3.3 Smoking

Smoking meat produces compounds that possess preservative properties on meat products. Smoking also dehydrates the meat surface and induces characteristic flavour, appearance and colour. More than 200 compounds have been identified in smoke; the smoke composition been dependent on the source of wood, temperature of combustion and presence of oxygen during combustion. Smoke has a gas/ vapour phase and disperse/ particulate phase. In meat smoking, the gas phase is of importance since the compounds that have preservative effect are found in this phase with the major compounds being acids, phenols, carbonyls, alcohols and polycyclic hydrocarbons (Cassens, 2008). Optimal smoking is attained by controlling the smoke density, air flow, humidity and time.

1.3.4 Use of Spices and Herbs

Spices and herbs have been added by some communities to impart flavour, aroma and taste to food. Natural antimicrobials have a potential for preservation by inhibiting growth of, or inactivate pathogenic or spoilage microorganism and some of these are found in spices and herbs (Davidson *et al.*, 2013). The challenge with their application is that they have a limited spectrum of activity unlike conventional ones such as nitrite, therefore, a single antimicrobial is difficult to inhibit microbial and quality deterioration hence, a combination of natural antimicrobials are required (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005). During preservation, pastoral communities ensure no microorganism survives the cooking process by cooking prior boiling the products for almost

120 minutes. In addition, smoke has been used to sanitize the package containers to prolong shelf-life. Usually, products are packed while still hot in airtight containers made using wood and leather to create vacuum-like environment.

1.3.5 Under-oil Preservation

Modifying the composition of the atmosphere with respect to O₂, N₂ and CO₂ have been effective in control of microbiological, biological and chemical spoilage in perishable foods such as meat and meat products. The main spoilage agents, that is, aerobic bacteria and oxidative reactions, require oxygen (Metaxopoulos *et al.*, 2002). Therefore, its unavailability will inhibit spoilage and thus maximise quality and/or storage life. Generally, modifying the composition of packaging atmosphere entail enclosing food products in gas-barrier materials, in which the gaseous environment has been changed. There are two ways of modifying the atmosphere; the first is where oxygen is eliminated during packaging and the second is whereby the products are packed with atmospheric oxygen but more oxygen is denied from coming to the products (Mataragas *et al.*, 2007). In both techniques, oxygen will not be available for completion of spoilage processes.

Pastoralists in the ASALs have devised means of addressing presence of oxygen in storage. Some communities preserve meat products by submerging them in deep-frying media. This effectively reduces the oxygen available. In addition, submerging products in deep-frying media increases crude lipids content in the products effectively introducing the hydrophobic characteristics of the stored meat products (Gichure *et al.*, 2014).

1.4 MODERN MEAT PRESERVATION METHODS

Conventional meat preservation methods are usually based on curing, cooling and refrigeration, canning, fermentation, modified atmosphere packaging or combination of different methods

(Cassens, 2008). Meat preservation through the moisture reduction involves either extraction or binding of moisture to reduce the water activity (a_w) to a level that will not support microbial growth (Dzimba *et al.*, 2007; Labuza and Altunakar, 2007). The process involves diffusion of water from the interior to the surface and evaporation of this water from the surface.

1.4.1 Curing

Curing basically mean adding nitrites to fix colour of meat, prevent rancidity, decrease susceptibility by microorganisms, stabilize flavour and improve heat stability of products during the cooking process (Andrée *et al.*, 2010). Nitrite when added to meat reacts with myoglobin to stabilize colour. Cured meats products colour is a heat-stable red colour that results from the formation of nitrosylmyoglobin. This compound is also responsible for the cured flavour, which can be detected by sensory assessment. Cured meat does not experience variations in flavor as oxygen is unavailable for oxidative reactions during processing and storage. During processing and storage, chemical reactions on meat components, especially the fatty acids react with oxygen to produce rancid elements. Cured meats are less susceptible to rancidity as nitrite sequesters the oxygen to reduce this reaction. Nitrite is usually reduced to nitrite during processing and storage, hence the amount added during processing targets the specific shelf-life period (Honikel, 2008). Nitrite has been reported to possess antimicrobial properties against pathogenic bacteria mainly *Salmonella* and *Clostridium botulinum*. Nitrite does not act alone; rather microbiological hurdles such as salt, water activity, pH, redox potential and heating are required for stability.

Nitrite has been implicated in formation of nitrosamines/amides which are carcinogenic (Andrée *et al.*, 2010). However, formation of these compounds require an acidic environment (<5.5). At higher pH, formation of the compound is negligible in most meat products. The compounds are

also evaporated at high temperatures during cooking, therefore, processes such as deep-frying results in negligible amounts of the amines/ amides (Oz and Kaya, 2011).

Nitrite is added as sodium or potassium salts. Mostly, common salt (NaCl) is added to prevent nitrite overdose. Up-to four percent of NaCl is added as brine to the jerkies (Yang *et al.*, 2012). Sausages and other meat products usually have less common salt. Ascorbic acid is added to the curing brine to facilitate formation and maintenance of the cured colour. In addition, ascorbates minimize the formation of amines/ amides. Sugars and other sweeteners are added to impart flavour and moderate the harshness of salt. Sugars, specifically reducing sugars, are also added to take part in non-enzymatic reactions that results in development of desirable colour of heat processed products. Phosphates and polyphosphates increase the water-holding in the final products (Honikel, 2008). There are two techniques used in curing; these are pickle curing (also known as immersion) and pickle injection either by arterial pumping, stitch and spray pumping, multi-needle injection and massaging and tumbling.

1.4.2 Heat treatment and Canning

Cooking is the main form of heat treatment used to cause structural and chemical changes that increases palatability of meat. Unlike pasteurization which aims at destroying vegetative pathogens and spoilage, sterilization aims at complete killing of all the microorganisms and their spores. The main structural change that occurs is coagulation of proteins at between 70°C and 80°C. In addition, connective tissues and collagens are solubilized making the products tenderer. Pasteurization of meat is done mainly by cooking by steaming, stewing, roasting, braising, baking, grilling, shallow frying, deep-frying, microwaving among other techniques. Sterilization is mostly done by canning (Zhuo *et al.*, 2010).

Canning destroys virtually all spoilage vegetative microorganisms and their spores. In storage, the spores lose their ability to proliferate and/or produce toxins. A food is commercially sterile if *Bacillus stearothermophilus* or *C. perfringens* have been eliminated in the heating processes. In case the food is to be stored at high temperatures, Sporulated thermophiles are of concern. Elimination of *C. botulinum* and *C. sporogenes* in a thermal process produce a thermostable food with long shelf life. Therefore, such process will not require use of other preservation method (Guerrero-Legarreta and García-Barrientos, 2012).

During canning, either water or steam is used as the main heating media. Usually ground meat is put in the cans and heated at a specific temperature for a given time. Heat penetration into the cans depends on the transfer mechanisms within the meat. If the products are very viscous, conduction which is a slower mechanism takes place. On the other hand, viscosity is reduced, heat penetration coefficients will be increased as heating will be convection and canning takes a shorter time. The processes can also be accelerated if the can is rotated or stirred, as is the case of continuous retorts (Guerrero-Legarreta and García-Barrientos, 2012).

1.4.3 Water Removal (Drying)

Drying meat basically means removal of most of the water present in the meat through evaporation or sublimation (Guerrero-Legarreta and García-Barrientos, 2012). Through this process, water activity is lowered thereby hindering the main microbial and biochemical spoilage mechanisms. Dried meats will therefore have longer shelf life. Sun-drying has been practiced for centuries globally. There exists a broad range of traditional dried or intermediate moisture meats originating from different developing countries, such as the Brazilian *jerky* and *charque*, the Sahelian *kilishi* and the Southern Africa *biltong* (Petit *et al.*, 2014; Salvá *et al.*, 2012)

Under this technique, meat, either raw or seasoned, is cut into strips or flakes which then exposed to the sun by directly laying them on the ground or on a raised locally made trays, or by hanging on hooks. Sun-drying is a simple and cheap technique that utilizes natural and renewable sun energy (Rahman *et al.*, 2005). However, the end-products are of inferior quality since the processing lacks hygiene and the meat contamination by blueflies, insects, rodents, and dust may occur.

Despite advancement in meat processing, such drying is still practiced today in many developing countries where chilling and refrigeration infrastructure may restrict adoption of other means of meat preservation. Drying may be combined with other preservation techniques such as salting, fermentation, curing, or smoking. These adjunct processes mainly aim at improving the organoleptic characteristics (flavour and texture) and palatability of the end-product, to suit consumer requirements (Arnau *et al.*, 2007; Ratti, 2001). In Kenya, pastoral communities not only dry meat to improve its stability, but also since dried meats are considered part of communities' heritage. There exists variations between and within different communities; variations may be as a result of shape, size and thickness of meat to be dried, ingredients in marinates are to be used as adjuncts, and time and temperature of drying.

To address the challenges associated with sun-drying, cabinet solar dryers have been developed. Warm air is passed through a hermetically closed chamber to avoid any undesirable contamination from outside. Different designs of low-cost solar dryers are being used in Sub-Saharan African (FAO, 1995). To increase efficiency of solar cabinets, convective hot air-drying is done for period of time to achieve the required characteristics of the end-product.

1.4.4 Low Temperature Treatment (Chilling and Freezing)

Unlike the other processing and preservation techniques commonly used in meat processing, low temperature treatment leaves the form of the meat product almost unchanged. Chilling reduces the rate of chemical reactions thereby retarding fat oxidation as well as decrease growth of microorganisms. Basically, chilling removes heat from an object. Naturally, heat flows from hotter objects to colder objects thereby cooling the object to which the heat is removed. During this process, mass transfer of gases and liquids occur between the objects being cooled and the cooling media (Leygonie *et al.*, 2012; Zhuo *et al.*, 2010).

Freezing is similar to chilling except that temperature used is lower than the initial freezing temperature of the food. In this process, ice crystals grow in the food matrix. During freezing, ice crystals are basically made of pure water but with storage, solutes diffuse away from the growing ice crystals. Slow freezing results to formation of larger ice crystals while fast freezing results to smaller crystals. Irrespective of the speed used to cool the products, recrystallization takes place resulting to larger crystals during storage. Crystal growth cause mechanical damage to cells (Han and Bischof, 2004).

Biochemical reactions still occur at normal frozen temperatures of -18 °C or higher. However, at -40 °C biochemical reactions are greatly reduced since the percentage of unfrozen water is so small (Estévez, 2011). In addition, the unfrozen water has been seen to bind other food constituents and thus is chemically inactive. Freezing the water fraction increases the solute concentration, both intracellular and extracellular, and this justifies the increased chemical reactivity during frozen storage (Leygonie *et al.*, 2012). Unfrozen water is also responsible for oxidation as chemical reactions such as lipid oxidation (peroxidation) have been reported in

meat. In addition, radical secondary lipid oxidation is accelerated upon thawing causing adverse changes in colour, odour, flavour and safety (Estévez, 2011).

1.4.5 Irradiation

Irradiation has been seen to be the most effective technology for inactivating pathogens such as *E. coli* O157:H7, *Listeria*, *Salmonella*, *Campylobacter*, among other food borne pathogens in meat and meat-based products. In addition, since irradiation can be performed at ambient or lower temperatures, the nutritive values and physicochemical properties of food products are better maintained. In addition, irradiation can be done after sealing the packaging, thereby reducing or eliminating entirely the possibility of recontamination during storage (Borsa 2006, O'Bryan and others 2008).

In commercial food radiation systems, three types of ionizing radiation are used namely, γ -rays, x-rays, and accelerated electrons. The Codex General standard for Irradiated Food allows use of γ -Rays emitted by the radioactive elements Cobalt-60 (^{60}Co) or Cesium-137 (^{137}Cs), x-rays generated from machine sources operated at or below an energy level of 5 MeV and electrons generated from machine sources operated at or below an energy level of 10 MeV (Codex Alimentarius Commission 2003).

When irradiation food, the product is exposed to the ionizing energy source to ensure that a precise and specific dose is absorbed. The absorbed dose is the mean energy imparted by the ionizing radiation to the matter in a volume element divided by the mass of the matter in that volume element. The dose of irradiation or the amount of absorbed radiation is measured in Gray (Gy) in the SI unit. 1 Gy is equal to 1 joule (J) of absorbed energy per kilogram. 1 kilogray (kGy) equals 1000 Gy. Energies from the authorized radiation sources are too low to induce

radioactivity in the irradiated food; thus, the irradiated food does not become radioactive (Badr, 2012).

1.5 ADOPTION OF INDIGENOUS PRESERVATION METHODS TO COMMERCIAL PRODUCTS

1.5.1 Overview of the challenges faced in adoption

Despite the numerous options for adoption of commercial techniques, pastoralists have not taken up these preservation methods to upgrade their indigenous products. The major reasons for this include the physical remoteness, limited knowledge among processors and consumer concerns on quality and safety of these techniques (Homewood *et al.*, 2012). Commercial techniques based on antioxidants such as nitrites, artificial antioxidants and spice/ herbs extracts and anaerobic packaging require temperature reduction for prolonged storage. However, pastoral areas have limited connection to the national power grid and therefore cannot rely on temperature reduction. This has greatly affected uptake of cooling and refrigeration technologies among pastoralists (Lokuruka, 2006).

On top of this, pastoralists generally have limited knowledge on modern preservation techniques. Majority of them have no formal education, leave alone attaining technical/ university education. Consequently, the roles of the different processing and preservation ingredients is poorly understood and this affects its application. Natural antioxidants such as smoke, spice and herbs have been used to extend shelf-life in these communities. However, the residents in these communities have limited understanding on the roles of these ingredients in preservation. Consequently, use of natural antioxidants is being abandoned as urbanization, climate change and other dynamics sets in in the pastoral areas (Lokuruka, 2006).

Lastly, consumers have raised health concerns associated with consumption of red meat. WHO latest report on bowel cancer shows an association with processed meats (Thompson, 2015). Consumers have raised issues with respect to cholesterol level, calorie content, artificial ingredients such as nitrite, convenience/ ready-to-eat packaging, shelf-life, sensory attributes, purchase price, among others (Resurreccion, 2003).

Consumer perception on the quality of meat products have directly affected uptake of commercial technology. Perception is based on perceived quality cues; therefore, it is necessary for the meat industry to understand these cues, how they affect different actors along the meat value chain (producers, processors and retailers), and how to maintain and enhance these cues for existing and new products (Troy and Kerry, 2010).

1.5.2 Concerns on Sensory Quality

The sensory quality of meat products are a factor of tenderness, juiciness, flavour, appearance characteristics, oiliness, and textural appearance (Brewer and Novakofski, 2008; Miller *et al.*, 2000; Brewer *et al.* 1998). Meat flavour is brought about by the combination of the basic tastes (that is, sweet, sour, bitter, salt, and umami) from the water - soluble compounds and also the smell derived from a variety of substances present in the raw meat. Flavour and aroma active volatiles include alcohols, aldehydes, aromatic compounds, esters, ethers, furans, hydrocarbons, ketones, lactones, pyrazines, pyridines, pyrroles, and sulphides (Shahidi, 1994). The lipids present in muscle tissue (subcutaneous fat, intramuscular fat, intermuscular fat, intramyocellular lipid, and structural phospholipids) at slaughter serve as a source of many of these flavor constituents. These lipids are composed of fatty acids that may be saturated, unsaturated and/or methyl –branched.

Tenderness represents all the mouth feel characteristics perceived kinaesthetically. The particle size and oiliness are perceived prior to mastication, tenderness and juiciness during mastication while fibrous residue and mouth coating after mastication (Bourne 1992). Tenderness encompasses mechanical (cohesiveness, elasticity, hardness), particulate (fibrousness and grittiness), and chemical components (oiliness and juiciness).

Factors that affect the sensory quality characteristics of meat include breed, intramuscular fat content (Brewer and Novakofski, 2008), diet, ante-mortem handling (Ohene - Adjai *et al.* 2003), and ultimate pH. Post-mortem biochemical changes may affect tenderness and flavour. Once life ceases, there is loss of circulatory competency which changes the metabolism from aerobic to anaerobic. The muscles accumulate metabolic by- products, such as lactic acid and pH reduces from about 6.8 to 5.7 (Brewer, 2010).

1.5.2 Concerns on Microbiological Quality

Meat can be contaminated with microorganisms at different stages during processing (Arthur *et al.*, 2004). Consumers perceive traditional processing increases incidences of contamination by bacteria, yeasts and moulds during slaughtering and carcass dressing. Spoilage microflora of unprocessed meats consists mostly of Gram-negative rods (pseudomonads) and micrococci (Micrococcus and Staphylococcus). However, environmental conditions during storage, processing and handling are a great determinant of the spoilage microflora. Therefore, meat needs to be handled and processed in sanitary and hygienic conditions to reduce the levels of pathogens (Heinz and Hautzinger, 2009).

For meat products, the most important pathogens include Salmonella, *Escherichia coli*, Staphylococcus, *Clostridium perfringens*, *Campylobacter jejuni/coli*, *Listeria monocytogenes*,

Yersinia enterocolitica and *Aeromonas hydrophila*. Salmonella is a Gram-negative Enterobacteriaceae, same as *Escherichia coli*, *Yersinia*, and *Shigella*. *Listeria monocytogenes* is a Gram-positive, short rods with rounded ends. *Staphylococcus aureus* is also a Gram-positive, catalase positive coccus. The level of organisms in processed products is indicative of sanitation and hygienic practices during handling and processing. It also brings out effectiveness of decontamination interventions and environment factors of storage (Mor-Mur and Yuste, 2010).

E. coli, *L. monocytogenes*, Salmonella and Campylobacter are the common pathogens associated with meat products. *L. monocytogenes* is considered to be the most dangerous heat-tolerant pathogen in refrigerated meat products. Therefore, microbiological criteria for heat treated meat products are often based on this organism. It is assumed to be destroyed by processing at 70 °C for 2 min, or equivalent. For vacuum packed products, *C. botulinum* is used as the criteria and often, severe treatment at 90 °C for 10 min, or equivalent is required (Mor-Mur and Yuste, 2010; Zhou *et al.*, 2010).

Since processed meats have been seen to have low frequencies of occurrence of pathogens, evaluation of all microorganisms provides limited information on the performance of a processing step. Microbiological monitoring mostly focuses on testing for indicator organisms. The organisms mostly used for minimally processed meat are *E. coli*, coliforms, enterobacteriaceae and total viable bacteria. On the other hand, *E. coli* and Salmonella show adequacy of heat processing (Mor-Mur and Yuste, 2010).

1.6 GAPS IN KNOWLEDGE

Pastoral communities have overtime relied on moisture reduction as the primary preservation technique for meat and meat products. Moisture reduction has been done using two techniques:

deep-frying and sun –drying. Unlike sun-drying which has been extensively researched, there has been limited empirical information on deep-fried red meat. Research has been done on fish and poultry, since they are common meat snacks in most urban areas globally. Several adjunct steps have been assessed to bring out the physiochemical, microbiological and sensory qualities of deep-fried products (Dana and Saguy, 2006). Data on deep-fried products have shown that pre-drying, geometric orientation of chunks, deep-frying media, deep-frying temperature and time, addition of antioxidants, draining oil immediately after deep-frying, vacuum packaging, among other processes contribute to the quality of deep-fried products (Dana and Saguy, 2006; Shahidi and Wanasundara, 2002). However, research has been limited to starchy foods, mainly potatoes, and white meats. Pastoral communities around the world have used nitrite to improve quality and safety of dried meat products (Andrée *et al.*, 2010). However, this technology has failed to be adopted by pastoral communities in East Africa and there exists limited empirical information to explain this.

Research have also indicated low uptake of commercial technologies in the pastoral regions. Data have shown that rudimentary techniques are still in use despite advancement in meat science (Lokuruka, 2006). For instance, storage of deep-fried beef is under anaerobic conditions through immersing products under deep-frying media. Despite this improved microbial stability, storing deep-fried chunks under deep-frying media has been reported to reduce the chemical stability as the products gets more susceptible to autoxidation (Saguy and Dana, 2003).

Pastoral communities have used smoke not only to impart unique sensory characteristics in the deep-fried meats but also to sanitize storage containers. However, limited research exists on impact of smoke on stability of deep-fried beef. Research has brought out the impact of spices and herbs on shelf stability of processed meats, however, this has been limited to fresh processed

meats and not deep-fried beef (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005).

1.7 PROBLEM STATEMENT

Despite the advances in meat science globally, beef and other red meats continue to be deep-fried using archaic rudimentary processing techniques by pastoralists in Sub-Saharan Africa (Gichure *et al.*, 2014). Being their main indigenous products, deep-fried meat play a big role in heritage of these communities and consumption of these products is on special occasions (Lokuruka, 2006). Adjunct processing steps during deep-frying process has also been based on elementary techniques that greatly contribute to quality and shelf-life. Due to variations in the adjunct processing steps, these products have failed to become competitive along formal value chains (Parfitt *et al.*, 2010). Lack of standardization with regards to processing have limited uptake of these products/ technologies.

Urbanization and rural-urban migration have also introduced deep-fried poultry and fish products as the main fast foods in urban areas (Teshome and Bayissa, 2014; Olson, 2006). This has created an opportunity for mainstreaming deep-fried beef in the formal markets (Satterthwaite *et al.*, 2010). However, lack of empirical information on deep-fried beef, chevon and camel meat limit their performance and competitiveness as compared to similar deep-fried meats. Empirical evidence of the effect of geometrical shape, size and thickness of cuts on the acceptability and stability exists for deep-fried poultry and fish and not red meat (Sosa-Morales *et al.*, 2006; Ziaifar *et al.*, 2008).

To add to these, research has failed to show the impact of both the natural and artificial antioxidants on the stability of deep-fried beef. The most researched artificial antioxidant in meat products is nitrite (Andrée *et al.*, 2010). Despite its extensive use in sun-dried meats, little has been researched on its use and impact in deep-fried beef. Spices and herbs have also been considered as antioxidants in food products (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005). Despite this knowledge, there lacks adequate empirical data to justify use of spices and herbs in deep-fried beef. Pastoralists have over time used spices and herbs to bring out characteristic sensory attributes. The impact of smoke to sanitize storage containers by pastoralists have not been empirically tested for effectiveness.

1.8 JUSTIFICATION OF THE STUDY

Deep-frying is basically a cooking method where food products are immersed in hot oil for a given time (Saguy and Dana, 2003). Deep frying, as done in pastoral areas, is a form of hurdle technology that comprises several other intermediate preservation steps (Krokida *et al.*, 2000). Similarly, research have shown that commercial deep-frying of fish and poultry incorporates intermediate adjunct steps to precede and follow the deep-frying process. All these steps have a direct influence on the physiochemical, microbiological and sensory qualities of deep-fried products (Dana and Saguy, 2006). Empirical data on deep-fried products have shown that pre-drying, geometric orientation of chunks, deep-frying media, deep-frying temperature and time, addition of antioxidants, draining oil immediately after deep-frying, vacuum packaging, among other processes contribute to the quality of deep-fried products (Dana and Saguy, 2006). Pastoral

communities either add common salt, pre-drying, shallow-frying, use of herbs and spices, and cooling products while submerged in the deep-frying fat to encapsulate the meat chunks. For instance, rudimentarily, storage under anaerobic conditions is mostly by immersing products under deep-frying media which have been reported to be a health concern. In addition, it reduces the shelf-life by making products more susceptible to autoxidation. Variations in these preservation processes amongst the pastoral communities are indicative of the rich culture and ethnic identity in terms of meat preservation, and therefore the urgent need to preserve the technologies (Lokuruka, 2006).

Urbanization and globalization may require traditional products to be brought to urban areas. Globalization will make pastoral products accessible to the pastoral communities in the urban areas and towns (Satterthwaite *et al.*, 2010). Since deep-fried red meats are yet to be mainstreamed into the formal meat value chains; this research creates an opportunity to bring out factors to consider for standardizing and upgrading pastoral products. As may be the case with similar products such as biltong from Southern Africa, Kilishi from West Africa, beef jerky from Southern America, and corned beef from Europe, pastoral deep-fried meat products in Sub-Saharan Africa need to be upgraded and standardized into the formal meat value chains (Wanyoike *et al.*, 2009; Lokuruka, 2006).

The development of meat products poses some technological challenges, mainly with regards to optimizing the formulation, processing, and subsequent storage (Sosa-Morales *et al.*, 2006; Ziaifar *et al.*, 2008; Colmenero, 2003; Acebron and Dopico, 2000). In the case of pastoral meats, geometrical orientation, extent of pre-drying, use of antioxidants (both natural and artificial) and packaging material may contribute to physiochemical, microbiological and sensory qualities and shelf-life (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*,

2007; Holley and Patel, 2005). Generating empirical information on these processes will go a long way in upgrading the products

Pre-drying has been seen to improve the overall quality of deep-fried foods, although research has been limited to root crops and wheat (Sosa-Morales *et al.*, 2006; Ziaifar *et al.*, 2008). In addition, use of antioxidants has been evaluated with respect to shelf-life of food products. With regards to meat products, research has been limited to products that require refrigeration after processing. Animal fats have been used as frying medium for a long time by pastoralists; however health concern and demand for convenient 'snack-like' products has prompted a shift to use of vegetable oils as frying medium. Previous research on willingness to pay for pastoral meats indicate that important factors are sensory attributes, use of animal fat (rendered fat or ghee), use of spices (Wanyoike *et al.*, 2009).

Finally, the main reason beef needs to be upgraded is because indigenous cattle meats are among the main agricultural commodities in Kenya. Cattle support more than 6 million pastoralists (Behnke and Muthami, 2011) and therefore upgrading pastoral beef processing would have a positive effect on their incomes. In addition, processing and preservation of beef will increase food security as animals will be slaughtered and their meats preserved in pastoral areas (MOLD, 2010, Lewa 2010). There is unmet demand of meat products which creates an opportunity for commercialization of beef products. Integration of indigenous knowledge with conventional meat processing techniques and use of locally available material will increase small-scale processing, preservation and commercialisation of meat products.

1.9 STUDY OBJECTIVES

1.9.1 Main Objective

The main objective of the study is to integrate traditional techniques into modern commercial technologies to upgrade indigenous pastoral deep-fried beef products for upgrading into formal markets

1.9.2 Specific Objectives

1. To document the current status and technology of beef preservation in the pastoral regions of Kenya
2. To quantify the competitiveness of selected indigenous deep-fried meat products from Kenya's pastoral regions in the formal markets.
3. To determine the chemical and sensory properties of deep-fried meat products processed and preserved in the pastoral areas in Kenya
4. To determine the influence of chunk size and pre-drying on the nutritional and sensory characteristics of the deep-fried beef chunks
5. To measure the effects of smoking, curing, and package type on the microbial and chemical stability of deep-fried products.

1.10 RESEARCH QUESTIONS

1. Which are the main indigenous deep-fried beef products from Kenya's pastoral region?
2. Based on quality cues and comparative advantage, which are the most competitive deep-fried beef products from Kenya's pastoral region?
3. Is there great variations in chemical and sensory attributes of deep-fried beef products from Kenya's pastoral region?
4. To what extent do chunk size and pre-drying contribute to nutritional and sensory characteristics of deep-fried beef chunks?

5. Does smoke, nitrite and vacuum packaging increase shelf stability of deep-fried beef chunks?

1.11 OUTPUTS

1. Empirical information on the diversity of technologies and description for processing meat employed in the ASAL.
2. Empirical information on market competitiveness of selected pastoral deep-fried meat.
3. Empirical information on the chemical and sensory quality of traditional pastoral deep-fried meat.
4. Empirical information on the effect of chunk size and pre-drying on quality of deep-fried meat chunks
5. Empirical information on the effects of smoke, nitrite and spices on quality and shelf stability of packaged deep-fried products
6. A PhD thesis
7. Two article published and three more submitted to peer reviewed journals.

1.12 THESIS LAYOUT

This thesis is divided into eight chapters. **Chapter one** is the general introduction. It introduces the research and brings out the key concepts used in the study. **Chapter two** brings out the present status of meat processing and preservation in the pastoral regions of Kenya. **Chapter three** brings out competitiveness of selected traditional pastoral meat products in Kenya. **Chapter four** is on chemical and sensory quality evaluation of meat products from pastoral communities: Case of *Nyirinyiri*, *Enyas*, *Ng'amorumoru* and *Olpurda* in Kenya. **Chapter five** brings out how standardization of the size of cut and pre-drying time of beef can be modelled for mainstreaming pastoral processing in meat business in Kenya. **Chapter six** brings out the effect of nitrite, spices, smoking and packaging on the quality and stability of deep-fried meat products.

Chapter seven summarizes the general discussion of the study while **Chapter eight** brings out the general conclusions and recommendations.

CHAPTER TWO: THE PRESENT STATUS OF MEAT PROCESSING AND PRESERVATION IN THE PASTORAL REGIONS OF KENYA

ABSTRACT

Sun-drying, salting and deep frying have been used to preserve meat in the pastoral regions but there is limited empirical information on the manner and extent of practice of these methods. This study was therefore designed to collect and authenticate information on meat preservation technologies practiced in the pastoral areas. Using a structured questionnaire, key informants interviews and focused group discussions, data was collected from four pastoral counties, namely Marsabit, Turkana, Garissa and Kajiado counties, in a cross-sectional survey. Data was also collected from processors and handlers in Nairobi County to provide reference of modern handling and processing. Results revealed that different communities in the pastoral areas have adopted preservation technologies based on deep frying, salting and sun-drying while cooling and curing are practiced in the modern processing facilities in Nairobi. The main storage containers used in the pastoral districts are wooden, metallic and plastic containers. Meat handling was done by men, while by-products handling was by women, the two processes are usually separated in the production floor. Deep-frying, salting and sun-drying were predominantly done to extend the shelf life and to impart the distinct flavour of pastoral meat products. Where wooden containers were used, the containers were fumigated with smoke from burned wood (*Adung*). Meat quality deterioration was caused mainly by unhygienic handling practices which results to microbial contamination. Spoilage was aggravated during sun-drying which is a slow process. The study concludes that deep-frying of beef in the pastoral areas has potential for upgrading in terms of process hygiene and product quality.

Keywords: Indigenous preservation technologies, Meat products, Pastoral regions

Article published as: Gichure, J. N., Kunyanga, C. N., Mathi, P. and Imungi, J. K. (2014). The Present Status of Meat Processing and Preservation in the Pastoral Regions of Kenya. *Food Science and Quality Management*, 34, 42-50

2.0 INTRODUCTION

Beef is the main source of red meat (EPZA, 2005) and represented about 73 % of the total meat consumed in Kenya in 2009 (FAOSTAT, 2012). Approximately 67% of red meat is from the arid and semi-arid lands under pastoral production system. Red meat in Kenya accounts for over 80 per cent of all the meat and is derived mainly from cattle, sheep, goats and camels. Indigenous cattle meats are among the main agricultural commodities in Kenya with a potential in terms of economic growth, food security, poverty reduction and creation of employment (FAOSTAT, 2012). Kenya has an estimated livestock resource of 14.1 million indigenous cattle as compared to 3.4 million exotic cattle (KNBS, 2009). Almost 66% of the national meat production goes through formal slaughter process, while the rest uses informal channels.

Meat is highly perishable; hence the importance of its preservation (Aymerich *et al.*, 2008). Post-harvest losses can be as high as 50 % of the meat produced, which may cause food insecurity and reduced profit margins to value chain actors (MOLD, 2010; Lewa 2010). Most of these losses are caused by inappropriate post-harvest handling, processing and preservation techniques. Slaughter post-harvest losses can be reduced by increasing efficiency along the chains and value added product development. Meat is highly perishable; hence the importance of preservation (Aymerich *et al.*, 2008). Post-harvest meat handling and preservation in the pastoral regions is poorly understood. Few authors have written on how different communities

prepare and preserve meat products using indigenous technologies. This study was designed to document and assess the diversity of meat preservation technologies used in pastoral regions, to identify the weakness of these technologies and opportunities for upgrading the technologies. Such knowledge can be used by players along the value chain to develop products so as to reduce losses incurred by stakeholders. The objective of this research was to describe the meat products, handling and preservation technologies used in pastoral regions.

The main preservation techniques in pastoral/ nomadic regions of Africa are sun-drying and deep frying (Heinz and Hautzinger, 2009). Sun-drying can lead to higher microbial counts since the meat is exposed to the sun and also the drying rate takes long. Drying in the pastoral areas utilizes heat radiation (from the sun) and draft to remove water from the interior of the raw meat (Apata *et al.*, 2013). Mechanical energy has been used to remove water from the meat surface mostly through drip as the meat is hung. Deterioration of meat products depends on factors that increase growth of microorganism such as temperature, reduction-oxidation potential, endogenous enzymes, water content, and UV radiation among others (Faustmann and Cassens, 1990). Physio-chemical changes such as proteolysis, lipolysis and oxidation can also cause deterioration of meat products besides microbial degradation (Esmer *et al.*, 2011). Processing meat impart significant desirable changes on the quality attributes of meat and meat product. However, meat products development poses some technological challenges, mainly with regards to optimizing the formulation, processing, and subsequent storage. The technological feasibility of achieving the desired composition with optimum palatability depends mostly on the product type, composition, and processing done.

2.2 METHODOLOGY

2.2.1 Study Setting

A market survey was conducted to describe the diversity of current meat products in the pastoral regions of Kenya. Four counties, that is, Marsabit, Turkana, Garissa and Kajiado were purposively sampled to identify diversity of meat products made using rudimentary preservation techniques. Figure 2.1 diagrammatically brings out the study region for this study.

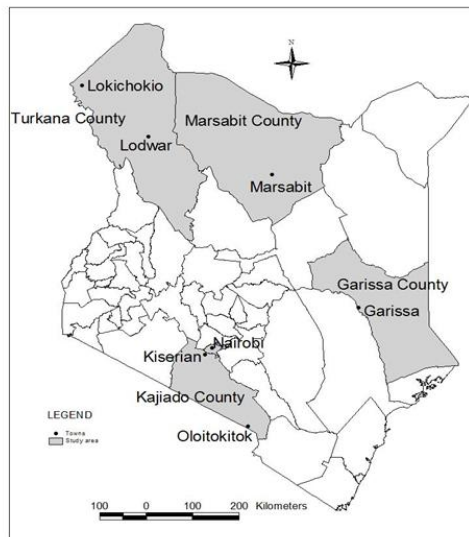


Figure 2.1: Map of Kenya, highlighting the study regions

2.2.2 Study Design

Purposive sampling was used to identify initial respondents from the pastoral regions and in Nairobi. From the pastoral regions, knowledgeable people were identified with the help of the

local government officers in the Veterinary department. Snowballing was done to identify participants for the focused group discussion and the key informants at the communities by asking the officers in the Department of Veterinary Services to introduce the knowledgeable people on meat handling and preservation in the communities.

In Nairobi, a visit to the major meat retail outlets including six supermarkets chains, five high end butcheries and two meat processing outlets was done to provide extra data on preservation and storage. Four slaughterhouses (Dagorretti, Athi River, Limuru and Kiserian) which are the major suppliers of beef consumed in Nairobi were also visited to bring out opportunities deep-fried beef from pastoral regions can have in the city.

2.2.3 Methods of Data Collection

Twenty eight focus group discussions (FGDs) with community members from pastoral communities were conducted to assess the present status of processing and preservation of meat products. All the FGDs had between eight to twelve participants of either gender. To triangulate data received from the FGDs, fifteen key informant interviews (KIIs) were conducted with officers from the Department of Veterinary Services (DVS) and officers along livestock value chains in the pastoral community. Unstructured interview guides were used to guide data collections for the FGDs and KIIs. Observations was also done to ascertain processing, preservation and hygiene, and all this was recorded in a field note book. Information on perceived shelf-life and mode of spoilage of the products was also recorded.

2.2.3 Data Analysis

The field data being quantitative in nature was entered in Nvivo application, grouped and analysed to bring out proportions and narratives from the group discussions and key informant interviews. Observations done were also recorded in the application and summarized in paragraphs.

2.3 RESULTS

2.3.1 Post-slaughter Handling of Meat in the Pastoral Regions

Meat value chain in Kenya can either be formal or informal. Along the formal value chains, the slaughter operation must be conducted in registered slaughterhouses. It's a requirement that meat is inspected both pre- and post-slaughter by a qualified veterinary officer. Mostly, the slaughterhouses are certified by the government to provide slaughter services at a fee. It's recommended that adequate measures are implemented to ensure hygienic handling post-slaughter through measures such as adequate water supply during slaughter, separation of by-products from main products, protective clothing worn by personnel among others. Usually, meat is transported in metallic boxes, specifically designed for meat products although polythene bags are at times used to carry meat. Mostly meat is not differentiated based on grade/ quality. In the pastoral areas, informal value chains are found further away from the major towns or at the household level. Slaughter operation is not inspected by a veterinary officer. Mostly, sheep and goats are slaughtered; most of which is sold fresh to the neighbours while the rest is preserved. Due to the long distances and poor infrastructure, veterinary

services are inaccessible. Table 2.1 highlights the hygiene status of the slaughterhouses in the major towns in the selected pastoral regions.

Table 2.1: Hygiene status of slaughterhouses in pastoral regions




	Garissa	Marsabit	Turkana		Kajiado		Nairobi
	Garissa	Marsabit	Lodwar	Lokichokio	Kiserian	Oloitokitok	Nairobi
	n=7	n=7	n=7	n=7	n=7	n=7	n=7
Slaughterhouse enclosed	28.6	42.9	0.0	0.0	100.0	71.4	100.0
Inspection by Veterinary officer	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Adequacy of water	85.7	57.1	71.4	85.7	85.7	71.4	100.0
Workers use protective clothing	71.4	57.1	28.6	100.0	100.0	57.1	100.0
Cooling meat before dispatch	0.0	0.0	0.0	71.4	14.3	0.0	28.6
Separation of meat from by-products	42.9	42.9	14.3	85.7	85.7	28.6	100.0
Hygiene of mode of transport	28.6	14.3	28.6	71.4	71.4	57.1	71.4
Grading meat	0.0	0.0	0.0	42.9	28.6	0.0	71.4

2.3.2 Meat Processing in the Pastoral Regions

In the pastoral regions, the main preservation techniques by the different communities were salting, sun-drying and deep frying. Common salt was used to extend shelf-life by reducing the water activity. Sun-drying by hanging slender meat stripes directly under the sun was done while hanging in a windy area accelerated removal of water from the meat. Deep-frying was

used to longer shelf-life products; around two to six months based on degree hygienically handling during storage. Sun-dried meat products that resembled South African biltong were made in Turkana and Marsabit Counties by conventional and small-scale processors. These products were occasionally marinated to improve on acceptability. All the communities deep-fried the meat. Table 2.2 summarizes the characteristics of the main deep-fried meat products by different pastoral communities.

Table 2.2: Attributes of deep-fried meat products by different pastoral communities

County	Community	Local name	Characteristics of meat products	Photo of final product	Estimated shelf-life
Garissa, Marsabit	Somali, Borana,	<i>Nyirinyiri</i>	Appearance: <ul style="list-style-type: none"> • evenly granular, • oil oozing out from the surface of the product About 4mm*4mm*4mm Taste: Spicy		2 months
Turkana	Turkana	<i>Enyas</i>	Appearance: <ul style="list-style-type: none"> • Uneven • Fibrous, • oil oozing out from the surface of the product Taste: salty		2 months
Kajiado	Maasai	<i>Olpurda</i>	Appearance: <ul style="list-style-type: none"> • oil oozing out from the surface of the product • solid at 20°C storage • Unevenly granular • Particle: range 4 mm-10 mm Taste: meaty		3 months

Differences in the final quality of the products were caused by type of meat used, extent of sun-drying, extent of size reduction, type of fat/ oil used, amount of salt and spices, time of frying, container used for storage and extent of smoking. Figure 2.2 summarizes the steps used to deep-fry and preserve meat by different communities in the pastoral area.

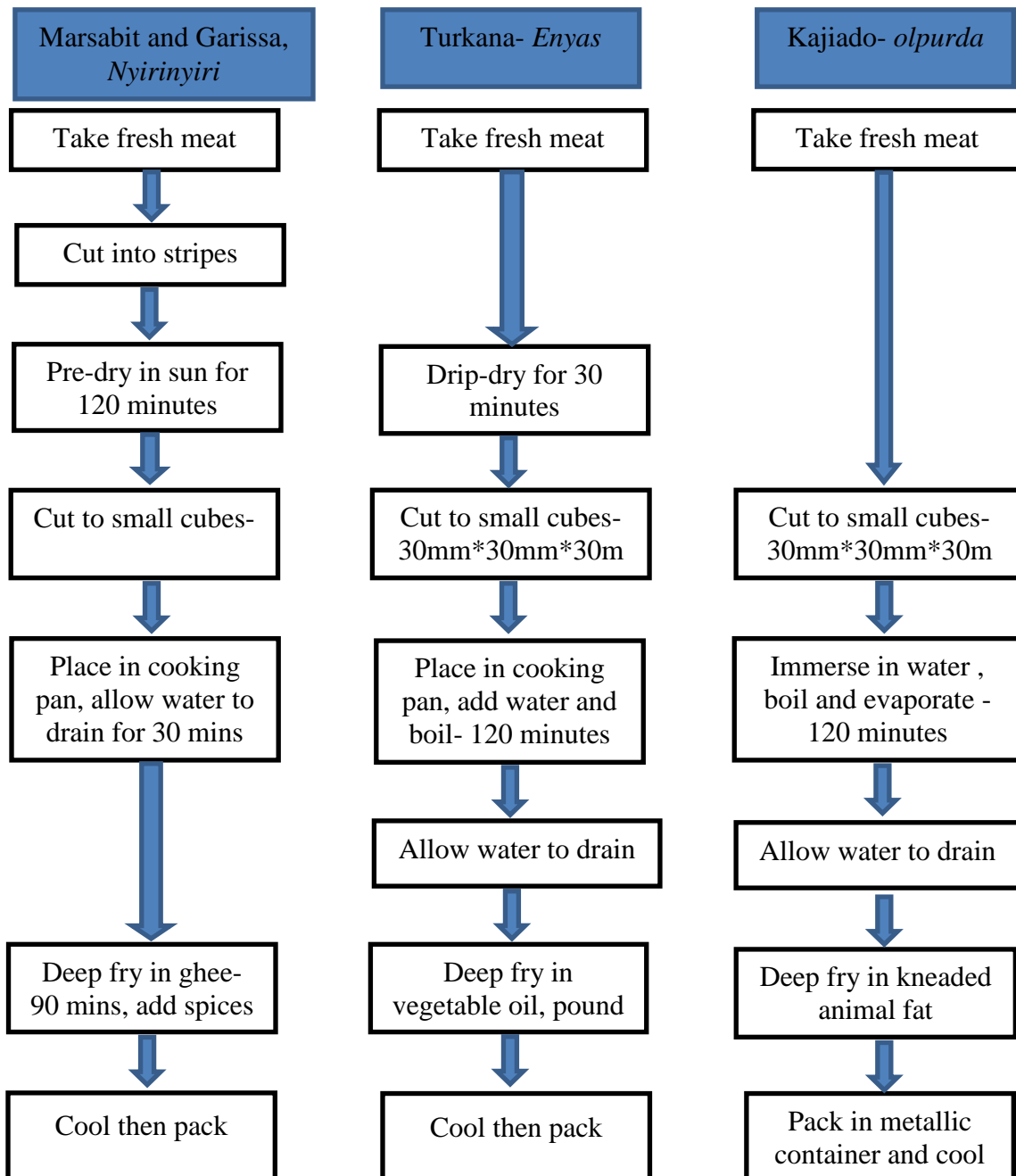


Figure 2.2: Process flow for deep-fried meats in the pastoral regions

2.3.3 Meat Products Packaging

In the pastoral areas, each community use specific containers to pack the meat products. The packaging material is used to prolong shelf-life of the products and to minimize contamination by external agents. Traditionally, wooden containers with leather base and lid were used by all the communities. However, due to scarcity coupled up with the high cost of these containers, metallic (similar to those used to transport milk) and plastic (recycled cooking oil) containers are now used. Wooden containers are still used in Turkana County (Lodwar); it is fumigated using smoke from (*Elamach* and *Adung*) trees to sanitize the containers and impart characteristic flavor to the products stored. The meat products was packed into the metallic containers in Kajiado County while still hot, hence minimize contamination thereby prolonging shelf-life; however, the product solidified during storage in the container. The main challenge with these packaging containers is the difficulty to remove meat during consumption. Figure 2.3 show the metallic and wooden-leather containers used to preserve indigenous deep-fried meats.



Figure 2.3: Containers used to package indigenous deep-fried meat

2.3.4 Diversity of Meat Products in High Market Ends of Nairobi County

There was a great variety of meat products at the supermarkets and high-end butcher shops. The meat products were categorized into three groups based on the processing and preservation technique; cured, smoked and fermented products. Occasionally, more than one preservation methods was used in the same products, for example, bacons and some sausages were preserved by curing and smoking while some sausages were cured and fermented. For curing, salts and spices were added in small quantities to improve the flavour and binding properties. Smoking was done through fumigation of the products using gaseous smoke from specific wood in a cabinet where humidity was increased by pumping steam into the chamber and temperature maintained at 80°C to 90°C for about an hour. Precooking/ cooking was done either through frying (mostly for sausages), steaming at 95°C (for hams) or boiling (for brawns) to make the products palatable. Non-meat ingredients were added to the products to increase functionality: dextrose to regulate the pH, monosodium glutamate (MSG) to enhance flavour in sausages and phosphates to improve binding properties by creating a 3-dimension network. Binders, fillers and meat substitutes were also used to improve acceptability and lower production costs.

From the study, meat and meat products in Nairobi County could also be grouped into three based on palatability; fresh meat, fresh-processed products and precooked/ cooked products. The fresh meats and fresh-processed products require heat treatment to make the products palatable while the precooked/ cooked products were ready-to-eat and comprised of fried sausages, kebabs, meat loafs and hamburgers. High grade fresh meats, mostly prime cuts, meat-on-bone and steak were usually tenderized by chilling meat at 4°C for about 10 days. Table 2.3

summarizes the preservation techniques for conventional meat products in Nairobi’s middle and high-end markets.

Table 2.3: Range of preserved meat products in formal markets in Nairobi

Basis of preservation	Type of meat product	Source of meat used for processing
Fresh meat	Prime cuts, minced, meat balls	Beef, muttons/ chevron, poultry, pork, others
Frozen meat products	Prime cuts, minced, meat balls	Beef, muttons/ chevron, poultry, pork, others
Cured but uncooked	Fresh sausages	Beef, pork, chicken
Cured and cooked	Ready to eat sausages, hams, brawns, polonies, vienna	Beef, pork, chicken
Cured, smoked and cooked products	Smokies, bacons	Beef, pork
Smoked and fermented	Salami	Beef, pork

2.3.5 Meat Handling and Processing in Nairobi’s Middle and Low Market Butcheries

Unlike the high market ends where there were prime cuts, the carcass was hang into halves and displayed for customers to select the cuts to purchase. Meat was rarely tenderized and was usually sold within 24 hours after slaughter. At the middle market ends, steak and meat on bones were the main products. Refrigeration and chilling were occasionally done to prolong shelf-life of the meat. At the low market ends, in addition to meat on bone, green and white offal were on display. Chilling at the display was not practised although excess meat was usually refrigerated. Occasionally, traditional sausage cased in animal intestines locally known as *mutura* were prepared and sold. Some outlets roasted or boiled meat chunks, slaughter by-products such as heads, trotters, lungs, green offal and bones. These traditional sausages boiled/roasted meat and slaughter by-products and soup from boiled products were usually sold along the road.

2.4. DISCUSSION

From the study, it was evident that the main techniques used to preserve beef in the pastoral areas were sun-drying, salting and deep. Salting was used as an adjunct process to deep-frying or sun-drying. Sun-drying was done by placing meat, preferably steak, in the open for the sun's rays to get to the product being dried. To accelerate the drying process, slender strips were cut to increase the surface-area to volume ratio. Sun-drying increased the risk to microbial deterioration as the meat was exposed to the sun, hence more post-harvest losses. In addition, the drying rate was long as the energy from direct sun rays wasn't adequate to dry the product. Deep frying was done to reduce the water activity of the products and was usually done after sun-drying. Deep-fried products contained a lot of fat and the products had to be stored and consumed with that fat/oil used to deep-fry the products. Depending on the fat/oil used to fry the products and the extent of frying, the products could be stored for up-to six months under room temperature (20°C). The findings further confirm that processing meat chunks of different sizes leads to differences in the rheological, sensory and structural characteristics (Tornberg, 2005). However, previous research highlight that such products are susceptible to chemical deterioration as a result of lipid oxidation (Du and Li, 2008). The high fat content of such products can cause health implications resulting from high lipids intake (WHO, 2003). In addition, deep-fried products are susceptible to deterioration in texture, flavour, colour, and nutritive value in addition to production of toxic compounds (Scollan *et al.*, 2006; Mohamed *et al.*, 2008).

Sensory evaluation is a definitive way of assessing the different physical–chemical characteristics of meat products (Russell *et al.*, 2005). The study brings out the diversity of meat preserved by sun-drying and deep frying and further confirms that acceptance of meat

products depends on social-economic, cultural, ethnic and geographical location of consumers (Jimenez-Colmenero *et al.*, 2001). From the study, the products from these selected pastoral regions were oily in appearance. Apart from *nyirinyiri*, the rest of the products had uneven particle sizes. Addition of spices in *nyirinyiri* was used to impart flavor. In addition, these spices could have some antioxidant effect which may retards lipid oxidation as highlighted in previous studies (Karpinska *et al.*, 2001). Smoke from specific trees was used to sanitize the containers and to impart desirable flavour by some communities. Previous researches bring out the antimicrobial effect of different package materials, spices and smoke on meat (Karpinska *et al.*, 2001; Lee, 2010). Common salt was normally added to meat products to improve flavour and inhibit microorganisms by lowering water activity despite research indicating it may promote lipid oxidation in meat products and discoloration of raw meat by accelerating metmyoglobin formation (Gheisari and Motamedi, 2010). All the deep-fried products from the pastoral communities were brown as the red colour associated with raw meat had been discoloured during the frying process and the salt added had aggravated the discoloration. Sundried products which were similar to biltong from South Africa were produced in some pastoral regions. Occasionally, these products were marinated to improve the flavour.

From Nairobi County, products preserved using modern technologies can be grouped into three based on the processing and preservation technique; curing, smoking and fermentation. These grouping are similar to previous study conducted by Heinz and Hautzinger (2009). In these products, non-meat ingredients are used to enhance functionality. Phosphate is used to enhance water holding capacity and improve yield in processed meat products, monosodium glutamate (MSG) to enhance flavour, while dextrose to regulate pH. In some products, soya protein and blood plasma were used to replace meat protein thereby reducing cost of production while

maintaining the protein level. The protein levels and minimum meat content used in production were the major factors that attribute the retail price of the products. In sausages, the viscosity of the emulsion was varied for the different markets with catering packs being less viscous. Other products used as ingredients for functionality were spices, cereal starch, fillers and binders.

2.5 CONCLUSION AND RECOMMENDATIONS

Different communities in pastoral regions have different preservation techniques for beef. The study confirms that preservation in the pastoral region is mostly based on sun-drying and deep frying. The sun-dried and deep-fried meat products from the pastoral area are not standardized; hence the process and products parameters have to be optimized to improve the quality of these products. The study recommends upgrading the preservation operations based on deep-frying process including the intermediate adjunct steps identified in the study. Once standardized, these products will be mainstreamed to the formal markets. To do this, the impact of particle size, type of frying oil/ fat, time of frying, salting, smoking, moisture reduction and spices needs to be scientifically investigated. This will contribute to design of strategies for reduction of post-harvest losses by increasing efficiency along the chains, product development and by-products utilization.

CHAPTER THREE: ASSESSMENT OF MARKET COMPETITIVENESS OF TRADITIONAL PASTORAL DEEP-FRIED BEEF PRODUCTS IN THE FORMAL MEAT MARKETS

ABSTRACT

In Sub-Saharan Africa, pastoral communities have relied on reduction of water activity and denial of oxygen to the products during storage as means of increasing shelf-life of meat. Empirical data show that deep-frying, drip-drying, cooling products over deep-frying oil and use of spices/ smoke are the main meat processing and preservation techniques that present the greatest potential for improvement. However, low engagement in the formal markets and dynamics in processing and preservation limit competitiveness of pastoral meat products in formal markets. This created the need to assess competitiveness of traditional pastoral meat products made using these processes. Focus group discussions (FDGs) and field observations were used to conduct a survey in the pastoral regions. From the information obtained in the FDGs, similar products were prepared at the University of Nairobi food science pilot plant. Field and pilot plant samples for the four products; *Nyirinyiri*, *Enyas*, *Ng'amorumoru* and *Olpurda* were evaluated using trained panellists. Expected quality cues and comparative advantage were used to bringing out the competitiveness using a 5-point Likert scale. The findings revealed that *Nyirinyiri* had the greatest potential for improvement with a score of 72%. *Ng'amorumoru* with 66%, *Olpurda* with 62% and *Enyas* with 61% also had potential. The low-cost associated with deep-fried products, and the vast appeal based on shelf life, appearance, texture, and flavour were identified as essential for competitiveness of pastoral products. Smoking, addition of spices, deep-frying media, mode of packaging, deep-frying

process characteristics and products geometry were important factors that contribute to competitiveness of the products. The study concluded that pre-drying prior to deep-frying, cardamom flavour, smoke from *Balanites rotundifolia* and deep-frying in rendered animal fat improved competitiveness by the greatest margins while cooling in deep-frying oil and excessive deep-frying reduced competitiveness. The study recommends further research to standardize processing of pastoral products with the aim of improving their competitiveness in the formal value chains.

Keywords: Pastoral areas, Traditional meat products, Quality cues, Competitiveness, Meat preservation techniques

Paper accepted for publication as: Gichure, J. N., Kunyanga, C. N., Mathi, P. and Imungi, J. K. Competitiveness of selected traditional pastoral meat products in Kenya. *African Journal of Food, Agriculture, Nutrition and Development*

3.1 INTRODUCTION

Proper processing and preservation of meat should enhance quality and elongate shelf-life of meat products (Ogunsola and Omojola, 2006). Over the years, different regions have developed technologies to suit the prevailing environmental conditions in that area. In the pastoral regions of Kenya, preservation of meat is mainly through reduction of water activity and denial of oxygen to the products during storage. These technologies have neither been standardized nor attempts been made to mainstream them into the formal markets. Our earlier study found that pastoral meat products include *Nyirinyiri* which is prepared and consumed in North-Eastern Kenya mostly by the Somali and Borana communities in Garissa County, *Enyas* and *Ng'amorumoru* commonly in Turkana County in Northern Kenya by the Turkana community and *Olpurda* in Kajiado County by the Maasai community (Gichure *et al.*, 2015; Gichure *et al.*, 2014).

Deep frying is a form of hurdle technology that comprises several other intermediate preservation steps. Among the intermediate steps that have been reported include addition of common salt, pre-drying, shallow-frying, addition of herbs and spices, and cooling products while submerged in the deep-frying fat to encapsulate the meat chunks. Variations in these preservation processes amongst the pastoralist communities are indicative of the rich culture and ethnic identity in terms of meat preservation (Gichure *et al.*, 2015).

With rapid urbanization in Africa, demand for indigenous food products in the urban centers has increased (Satterthwaite *et al.*, 2010). With this, members of pastoral communities who have moved in to urban areas have felt the need to consume their traditional products. Since

deep-fried cattle, goats/ sheep and camel meats are yet to be mainstreamed into the formal meat value chains; this has created an opportunity for standardizing and upgrading the most competitive products and processes. As may be the case with similar products such as biltong from Southern Africa and beef jerky from Southern America, pastoral meat products in Kenya need to be upgraded and standardized into the formal meat value chains. Based on chemical and sensory data from our previous research, pastoral products may be processed to produce snack-like products both at commercial and at household level (Gichure *et al.*, 2015; Gichure *et al.*, 2016).

To mainstream pastoral products into the formal value chain, it is of utmost importance to evaluate their competitiveness. Competitiveness has been approached from two perspectives; organizational perspective and consumer perspective. Consumer perspective is based on expectations which are in-turn based on intrinsic and extrinsic cues (Troy and Kerry, 2010; Acebron and Dopico, 2000; Steenkamp and van Trijp, 1996). Intrinsic quality cues represent the physical attributes of the product; those that cannot be changed without changing the physical product. They include attributes such as colour, fat content and tenderness. Extrinsic quality cues represent product-related attributes; those that are not physically part of a product and may therefore be changed without affecting the product. They include attributes such as price, convenience and packaging (Bredahl, 2004; Acebron and Dopico, 2000).

From consumer perspective, quality is regarded as an essential component in assessing competitiveness. Quality is not only an inherent characteristic, but rather it has been linked with how acceptable the food is (Issanchou, 1996). Most researches from consumer point of view have described quality based on perceived attributes rather than quality in an objective sense. Therefore, the need to view quality from a multi-dimensional view as perceived by the

consumers has been recognized (Grunert, 1997). Consumers perceive quality as dependent on the sensory, health, convenience and process dimensions. Sensory, health and convenience cannot be established at time of purchase by consumers; hence, represents the credence attributes. Therefore, most researchers on consumer perception opt to use expectations to predict quality (Bredahl, 2004).

As earlier stated, competitiveness is also approached from the organizational perspective. On this perspective, competitiveness depends on the ability to sustainably gain and maintain market share (Henard and Szymanski, 2001). Competitive potential, expected performance and competitive process have been used to establish market competitiveness from an organizational point (Porter, 2008). Competitive potential depends on availability and quantity of inputs, cost of raw materials and productivity. Expected performance depends on how well the products are positioned relative to competing products while competitive process measures the degree by which competitive potential is converted into competitive performance (Garcia and Calantone, 2002).

Since the products were subjected to different treatments, analytic hierarchy process was not applicable in the study. Pastoral meat products are yet to be mainstreamed into the formal value chains, hence performance measure and competitive process cannot be estimated; and therefore only competitive potential and expected quality cues were used to model this research. These factors have been shown to increase competitiveness in meat products development in previous research (Leroy and Degreef, 2015). High score for the quality cues and measures of competitiveness is an indicator for better performance in the market.

3.2 STUDY DESIGN AND METHODOLOGY

3.2.1 Study Design

The study design was cross-sectional consisting of a survey in three Counties: Turkana, Garissa and Kajiado. Data was collected using focus group discussions (FGDs) and field observations. From each county, seven FGDs were conducted. Each FGD comprised nine participants of either gender. Each group was provided with 5 kilograms of goat meat from the hind limb purchased from the nearby local slaughterhouse. The groups were requested to prepare a specific product based on traditional preservation techniques. The researcher keenly observed and recorded the process flow and inquired on the intermediate steps in attaining the required quality of the final products.

Expected quality cues and comparative advantages were used to bring out competitiveness of the products identified. Figure 3.1 shows the conceptual framework used to bring out competitiveness based on intrinsic quality cues, extrinsic quality cues and comparative advantage.

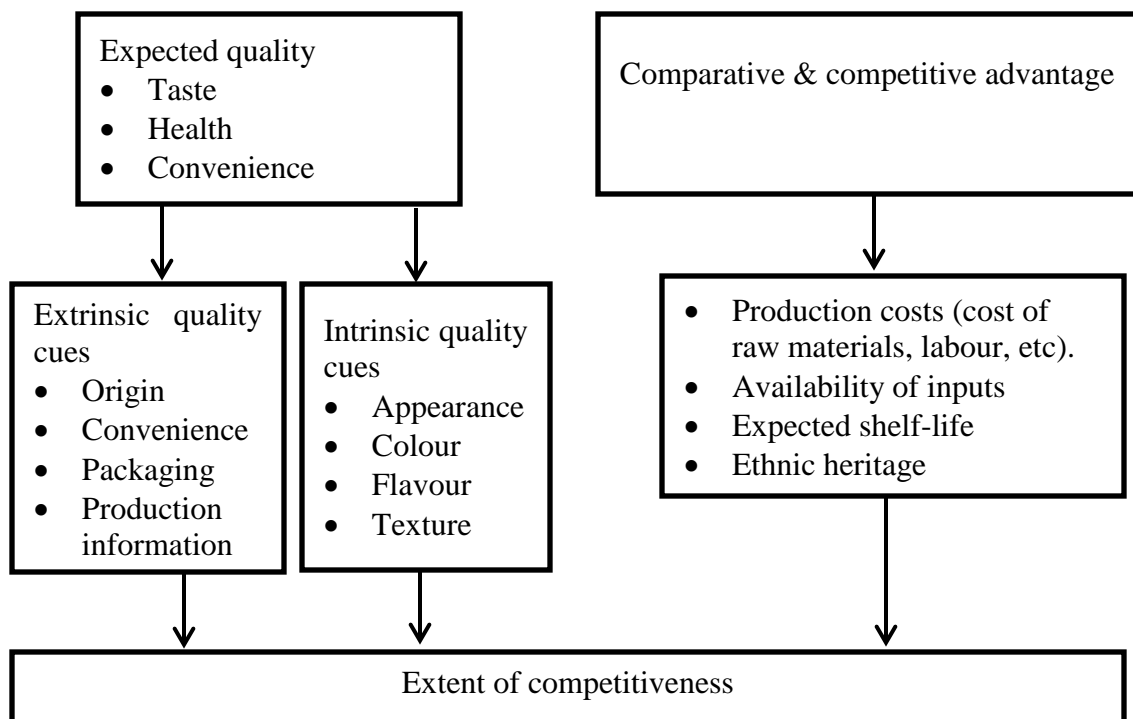


Figure 3.1: Concept for assessing competitiveness of pastoral deep-fried meat

3.2.2 Description of Sample Preparation by FGD Members

Participants in each focus group discussion were required to identify someone to be in charge of product preparation. From the discussions, a general process was developed for each product. The following paragraphs bring out the process flows.

3.2.2.1 Nyirinyiri Process flow

For Nyirinyiri which was produced by the Somali and Borana communities in Garissa County, five kilograms of fresh goat meat was cut into long-thin cuboids stripes of 1×1×30 cm. The strips were drip-dried in direct sun for about two hours, and then cut into approximately 1 cm cubes chunks. The chunks were then placed in a hot pan for five minutes to drain excess water, and thereafter deep-fried for 25 minutes. About one kilogram of traditional ghee was used as deep-frying media. During deep-frying, about 10 grams of crushed cardamom seeds (*Elettaria*

cardamomum) and 10 grams of common salt were added and mixed thoroughly. The fried meat was put in 500ml plastic bowls (Plastic #5 - Polypropylene (PP)) then cooled for 10 minutes at ambient temperature, and then placed inside iced cool-boxes.

3.2.2.2 Enyas Process Flow

For Enyas which was prepared by the Turkana community in Turkana County, five kilograms of fresh goat meat from the hind leg was pre-dried by drip-drying under shade for about two hours, then deboned and cut into approximately 4 cm cube chunks. About 10 grams of common salt was added and mixed thoroughly. Boiling with approximately 5 litres of water was done for 150 minutes in an open pan. The chunks were then placed in a hot pan for five minutes to drain off excess water, and thereafter deep-fried in about one litre palm oil for about forty minutes. During the deep-frying process, the chunks were continuously pounded until they became “fibrous”. Immediately after deep-frying, the products were packed into smoked local container made of leather and wood. *Balanites rotundifolia*, locally known as *Ebei* by the Turkana community was burnt to generate smoke. The local containers (known as *Ebur*) were smoked by blowing *Ebei* smoke into the empty *Ebur*, then covering it for about 10 minutes prior to putting the meat products, and the products were packaged while still hot.

3.2.2.3 Ng’amorumoru Process Flow

For Ng’amorumoru which was prepared by the Turkana community in Turkana County, five kilograms of fresh goat steak from the hind leg was cut into approximately 4 cm cube chunks. About 10 grams of common salt was added and mixed thoroughly. Boiling with approximately 5 litres of water was done for 60 minutes in a covered pan. The soup was drained off, and then the chunks placed on a hot pan for five minutes to drain off excess water, and thereafter deep-fried in approximately one litre palm oil for twenty minutes. The products was cooled at

ambient temperature before being packed in 500ml plastic bowls (Plastic #5 - Polypropylene (PP)) and then placed inside iced cool-boxes.

3.2.2.4 Olpurda Process flow

For Olpurda which was prepared by the Maasai community in Kajiado County, five kilograms of fresh goat meat steak from the hind leg was cut into approximately 4 cm cubes. About ten grams of common salt and approximately five litres of water were added to submerge the meat chunks. Boiling was done for 30 minutes. Excess water was drained off as soup, and then the chunks were placed on a hot pan for about four minutes. Deep-fried was thereafter done using about one kilogram rendered animal fat for twenty minutes. After deep-frying, the products were packed in metallic containers while still hot.

3.2.3 Data Collection

Samples of the final products were delivered for analysis within 72 hours to the University of Nairobi in the Food Chemistry Laboratory. Nine trained panellist were asked to rank the products based on sensory attributes and market competitiveness. Random digits were used to code the samples for identification and each panellist was requested to evaluate all the products. The panellists were requested to evaluate the same samples in three sessions on the same day, that is, at 10:00 AM, 12:00 PM and 3:00 PM. Sample order was randomized across the sessions to minimize bias due to positional effects. After the three sensory sessions, the scores were averaged for each panellist and the means for the replicated sessions obtained.

3.2.3.1 Evaluation of Sensory Attributes of pastoral products

According to Saguy and Dana (2003), intrinsic quality cues, namely appearance, flavour and texture bring out the sensory characteristics of deep-fried products. Similarly, this study used a

different approach to access the intrinsic quality cues. The panellists were required to evaluate all attributes for each sample before receiving the next sample. Sample order was also randomized to minimize bias due to positional effects. The sensory evaluation room was under similar light intensity, colour, aroma and texture, thus final scores for the products are comparable to each other. Evaluation was based on hedonic scale; a sensory analysis score sheet was used. This approach was modified from Elortondo et al. (2007)

3.2.3.2 Evaluation of extrinsic quality cues and comparative advantage of pastoral products

According to Leroy and Degreef, 2015, extrinsic quality cues and comparative advantage are good predictors of market competitiveness of food products. For extrinsic quality cues, convenience and ease of use of products were assessed while for comparative advantage, availability and cost of raw materials, expected market performance, market price of products as compared to similar products and expected shelf-life were evaluated (Porter, 2008; Bredahl, 2004; Garcia and Calantone, 2002; Henard and Szymanski, 2001; Acebron and Dopico, 2000). To collect data on market competitiveness, brief descriptions of the products were presented to the panellists in a scorecard, while weighted ranking used to score product attributes.

3.2.4 Data Analysis

Ranking for intrinsic cues, extrinsic cues and comparative attributes was based on a 5-point likert scale where, 5 = like very much, 4 = like slightly, 3 = neither like nor dislike, 2 = dislike slightly while 1 = dislike very much. Data was subjected to Analysis of Variance (ANOVA) while Duncan's multiple range test at $P \leq 0.05$ was used to compare the least significant differences of the scores for the attributes. Data analysis was done using Genstat version 12 for

windows. The cumulative scores for intrinsic cues, extrinsic cues and comparative attributes were converted into percentages to represent competitiveness.

3.3 RESULTS

3.3.1 Results on process analysis

The focus group discussions revealed that use of common salt (NaCl), pre-drying in either direct sunlight or under a shade, use of either vegetable oil, ghee or rendered tallow as deep-frying media, addition of spices and herbs to products, smoking of the packaging container prior to filling in the products, cooling products in oil to encapsulate meat chunks with oil and packaging using locally made containers were techniques used to preserve deep-fried meats.

Common salt was used to bring out characteristic taste and to slow down microbial spoilage during pre-drying. Pre-drying was done not only to reduce time required to deep-fry the products, but also to ensure as much moisture is removed from the meat chunks. Bound water was removed through evaporation; heat was used to increase the rate of moisture loss. Local spices and herbs were used to bring out characteristic taste, flavour and aroma while smoke was used to sanitize the locally-made wooden packaging containers. Cooling products to solidify the oil over the meat chunks was done to create anaerobic conditions thereby reducing rate of microbial spoilage. The locally made containers were used as they imparted characteristic woody flavour to the final products.

These techniques were considered adjunct and each step had a unique contribution to products competitiveness. Participants in the focus groups were aware how each technique contributed to the unique sensory characteristics as desired by members from the pastoral communities.

The main processing techniques used in deep-frying beef products among pastoral communities are summarized in Table 3.1.

Table 3.1 Variations during deep-frying meats among pastoral communities

Extent (Percentage)	Somali, Borana	Turkana	Maasai
Sample size (number of FGDs)	7	7	7
Deep-fried products	<i>Nyirinyiri</i>	<i>Ng'amorumoru</i>	<i>Enyas</i> <i>Olpurda</i>
1 Addition of common salt	71.4	100.0	100.0 57.1
2 Pre-drying in the sun	100.0	28.6	42.9 71.4
3 Pre-drying under shade	14.3	100.0	100.0 57.1
4 Pre-drying through evaporation	14.3	100.0	100.0 100.0
5 Addition of spices and herbs	100.0	0.0	0.0 14.3
6 Smoking of the packaging container prior to hot-filling	0.0	71.4	100.0 0.0
7 Cooling to solidify the oil over the meat	100.0	100.0	100.0 100.0
8 Preference of locally made container	28.6	57.1	85.7 71.4

3.3.2 Results on market competitiveness based on sensory attributes

The main attributes used to bring out the sensory characteristics were appearance, flavour (combination of aroma and taste), texture and convenience. Nyirinyiri scored highest with regards to the three attributes with scores of 3.9 for appearance, 3.6 for flavour, 3.4 for texture and 3.7 for convenience. Enyas and Olpurda had the least scores for appearance and flavour, both had scores of 2.7. Ngamorumoru had the least scores for flavour (2.9) and convenience

(2.7). Table 3.2 brings out the market competitiveness of deep-fried pastoral meat products, with the first four attributes representing the sensory attributes.

3.3.3 Results on market competitiveness based on extrinsic quality cues and comparative advantage

Availability and cost of raw materials, expected market performance, expected market price and perceived shelf-life were used to subjectively bring out extrinsic quality cues and comparative advantage for the pastoral deep-fried beef products. Results revealed that Ng'amorumoru had the highest score for availability of raw materials with a score of 4.4 while the price of the raw material being reasonably pocket friendly (score of 3.7). The main raw materials used in processing and preserving Ng'amorumoru were found along the banks of river Turkwel that runs across the county. Nyirinyiri score highest with regards to expected market price. This was due to the fact that some research had been conducted on Nyirinyiri and it had been partly mainstreamed along the formal markets around Nairobi. Enyas scored highest with regards to perceived shelf-life and stability during storage. Table 3.2 brings out the competitiveness scores of pastoral deep-fried meat products based on extrinsic quality cues and comparative advantage.

Table 3.2: Market competitiveness of deep-fried meats from different communities

Attributes to measure competitiveness	Nyirinyiri	Ng'amorumoru	Enyas	Olpurda
1 Appearance	3.9 ^b	3.4 ^{ab}	2.7 ^a	2.7 ^a
2 Flavor (aroma and taste)	3.6 ^b	2.9 ^a	3.0 ^{ab}	3.1 ^{ab}
3 Texture (mouth feel)	3.4 ^a	3.1 ^a	3.3 ^a	2.9 ^a
4 Convenience	3.7 ^c	2.7 ^{ab}	3.0 ^{bc}	2.4 ^a
5 Availability of raw materials	3.6 ^{ab}	4.4 ^b	3.0 ^a	3.9 ^{ab}
6 Cost of raw materials	3.7 ^a	3.7 ^a	3.1 ^b	3.8 ^a
7 Expected market performance of the products	3.3 ^a	2.7 ^a	2.7 ^a	2.7 ^a
8 Expected market price of the meat product	3.9 ^b	3.1 ^a	2.6 ^a	3.0 ^a
9 Perceived shelf-life and storage	3.4 ^a	3.6 ^a	4.0 ^a	3.6 ^a
Sum of attributes (Score out of 45)	32.4	29.7	27.5	28.1
Percentage of the sum of attributes	72.1%	66.0%	60.9%	62.5%

***Mean ± standard deviation (N= at least three determinations). Means followed by the same letter are not significantly different from each other (p < 0.05)**

3.4 DISCUSSION

3.4.1 Process analysis

It was evident that the pastoral communities were aware of the role of smoking and spicing with regards to prolonging shelf-life. Previous research reported similar findings on spices and smoke with regards to inhibiting microbial spoilage and chemical oxidation of products (Cassens, 2008; Singh *et al.*, 2008; El Malti *et al.*, 2007; Fasseas *et al.*, 2007; Zegeye, 1999). Smoke has been reported to contain chemical compounds such as the carbonyl compounds to meat products which inhibit bacterial growth by acting as bacterial static and antioxidant agent

in addition to imparting characteristic flavour to the product (Schwanke *et al.*, 1996; Tateo *et al.*, 1995).

Use of spices during deep-frying have also been reported to reduce hydrolyses of frying oil, and thereby increased shelf-life. Pre-drying was used to reduce moisture content from about 75% to about 67%, hence it's an effective means of reducing free water in the muscles prior to deep-frying (Offer and Cousins; 1992). Ionic strength, pH and lipid oxidation during pre-drying have greatest role in reduction of moisture content (Huff-Lonergan and Lonergan, 2005). During the pre-drying process, lactic acid has been reported in the muscles, which lower the pH; thereby improving texture and colour of meat products (Koochmaraie, 1996).

The use of the wooden-leather container was also seen as a cheaper alternative as these packages would be recycled, all that was required was to sanitize it prior to packaging. Smoke was used to fumigate wooden packaging containers as a means of sanitizing it. Residual fat remaining from the previous batch was not cleaned off as it has been reported by the focus group discussions to facilitate smoke retention thereby increasing efficiency of the smoking process.

Pre-drying and placing products on a hot pan prior to deep-frying were reported to bring down moisture content prior to deep-frying. Empirical data show that these processes may potentially reduce the time required to deep-fry products, reduce fat/ oil absorption by the products, and reduce rate of hydrolyses of deep-frying oil. All these benefits reduce product susceptibility to oxidation as reported previously (Choe and Min, 2007).

All the products were cooled to solidify the deep-frying media over meat chunks. This created anaerobic conditions in the products thereby prolonged shelf-life. After solidifying the media,

the products were less convenient hence the low score observed. As an extreme case, rendered animal fat as used for Olpurda solidified and encapsulated the meat chunks at room temperature and the chunks could not be removed unless the product was heated to melt the fat. In addition, cooling products over fat may predispose products to lipid oxidation during storage as suggested by Mohamed *et al.* (1996). In addition, cooling products over oil may cause the meat chunks to take up more fats, hence products appearing oilier which is not desirable (Dobarganes *et al.*, 2000).

3.4.2 Discussion on market competitiveness based on sensory attributes

Smoking was not standardized; therefore, great variation in appearance, flavour, texture and aroma were reported. In extreme cases, smoking resulted to burnt and woody flavour, which despite being uniquely acceptable to members from Turkana community was unacceptable to the panellists used in this study, and hence the lower scores for flavour. Deep-frying time and temperatures were not standardized. Acceptability was affected by deep-frying time and temperature. For instance, deep-frying for more than 20 minutes resulted in lower scores for flavour and texture for olpurda as the over-cooked meat chunks became tough. Burnt and woody flavour and tough texture were desirable by the Maasai communities, despite the fact that these attributes were less desirable to the panellists especially those from the urban areas.

The desirable flavour, colour, texture and appearance of deep- fried meat results from protein-carbohydrates reactions (Choe and Min, 2007; Dobarganes *et al.*, 2000). From the products ranking, Nyirinyiri which scored the highest with respect to appearance, flavour and texture was the most preferred based on intrinsic cues. Previous research shows that volatile free fatty acids from oxidative and thermal pyrolysis of meat lipids and deep-frying oils as being the

major contributors to the desirable sensory attributes of deep-fried products (Choe and Min, 2007). In addition to the volatiles, the relatively high score for flavour was attributed to the added cardamom spices in Nyirinyiri, deep-frying in rendered animal fat for Olpurda and use of smoke for Enyas and Ng'amorumoru. The animal fat extracted through rendering processes picks up flavours produced from the thermal breakdown of some fat and amino acid molecules.

3.4.3 Discussion on market competitiveness based on extrinsic quality cues and comparative advantage

Pastoral deep-fried meat products were seen to have some competitive advantage in case they were to be mainstreamed into the formal value chains. For instances, the deep-frying process and the adjunct preservation techniques were seen to improve uniqueness associated with indigenous products. In addition, most of the additives were locally available and were not expensive in case they were to be used. This research confirms previous findings that the low-cost associated with deep-fried products, and the vast appeal based on shelf life, colour, texture, and flavour of deep-fried products was key for competitiveness of pastoral products (Saguy and Dana, 2003). Higher scores for quality cues and comparative advantage is an indicator for better performance in the market. Nyirinyiri and Ng'amorumoru were found to be the most competitive products based on both quality cues and comparative advantage.

3.5 CONCLUSION

Results showed that pre-drying, smoking of local containers for packaging, use of spice and encapsulating products in deep-frying media during storage would increase competitiveness of pastoral deep-fried meat products in the formal markets to target the urban areas. High score for quality cues and comparative advantage indicates better performance, if the products were to be

introduced into the market. *Ng'amorumoru* and *Nyirinyiri* were found to be the most competitive pastoral products. *Balanites rotundifolia* when burnt was used to sanitize indigenous locally made wood and leather packaging containers, locally known as *Ebur*. The choice to use *ebei* was based on production of characteristic flavour and its ease of availability as the tree grows wildly along River Turkwel which passes through Turkana County.

The Somali and Borana communities used crushed seeds of cardamom (*Elettaria cardamomum*) to spice up Nyirinyiri to produce characteristic flavour and aroma. These communities have rich history in spicing up their food and therefore the spices are quite acceptable by members in these communities. Consequently, the spices were reported to increase shelf-life possibly due to their antioxidants and antimicrobial properties. Cooling products over deep-frying media was used to prolong shelf-life by creating an anaerobic condition, thereby reducing microbial spoilage.

This study brings out the possibility of evaluating competitiveness of food products based on their comparative advantage and quality cues. Ranking questions provides a good framework to convert attributes into values for analysis. Equal weights for each attribute were used. The main limitation with ranking questions is error caused by subjectivity amongst the panellist. To address this, the panellists were trained on the attributes. In addition, the panellists were required to rate all the attributes for one products before moving to the next.

CHAPTER FOUR: PHYSICO-CHEMICAL AND SENSORY QUALITY OF DEEP-FRIED BEEF PRODUCTS BY PASTORAL COMMUNITIES IN KENYA

ABSTRACT

Despite the arid and semi-arid lands in East Africa being home to many of the world's pastoralists who supply the region with meat, there lacks a standardized processing and preservation technique for their indigenous products. A lot of research having been done on sun-dried meat products from West and Southern Africa, but there exist limited empirical data on quality of pastoral deep-fried meat products which is the main pastoral products in Kenya. However, there exist variations with respect to processing and quality not only among different communities but also within the same communities. This study was therefore designed to assess the chemical and sensory attributes of selected indigenous pastoral meat products in Kenya. Results show moisture range between 8.1% and 28.5%, protein between 42.6% and 46.9%, lipids between 15.4% and 37.9%, ash between 3.1% and 4.3%, and energy between 424.65 Kcal/100g and 542.24 Kcal/100g. Pastoralist cooled deep-fried meats in the frying media to encapsulate the chunks while indigenous wooden-leather packages sanitized by smoking were occasionally used. In terms of sensory attributes, Nyirinyiri was most preferred (5.34 ± 0.337), then Ng'amorumoru (5.23 ± 0.00) ($P < 0.05$). Smoking by fumigation of packaging containers prior hot filling the products, spicing with 5% cardamom, and deep-frying in ghee and rendered animal fat significantly improved sensory quality. The study concludes that indigenous deep-fried products are nutritionally dense and highly acceptable. Variations in quality bring out cultural diversity among pastoral communities.

Keywords: *Pastoralist, Preservation technique, Deep-frying, Pastoral meat products*

Manuscript submitted as: Gichure, J.N., Kunyanga, C.N. and Imungi, J.K. Chemical and sensory attributes of selected meat products from the Kenyan pastoral communities. *Meat Science*

4.1 INTRODUCTION

Based on the nature of the lifestyle of pastoralist, they require high energy foods as they move around in search for pasture for their animals (Ayantunde *et al.*, 2011; Fabusoro and Oyegbami, 2009). Deep-fried meat is still the most appropriate with regards to stability against microbial spoilage and provision of nutrient-dense diets. Traditionally, different pastoral communities have over time devised different means of handling, processing and preservation to prolong the shelf-life meat products. Despite similarities in processing and preservation of deep-fried beef, great variations have been reported on the chemical and sensory attributes of these products. On this, pastoral communities in Africa still rely on indigenous techniques that are mainly based on reduction of water activity through sun-drying, salting, use of spices, smoking and deep frying (Gichure *et al.*, 2014; FAO, 1995). Variations in processing caused by differences in indigenous knowledge among pastoral communities are responsible for the deviations in chemical and sensory properties. Indigenous knowledge has been described by Stabinsky and Brush (2007), as a body of knowledge built up by a group of people living in close contact with nature. It is a product of time, society and environment. Through time, the beneficial parts of knowledge persist while the dysfunctional components get discarded. This form of knowledge is passed from generation to generation through the process of socialization. As has been reported in earlier studies, great variations exists with regards to intermediate steps and deep-frying process designs within and across different pastoral communities (Gichure *et al.*, 2014).

Pastoral meat products which are generally preserved through sun-drying and deep-frying are susceptible to proteolysis, lipolysis, oxidation and microbial spoilage (Gichure *et al.*, 2015). These spoilage processes may cause detrimental changes in the color, texture, odor and flavor during storage (Zhou *et al.*, 2010; Scollan *et al.*, 2006). The rate of spoilage is dependent on the oxygen concentration, presence of endogenous enzymes, high water activity, light and microbial contamination (Zhou *et al.*, 2010).

Lipids have been seen to considerably increase the energy content and improve flavor, texture and satiety (Nieuwenhuizen *et al.*, 2010; Fernández-Ginés *et al.*, 2005). Lipids also acts as an important source of fat-soluble vitamins (A, D, E and K), essential fatty acids and as precursor of compounds that regulate a number of physiological functions. To address nutritional concerns among consumers, vegetable oils are increasingly being used in cooking (Jiménez-Colmenero, 2007; Fernández-Ginés *et al.*, 2005). With regards to storage, lipids reduce the moisture content thereby prolonging shelf-life of the products. Higher lipid content reduces the time required to cook products by reducing the time to reach higher internal temperature (Colmenero, 2000).

In as much as physiochemical analysis has been used to estimate valuable information on expected sensations that meat products induce, sensory analysis is the definitive way of assessing them (Russell *et al.*, 2005). Sensory analysis has been used to bring out sensory description while assessing effects of sensory characteristics based on different processing methods. In addition to this, sensory analysis has also been used to study consumer preferences (Etaio *et al.*, 2013). Generally, sensory analysis may be based on affective classes (hedonic type test) or on descriptive classes (analytic type test) (Pérez-Elortondo *et al.*, 2007).

This research was therefore used to evaluate the nutritional and sensory qualities of indigenous pastoral meat products in Kenya's pastoral region. The empirical information generated will bring out indigenous knowledge on preservation and diversity in deep-frying process and intermediate steps amongst different communities contributes to overall quality of deep-fried products.

4.2 STUDY DESIGN AND METHODOLOGY

The study design was cross-sectional consisting of a survey in four Counties: Turkana, Marsabit, Garissa and Kajiado. The counties were purposively selected; Garissa County being the largest livestock market in Kenya; Turkana County being the largest County in terms of land size; Marsabit County having the biggest diversity with regards to cultural practices while Kajiado County being the largest livestock producer in Kenya. Most of the residents from the three counties are of pastoral origin and depend largely on meat and milk products for their basic food needs (Homewood *et al.*, 2012). Figure 4.1 shows the Counties and towns visited during the survey.

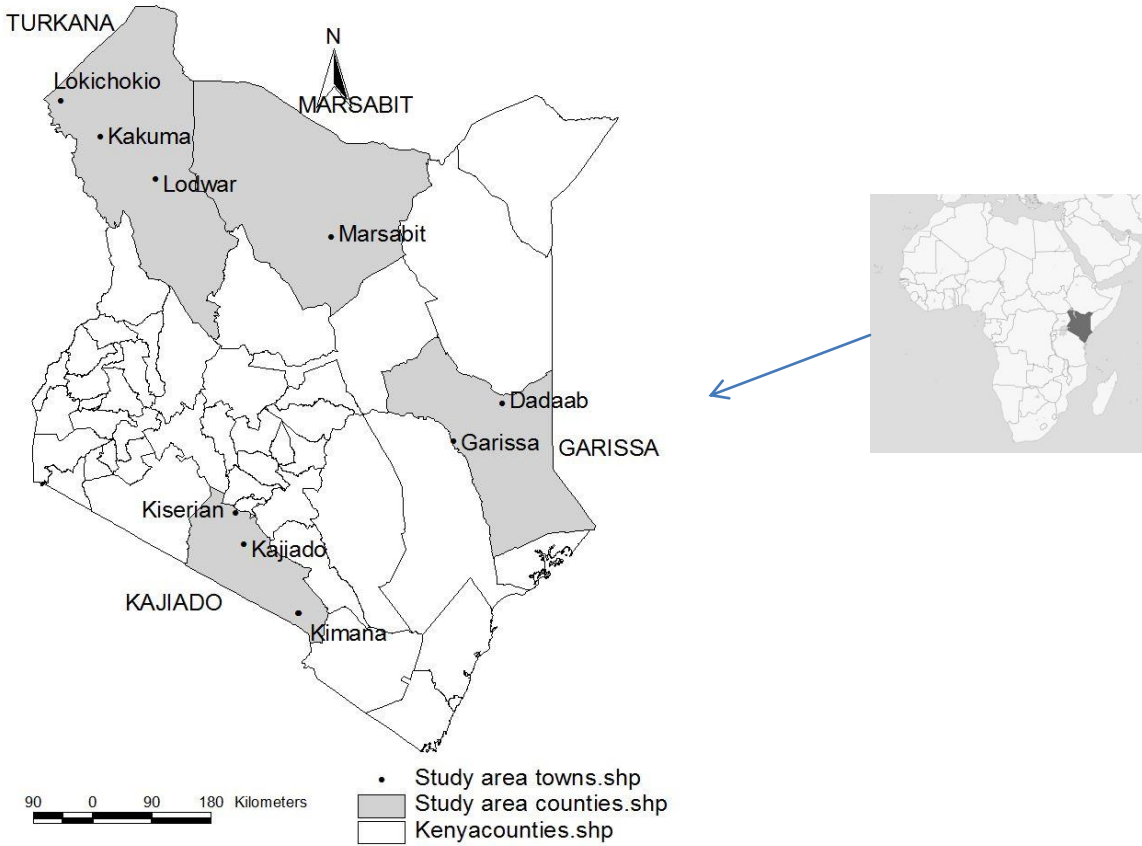


Figure 4.1: Map of Kenya showing residence of pastoralists based on population size

Data was collected using Focus Group Discussions (FGDs) and field observations. From each county, five FGDs were conducted. Homogeneous sampling scheme was used to identify eight to twelve participants for the FGDs based on age, gender and occupation as recommended by Onwuegbuzie and Frels (2015). Each group was provided with three kilograms (3 kg) of goat meat steak from the hind limb purchased from a local slaughterhouse. With the three kilograms, each group was required to make a specific indigenous deep-fried meat product. The researcher recorded the processing steps, time-taken and amounts of other ingredients added. In addition,

personal interviews and observations were used to validate the processing steps by providing information on the critical points with regards to product quality.

4.2.1 Description of Sample Preparation by FGDs

Four pastoral meat products were prepared during the survey. These were *Nyirinyiri* which was prepared in Garissa and Marsabit Counties by Somali and Borana communities, *Enyas* and *Ng'amorumoru* in Turkana County by Turkana community and *Olpurda* in Kajiado County by the Maasai community. Figure 4.2 shows the main deep-fried meat products indigenous in the pastoral communities.



a) Nyirinyiri



d) Olpurda



b) Enyas



c) Ng'amorumoru

Figure 4.2: The main deep-fried meats indigenous to pastoral communities

Where major cultural variations in intermediate processing steps were observed as was the case with Nyirinyiri in Garissa County, Marsabit County was used to provide more FGDs. On the other hand, Enyas and Ng'amorumoru were predominantly prepared by the Turkana Community; therefore, a total of 10 FGDs were conducted in Turkana County, five for each product. Since Enyas, was smoked during packaging, the sample was divided into two after deep-frying and one sample smoked while the other sample packaged in the plastic containers.

All the samples were packed in plastic containers (Plastic #5 - Polypropylene (PP)). In addition, some samples of Enyas were smoked and therefore, traditional wooden-leather containers were used for the smoked samples. Figure 4.3 shows the indigenous wooden-leather package containers for smoking Enyas.



Figure 4.3: Indigenous wooden-leather packaging used to smoke and store Enyas

4.2.2 Process description for the pastoral products

Product 1: Nyirinyiri

Nyirinyiri was prepared using 3 kg steak from the hind leg of mature goat. The fresh lean meat was cut into thin strips approximately 1 cm by 1 cm by 30 cm immediately after the animal was slaughtered. Solar drying was done for 3 hours. The average ambient temperature during that period was about 37°C. After drip-drying, the strips were cut into small cubes 1 cm by 1 cm by 1 cm, and placed in a hot pan for about 5 minutes to drain excess water. About 10 grams of crushed cardamom seeds (*Elettaria cardamomum* Maton) and 10 grams of common salt were added to the deep frying media. After this, the sample was divided into two equal portions. The first portion was deep-fried in 1500 ml palm oil for about 21 minutes while the second portion

was deep-fried in about 1 kg traditional locally made ghee for about 27 minutes. The products were packed in plastic containers (Plastic #5 - Polypropylene (PP), then cooled for 10 minutes at ambient temperature, then placed inside iced cool-boxes.

Product 2: Enyas

Enyas was prepared using 3 kg steak from the hind leg of mature goat. It was pre-dried in the shade for 2 hours, then cut into small cubes (2 cm by 2 cm by 2 cm), placed onto a pan and about 10 grams of common salt added. About 5 litres of water was added to the pan to completely submerge the meat chunks and boiling was done for about 150 minutes. Continuously stirring was done to evaporate the water after which about 1500 ml of palm oil was added, the meat chunks were deep fried for about 40 minutes. During the deep-frying process, the chunks were continuously pondered with a wooden rod until the product appeared fibrous. The samples were divided into two equal parts. One portion was packed in plastic containers (Plastic #5 - Polypropylene (PP), then cooled for 10 minutes at ambient temperature, then placed inside iced cool-boxes. The other portion was packed in traditional wooden-leather containers locally known as *ebur*. The wooden container was sanitized using smoke from *Balanites rotundifolia*, locally known as *Ebei* among the Turkana community.

Product 3: Ng'amorumoru

Ng'amorumoru was prepared using 3 kg steak from the hind leg of mature goat. It was pre-dried in the shade for 2 hours, then cut into small cubes (4 cm by 4 cm by 4 cm), placed onto a pan, 10 grams common salt added and about 5 litres of water added to completely submerge the meat chunks. The meat chunks were boiled for 90 minutes, and throughout the boiling process, the chunks were continuously stirred to facilitate evaporation. Afterwards, about 1500 ml of palm oil was added, and the product deep fried for 22 minutes. The product was packed in

plastic containers (Plastic #5 - Polypropylene (PP), then cooled for 10 minutes at ambient temperature, then placed inside iced cool-boxes.

Product 4: Olpurda

Olpurda was prepared using 3 kg steak from the hind leg of mature goat. It was cut into small cubes (4 cm by 4 cm by 4 cm), put in a hot pan, 10 grams of common salt added and about 5 litres of water added to the pan so as to completely submerge the meat pieces. The meat chunks were boiled for 30 minutes, after which, the boiling water was drained off. The chunks were further heated to evaporate excess water for about 4 minutes. Thereafter, 1 kg rendered goat fat was added and the chunks were deep fried for about 18 minutes. Simmering at about 70°C while still in deep-frying oil was further done for 8 minutes for the products to attain its characteristic brown colour. The products were packed in plastic containers (Plastic #5 - Polypropylene (PP), then cooled for 10 minutes at ambient temperature, then placed inside iced cool-boxes.

4.2.3 Analytical Methods

All the samples were delivered to the Department of Food Science, Nutrition and Technology at the University of Nairobi within 72 hours. In addition, samples of the products after each critical intermediate step (pre-drying, boiling and deep-frying) were taken for chemical analysis. Chemical analysis was based on AOAC standard methods (AOAC, 2008) while sensory analysis was based on ISO standard methods (ISO 8587:2006). For each sample, analytical evaluation was conducted in three replicates.

4.2.2.1 Chemical Analysis

Moisture content was determined by drying at 105 °C using an air oven to a constant weight according to the AOAC methods (AOAC, 2008 method 967.08), crude protein was analysed as (total nitrogen and multiplied by factor 6.25) by the Kjeldahl method according to AOAC method 988.05 (AOAC, 2008) while Soxhlet extraction method was used to determine the fat content (AOAC 2008 method 2003.06).

Dietary fibre was determined using the gravimetric method (AOAC 2008 method 958.06). About 10 g of the sample was weighed accurately and placed in a 500 ml conical flask. Then 50 ml of acid detergent fibre was added. The mixture was boiled for one hour, after which it was filtered over a Buchner funnel connected to a vacuum pump using a sinter glass. The sinter glass crucibles were oven dried at 100 °C for 45 minutes. Dietary fibre was obtained as the difference between the weight of the empty sinter-glass and that after removal from the oven.

For the ash content, approximately 10 g of the meat products sample were minced and combusted in a muffle furnace at 550 °C for 5 h according to standard AOAC methods (942.05).

Ash was calculated as follows:

$$\frac{\text{weight of ash}}{\text{weight of sample (10g)}} * 100$$

Soluble carbohydrates were determined as the difference between the sums by subtracting the sum of all other components from 100%.

The energy in Kcal was calculated from carbohydrates, proteins and lipids in grams by multiplying with the appropriate Wilwater factors of 4.0, 4.0 and 7.0 based on modifications to the Pearson (1976) formula:

4.2.2.2 Sensory evaluation

The samples were placed in water-baths at 80 °C for 20 minutes to melt the fat and the excess oil was drained off. Samples of 20 grams were then filled in 20 ml PVC containers and presented to the panellists. Eleven trained panellists were asked to evaluate the products on the basis of colour, appearance, convenience of scooping with a spoon, size of chunks, oiliness, odour, taste and chewiness and overall acceptance according to method by Pérez-Elortondo *et al.* (2007) and Etaio *et al.* (2013).

Random digits were used to code the samples for identification and each panellist was requested to evaluate all the products. Colour, appearance, convenience of scooping, size of chunk and oiliness were evaluated based on ophthalmoception (sight) and olfacoception (smell) senses while odour, taste and chewiness were based on the taste and smell senses. Overall acceptability was based on taste, sight and smell senses.

Panellists evaluated all attributes for each sample before receiving the next sample. Water was provided, and panellists were asked to expectorate and rinse their mouths between the samples. The sensory evaluation room was under similar light intensity, colour, odour and texture, thus final scores for the products are comparable to each other. The panellists were requested to evaluate the same samples in three sessions on the same day, that is, at 10:00 AM, 12:00 PM and 3:00 PM. Sample order was randomized across the sessions to minimize bias due to positional effects. After the three sensory sessions, the sensory scores were averaged for each panellist and the means for the replicated sessions obtained.

The panellists evaluated the potential competitiveness of the products based on sensory attributes using a 7-pont hedonic rating scale with 7= like very much, 6= like moderately, 5=

like slightly, 4= neither like nor dislike, 3= dislike slightly, 2= dislike moderately, while 1= dislike extremely (Etaio *et al.*, 2013)

4.2.4 Data Analysis

Data was subjected to Analysis of Variance (ANOVA) while Duncan's multiple range test at $P \leq 0.05$ was used to compare the means and least significant differences of the scores for the attributes. Data analysis was done using Genstat version 12 for windows.

4.3 RESULTS

4.3.1 Chemical Composition of Four Pre-dried Pastoral Meat Products

Raw meat had approximately 78% moisture, 18% proteins, 2 % lipids, 2% carbohydrates and 2% total ash content. Nyirinyiri was pre-dried in the open sun for approximately two hours while Enyas, Ng'amorumoru and Olpurda were pre-dried under shade for about two hours, and then cut into small chunks, and then enough water added to cover the chunks. Boiled and evaporation of excess water to near dryness was then done. Results show that boiling and evaporating excess were more effective in moisture reduction than sun-drying. Table 4.1 shows the chemical analysis of meat chunks after pre-drying.

Table 4.1: Chemical analysis pre-dried beef chunks prior to deep-frying

Sample name	Moisture %	Protein %	Fat %	Fiber %	Ash %	CHO %	Energy Kcal/100g
Nyirinyiri (made with ghee)	66.75 (2.06)	28.95 (1.21)	1.50 (0.26)	0.00 (0.00)	2.10 (0.17)	0.70 (0.42)	132.08 (8.87)
Nyirinyiri (made with palm oil)	66.75 (2.06)	28.95 (1.21)	1.50 (0.26)	0.00 (0.00)	2.10 (0.17)	0.70 (0.42)	132.08 (8.87)
Enyas (smoked)	58.05 (0.92)	29.63 (2.73)	9.60 (0.60)	0.01 (0.00)	2.73 (0.09)	0.01 (0.01)	204.88 (10.56)
Enyas (not smoked)	58.05 (0.92)	29.63 (2.73)	9.60 (0.60)	0.01 (0.00)	2.73 (0.09)	0.01 (0.02)	204.88 (10.56)
Ng'amorumoru*	61.79 (2.65)	30.61 (1.00)	4.61 (0.26)	0.00 (0.00)	2.27 (0.14)	0.73 (0.07)	166.76 (4.59)
Olpurda*	58.04 (4.39)	33.76 (2.52)	5.61 (0.42)	0.01 (0.00)	2.47 (0.24)	0.00 (0.00)	185.53 (4.15)

Figure in parenthesis represent the standard error of mean (n= three replications)

* No cultural variations exists in processing these products

4.3.2 Chemical composition of deep-fried beef products

After deep-frying of the pre-dried products, moisture content varied between 8.1% and 28.5%, protein content between 42.6% and 46.9%, fat content between 15.4% and 37.9%, fibre content between 0.01% and 0.03%, ash content between 3.1% and 4.3%, carbohydrates content between 3.3% and 9.2% while energy content varied between 424.65 Kcal/100g and 542.24 Kcal/100g.

Deep-frying and cooling products in the frying media were seen to increase the fat content, carbohydrates and caloric value of the products. Different communities cut the chunk into different sizes; generally, the smaller the meat chunks, the higher the fat content mainly because of increased surface area to volume ratio of the meat chunks. The products were cooled

in the deep-frying media to create anaerobic environment for storage. Table 4.2 brings out the chemical analysis of the deep-fried beef chunks indigenous to pastoralists in Kenya.

Table 4.2: Chemical analysis of deep-fried beef indigenous to pastoralists in Kenya

Sample name	Moisture %	Protein %	Fat %	Fiber %	Ash %	CHO %	Energy Kcal/100g
Nyirinyiri (made with ghee)	28.47 (2.20)	43.58 (1.71)	15.35 (1.20)	0.01 (0.00)	3.53 (0.20)	9.05 (0.94)	424.65 (64.29)
Nyirinyiri (made with palm oil)	30.82 (1.93)	43.27 (1.34)	14.90 (1.55)	0.01 (0.00)	3.47 (0.04)	6.82 (0.74)	425.01 (7.38)
Enyas (smoked)	8.09 (0.65)	42.61 (1.79)	37.90 (1.71)	0.03 (0.01)	3.70 (0.12)	7.69 (0.06)	539.18 (6.53)
Enyas (not smoked)	8.17 (0.90)	42.72 (1.59)	37.93 (1.23)	0.03 (0.01)	3.68 (0.04)	8.03 (0.64)	542.24 (0.90)
Ng'amorumoru*	17.59 (1.63)	43.75 (2.37)	31.06 (2.16)	0.02 (0.00)	4.30 (0.28)	3.28 (0.21)	454.54 (20.37)
Olpurda*	13.52 (3.05)	46.94 (3.26)	27.26 (1.40)	0.02 (0.00)	3.08 (0.58)	9.18 (1.00)	469.85 (5.13)

Figure in parenthesis represent the standard error of mean (n= three replications)

* No cultural variations exists in processing these products

4.3.2 Sensory Evaluation

From the study, all pastoral products were acceptable to the panellist. Taste, overall acceptability, convenience and colour were the most preferred attributes while texture, size, odour and oiliness were scored least mean values ($P < 0.05$). Duncan's Multiple Range Test at 5% significance level revealed significant differences even among similar products under different treatments. Nyirinyiri that had been deep-fried in traditional ghee was most acceptable with a score of 6.00. Ng'amorumoru and nyirinyiri deep-fried using palm oil had overall acceptability of 5.62. Olpurda and Enyas (smoked sample) scored the least with scores of 4.21 and 4.46 respectively. With respect product attributes, taste (5.22), convenience to scoop (5.12) and colour (5.12). On the other hand, chewiness (4.85), size of chunks (4.88) and aroma (4.88)

scored the least. Table 4.3 brings out the sensory analysis of indigenous deep-fried meat products from pastoral communities.

Table 4.3: Sensory analysis of deep-fried meat products indigenous to Kenyan pastoralists

Product	Appearance	Color	Convenience to scoop	Size of chunks	Oiliness	Aroma	Taste	Chewiness	Overall acceptability
Nyirinyiri (made with ghee)	5.54 ^a	5.62 ^a	5.15 ^b	5.00 ^b	4.85 ^a	5.62 ^a	6.08 ^a	5.92 ^a	6.00 ^a
Nyirinyiri (made with palm oil)	5.47 ^a	5.27 ^{ab}	5.62 ^a	5.31 ^a	4.97 ^a	5.31 ^{ab}	5.77 ^{ab}	5.73 ^{ab}	5.62 ^b
Ng'amorumoru	5.08 ^b	5.23 ^{ab}	5.62 ^a	5.46 ^a	5.15 ^a	4.85 ^{bc}	5.31 ^b	5.30 ^b	5.62 ^b
Enyas (smoked)	4.77 ^b	5.08 ^b	4.46 ^c	3.85 ^d	5.15 ^a	4.46 ^{cd}	4.46 ^c	4.62 ^c	4.46 ^d
Enyas (not smoked)	4.69 ^{bc}	4.92 ^b	4.92 ^b	4.15 ^c	5.15 ^a	4.85 ^{bc}	5.39 ^b	4.23 ^c	5.00 ^c
Olpurda	4.33 ^c	4.21 ^c	4.95 ^b	4.92 ^b	4.18 ^b	4.20 ^d	4.28 ^c	3.28 ^d	4.21 ^d
Mean score	4.98	5.05	5.12	4.88	4.91	4.88	5.22	4.85	5.15

*means (n= three replications)

Means followed by the same letter are not significantly different from each other ($P < 0.05$)

4.4 DISCUSSION

4.4.1 Chemical Composition of the Products

The chunks deep-fried in rendered animal fat had lower moisture contents and higher proteins, fats and carbohydrates contents as compared to those deep-fried in palm oil and ghee. In case rendered animal fat was used as the deep-frying media, the solidified fat formed a network that is tough and products had to be reheated before consumption. This translated into lower score on convenience as observed for Olpurda. Ghee and vegetable oils were semi-liquid during storage; hence the chunks could be easily scooped. Palm oil was used since it was cheaper than sunflower or corn oil. Similar results were reported by Weber and others (2008).

Pastoral products were cooled in the deep-frying oil so as to create anaerobic condition as the chunks are encapsulated in the solidified fat. Cortés and others (2014) found out that products tend to take up oil during post-frying cooling; this explains the high lipids content in the products cooled with deep-frying media. The challenge with cooling products under fat is that this may increase susceptibility to lipid oxidation during storage (Mohamed *et al.*, 2008; Scollan *et al.*, 2006).

The general trend observed for the pastoral products was increased nutrients density (protein, lipid and ash contents) as moisture content reduced. This was similar to empirical data reported by Fernández-Ginés and others (2005). Of great importance was the moisture content, which decreased as lipid content increased. This was in line with previous research (Krokida *et al.*, 2000). Firewood was the main source of fuel, and therefore, deep-frying temperature was not controlled. Choe and Min (2007) reported that uncontrolled temperatures during deep-frying may result in loss of nutritional components, which might be the case for reduction in carbohydrates

and fibres contents in this research. All pastoral deep-fried products had high lipid contents; lipids contribute to flavour, texture, pro-longed shelf-life, heat transfer and satiety as has been reported in earlier research (Colmenero, 2000; Acebron and Dopico, 2000).

4.4.2 Sensory Characteristics

From the study, Ng'amorumoru and Enyas scored the highest followed by Nyirinyiri and Olpurda with regards to preference based on oiliness. A positive relationship was seen with regards to using palm oil as deep-frying media and ease of scooping. On the other hand, Nyirinyiri and Enyas which had smaller chunk sizes was oilier and hence less preferred. Deep frying contributes greatly to sensory characteristics and the method of processing is popular since it uses relatively simple technology (Saguy and Dana, 2003). Palatability of deep-fried products was also seen to be influenced by characteristics such as a unique desirable, flavour, colour, texture and appearance (Adegoke and Falade, 2005; Troy and Kerry, 2010).

The panellists preferred Nyirinyiri the most, followed by Ng'amorumoru. All the products scored highly with regards to ease of scooping and preference based on size of meat chunks. This would indicate that consumers prefer smaller meat chunks to larger meat chunks. However, Enyas was least preferred with regards to appearance and convenience. This could be due to its fibrous appearance which most panellists would not associate with meats.

The relatively high scores for colour and appearance in Nyirinyiri and Ng'amorumoru was attributed to use of palm oil which remained liquid and therefore revealed the colour of the chunks, while the low score for colour and appearance in Olpurda was attributed to use of rendered animal fat which solidified and formed a whitish coat on the pieces, which masked the desirable brownish colour of the deep-fried chunks. This was in line with the reports by Sugay

and Dana (2003) that vegetable oil improves sensory attributes of deep-fried products. With regards to sensory attributes, use of vegetable oil significantly reduced the aroma in the products.

Pre-drying brought down moisture content from about 75% to about 67%. This process had a positive effect on the colour and appearance scores of the products similar to what was reported by Choe and Min (2007). Pastoralist pre-dried their meats using two techniques; through sun-drying as done by the Somali and Borana communities and boiling meat and allowing water to evaporate as done by Turkana and Maasai communities. During sun-drying, lactic acid is produced in the muscles which lowers the pH; which improved texture and colour of meat chunks (Neath *et al.*, 2007). Boiling produced similar results in that the proteins get denatured thereby decreasing the water holding capacity in addition to rendering the fat out of the tissues. All in all, pre-drying by either sun-drying or evaporation improved on the nutritional characteristics in that it reduces the amount of fats absorbed during deep-frying process.

The high scores for aroma in Nyirinyiri were due to addition of ground cardamom (*Elettaria cardamomum* Maton) seeds. *Elettaria cardamomum* is known as “iliki” in Kiswahili dialect and belong to the family Zingiberaceae. On the other hand, smoking imparted characteristic flavor in Enyas; however, the product developed woody and burnt flavor and thereby the product was less acceptable. Despite this being desirable to individuals from pastoral communities, it was unacceptable to the panelists. *Balanites rotundifolia*, is known as *Ebei* in Turkana dialect was burnt to generate smoke for fumigating the wooden packaging containers known as *ebur* to impart flavor and sanitize the *ebur* as reported in an earlier publication (Gichure *et al.*, 2014). Wooden containers with leather lids were used since these materials would absorb smoke. Spices and smoke have been reported to contribute to antioxidant and bacteriostatic properties in meat

products (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005).

4.5 CONCLUSION

Pastoral meat products have high proteins, lipids, calorie and ash contents, hence may be considered functional food as they are nutrient dense with high satiety. Different communities had different intermediate steps which bring out diversity in processing; and this was responsible for the variations observed with regards to chemical and sensory attributes. Some sensory attributes may be acceptable by certain communities but less acceptable to the trained panellist; for example, fibrous appearance of Enyas, burnt flavour of Enyas, deep-frying and submerging Olpurda in rendered animal fat, and use of traditional ghee and the very dark appearance of Nyirinyiri. The products are mostly stored in solidified frying media to create an anaerobic environment. Spice and smoke were used to improve shelf stability by acting as antioxidant and bacteriastatic agents. Spicing with cardamom, using rendered animal fat and ghee as deep-frying media and smoking impart characteristic sensory attributes which were acceptable by different communities. Pre-drying by either sun-drying or evaporating was used to improve nutritional and sensory attributes of the products.

**CHAPTER FIVE: STANDARDIZATION OF CUT SIZE AND PRE-DRYING TIME OF
DEEP FRIED BEEF TO MAINSTREAM PASTORAL PROCESSING IN KENYA'S
MEAT INDUSTRY**

ABSTRACT

Deep fried and sun-dried meat products represent a large part of the traditional meat products from pastoral regions of Sub-Saharan Africa. However, unlike the sun-dried products, deep-fried products are not properly mainstreamed into the meat business operation due to lack of product standardization especially in terms of the size of cut and product quality. The quality of the products at processing is probably dependent on the time of pre-drying that precedes deep frying. This study was designed to standardize the size of cut and the pre-drying time with view to improving quality at the product at processing. Three sets of beef chunks from the silverside portion of mature Borana cattle was cut into sizes 10 mm, 15 mm and 20 mm. Each set was then pre-dried in a thermostatically controlled air-oven at 40 °C each for 0, 60 and 120 minutes then deep-fried in palm oil at 170°C for 10 minutes. The products were analysed for chemical composition using standard AOAC methods and sensory analysis based on seven-point hedonic rating scale. Data was statistically analysed for differences. Results show that the products had moisture contents between 14.1 and 19.4%, protein between 52.1 and 66.5%, lipids between 10.8 and 15.4% and the energy between 329.7 to 404.2 Kcal/100g. Peroxide values were within acceptable limits and ranged between 0.5 and 3.7 mEq/kg. Sensory evaluation indicated that the 20 mm cuts without pre-drying had significantly the highest scores of colour (6.1), appearance (5.8), oiliness (5.7) and size acceptability (6.3). On the other hand, the 15 mm cuts pre-dried for 120 minutes had significantly the highest protein (66.5%) and energy contents (402.1) and significantly the lowest moisture (14.1), total lipids (12.0) and peroxide values (0.5). Both

treatments had significantly different scores in colour and appearance, which were both within the acceptable range. The study concludes that in terms of nutritional quality the 15mm cut, pre-dried for 120 minutes would be most suited for commercialization. Based on sensory attributes, the decision to standardize and commercialize pastoral deep-fried products would have to be based on economic and cultural considerations.

Keywords: Deep-fried, Pre-drying, Chunk size, Pastoral meats, Physico-chemical, Quality sensory acceptability

Article published as: Gichure, J.N., Kunyanga, C.N. and Imungi, J.K. (2017). Standardization of the size of cut and pre-drying time of beef to mainstream pastoral processing in Kenya's meat industry. *Pastoralism*, 7(1), 1

5.1 INTRODUCTION

In Sub-Saharan regions, processing and preservation of meat by pastoralist is done locally in the villages, on-demand, mostly by women who rely on rudimentary technologies. The meat does not find its way to the formal market because of the challenges of lack of ease in package handling and unstandardized, unoptimized quality in processing and storage. The processing is mainly based on indigenous knowledge and the packaging lacks the finesse and the attractiveness of the modern meat package. The size of the cut varies extensively, between and within communities, even for the same product. The package used moreover may expose the products to vagaries of the weather increasing the susceptibility to autoxidation of the fat that the product is abundantly associated. The package used for these products has been demonstrated in our earlier publication (Gichure *et al.*, 2015). Currently, less than 5% of these products are marketed, mainly in the informal markets within the communities, while the rest is consumed at home. The products are not able to surmount the restrictions of the formal market due to various

limitations already described (Gichure *et al.*, 2016). In these communities, women rarely own resources and may have less education, and cannot access modern infrastructure. This additionally limits their participation in the formal meat products value chain. Previous research on willingness to pay for pastoral meats indicate that finely chopped meat that is tender is most preferred (Wanyoike *et al.*, 2009).

An earlier study reported that the most popular methods of processing and preservation in the pastoral regions of sub-Saharan Africa are deep-frying and sun-drying (Gichure *et al.*, 2014). These methods are considered part of traditional heritage in provision of high energy and protein diets (Lokuruka, 2006). In the past decade, studies have been conducted on optimization of the quality traits of these products but most of the studies have been limited to sundried products. However, as earlier stated, this practice only exists in the rural areas. Globalization and urbanization have introduced deep-fried poultry and fish products with considerable success in urban centres in the recent decades. This would indicate a possible opportunity for deep-fried beef, goat and camel snacks, which are traditionally processed and consumed in the rural areas of the pastoral regions, opening an opportunity for them to be mainstreamed into the commercial meat chains. This would in turn boost income generation by the communities, especially the women who are the main processors.

Deep-frying is considered more of a cooking and dehydration process in which the frying media, the oil attains 160 °C to 180 °C. Deep-frying involves simultaneous heat and mass transfer processes (Sosa-Morales *et al.*, 2006). These processes result in extensive changes in products appearance and physical properties; changes which are dependent on the time–temperature and the size of meat chunks (Sosa-Morales *et al.*, 2006; Ziaifar *et al.*, 2008). During frying, protein are denatured, water vaporized and a crust formed on the product surface; hence, deep-fried

snacks have characteristic flavour, texture, cooking-effect and satiety as reported by Colmenero (2003) and Acebron and Dopico (2000). The flavour, colour, texture and appearance of deep-fried meats results mainly from protein-carbohydrates interactive reactions (Dobarganes *et al.*, 2000; Choe and Min, 2007). Deep-frying by the pastoralists is often preceded by pre-drying in the sun to cut down on the moisture content and therefore reduce the oil damage during frying.

Animal fats have been used as frying medium for a long time by pastoralists; however health concern and demand for convenient ‘snack-like’ products has prompted a shift to use of vegetable oils as frying medium (Gichure *et al.*, 2014). Generally, animal fat have better heat transfer coefficient than vegetable oils. Vegetable oils with high contents of saturated fatty acids such as palm oil are increasing replacing use of rendered animal fats during deep-frying (Gichure *et al.*, 2015). In addition, saturated vegetable oils are more thermal stable, have better heat transfer coefficient and are less susceptible to oxidation than unsaturated vegetable oils (Ziaifar *et al.*, 2008). From this review, the study used palm oil as the frying media to capitalize on it’s high saturated fatty acids content; hence better heat transfer coefficient.

Hydrolysis, oxidation, and polymerization may occur during the deep-frying process (Choe and Min, 2007) and these influence the quality and acceptability of the product. The residual fat in the final products increases susceptibility to oxidative deterioration in nutritional and sensory qualities during storage.

This study was designed to standardize the size of cut and pre-drying time with a view to developing the most acceptable product quality with regard to physico-chemical characteristics and sensory acceptability. This would ease enable product mainstreaming into the formal market for enhanced income generation by pastoral communities from their livestock production.

5.2 METHODOLOGY

5.2.1 Study area

The study was done to mimic processing as done in the pastoral regions in Sub-Saharan Africa which are estimated to have 20 million pastoralists who depend largely on livestock and livestock products for income and food (Wellard-Dyer, 2012). In Kenya, there are approximately 4 million pastoralists (Kirkbride and Grahn, 2008) with an estimated livestock worth of US\$ 800 million per year (Lindqvist and Verba, 2009). Deep-fried products from the largest pastoral communities in Kenya were identified in our earlier research, processing steps identified and this study attempts to standardize the deep-frying process. Population-wise, the Somali, Turkana and Maasai are the main pastoral communities in Kenya (KNBS, 2009). The distribution of these communities is as shown in the map in Figure 5.1.

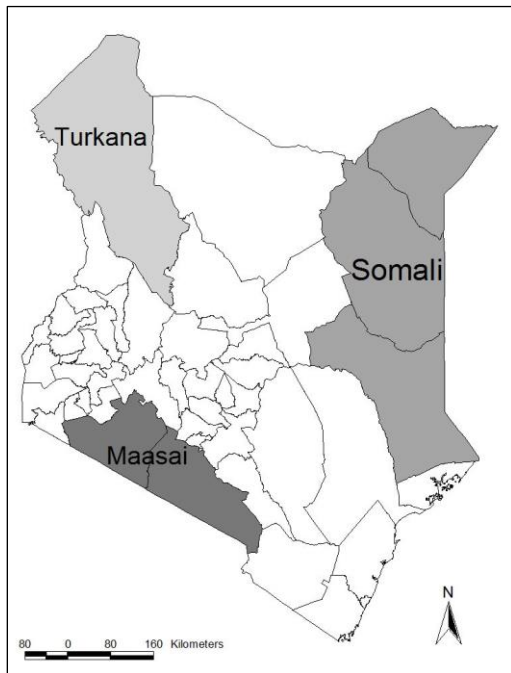


Figure 5.1: Map of Kenya showing the main pastoral communities

5.2.1 Study design

Split-plot design was used comprising three product sizes and three pre-drying times for each product size. The pre-drying temperature was 40 °C and the average deep-frying temperature was 170 °C.

Products Processing Procedures

Six kilograms of lean steak was obtained from the silver side of a mature cow, slaughtered in a local abattoir in Nairobi. The steak was divided into three chunks of approximately 2 kg each. The three chunks were each cut into approximately 10 mm, 15 mm and 20 mm cubical chunks. The three batches were then pre-dried at 40 °C for 0, 60 and 120 minutes using a thermostatically controlled cabinet dryer (Innotech model, Ingenieursgesellschaft mbH, Germany). The pre-drying environment was designed to simulate the prevailing environmental atmosphere conditions in the Kenyan pastoral regions during dry weather.

From each batch of pre-dried chunks, three samples of approximately 500 g each were taken and each deep fried at 170 °C in palm oil using a thermostatically controlled electric fryer (Caterina, model EF101CT/109, China) until the chunks showed a red-brown colour. After deep-frying, excess oil was decanted and the meat chunks placed on a stainless steel sieve for 120 seconds to drain off the excess oil. The chunks were then filled into coloured glass jars, and the jars tightly closed with metallic lids. This process is as shown in Figure 5.2.

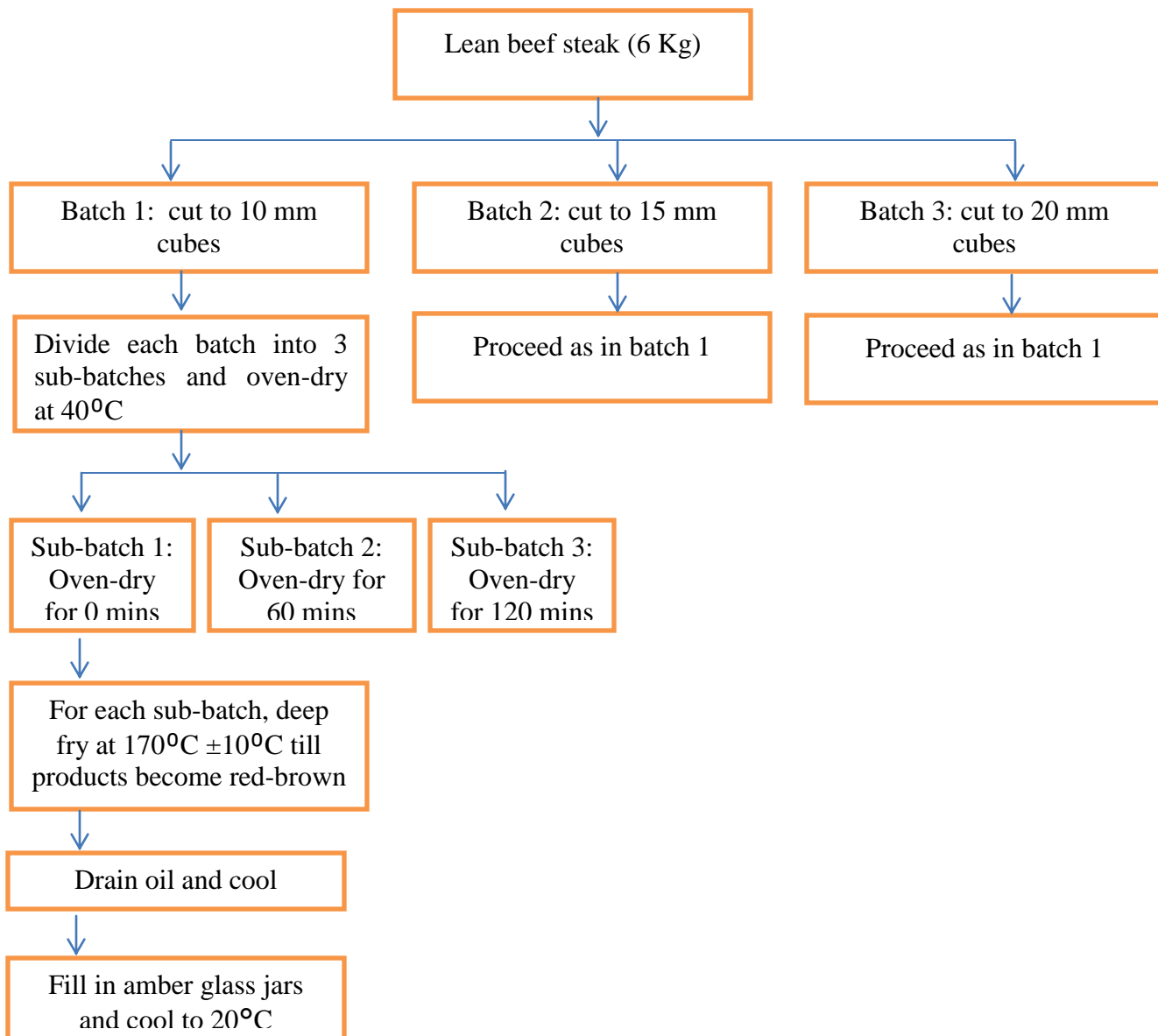


Figure 5.2: Processing flow diagram of meat chunks

5.2.2 Chemical Analyses

Immediately after frying, a sample from each frying was taken and analysed for proximate composition and sensory characteristics. Proximate composition comprising moisture, proteins, lipids, crude fibre, total ash and soluble carbohydrates were analysed by AOAC methods (AOAC, 2008). Moisture was determined in a thermostatically controlled air-oven by drying

about 5 g sample accurately weighed in a porcelain crucible at 105°C to constant weight. Soluble carbohydrates were calculated as a difference. Pearson (1976) formula was used to calculate the energy values from proteins, lipids and soluble carbohydrates using appropriate factors. Peroxide value was determined using AOAC methods (AOCS, 1993) and was expressed as milliequivalents (mEq) of active oxygen per kg of product.

5.2.3 Sensory Evaluation

For the final products, colour, appearance, ease of scooping, oiliness, size of chunks, aroma, taste, chewiness and overall acceptability were assessed using 11 trained panellists based on the methods of Elortondo *et al.* (2007) and Etaio *et al.* (2013), which are based on ISO 8587:2006 regulations. Random digits were used to code the samples for identification and the panellists were required to evaluate all attributes for each sample before receiving the next sample. Sample order was randomized to minimize bias due to positional effects. Water was provided, and where panellists were required to taste the samples, they were asked to expectorate and rinse their mouths after each sample. The sensory evaluation room was under similar light intensity, colour, aroma and texture, thus final scores for the products are comparable to each other. The panellists scored each attribute based on a 7-point hedonic rating scale with 7= like very much and 1= dislike very much.

5.2.4 Statistical Analysis

Genstat 15 (for windows) was used for statistical analysis. Analysis of Variance (ANOVA) was used to compare the sensory attributes while Duncan's multiple range tests at $P \leq 0.05$ was used to compare the least significant differences of the means.

5.3 RESULTS

5.3.1 Chemical Composition of Raw and Pre-dried Beef Chunks

After pre-drying in the oven, moisture content was seen to range between 74.2% and 77.6%, lipids range between 1.2% and 2.1%, proteins range between 19.5% and 21.9%, fibre range between 0.1% and 0.2%, total ash range between 1.0% and 1.2% while carbohydrates range between 0.1% and 1.3%. The chemical composition of oven-dried beef chunks is shown in Table 5.1.

5.3.2 Chemical Composition and Peroxide Value of Deep-fried Products

After deep-frying moisture content range was 14.1% and 19.4%, lipid content range between 10.8% and 15.4%, protein content range 52.1% and 66.5%, total ash range 3.7% and 3.9%, soluble carbohydrates 0.4% and 1.2%, energy content range between 329.7 Kcal/100g and 404.2 Kcal/ 100g while peroxide value range was 0.5% and 3.4%. The proximate composition of beef chunks after the deep-frying is shown in Table 5.2.

5.3.3 Sensory Characteristics of Deep-Fried Products

Based on a 7-point likert scale, the 20 mm cubes that had not being pre-dried were most preferred (overall acceptability score of 5.3). The products scored highest on ease of scooping (5.5), oiliness (5.4) and chunk size (5.4). The results of sensory evaluation of the deep-fried products are shown in Table 5.3.

Table 5.1: Proximate chemical composition of oven-dried beef chunks

Size of chunks (mm)	Pre-drying time (minutes)	Moisture (%)	Lipids (%)	Protein (%)	Fibre (%)	Total Ash (%)	Soluble carbohydrates (%)	Energy Kcal/100g
10	0	78.7 ^b ±6.5	1.9 ^c ±0.1	18.5 ^a ±3.5	0.1 ^a ±0.1	0.6 ^a ±0.1	0.1 ^a ±0.0	91.8 ^a ±7.9
10	60	77.6 ^{ab} ±7.6	1.3 ^{ab} ±0.7	19.9 ^a ±4.4	0.1 ^a ±0.1	1.0 ^a ±0.7	0.1 ^a ±0.1	91.4 ^a ±9.1
10	120	74.2 ^a ±9.8	1.2 ^a ±0.7	21.9 ^a ±3.9	0.2 ^a ±0.1	1.2 ^a ±0.2	1.3 ^b ±0.6	103.6 ^a ±8.8
15	0	78.7 ^b ±6.5	1.9 ^c ±0.2	18.5 ^a ±3.5	0.1 ^a ±0.1	0.6 ^a ±0.1	0.1 ^a ±0.1	91.8 ^a ±7.9
15	60	76.3 ^{ab} ±6.0	2.1 ^d ±0.4	19.5 ^a ±3.9	0.2 ^a ±0.1	1.0 ^a ±0.1	1.0 ^b ±0.3	101.0 ^a ±26.0
15	120	75.9 ^{ab} ±5.8	1.3 ^{ab} ±1.0	20.7 ^a ±4.2	0.1 ^a ±0.1	1.1 ^a ±0.5	1.0 ^b ±0.1	105.8 ^a ±8.8
20	0	78.7 ^b ±6.5	1.9 ^c ±0.2	18.5 ^a ±3.5	0.1 ^a ±0.1	0.6 ^a ±0.1	0.1 ^a ±0.1	91.8 ^a ±7.9
20	60	77.1 ^{ab} ±8.5	1.4 ^b ±0.5	20.3 ^a ±5.0	0.2 ^a ±0.1	1.0 ^a ±0.3	0.1 ^a ±0.1	93.9 ^a ±6.2
20	120	76.6 ^{ab} ±8.5	1.3 ^{ab} ±0.4	19.9 ^a ±4.3	0.2 ^a ±0.1	1.1 ^a ±0.1	1.0 ^b ±0.4	95.1 ^a ±13.3

Mean ± standard deviation (N= at least three determinations)

Table 5.2: Proximate analysis and peroxide values of deep-fried beef chunks

Size of chunks (mm)	Pre-drying time (minutes)	Moisture (%)	Lipids (%)	Proteins (%)	Total ash (%)	Soluble carbohydrates (%)	Energy (Kcal/100g)	Peroxide value (mEq/kg)
10	0	15.7±1.7 ^{bc}	15.4±1.9 ^e	65.4±5.2 ^{de}	3.9±0.1 ^a	1.0±0.4 ^a	404.2±20.4 ^d	2.5±0.1 ^c
10	60	14.9±3.6 ^{ab}	14.0±2.1 ^d	65.1±6.4 ^{de}	3.8±0.6 ^a	1.0±0.2 ^a	394.9±36.2 ^d	1.3±0.7 ^b
10	120	14.2±2.3 ^a	11.8±1.2 ^b	63.7±5.7 ^{cd}	3.8±1.2 ^a	4.9±1.5 ^d	380.8±18.5 ^c	1.2±0.2 ^b
15	0	17.1±3.0 ^d	15.0±2.1 ^e	64.0±6.7 ^{cde}	3.9±0.9 ^a	2.9±1.1 ^c	375.7±40.3 ^{bc}	1.3±0.7 ^b
15	60	16.0±2.4 ^c	10.8±1.7 ^a	65.3±6.0 ^e	3.9±1.0 ^a	2.2±0.3 ^{bc}	396.1±15.1 ^d	0.8±0.7 ^{ab}
15	120	14.1±3.6 ^a	12.0±1.5 ^b	66.5±9.3 ^e	3.9±1.4 ^a	0.4±0.1 ^a	402.1±29.6 ^d	0.5±0.1 ^a
20	0	19.4±5.5 ^e	12.6±3.9 ^{bc}	52.1±6.5 ^a	3.8±2.0 ^a	2.0±0.6 ^b	329.7±22.9 ^a	3.7±1.8 ^d
20	60	18.8±3.7 ^e	13.1±2.0 ^c	60.2±4.2 ^b	3.8±1.0 ^a	2.0±0.8 ^b	367.9±15.2 ^b	2.6±0.5 ^c
20	120	14.6±3.1 ^a	14.1±2.0 ^d	62.7±7.7 ^c	3.7±0.4 ^a	0.5±0.6 ^a	379.9±43.8 ^c	3.4±2.8 ^d

Mean ± standard deviation (N= at least three determinations)

Table 5.3: Mean score of sensory attributes of deep fried beef chunks

Size of cut (mm)	Pre-drying period (mins)	Colour	Appearance	Ease of scoping	Oiliness	Size of cut	Aroma	Taste	Chewiness	Overall acceptability	Mean score
10	0	4.5 ^a	4.5 ^a	5.9 ^a	5.8 ^a	5.3 ^{ab}	4.9 ^a	4.9 ^a	3.3 ^a	4.6 ^a	4.9
10	60	4.3 ^a	4.3 ^a	5.9 ^a	5.7 ^a	5.1 ^{ab}	4.8 ^a	4.9 ^a	3.8 ^{ab}	4.6 ^a	4.8
10	120	4.3 ^a	3.9 ^a	5.5 ^a	5.5 ^a	4.7 ^a	4.7 ^a	4.9 ^a	3.9 ^{ab}	4.7 ^a	4.7
15	0	4.9 ^a	4.7 ^{ab}	5.3 ^a	5.2 ^a	5.0 ^{ab}	5.0 ^a	5.2 ^a	4.4 ^b	4.9 ^a	5.0
15	60	4.9 ^a	4.5 ^a	5.4 ^a	5.3 ^a	5.6 ^{ab}	5.1 ^a	5.2 ^a	4.2 ^{ab}	4.9 ^a	5.0
15	120	4.8 ^a	4.5 ^a	5.7 ^a	5.3 ^a	5.8 ^{ab}	5.1 ^a	5.0 ^a	3.7 ^{ab}	4.8 ^a	5.0
20	0	6.1 ^b	5.8 ^b	5.5 ^a	5.7 ^a	6.3 ^b	5.0 ^a	4.9 ^a	3.5 ^a	4.6 ^a	5.3
20	60	5.1 ^{ab}	5.7 ^b	5.3 ^a	5.4 ^a	5.6 ^{ab}	5.4 ^a	4.7 ^a	4.3 ^b	4.7 ^a	5.1
20	120	5.1 ^{ab}	5.1 ^{ab}	5.3 ^a	5.1 ^a	5.4 ^{ab}	5.6 ^a	4.6 ^a	4.6 ^b	4.8 ^a	5.1
Mean		4.9	4.8	5.5	5.4	5.4	5.1	4.9	4.0	4.7	

Means followed by the same letter are not significantly different from each other ($p < 0.05$)

5.4 DISCUSSION

5.4.1 Chemical Composition of Raw and Pre-dried Beef Chunks

Pre-drying did not reduce the water content significantly within the cuts for the drying times tested. The percentage reduction in moisture content after drying decreased with increase in the size of the chunks, that is, from 4.5% in 10 mm cuts to 1.1% in 20 mm cuts. This was probably because of the decrease in the surface area to volume ratio and the increased distance which the water had to traverse from the inner to the surface. Previous researchers highlighted similar findings with regards to size and shape of the chunks (Sosa-Morales *et al.*, 2006; Ziaififar *et al.*, 2008). There was also considerable loss in lipids content during pre-drying which was attributed to melting abstraction from the tissues of part of the intramuscular fat. The protein and total ash showed an apparent increase after drying, especially for the 15 mm and 20 mm chunks. This could be due to the fact that pre-drying increased the dry matter with concentration effect of the components. Fibre in the meat represents indigestible carbohydrates while the carbohydrates value refers to sugars, mainly glycogen (Fernández-Ginés *et al.*, 2005). After pre-drying, these showed similar trends to proteins and total ash, due to the same reasons.

5.4.2 Chemical Composition and Peroxide Value of Deep-fried Products

Results show that smaller chunks had significantly more final total lipids and less moisture content than larger chunks. This may be due to the fact that smaller chunks have larger surface area to volume ratio; therefore, a larger area for oil uptake and moisture loss. In addition, smaller chunks have larger surface for oil to cling on thereby reducing the amount of oil that can be drained off. Deep-frying consists of two processes, dehydration and net fat absorption. The, moisture and lipid contents therefore depend on the continuous fat absorption to replace the water moisture lost due to evaporation and the continued oil

absorption after frying (Saguy and Dana, 2003). Heat and mass transfer during and after the deep-frying process depend on size, shape and proximate characteristics of the product. Oil uptake and moisture loss depends on the size and initial moisture content of food (Ziaifar, *et al.*, 2008; Vitrac *et al.*, 2002).

Protein and total ash content reported an apparent increase after deep-frying especially for the 10 mm and 15 mm chunks. Deep-frying extracted the water thereby increasing dry matter of the final products. The reduction in fibre and soluble carbohydrates contents after deep-frying points out their possible decomposition at 170°C. Fibre and soluble carbohydrates may have been further reduced as they take part in carbohydrates-proteins interactive chemical reactions such as the Maillard reactions (Choe and Min, 2007). The observed data do not bring out any particular trend in carbohydrates reduction signifying that these reactions use up the available carbohydrates.

Previous research by Dana and Saguy (2006) indicate that pre-drying prior to deep-frying reduces the time required for deep-fry, reduces the fat/ oil absorption of the products, and reduces rate of hydrolyses of deep-frying oil. Oven-drying was done for two hours to mimic sun-drying in pastoral regions. From the results, pre-drying at 40°C for less than two hours did not cause significant decrease in moisture content. This notwithstanding, pre-drying caused a significant decrease in lipids and moisture content of the final deep-fried products. As reported by Aprajeeta and others (2015), drying kinetics of foods may have caused the 20 mm chunks to develop mechanical stress and strain equilibrium inside the chunk matrix structure leading to non-uniform shrinkage. These cause porosity changes and cracking on the foods surface thereby increasing oil absorption and moisture loss in the final products.

Placing products on stainless steel sieves immediately after deep-frying to drain the deep-frying oil reduced the lipids content of the products. Other studies show that draining the

frying media immediately after deep-frying and before cooling considerably decrease the rate of oil absorption (Dana and Saguy, 2006). Similarly, in an earlier study, we reported that deep fried beef chunks cooled in deep-frying oil have fat content of 15.4% - 37.9% (Gichure *et al.*, 2016), which shows considerably reduction when oil is drained from products immediately after deep-frying.

Moisture loss and fat uptake during deep-frying have been reported to increase oxidation, hydrolysis and polymerization reactions of the oil (Choe and Min, 2007). Peroxide values were used to measure the extent of oxidation during the deep-frying process. All products had low and acceptable levels of peroxide value. Generally, increasing the pre-drying time reduced the peroxide values. This brings out the fact that pre-drying reduces moisture and lipids available for the oxidative reactions. On the other hand, chunk size contributed to the rate of chemical reactions; 10 mm cubes had higher peroxide values when compared to 15 mm cubes. This points out the fact that larger surface area to volume ratio increase oxidative reactions. The peroxide values decrease to some point and then increase as reactions between lipids, carbohydrates and moisture becomes more evident as was the case of the larger (20 mm) chunks.

5.4.3 Sensory Characteristics of Deep-Fried Products

Duncan's Multiple Range Test at 5% significance level reveals that chunk size and pre-drying had no significant influence on products' sensory qualities apart from colour, appearance, size and chewiness attributes. With the except of 10 mm chunks that had not been pre-dried, the mean scores for sensory attributes were greater than 3.5; and therefore were considered acceptable. Generally, larger chunks (20 mm cubes) were more preferred to smaller chunks (10 mm cubes). On the other hand, pre-drying time had a negative influence on sensory preference of the chunks. This study show acceptable scores for all attributes apart from

texture (chewiness). In terms of individual attributes, ease of scooping, oiliness, size, chewiness and aroma were the most preferred attributes. This was in line with previous studies (Adegoke and Falade, 2005; Troy and Kerry, 2010).

5.4 CONCLUSION AND RECOMMENDATION

The study shows that chunk size and pre-drying were the main factors that contribute to the chemical characteristics of deep-fried beef. Other factors that were identified were chemical composition after pre-drying and the amount of oil-draining after the deep-frying process. On the other hand, pre-drying and increasing the chunk size improved the sensory characteristics. Oxidation which has been reported to be the main cause of chemical spoilage was least in the 15-mm chunks while larger chunks (20 mm) had higher moisture content while smaller chunks (10 mm) had more lipids. Fibre, soluble carbohydrate and protein interactive reactions were seen to be associated with colour, appearance and aroma of deep-fried chunks. Pre-drying was seen to improve oiliness, aroma, chewiness and overall acceptability of deep-fried beef. Increasing the size of chunks was seen to improve the colour, appearance, aroma, taste, chewiness and overall acceptability.

CHAPTER SIX: EFFECT OF NITRITE CURING, HOT-SMOKING AND SUBMERGING CHUNKS IN FRYING OIL ON SHELF STABILITY OF DEEP-FRIED BEEF

ABSTRACT

Despite advances in meat preservation, pastoral communities are yet to mainstream indigenous deep-frying methods into formal value chains. Cold smoking, spices and immersing chunks in deep-frying media are used to increase shelf-stability. This study was therefore designed to evaluate the effect of nitrite curing, cooling chunks in deep-frying media and smoking on the shelf stability with regards to microbial, chemical and sensory attributes of deep-fried products packaged in plastic jars, glass jars and vacuum polythene bags. Accelerated shelf-life at 37°C for 15 days was conducted to simulate storage at room temperature 20°C for 90 days. Results show that hot-smoking at 65 °C for one hour reduced moisture content to (20.77±0.81), decreased free fatty acids and increased peroxide values and retarded microbial growth during storage. Nitrite curing greatly reduced the rate of increase in free fatty acids and peroxide values during storage. Curing also increased water holding capacity and this was attributed to presence of polyphosphate; final moisture content was 35.90±5.47% after deep-frying. Cured products performed best with regards to overall sensory acceptability. Storing the products in the deep-frying media decreased microbial spoilage, but chemical spoilage increased during prolonged storage. Plastic jars increased shelf-life the most while vacuum packaging in polythene bags performed poorly as the bags lost integrity during storage. The study recommends curing using nitrites, hot smoking after deep-frying for one hour at 65 °C and use of plastic or glass airtight jars as means of increasing shelf- stability of deep-fried beef chunks by pastoralists.

Keywords: *Smoking, Nitrite curing, Pastoral techniques, Deep-fried beef*

Article submitted as: Gichure, J.N., Kunyanga, C.N. and Imungi, J.K. Chemical and sensory attributes of selected meat products from the Kenyan pastoral communities. *Journal of Food Science and Technology*

6.1 INTRODUCTION

Deep-frying is one of the main meat processing and preservation techniques used by pastoral communities in Africa. Over time, spices, smoke, encapsulating meat in deep-frying oil or spiced-syrup to create anaerobic environment and containers made from wood and leather have been used to package the products for storage deep-fried meats by pastoralists in Kenya (Gichure *et al.*, 2014). Previous studies showed that ground cardamom seeds is used by some communities to improve aroma while the wooden containers are sanitized by fumigated them using *Balanites rotundifolia* prior to packaging. Anaerobic storage is done by cooling deep-fried chunks in the deep-frying media to encapsulate the products (Gichure *et al.*, 2016).

However, these indigenous technologies are yet to be mainstreamed into the formal meat value chain primarily because they lack a competitive edge over modern preservation techniques. Empirical data have shown that smoke and spices have antioxidants which retard chemical spoilage in foods that are prone to autoxidation (Velasco and Williams, 2011; Tajkarimi *et al.*, 2010; Singh *et al.*, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005). In addition, smoke and spices retard growth of most pathogenic and spoilage microorganisms. Our earlier study reported that storage of beef chunks stored submerged in oil creates anaerobic condition that may retard microbial quality but increase chemical spoilage (Gichure *et al.*, 2016). Curing entails addition of nitrites to fix colour of meat, prevent rancidity, decrease susceptibility to spoilage by microorganisms, stabilize flavour and improve heat stability of products during the cooking process (Andrée *et al.*, 2010). Nitrate is usually

reduced to nitrite during processing and storage, hence the amount added during processing targets the specific shelf-life period. About 150 ppm of nitrite have been shown to prevent oxidation of meat lipids for about five weeks while 25 and 50 ppm nitrite reduced oxidation by about 25% and 44% respectively (Honikel, 2008). Nitrite has not been used in deep-fried pastoral meat but it forms a key component in sun-dried pastoral beef in Africa (Petit *et al.*, 2014).

Sensory attributes such as colour, flavour, texture and appearance; and physiochemical attributes such as lipid oxidation, moisture content and fat content and microbial safety are important factors that determine the shelf life of low water activity meat products (Petit *et al.*, 2014; Choe and Min, 2007; Saguy and Dana, 2003). Presence of oxygen and moisture negatively affects flavour stability, texture and lipid oxidation of deep-fried products. Deep-fried products tend to absorb moisture during storage and this affects their colour, aroma and crispiness. Lipid oxidation produces free radicals, which are responsible for rancid aromas associated with deep-fried products.

With regards to packaging, some of the factors to consider during package design are cost, safety, package material, size of product, recyclability, design, convenience and utility (Lee, 2010; Duizer *et al.*, 2009; Han, 2009). Packaging is supposed to extend shelf-life and preserves quality of food (Brody *et al.*, 2008). It should protect products against deteriorative effects from the environment that may cause off-flavour and off-aroma development, discoloration, nutrient loss, texture changes, microbial growth among others. In addition, packaging increases product value, promotes sales and communicates important information on the product (Han, 2009). Experimental designs for stability assessments are mostly based on development or degradation of undesirable characteristics over time (Guillet and Rodrigue, 2009; Min *et al.*, 2009).

Depending on the processing treatments and packaging, hydrolytic and oxidative rancidity can occur during processing and storage of fried foods (Saguy and Dana, 2003; Shahidi and Wanasundara, 2002). Hydrolytic rancidity is hydrolysis of triglycerides into free fatty acids and glycerol while oxidative rancidity is oxidation of lipid into hydro-peroxides. Free fatty acids value is used to show the extent of hydrolysis of triglycerides. On the other hand, peroxide value is used to show extent of fat oxidation (Singh and Anderson, 2004). Generally, the peroxide value increases during storage as fat gets oxidized. During processing and storage, polyunsaturated and unsaturated fatty acids present in the fats usually react with oxygen to form hydro-peroxides. Hydro-peroxides are unstable, and breakdown into various compounds which consequently produce off-flavours; leading to a stale, rancid flavour in foods (Angelo, 1992). In as much as chemical analysis provides valuable information on expected effects of process treatment, sensory analysis is a definitive way of assessing acceptability (Russell *et al.*, 2005). Sensory analysis can be used assess the effect of oxidation, non-enzymatic processes, dehydration, among other important reactions on the quality of processed meats.

During the deep-frying process, the frying media attains almost 150°C and products are cooked for almost 10 minutes. This implies that survival of microorganism during deep-frying is limited. Improper handling and packaging in containers that are not adequately sanitized may introduce pathogenic and spoilage microorganisms in foods. Whether microorganisms would be present in deep-fried products which have antimicrobials and antioxidants present have not been fully investigated. *E. coli*, *L. monocytogenes*, Salmonella and Campylobacter are the common pathogens associated with meat products (Véronique, 2008; Cutter, 2000). Microbiological monitoring mostly focuses on testing for indicator organisms. *L. monocytogenes* is considered to be the most dangerous heat-tolerant pathogen in meat products and therefore, microbiological criteria for heat treated meat products are often based

on this organism. It is assumed to be destroyed by processing at 70 °C for 2 min, or equivalent. In addition, *Listeria* is able to survive and multiply in oxygen and temperature stresses environments (Lungu *et al.*, 2009). For ready to eat meat products, microbiological safety is based on *E. coli*, total viable bacteria and Salmonella. *Staphylococci aureus* is an important indicator of personal hygiene during processing and handling (Lues and van Tonder, 2007).

6.2 RESEARCH DESIGN AND METHODOLOGY

6.2.1 Experimental Design

Split-plot design was used to evaluate the effect of different processing treatments and packaging on shelf-life of the deep-fried meat products. The dependent variables in the study were chemical, microbial and sensory attributes while the independent variables were processing treatments, package and number of days during storage. Three replicates were used to block the experimental design.

Processing treatments

Twelve-kilogram lean steak from hind leg of mature Borana bull were obtained from Dagoretti slaughter house in Nairobi, and taken to the University of Nairobi, Department of Food Science Nutrition and Technology pilot plant within two hours of slaughter. The meat was divided into four equal portions, each three kilograms.

Batch 1: The first portion was placed for 6 days in a cold room at 4°C after which it was cut to smaller cubes of approximately 2cms³. The cubes were pre-dried using a thermostatically controlled cabinet dryer (Innotech model, Ingenieurgesellschaft mbH, Germany) for 120 minutes at 40 °C. After pre-drying, the chunks were deep-fried using palm oil at 170 °C in palm oil using a thermostatically controlled electric fryer (Caterina, model EF101CT/109,

China) for 10 minutes. Excess oil was drained off by placing the chunks on a stainless steel sieve for two minutes. The chunks were then placed in a smoke chamber (Wilhelm Fessmann, Germany) for 60 minutes at 65 °C. Cyprus wood was burnt to generate the smoke. The smoked products were then cooled in ambient temperatures and packaged.

The batch was divided into three sets, each set was about 100 grams. The first set was vacuum packed in a polythene bag (gauge 300), the second set was packed in an airtight colorless plastic jars while the third set was packed in an airtight colorless glass jar.

Batch 2: The second portion was placed for 6 days in a cold room at 4°C after which it was cut to smaller cubes of approximately 2cms. The cubes were pre-dried using a thermostatically controlled cabinet dryer (Innotech model, Ingenieursgesellschaft mbH, Germany) for 120 minutes at 40 °C. After pre-drying, the chunks were deep-fried using palm oil at 170 °C in palm oil using a thermostatically controlled electric fryer (Caterina, model EF101CT/109, China) for 10 minutes. About 10 grams cardamom spice had been added to the five litres oil used to deep-frying. Excess oil was drained off by placing the chunks on a stainless steel sieve for two minutes. The products were then cooled in ambient temperatures and packaged.

The batch was divided into three sets, each set was about 100 grams. The first set was vacuum packed in a polythene bag (gauge 300), the second set was packed in an airtight colorless plastic jars while the third set was packed in an airtight colorless glass jar.

Batch 3: The third portion was placed for 6 days in a cold room at 4 °C after which it was cut to smaller cubes of approximately 2cms. The cubes were pre-dried using a thermostatically controlled cabinet dryer (Innotech model, Ingenieursgesellschaft mbH, Germany) for 120 minutes at 40°C. After pre-drying, the chunks were deep-fried using palm oil at 170 °C in palm oil using a thermostatically controlled electric fryer (Caterina, model EF101CT/109,

China) for 10 minutes. The product was cooled at ambient temperature and packaged. The deep-frying media was added to submerge the products in the package.

The batch was divided into three sets each about 100 grams. The first set was vacuum packed in a polythene bag (gauge 300), the second set was packed in an airtight transparent plastic jars while the third set was packed in an airtight clear glass jar.

Batch 4: The fourth portion was immediately put in curing brine (100 ppm nitrite solution) for 6 days in a cold room at 4°C. After six days, the chunks were cut to smaller cubes of approximately 2 cms. The cubes were pre-dried using a thermostatically controlled cabinet dryer (Innotech model, Ingenieursgesellschaft mbH, Germany) for 120 minutes at 40 °C. After pre-drying, the chunks were deep-fried using palm oil at 170 °C in palm oil using a thermostatically controlled electric fryer (Caterina, model EF101CT/109, China) for 10 minutes. Excess oil was drained off by placing the chunks on a stainless steel sieve for two minutes. After draining, the products were cooled in ambient temperatures and packaged.

The batch was divided into three sets, each set was about 100 grams. The first set was vacuum packed in a polythene bag (gauge 300), the second set was packed in an airtight colourless plastic jars while the third set was packed in an airtight colourless glass jar.

6.2.2 Accelerated Storage to Product Shelf-life

Accelerated storage has been used to study shelf-life of foods. Storage at elevated temperatures is used to simulate product shelf-life at typical storage conditions. This process is based on Q_{10} value, that is, the temperature quotient for a 10°C temperature difference.

$$Q_{10} = \frac{\text{storage at given temperature}(t^{\circ}\text{C})}{\text{Shelf – life at accelerated temperature } (t^{\circ}\text{C} + 10^{\circ}\text{C})}$$

Based on previous research, deep-fried beef have a shelf-life of 90 days at 20°C (Gichure *et al.*, 2016). Using the basic assumption that Q10 value for fried foods is 2, storage at 37°C can be used to predict shelf-life for products using 15 days based on the formula.

Samples under accelerated shelf-life were analysed on Day 0, Day 5, Day 10 and Day 15.

Table 6.1 presents the experimental design used in the study.

Table 6.1: Experimental design used in the study

	Day 0			Day 5			Day 10			Day 15		
	Package 1	Package 2	Package 3	Package 1	Package 2	Package 3	Package 1	Package 2	Package 3	Package 1	Package 2	Package 3
Treatment 1												
Treatment 2												
Treatment 3												
Treatment 4												

6.2.3 Analytical methods

6.2.3.1 Chemical analysis

Moisture content, free fatty acids and peroxide values were analysed using standard methods. Moisture content was determined by drying to constant weight at 105 °C in an air oven according to the AOAC Methods (AOAC, 2008- Method 967.08).

Peroxide value was based on AOAC methods (AOAC, 2008 -Method 965.33). About 5 g sample was dissolved in 20 mL glacial acetic acid/chloroform (2:1) mixture. 1 g powdered potassium iodide solution was added. The mixture was heated for about 30 seconds. The liberated iodine was then titrated with 0.002 M sodium thiosulfate. The results were expressed as milliequivalents (mEq) of active oxygen per kg of product.

Free fatty acid value was based on standard methods (ISO 660:2009). Twenty-five-millilitres diethyl ether and 25 mL ethanol were mixed and the solution neutralized with 0.1 N sodium hydroxide solution. About 5 g of the sample weighed accurately was placed into the mixed neutral solution. This solution was then titrated with a 0.1 M sodium hydroxide solution to the end point. Phenolphthalein was used as the colour indicator. Free Fatty Acids was expressed as the g of potassium hydroxide required to neutralize free acid in 100 g sample.

6.2.3.2 Microbial analysis

Microbial quality of the products was evaluated to establish the time period for detectable changes in microbial quality during storage. *Listeria monocytogenes* was analysed using ISO 11290-1:2004 methodology, *E. coli* using ISO 16649-3:2001 methodology, *Staphylococcus aureus* using ISO 6888-1:1999 methodology, *Salmonella* using ISO 6579 methodology while Total Plate Count was analysed using ISO 4833-2:2013 methodology. Spread plating was done for individual organisms while pour plating was done for Total Plate Count only. Ten grams of each sample was aseptically placed into a stomacher bag, then homogenised with 90

mL of sterile 0.1% peptone water in a masticator blender for 2 min at room temperature. The microbiological data was then transformed into logarithms of the number of colony forming units (CFU/g).

6.2.4 Sensory Evaluation

Color, appearance, ease of scooping, preference based on size of meat chunks, preference based on oiliness, aroma, taste and chewiness was evaluated using 11 trained panellists based on the method of Elortondo *et al.* (2007) and Etaio *et al.* (2013), which are based on ISO 8587:2006 regulations.. The products were given unique codes and the panellists were requested to rank them using the following 7-points Likert scale based on their preference, where, 7 = Like very much; 6 = Like moderately; 5 = slightly like; 4 = neither like nor dislike; 3 = slightly dislike; 2 = Dislike moderately; 1 = extremely bad. After assessing each sample, the panellists were requested to rinse their mouth with distilled water which was provided.

6.2.5 Statistical Analysis

Values for chemical analysis were presented at mean of three determination \pm standard deviation.

For microbial assessment, the counts were represented as colony forming units per gram (CFU/g) after enumeration. The counts were then converted into logarithms which were presented as \log_{10} using Microsoft excel package.

For sensory evaluation, Genstat for Windows Version 15 (VSN International Limited) was used for statistical analysis. Analysis of Variance (ANOVA) for the four treatments was determined using the least significant difference (LSD) method at 5% level. Duncan's multiple comparison tests at $P \leq 0.05$ was used to compare the means.

6.3 RESULTS

6.3.1 Chemical analysis

6.3.1.1 Moisture content

From the study, the moisture content ranged between 20.8% and 35.9%. The smoked batch had the lowest moisture content while the cured batch had the most. During storage, plastic and glass jar recorded least increases in moisture increase compared to polythene bag. The chunks submerged in deep-frying oil also recorded the least increase in moisture content. The means and standard deviation of moisture content values are presented in Table 6.2.

Table 6.2: Changes in moisture content of differently packaged deep-fried beef chunks

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	20.77±0.81 ^a	20.82±2.88 ^a	21.66±1.08 ^b	23.03±2.14 ^c
	P2	20.77±0.81 ^a	21.03±1.83 ^a	21.42±1.09 ^b	22.31±1.25 ^b
	P3	20.77±0.81 ^a	21.14±2.18 ^a	21.19±1.25 ^{ab}	22.51±2.08 ^{bc}
T2	P1	33.75±6.65 ^b	35.25±2.15 ^b	35.39±3.27 ^c	36.29±3.23 ^d
	P2	33.75±6.65 ^b	36.07±2.43 ^{bc}	37.79±3.03 ^d	38.25±1.08 ^e
	P3	33.75±6.05 ^b	37.31±0.74 ^{de}	37.37±2.47 ^d	38.17±3.30 ^e
T3	P1	21.51±1.49 ^a	20.57±0.52 ^a	20.61±2.04 ^a	20.15±1.76 ^a
	P2	21.51±1.49 ^a	21.23±0.77 ^a	21.65±1.24 ^b	22.33±2.14 ^b
	P3	21.51±1.49 ^a	21.35±0.04 ^a	21.52±1.44 ^b	22.62±1.21 ^{bc}
T4	P1	35.90±5.47 ^c	36.45±6.57 ^{cd}	35.95±5.74 ^c	39.70±3.45 ^f
	P2	35.89±5.47 ^c	37.60±4.48 ^e	39.10±2.23 ^e	41.00±2.34 ^h
	P3	35.89±5.47 ^c	37.47±3.27 ^{de}	38.99±2.23 ^e	40.39±2.86 ^g

Legend:

Means ± SD (N=two replications) followed by different letter in same column are significantly different (P<0.05).

Day 0: Treatment F<0.001, Package F= 1.000 while Treatment-Package F=1.000

Day 5: Treatment F<.001, Package F=0.002 while Treatment-Package F= 0.185

Day 10: Treatment, Package and Treatment-Package F<.001

Day 15: Treatment, Package and Treatment-Package F<.001

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.1.2 Free fatty acids

Lipolysis was measured using free fatty acids whose values was seen to range between 0.18% and 0.57% after process treatment. The smoked batch had the least free fatty acids value after process treatment while curing had the most. After 15 days at 37 °C, the batch cured with nitrite and the smoked batch had significantly the least acid values. Vacuum packed polythene bags had significantly lower free fatty acid values. Table 6.3 brings out the changes in free fatty acid of differently packaged deep-fried beef chunks under different treatments and storage times.

Table 6.3: Changes in free fatty acid of differently packaged deep-fried beef chunks

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	0.18±0.08 ^a	0.47±0.03 ^a	0.92±0.01 ^b	1.04±0.02 ^{ab}
	P2	0.18±0.08 ^a	0.93±0.08 ^{bc}	0.84±0.07 ^{ab}	0.92±0.06 ^a
	P3	0.18±0.08 ^a	0.87±0.02 ^{bc}	0.98±0.00 ^b	1.05±0.04 ^{ab}
T2	P1	0.28±0.07 ^a	0.90±0.49 ^{bc}	1.59±0.07 ^c	1.29±0.23 ^c
	P2	0.28±0.07 ^a	0.84±0.01 ^{bc}	1.28±0.06 ^c	1.62±0.01 ^d
	P3	0.28±0.07 ^a	0.90±0.23 ^{bc}	1.55±0.07 ^c	1.72±0.01 ^d
T3	P1	0.28±0.40 ^a	0.73±0.08 ^{ab}	0.89±0.10 ^{ab}	1.49±0.04 ^{cd}
	P2	0.28±0.40 ^a	0.67±0.02 ^{ab}	0.87±0.03 ^{ab}	0.96±0.04 ^a
	P3	0.28±0.40 ^a	0.60±0.06 ^{ab}	0.87±0.02 ^{ab}	1.55±0.13 ^{cd}
T4	P1	0.57±0.03 ^a	1.00±0.01 ^c	0.64±0.16 ^a	0.94±0.18 ^a
	P2	0.57±0.03 ^a	0.71±0.14 ^{ab}	0.74±0.07 ^a	0.87±0.01 ^a
	P3	0.57±0.03 ^a	0.73±0.00 ^{ab}	0.76±0.03 ^a	0.99±0.02 ^{ab}

Legend:

Means ± SD (N=two replications) followed by different letter in same column are significantly different (P<0.05).

Day 0: Treatment F<0.001, Package F= 1.000 while Treatment-Package F=1.000

Day 5: Treatment F<0.001, Package F= 0.161 while Treatment-Package F=0.084

Day 10: Treatment, Package and Treatment-Package F<.001

Day 15: Treatment, Package and Treatment-Package F<.001

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.1.3 Peroxide values

Peroxide values were used to bring out oxidation during storage. After process treatment, peroxide values were seen to range between 1.00 and 1.82. The batch cured with nitrite recorded significantly lower peroxide values after processing and during storage. After accelerated storage, cured batch had significantly the least peroxide values, followed by the smoked batch. Peroxide values were seen to increase by the greatest margin on day 10 and day 15. Table 6.4 brings out the extent of peroxidation among differently packaged deep-fried beef chunks under different treatments and storage times.

Table 6.4: Peroxidation among differently packaged deep-fried beef chunks

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	1.00±0.05 ^c	1.87±0.16 ^d	2.91±0.11 ^{abc}	4.85±0.11 ^c
	P2	1.00±0.05 ^c	1.70±0.10 ^{bcd}	4.80±0.23 ^f	4.80±0.54 ^c
	P3	1.00±0.05 ^c	1.82±0.04 ^{cd}	2.32±0.11 ^a	6.07±0.02 ^d
T2	P1	0.65±0.22 ^b	1.37±0.38 ^b	3.65±0.06 ^{dc}	5.95±0.06 ^d
	P2	0.64±0.22 ^b	1.41±0.03 ^b	4.15±0.41 ^e	4.02±0.16 ^{ab}
	P3	0.64±0.22 ^b	1.46±0.16 ^c	3.48±0.07 ^{cd}	6.99±0.07 ^e
T3	P1	1.82±0.04 ^d	3.59±0.07 ^f	2.76±0.08 ^{ab}	7.89±0.09 ^f
	P2	1.82±0.04 ^d	2.38±0.13 ^e	3.15±0.04 ^{bcd}	7.23±0.07 ^e
	P3	1.82±0.04 ^d	1.81±0.16 ^{cd}	3.63±0.74 ^{de}	7.80±0.10 ^f
T4	P1	0.28±0.04 ^a	2.47±0.02 ^e	2.90±0.03 ^{abc}	4.20±0.28 ^b
	P2	0.28±0.04 ^a	1.39±0.13 ^b	2.27±0.06 ^a	3.60±0.02 ^a
	P3	0.28±0.04 ^a	1.01±0.15 ^a	3.05±0.03 ^{bcd}	4.06±0.02 ^{ab}

Legend:

Means ± SD (N=two replications) followed by different letter in same column are significantly different (P<0.05).

Day 0: Treatment F<0.001, Package F= 1.000 while Treatment-Package F=1.000

Day 5: Treatment, Package and Treatment-Package F<.001

Day 10: Treatment F<.001, Package F=0.004 and Treatment-Package F<.001

Day 15: Treatment, Package and Treatment-Package F<.001

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.2 Microbiological Characteristics

6.3.2.1 Total Viable Counts

The spiced batch had significantly more total aerobic microbes' viable counts after processing (3.4 log CFU/g). During storage, there was a least increase in the number of organisms in this batch (maximum of 1.55 log CFU/g). The smoked (maximum of 4.60 log CFU/g) and cured batches (maximum of 4.59 log CFU/g) recorded lowers scored during storage and there were no significant differences between these two samples. Storage in glass jars and plastic containers recorded significantly lower scores for total viable counts. Table 6.5 brings out the changes in Total Viable Counts in deep-fried beef chunks under different treatments and packaging materials during storage.

Table 6.5: Changes in Total Viable Counts in deep-fried beef chunks during storage

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	2.79 (0) ^a	3.17 (0.38) ^{abc}	3.84 (1.05) ^a	4.60 (1.81) ^a
	P2	2.79 (0) ^a	3.04 (0.25) ^a	3.80 (1.01) ^a	4.57 (1.78) ^a
	P3	2.79 (0) ^a	3.11 (0.32) ^{ab}	3.83 (1.04) ^a	4.35 (1.56) ^a
T2	P1	3.43 (0) ^b	4.60 (1.17) ^h	6.45 (3.02) ^h	6.55 (3.12) ^c
	P2	3.43 (0) ^b	4.55 (1.12) ^h	5.84 (2.41) ^g	6.42 (2.99) ^c
	P3	3.43 (0) ^b	4.53 (1.10) ^h	5.55 (2.12) ^f	6.48 (3.05) ^c
T3	P1	2.99 (0) ^a	3.81 (0.82) ^g	5.08 (2.18) ^e	5.94 (2.95) ^b
	P2	2.99 (0) ^a	3.66 (0.67) ^{fg}	4.76 (1.77) ^d	5.73 (2.74) ^b
	P3	2.99 (0) ^a	3.57 (0.58) ^{ef}	4.71 (1.72) ^d	5.88 (2.89) ^b
T4	P1	3.04 (0) ^a	3.44 (0.40) ^{de}	4.35 (1.31) ^c	4.46 (1.42) ^a
	P2	3.04 (0) ^a	3.33 (0.29) ^{cd}	3.99 (0.95) ^{ab}	4.33 (1.29) ^a
	P3	3.04 (0) ^a	3.30 (0.26) ^{bcd}	4.18 (1.14) ^{bc}	4.59 (1.55) ^a

Legend

Means followed by different letter are significantly different (P<0.05).

Figures in parenthesis represent log increase in microbial content.

Day 0: Treatment, Package and Treatment-Package interaction- F<0.001

Day 5: Treatment (F<0.001) and Package F=0.036 account for significant differences. Treatment-Package interaction (F=0.781)

Day 10: Treatment (F<0.001), Package (F<0.001) and Treatment-Package interactions (F=0.007) Day 15: Treatment (F<0.001), Package (F=0.020) and Treatment. Package interactions (F=0.028)

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.2.2 Catalase positive staphylococcus

Apart from the nitrite cured batch, deep-fried products had significantly low counts on day 0 with 1.15 log CFU/g identified at this day. During accelerated storage, there was a slight increase in the numbers of colonies in smoked (maximum of 1.62 log CFU/g) and cured sample (maximum of 1.44 log CFU/g). However, the spiced batch recorded the greatest increase in catalase positive staphylococcus colony forming units (maximum of 3.12 log CFU/g). The samples stored in polythene bags recorded significantly higher log CFU/g than that stored in glass and plastic jars. Table 6.6 brings out the changes in catalase positive staphylococcus in deep-fried beef chunks under different treatments and packaging materials during storage.

Table 6.6: Changes in staphylococcus in deep-fried beef chunks during storage

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	1.30 (0) ^{ab}	1.93 (0.63) ^{abc}	2.06 (0.76) ^{cd}	2.92 (1.62) ^c
	P2	1.30 (0) ^{ab}	1.69 (0.39) ^{ab}	2.00 (0.70) ^{bcd}	2.70 (1.40) ^{ab}
	P3	1.30 (0) ^{ab}	1.65 (0.35) ^a	1.90 (0.60) ^{abc}	2.51 (1.21) ^a
T2	P1	1.38 (0) ^{bc}	2.40 (1.02) ^{de}	2.69 (1.31) ^f	4.36 (2.98) ^d
	P2	1.38 (0) ^{bc}	2.58 (1.20) ^e	2.48 (1.10) ^e	4.39 (3.01) ^d
	P3	1.38 (0) ^{bc}	2.20 (0.82) ^{cd}	2.41 (1.03) ^e	4.50 (3.12) ^d
T3	P1	1.15 (0) ^a	1.95 (0.80) ^{abc}	2.18 (1.03) ^d	2.96 (1.81) ^c
	P2	1.15 (0) ^a	1.67 (0.52) ^{ab}	2.11 (0.96) ^{cd}	2.81 (1.66) ^{bc}
	P3	1.15 (0) ^a	1.65 (0.50) ^a	1.99 (0.84) ^{bcd}	2.83 (1.68) ^{bc}
T4	P1	1.56 (0) ^c	2.02 (0.46) ^{cd}	1.97 (0.41) ^{abcd}	2.92 (1.36) ^c
	P2	1.56 (0) ^c	1.90 (0.34) ^{abc}	1.83 (0.27) ^{ab}	3.00 (1.44) ^c
	P3	1.56 (0) ^c	2.00 (0.44) ^{bc}	1.78 (0.22) ^a	2.87 (1.31) ^{bc}

Legend

Means followed by different letter are significantly different (P<0.05).

Figures in parenthesis represent log increase in microbial content from day 0.

Day 0: Treatment F<0.001, Package F= 1.000 while Treatment-Package F=1.000

Day 5: Treatment, Package and Treatment. Package $F < .001$

Day 10: Treatment $F < .001$, Package $F = 0.004$ and Treatment-Package $F < .001$

Day 15: Treatment, Package and Treatment-Package $F < .001$

Day 5: Treatment ($F < 0.001$). Package and Treatment. Package interactions with $F = 0.057$ and $F = 0.250$ Day 10: Treatment ($F < 0.001$) and Package ($F = 0.002$). Treatment-Package interactions $F = 0.886$.

Day 15: Treatment ($F < 0.001$) and Treatment-Package interactions ($F = 0.023$). Package alone $F = 0.081$)

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.2.3 Listeria

There were no significant differences between the numbers of Listeria colony forming units after processing. During storage, the smoked batch recorded the least increase (maximum increase of 0.79 log CFU/g) followed by the batch submerged in deep-frying oil (maximum increase of 1.37 log CFU/g). Significantly higher numbers were recorded for the spiced batch (scores of up-to 3.98 log CFU/g). The samples stored in polythene bags recorded significantly higher log CFU/g than that stored in glass and plastic jars. Table 6.7 brings out the changes in Listeria in deep-fried beef chunks under different treatments and packaging materials during storage.

Table 6.7: Changes in Listeria in deep-fried beef chunks during storage

Treatment	Package	Day 0	Day 5	Day 10	Day 15
T1	P1	1.15 (0) ^a	1.54 (0.39) ^b	1.85 (0.70) ^{abc}	1.94 (0.79) ^{ab}
	P2	1.15 (0) ^a	1.39 (0.24) ^{ab}	1.45 (0.30) ^a	1.80 (0.65) ^a
	P3	1.15 (0) ^a	1.39 (0.24) ^{ab}	1.69 (0.54) ^{ab}	1.66 (0.51) ^a
T2	P1	1.57 (0) ^a	1.98 (0.41) ^{cd}	2.63 (1.06) ^{def}	3.90 (2.33) ^f
	P2	1.57 (0) ^a	2.04 (0.47) ^d	2.78 (1.21) ^{ef}	3.98 (2.41) ^f
	P3	1.57 (0) ^a	1.97 (0.40) ^{cd}	3.00 (1.43) ^f	3.70 (2.13) ^f
T3	P1	1.23 (0) ^a	1.15 (-0.08) ^a	2.40 (1.17) ^{cdef}	2.60 (1.37) ^{cde}
	P2	1.23 (0) ^a	1.74 (0.51) ^{bcd}	2.19 (0.96) ^{bcd}	2.25 (1.02) ^{bc}
	P3	1.23 (0) ^a	1.73 (0.50) ^{bcd}	2.08 (0.85) ^{bcd}	2.30 (1.07) ^{bc}
T4	P1	1.15 (0) ^a	1.48 (0.33) ^{ab}	2.26 (1.11) ^{bcd}	2.80 (1.65) ^e
	P2	1.15 (0) ^a	1.54 (0.39) ^b	2.02 (0.87) ^{abcd}	2.71 (1.56) ^{de}
	P3	1.15 (0) ^a	1.65 (0.50) ^{bc}	2.08 (0.93) ^{bcd}	2.32 (1.17) ^{bcd}

Legend

Means followed by different letter are significantly different ($P < 0.05$).

Figures in parenthesis represent log increase in microbial content.

Day 0: Treatment- $F=0.066$; Package- $F=1.000$ and Treatment-Package interaction- $F=1.000$)

Day 5: Treatment ($F < 0.001$) and Treatment-Package interaction ($F=0.044$) account for significant differences. Package alone ($F=0.116$)

Day 10: Treatment ($F < 0.001$) account for significant differences. Package alone ($F=0.359$) and Treatment-Package interaction ($F=0.535$)

Day 15: Treatment ($F < 0.001$) and Package ($F=0.010$) accounted for significant differences. Treatment-Package interactions $F=0.497$

T1 represent Smoked, T2 represent sample with cardamom spice, T3 represent sample stored in submerged deep-frying media, T4 represent sample with nitrite.

P1 represent vacuum packed sample in polythene sheet, P2 represent sample packed in plastic jars, P3 represent sample packed in glass jars

6.3.3 Sensory Characteristics

Curing with nitrite significantly increased appearance (6.46 ± 0.82), colour (6.64 ± 0.50), oiliness (6.00 ± 0.89), taste (6.45 ± 0.82), chewiness (6.09 ± 1.14) and overall acceptability (6.45 ± 0.52). Hot smoked chunks scored highly with regards to appearance (5.55 ± 1.44), colour (5.55 ± 1.57), oiliness (6.18 ± 1.47) and taste (5.18 ± 1.25). Addition of cardamom in the deep-frying media significantly improved colour (5.36 ± 1.63), oiliness (5.91 ± 1.22), aroma (5.45 ± 2.30), taste (6.09 ± 1.22), chewiness (5.64 ± 1.03) and overall acceptability (5.45 ± 1.75). On the other hand, submerging the chunks in deep-frying media negatively affected appearance (4.46 ± 1.81), oiliness (3.00 ± 2.32), aroma (4.36 ± 1.69), taste (4.55 ± 1.63), chewiness (4.36 ± 2.06) and overall acceptability (4.09 ± 1.87). The means \pm SD of sensory attributes score are presented in Table 6.8.

Table 6.8: Sensory analysis of deep-fried beef under different processing treatments

Treatments	Appearance	Color	Oiliness	Aroma	Taste	Chewiness	Overall acceptability
Smoked	5.55±1.44 ^{ab}	5.55±1.57 ^{ab}	6.18±1.47 ^a	4.91±1.64 ^a	5.18±1.25 ^{bc}	3.73±2.00 ^c	4.82±1.17 ^{bc}
Spiced	4.91±2.07 ^b	5.36±1.63 ^{ab}	5.91±1.22 ^a	5.45±2.30 ^a	6.09±1.22 ^{ab}	5.64±1.03 ^{ab}	5.45±1.75 ^{ab}
Submerged in oil	4.46±1.81 ^b	5.27±1.74 ^b	3.00±2.32 ^b	4.36±1.69 ^a	4.55±1.63 ^c	4.36±2.06 ^{bc}	4.09±1.87 ^c
Nitrite	6.46±0.82 ^a	6.64±0.50 ^a	6.00±0.89 ^a	5.82±1.25 ^a	6.45±0.82 ^a	6.09±1.14 ^a	6.45±0.52 ^a

Means followed by the same letter are not significantly different from each other (p < 0.05)

6.4 DISCUSSIONS

6.4.1 Chemical Characteristics

Smoking at 65°C for one hour did not cause a significant reduction in the moisture content. Curing and spicing resulted to significantly higher moisture content in the products. In curing, sodium tripolyphosphate added to improve colour during curing may have increased the water binding capacity, therefore reducing moisture loss during deep-frying. Similar findings on the effect of tripolyphosphate on water binding capacity have been reported (Peng *et al.*, 2009). Similarly, use of spices reduces moisture loss during deep-frying by increasing water holding ability of meat tissues as reported by Piñero and others (2008). During storage, moisture content increased by a small margin which points out to ‘sweating’ as moisture moves from inside the chunks to the package surface. There was significantly reduced moisture uptake in the chunks submerged in deep-frying oil. In addition, the chunks packaged in polythene bags recorded significantly higher moisture levels during accelerated storage.

The processing treatments used did not cause a significant change in free fatty acids but with storage the cured and the smoked batches recorded significantly lower free fatty acids values. This was attributed to anti-oxidation activity in smoke and nitrite (Honikel, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005). However, the spiced sample recorded a significantly higher increase during storage which was in contrast to earlier research by Tajkarimi and others (2010). According to Singh and others (2008), the use of whole cardamom rather than cardamom seeds reduce antioxidation and antimicrobial properties as majority of these beneficial agents are found in the seeds. In addition, as reported by Gómez-Estaca and others (2014), the antioxidant properties may have been destroyed by high heat treatment during the frying process. Of interest was the low free fatty acid values in meat chunks submerged in deep-frying media which points out encapsulation of beef chunks by the surrounding oil

thereby retarding chemical activity during initial storage. The low rates in production of free fatty acids points out minimal hydrolysis of triglycerides, as high deep-frying temperature denatures most lipase enzymes and storage temperatures were not high enough to cause non-enzymatic hydrolysis as suggested by Camire and others (1990). All the nitrite-cured samples were still acceptable even after 15 days of storage. The smoked samples maintained low levels of free fatty acid but on day 15, the levels exceeded the allowable limits. Spiced samples were considered unacceptable at day 10 of accelerated storage. All deep-fried beef chunks with free fatty acids values exceeding 1.00% was considered unacceptable (Tiwari *et al.*, 2011; Erickson and Frey 1994).

However, with storage, the values increased and exceeded 5 Meq/Kg in samples submerged in deep-frying oil (peroxide value was as high as 7.89 Meq/Kg) and those treated with ground cardamom (peroxide value was as high a 6.99 Meq/Kg). However, apart from smoked sample packed in glass jars (peroxide value was 6.07 ± 0.02 Meq/Kg), smoking and nitrite curing considerably reduced production of peroxide compounds in deep-fried chunks and their level was still acceptable even during storage. Packaging did not result to a significant difference in peroxide values in the same batch. Similar results were on peroxide value were reported by Tiwari and others (2011). Processing treatments applied on the meat chunks caused significant differences in the peroxide contents. However, the values observed were within the acceptable limits (Tiwari *et al.*, 2011).

6.4.2 Microbial Status

The study did not detect *E. coli* and Salmonella in freshly deep-fried beef chunks. Catalase positive staphylococcus and Listeria were present in low numbers (less than 10^2 CFU/g). These values were lower than the recommended values by Kenya Bureau of Standards (KEBS) (KS 2455:2013, KS59-2:2013) legal limits of below $6.0 \log_{10}$ cfu/g, $2.0 \log_{10}$ cfu/g and

2.0 log₁₀cfu/g for TVC, catalase positive staphylococcus and Listeria respectively. In contrast to Velasco and Williams's (2011) study, coagulase positive staphylococcus and Listeria were able to grow in the meat products treated with cardamom. This points out that the amount of spice used was less than the lower limit for microbial survival. In addition to this, use of whole cardamom increase the water binding ability of deep-fried meat products to make it conducive for microbial growth (Véronique, 2008). Subjecting spices to the deep-frying temperature may cause destruction of its antioxidant and antimicrobial properties, as was reported by earlier studies (Gómez-Estaca *et al.*, 2014). High count for total variable counts, staphylococcus and Listeria were observed in cured samples as addition of tripolyphosphate during the curing increases water-binding ability even during the deep-frying process.

Smoking and submerging meat chunks in the deep-frying oil reduced the rates of growth of microorganisms. Smoke was seen to be most effective in reducing Listeria and total viable bacteria contamination and growth although with time, Staphylococcus exceeded the legal limit. Smoke has been reported to retard growth of microorganisms as it has antimicrobial properties against a wide range of spoilage and pathogenic microorganisms (Aliet *al.*, 2011; Cadwallader, 2007; Toth and Potthast, 1984).

Plastic jars had considerably lower rates of microbial growth due to the fact that they can be tightly closed unlike glass jars. Vacuum packed samples were more susceptible to microbial growth as packages were seen to experience air absorption during storage. This is due to the fact that the when oil gets into contact with the packaging material, its sealing properties are adversely affected and the packaging material loses their integrity. Similarly, previous research highlighted that vacuum packaging in polythene bags is not ideal for deep-fried meat products (Guillet and Rodrigue, 2009; Min *et al.*, 2009).

6.4.3 Sensory Characteristics

During deep-frying, chemical reactions between carbohydrates and proteins and physical processes such as moisture loss, fat absorption, denaturation of proteins and combustion of carbohydrates and proteins contribute to aroma, appearance and textural attributes (Saguy and Dana, 2003). Smoking, use of cardamom and nitrite curing have been reported to reduce peroxide and free fatty acids value and these treatments were seen to indirectly impact on the sensory qualities of deep-fried beef chunks. During processing and storage, chemical reactions such as lipid oxidation and hydrolysis have previously been associated with sensory qualities of deep-fried meat products (Gandemer, 2002).

Smoke was found to significantly improve the appearance, colour and taste of beef chunks in addition to decreasing the oiliness. Curing with nitrite improved the colour, appearance, aroma, taste and chewiness in addition to reducing oiliness of deep-fried chunks. Similar findings on sensory attributes of cured and smoked meat have been reported (Ahmad *et al.*, 2005). Improved taste in the cured batch was basically due to addition of common salt in the curing brine. Tripolyphosphate was used to maintain the bright red colour even after deep-frying and hence the significantly higher colour and appearance scores. In addition, curing reduced the amount of moisture loss during deep-frying and thereby the texture was acceptable. Smoking had negative impact on chewiness and aroma as the products developed burnt flavour and had lower moisture content. Cardamom when added to deep-frying oil was found to improve colour, aroma, taste and chewiness of beef chunks. Similar findings on the effects of spices have been reported (Karre *et al.*, 2013). Colour and chewiness which are greatly dependent on moisture content had significantly increased due to higher water binding capacity during processing. Piñero and others (2008) in their earlier study had indicated the effect of spices on water holding ability of processed meats. However, using whole ground

cardamom had a negative impact on appearance as spice particles were seen on the surface of the chunks. Submerging deep-fried chunks in deep-frying media had a negative impact on appearance, oiliness, aroma, taste and chewiness. Based on previous research, this processing treatment represents the current techniques among pastoral communities (Gichure *et al.*, 2016).

6.5 CONCLUSION AND RECOMMENDATIONS

Smoking, nitrite curing and submerging deep-fried meat chunks in frying media improves stability against chemical and microbial spoilage. However, submerging the chunks in deep-frying media was not effective against chemical spoilage during prolonged storage. Incorporating tripolyphosphate in curing brine had a negative effect on chemical and microbial characteristics after processing. This notwithstanding, cured chunks were more stable against chemical and microbial deterioration. Whole ground cardamom spices was not as effective as smoking, nitrite curing and submerging chunks in deep-frying media.

With regards to safety, all the products were within acceptable ranges with regards to chemical quality, that is, <1 and <5meq/gram for free fatty acids and peroxide values respectively. However with storage, only the cured and smoked batches maintained their stability within the acceptable limits. With regards to microbial quality, deep-fried beef chunks were within the Kenya Bureau of Standards requirement (KEBS) legal limits (KS 2455:2013, KS59-2:2013) with regards to total variable counts, catalase positive staphylococcus, Salmonella, *E. coli* and Listeria. However, the products became unacceptable during storage at accelerated temperature with the smoked samples being most stable against microbial deterioration. Packaging in airtight plastic and glass jars was seen to increase stability of the products with regards to chemical and microbial spoilage. Vacuum packaging in polythene sheet was not effective in improving stability as it failed to maintain its integrity

during prolonged storage. The study recommends use of liquid absorbers to absorb moisture oozing from deep-fried chunks packaged in the plastic and glass jars in addition to incorporating antioxidant and antimicrobials during packaging.

CHAPTER SEVEN: GENERAL DISCUSSION

Out of the 20 million pastoralists living in Sub-Saharan Africa, about 6 million of them are in Kenya's Arid and Semi-Arid Lands. Their main diets and economic activities revolve around production of livestock and livestock products (Wellard-Dyer, 2012; Kirkbride and Grahn, 2008). Population-wise, the main pastoral communities in Kenya are the Somali, Turkana and Maasai (KNBS, 2009). Other pastoral communities include Rendile, Borana, Samburu, Pokot, among others. Since meat is their main diet, they have overtime devised means of preserving it.

Physical remoteness to infrastructure for modern preservation techniques such as chilling and refrigeration systems, canning systems, sophisticated drying systems, irradiation systems, among other techniques contributed to their reliance on indigenous techniques such as sun-drying, salting, submerging in deep-frying media and deep frying. This was in line to earlier reports (Homewood *et al.*, 2012). Additives such as nitrites and synthetic antimicrobials and antioxidants and modern packaging have not being adopted by pastoralist in processing their products (Gichure *et al.*, 2014).

According to this study, deep frying has been the main preservation technique; with variations within and among the pastoral communities. Several adjunct steps were reported and this had a significant contribution to overall quality and acceptability of the products as had been reported by Tornberg (2005). The fact that deep-frying resulted in extensive dehydration of the products within a short time made the process more acceptable as compared to sun-drying amongst the pastoral communities. The main challenge with indigenous pastoral deep-fried meat products was lack of standardization and susceptible to chemical deterioration (Du and Li, 2008).

Among the adjunct steps used during deep-frying include fumigating packaging containers with smoke generated by burning *Balanites rotundifolia*. This was used to sanitize indigenous packaging containers, increase shelf-stability and bring out woody flavour in the final products. Spices and herbs were used to increase shelf stability and bring out characteristic sensory attributes.

Quality cues and comparative advantage were seen to be good indicator of performance in case the products were to be mainstreamed into formal markets. This study found out that Nyirinyiri which scored the highest with respect to appearance, flavour and texture was the most preferred. Empirical data show that volatile free fatty acids from oxidative and thermal pyrolysis of meat lipids during deep-frying, protein-carbohydrates maillard reactions and mass movement of oils into the products and moisture out of the products were responsible for the product quality (Choe and Min, 2007). Similarly, cardamom was added to Nyirinyiri, animal fats were the main deep-frying media for Olpurda and cold-smoking of Enyas and Ng'amorumoru were used to prolong shelf-stability, and bring out characteristic sensory attributes. Research has showed that addition of spices, smoking and immersing meat chunks in animal fats has inhibitory effect to microbial spoilage and chemical oxidation of products (Cassens, 2008; Singh *et al.*, 2008; El Malti *et al.*, 2007; Fasseas *et al.*, 2007; Zegeye, 1999). Pre-drying done by either sun-drying or heat evaporation was used to increase moisture loss thereby increasing stability and reducing fat absorption during the deep-frying process.

Comparative advantage over conventional meat products along formal value chains was used to subjectively bring out performance in case products are to be mainstreamed. Using this view, availability of raw materials and low cost of production improved competitiveness. Cooling products to solidify the deep-frying media over meat chunks was done to create anaerobic conditions and this provided a cheap alternative to sophisticated packaging.

However, the products were less convenient hence the low score observed on comparative advantage. In addition, these predispose products to lipid oxidation during storage as suggested by Mohamed *et al.* (1996).

With regards to chemical composition, the indigenous deep-fried meat chunks had high lipid contents. Similarly to Weber and others (2008), deep-frying oil was seen to contribute to moisture, protein and lipids content of meat chunks. Rendered animal fat had superior products when compared to those deep-fried in vegetable oil. It was evident that deep-frying in rendered animal fat resulted in products with lower moisture contents and higher proteins, fats and carbohydrates contents as compared to those deep-fried in palm oil and ghee. Firewood being the main source of fuel caused uncontrollable deep-frying temperature that may have resulted to loss of nutritional components as described by Choe and Min (2007). Pre-drying brought down moisture content from an average of 75% to an average of 67% and this had a significant effect on the final moisture content and sensory characteristics of deep-fried beef chunks. Pastoralist pre-dried the products by either sun-drying under direct sun as done by the Somali and Borana communities or through heat evaporation as done by Turkana and Maasai communities.

On standardizing the pre-drying time, a thermostatically controlled oven dryer was used. With this dryer, moisture content was brought down by 4.5% in 10 mm cuts and by 1.1% in 20 mm cuts. Interestingly, there was considerable loss in total lipids which was attributed to melting abstraction from intramuscular fat. Similar results were reported on an inverse relationship between moisture content and lipids content (Saguy and Dana, 2003) and this was seen to be influenced by pre-drying and chunk size. Deep-frying at 170°C was seen to cause decomposition of fibre and soluble carbohydrates. As reported by Aprajeeta and others (2015), drying kinetics of foods may have caused the 20 mm chunks to develop mechanical

stress and strain equilibrium inside the chunk matrix structure leading to non-uniform shrinkage, hence the higher crude lipids content reported. Using this as the basis, the study found out that the optimum size of chunks should be 15 mm. Draining the deep-frying oil immediately after deep-frying before cooling was seen to cause a significant decrease in the crude lipids content. Similar results were reported by previous research (Gichure *et al.*, 2016; Dana and Saguy, 2006).

Despite the fact that all products had low and acceptable levels of peroxide value, pre-drying time and chunk size were seen to have inverse relationships to peroxide values. Chunk size and pre-drying time had no significant effect on products' sensory qualities apart from colour, appearance, size and chewiness attributes.

Curing and addition of spice significantly increased the moisture content of deep-fried food. As reported in earlier studies, both the sodium tripolyphosphate added in the curing brine and fibre in crushed whole cardamom increased the water binding capacity (Peng *et al.*, 2009; Piñero *et al.*, 2008). Submerging deep-fried chunks in the frying media during storage significantly increased stability against moisture uptake during storage. Vacuum packaging the deep-fried chunks in polythene bags was not effective as the packaging lost integrity with time. This may be attributed to oil getting in contact with the seal thereby affecting its sealing properties as had been reported earlier (Guillet and Rodrigue, 2009; Min *et al.*, 2009).

Both hydrolytic and oxidative rancidity were retarded in the deep-fried beef chunks by smoking and curing as had been reported in earlier studies (Honikel, 2008; Andrés *et al.*, 2007; Holley and Patel, 2005). However, in contrast to Tajkarimi and others (2010), addition of whole cardamom was not effective in retarding these processes as had earlier being anticipated and this was attributed to use of whole pods rather than the seeds only. Addition of cardamom in the deep-frying media during the deep-frying process, and heating it to 170°C

could have destroyed the antioxidant properties as was reported by Gómez-Estaca and others (2014). Submerging deep-fried chunks in deep-frying media was seen to retard rancidity for a short time. This could be attributed to denial of oxygen for these chemical processes. However, with pro-longed storage, the rate of chemical reactions in the submerged chunks increased significantly. All in all, the products were still acceptable up-to day 10 at accelerated storage as free fatty acids values was less than 1.00% (Tiwari *et al.*, 2011; Erickson and Frey 1994), while peroxide values were did not exceed 5 Meq/Kg (Tiwari *et al.*, 2011). Submerged deep-fried chunks had considerably low scores on sensory attributes.

The study did not detect any *E. coli* and Salmonella in deep-fried beef. However, total viable counts, catalase positive staphylococcus and Listeria was present in low numbers (less than 10^2 CFU/g) which was lower than Kenya bureau of standards (KEBS) (KS 2455:2013, KS59-2:2013) legal limits of below $6.0 \log_{10}\text{cfu/g}$, $2.0 \log_{10}\text{cfu/g}$ and $2.0 \log_{10}\text{cfu/g}$ for TVC, catalase positive staphylococcus and Listeria respectively. However with storage, smoking and nitrite curing was seen to increase stability against growth of coagulase positive staphylococcus and Listeria. This was in line to earlier reports (Ali *et al.*, 2011; Cadwallader, 2007; Toth and Potthast, 1984). Nitrite curing and addition of spices were also seen to improve the sensory attributes of deep-fried products. On the other hand, smoking had negative impact on texture and aroma. Submerging deep-fried chunks in deep-frying media had a significantly negative impact on acceptability.

CHAPTER EIGHT: CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

This study confirms that the main indigenous technique for meat preservation among pastoral communities is deep-frying. Variations exist along the deep-frying process and these are caused by cultural variations and diversity among and within pastoral communities. These variations are caused by flow of indigenous knowledge and cultural heritage. Some of the deep-fried meat products identified were Nyirinyiri by the Somali, Olpurda by the Maasai and Enyas and Ng'amorumoru by Turkana. Conventional preservation such as nitrite curing and vacuum packaging have not been taken up to mainstream these products into formal markets, rather, spices and herbs, smoke and encapsulating chunks in deep-frying media have been used.

Quality cues and comparative advantage were seen to be good predictors of performance and competitiveness in case beef chunks are to be mainstreamed in the formal markets. *Balanites rotundifolia* was used in smoking as it brought out characteristic flavour and had ease of availability as the tree grows wild along River Turkwel which passes through Turkana County. Crushed seeds of cardamom (*Elettaria cardamomum*) were used to produce characteristic flavour, colour and aroma. Encapsulating chunks with deep-frying media was used to increase microbial stability during storage. On comparative advantage, environmental conditions were conducive as source of energy for sun-drying, all of the raw materials were locally available, the products were regarded as part of community heritage and perceived stability against microbial deterioration all increased competitiveness.

The indigenous deep-fried meat chunks have high crude proteins, crude lipids, total ash, and calorie contents and based on this may be considered functional foods. However, due to differences in processing methods, variations exist with respect to chemical composition.

Prolonged deep-frying at high temperatures caused partial decomposition of proteins and carbohydrates. On the other hand, size of chunk and pre-drying influenced chemical and sensory characteristics of pastoral products. Interestingly, sensory acceptability by members of pastoral communities did not translate to acceptability by trained panellist. On this, fibrous appearance of Enyas, burnt flavour of Enyas, use of rendered animal fat in Olpurda and traditional ghee in Nyirinyiri and the very dark appearance of Nyirinyiri were characteristic attributes among pastoral communities despite the fact that they were less acceptable by the trained panellists.

Standardization of the chunks based on chunk size and pre-drying time-temperature revealed that smaller chunks have significantly less moisture contents and more lipids and protein contents. Pre-drying for 120 minutes significantly reduced moisture and total lipids content in the final products. Chunk size and pre-drying time were seen to significantly influence chemical oxidation during deep-frying. Draining frying oil before cooling was seen to significantly reduce crude lipids content in the packaged chunks. Hot smoking, nitrite curing and encapsulating deep-fried beef chunks with the frying media improved shelf stability against chemical and microbial spoilage. However, encapsulating deep-fried chunks in deep-frying media increased susceptibility to chemical spoilage.

Deep-fried beef chunks were seen to be within acceptable ranges with regard to chemical quality and stability. The free fatty acids values were less than one percent while peroxide value was less than 5 meq/gram. Smoking or nitrite cured were seen to maintain microbial stability within the Kenya bureau of standards requirement (KEBS) legal limits (KS 2455:2013, KS59-2:2013) with regards to total variable counts, catalase positive *staphylococcus*, *Salmonella*, *E. coli* and *Listeria*. Airtight plastic and glass jars increased shelf

stability against chemical and microbial deterioration while vacuum packaging in polythene sheet was not effective as the package was seen to lose its integrity during storage.

8.2 Recommendations

From this research, the possibility of upgrading pastoral beef deep-frying through integrating traditional and modern meat preservation techniques exists. Traditional processes such as smoking, use of spices and encapsulating deep-fried meat chunks in the deep-frying media needs to be standardized for better uptake of these technologies in the formal value chains. Further research on incorporation of antioxidants and antimicrobial during processing and storage need to be done. Airtight plastic and glass jars needs to have moisture absorbers to increase stability.

REFERENCES

- Abegaz, M. (2009). Mobilizing aid for trade for SPS-related technical cooperation in East Africa. SPS balance sheet for Kenya Research work for the Standards and Trade Development Facility. Last accessed 30/09/2013 http://www.standardsfacility.org/Files/AidForTrade/Final_Kenya.pdf
- Acebron, L.B. and Dopico, D.C. (2000). The importance of intrinsic and extrinsic cues to expected and experienced quality: an empirical application for beef. *Food Quality and Preference*, 11, 229-238
- Adegoke, G. O., and Falade, K. O. (2005). Quality of meat. *Journal of Food, Agriculture & Environment*, 3, 87-90.
- Ahmad, S., Anzar, A., Srivastava, A.K. and Srivastava, P.K. (2005). Effect of Curing, Antioxidant Treatment, and Smoking of Buffalo Meat on pH, Total Plate Count, Sensory Characteristics, and Shelf Life during Refrigerated Storage, *International Journal of Food Properties*, 8:1, 139-150,
- Aklilu, Y. (2008). Livestock marketing in Kenya and Ethiopia: a review of policies and practice. *Feinstein International Center, Addis Ababa*, 38.
- Ali, A., Ahmadou, D., Mohamadou, B., Saidou, C., and Tenin, D. (2011). Influence of traditional drying and smoke-drying on the quality of three fish species (*Tilapia nilotica*, *Silurus glanis* and *Arius parkii*) from Lagdo Lake, Cameroon. *Journal of animal and Veterinary Advances*, 10(3), 301-306.
- Andrée, S., Jira, W., Schwind, K. H., Wagner, H., and Schwägele, F. (2010). Chemical safety of meat and meat products. *Meat Science*, 86(1), 38-48.
- Andrés, A., Barat, J. M., Grau, R., and Fito, P. (2007). Principles of drying and smoking. In *Handbook of fermented meat and poultry*, 1, 37-50.

- Angelo, A.J. (1992). Lipid oxidation in food. *In ACS symposium series (USA)*. American Chemical Society.
- AOAC (2005). *Official methods of analysis of AOAC International*. 18th Ed. Published by the Association of Analytical Communities International. Gaithersburg, MD.
- AOCS. (1993). *Official Methods and Recommended Practices of the American Oil Chemists Society*, 4th Ed. Published by the American Oil Chemists Society, 1608, Broadmoor Drive, Champaign, Illinois 61826-3489.
- Apata, E. S., O. O. Osidibo, O. O., Apata, O. C. and Okubanjo, A. O. (2013), “Effects of Different Solar Drying Methods on Quality Attributes of Dried Meat Product (Kilishi)”, *Journal of Food Research*; 2(1), 80-86
- Aprajeeta, J., Gopirajah, R., and Anandharamakrishnan, C. (2015). Shrinkage and porosity effects on heat and mass transfer during potato drying. *Journal of Food Engineering*, 144, 119-128.
- Aristoy, M. C., and Toldrá, F. (2011). Essential amino acids. In L. M. L. Nollet, & F. Toldrá (Eds.), *Handbook of analysis of edible animal by-products* (pp. 123–135). Boca Raton, FL, USA: CRC Press
- Arnau J, Serra X, Comaposada J, Gou P, Garriga M. (2007). Technologies to shorten the drying period of dry-cured meat products. *Meat Science*, 77:81–89.
- Arthur, T. M., Bosilevac, J. M., Nou, X., Shackelford, S. D., Wheeler, T. L., Kent, M. P., Jaroni D, Pauling B, Allen DM, Koohmaraie M. and Koohmaraie, M. (2004). *Escherichia coli* O157 prevalence and enumeration of aerobic bacteria, *Enterobacteriaceae*, and *Escherichia coli* O157 at various steps in commercial beef processing plants. *Journal of Food Protection*, 67(4), 658-665.

- AU-IBAR and NEPDP (2006). Kenya Livestock Sector study: An Analysis of Pastoralists Livestock Products Market Value Chains and Potential External Markets for Live Animals and Meat.
- Ayantunde, A. A., De Leeuw, J., Turner, M. D., and Said, M. (2011). Challenges of assessing the sustainability of (agro)-pastoral systems. *Livestock Science*, 139(1), 30-43.
- Ayanwale, B. A., Ocheme, O. B., and Oloyede, O. O. (2007). The Effect of Sun-drying and Oven-drying on the nutritive value of meat pieces in hot humid environment. *Pakistan Journal of Nutrition*, 6(4), 370-374.
- Aymerich, T., Picouet, P. A., and Monfort, J. M. (2008). Decontamination technologies for meat products. *Meat Science*, 78(1), 114-129.
- Badr, H. M. (2012). Irradiation of Meat. In *Handbook of Meat and Meat Processing*, 2nd Ed (pp. 381-406). CRC Press.
- Behnke, R. and Muthami, D. (2011). *The Contribution of Livestock to the Kenyan Economy*. Great Wolford, UK, IGAD Livestock Policy Initiative.
- Borsa J. (2006). Introduction: Food irradiation moving. In: Sommers CH, Fan X, editors. *Food Irradiation Research and Technology*. 1st Ed., Ames, Iowa, USA: Blackwell Publishing and IFT Press. pp. 3–10.
- Bourne, M. (1992). Calibration of rheological techniques used for foods. *Journal of Food Engineering*, 16: 151 – 163 .
- Bouton, P.E., Harris, P.V., and Shorthose, W.R. (1975). Possible relationships between shear, tensile, and adhesion properties of meat and meat structure. *Journal of Textural Studies*, 6, 297
- Bredahl L. (2004). Cue utilization and quality perception with regard to branded beef. *Food Quality and Preference*, 15(1): 65-75.

- Brewer, S., and Novakofski, J. (2008). Consumer quality evaluation of aging of beef. *Journal of Food Science*, 73 (1): S78 – S82.
- Brewer, S., Lan, H. and McKeith, F. (1998). Consumer evaluation of pork appearance with differing physiological and packaging conditions. *Journal of Muscle Foods*, 9 (2): 173 – 183.
- Brewer, S. (2010) Technological Quality of Meat for Processing. *Handbook of Meat Processing*. Blackwell Publishing, Iowa, USA
- Brody, A.L., Bugusu, B., Han, J.H., Koelsch, C., and McHugh, T.H. (2008). Innovative food packaging solutions. *Journal of Food Science*, 73, 107–116.
- Cadwallader, K.R. (2007). Wood smoke flavor. *Handbook of meat, poultry and seafood quality*, 201-210.
- Camire, M.E., Camire, A.L., and Krumhar, K. (1990). Chemical and nutritional changes in foods during extrusion. *Critical Reviews in Food Science and Nutrition*, 29, 35–57.
- Cassens, R. G. (2008). Meat preservation: preventing losses and assuring safety. John Wiley and Sons
- Castigliero, L., Armani, A. and Guidi, A. (2012). *Meat Color*. In Handbook of meat and meat processing. CRC PressTaylor & Francis Group
- Cederberg, C., Sonesson, U., Van Otterdijk, R., and Meybeck, A. (2011). *Global food losses and food waste: extent, causes and prevention*. Rome: FAO.
- Choe, E. and Min, D.B. (2007). Chemistry of Deep-Fat Frying Oils. *Journal of Food Science* 72(5), 77-86
- Codex Alimentarius Commission (2003). Codex General Standards for Irradiated Foods and Recommended International Code of Practice for the Operation of Radiation Facilities Used for the Treatment of Foods. Rome: FAO.

- Colmenero, F.J. (2000) Relevant factors in strategies for fat reduction in meat products. *Trends in Food Science and Technology*, 11, 56-66
- Colmenero, FJ, Serrano, A, Ayo, J, Solas, MT, Cofrades, S, and Carballo, J. (2003). Physicochemical and sensory characteristics of restructured beef steak with added walnuts. *Meat Science*, 65(4), 1391-1397.
- Cortés, P., Badillo, G., Segura, L., and Bouchon, P. (2014). Experimental evidence of water loss and oil uptake during simulated deep-fat frying using glass micromodels. *Journal of Food Engineering*, 140, 19-27.
- Cutter, C.N. (2000). Antimicrobial effect of herb extracts against *Escherichia coli* O157: H7, *Listeria monocytogenes*, and *Salmonella typhimurium* associated with beef. *Journal of Food Protection*, 63(5), 601-607.
- Dana, D and Saguy, IS. (2006). Review: Mechanism of oil uptake during deep-fat frying and the surfactant effect-theory and myth. *Advances in Colloid and Interface Science*, 128, 267–272
- Davidson, P. M., Taylor, T. M., and Schmidt, S. E. (2013). Chemical preservatives and natural antimicrobial compounds. In *Food microbiology* (pp. 765-801). American Society of Microbiology.
- Dobarganes, C, Márquez-Ruiz, G, and Velasco, J. (2000). Interactions between fat and food during deep-frying. *European Journal of Lipid Science and Technology*, 102(8-9), 521-528.
- Du, H. and Li, H. (2008), “Antioxidant effect of Cassia essential oil on deep-fried beef during the frying process”, *Meat Science*, 78, 461–468
- Duarte, R. T., Carvalho-Simoes, M. C., and Sgarbieri, V. C. (1999). Bovine blood components: Fractionation, composition, and nutritive value. *Journal of Agricultural and Food Chemistry*, 47, 231–236.

- Duizer, L.M., Robertson, T., and Han, J. (2009). Requirements for packaging from an ageing consumer's perspective. *Packaging Technology and Science*, 22, 187–197.
- Dzimba, F. E. J., José de Assis, F. F., and Walter, E. H. M. (2007). Testing the sensory acceptability of biltong formulated with different spices. *African Journal of Agricultural Research*, 2(11), 574-577.
- El Malti J, Mountassif D and Amarouch H (2007). Antimicrobial activity of *Elettaria cardamomum*: Toxicity, biochemical and histological studies. *Food chemistry*, 104(4): 1560-1568.
- Elortondo, FP, Ojeda, M, Albisu, M, Salmerón, J, Etayo, I, and Molina, M. (2007). Food quality certification: An approach for the development of accredited sensory evaluation methods. *Food Quality and Preference*, 18(2), 425-439.
- EPZA (2005). Meat Production in Kenya 2005, Export Processing Zones Authority.
- Erickson, M.D., and Frey, N. (1994). Property-enhanced oils in food application. *Food Technologist*, 48, 63–68.
- Esmer, O. K., Irkin, R., Degirmencioglu, N., and Degirmencioglu, A. (2011). The effects of modified atmosphere gas composition on microbiological criteria, colour and oxidation values of minced beef meat, *Meat Science*, 88, 221–226.
- Estévez, M. (2011). Protein carbonyls in meat systems: A review. *Meat Science*, 89, 259–279.
- Etaio, I., Gil, P. F., Ojeda, M., Albisu, M., Salmerón, J., and Elortondo, F. P. (2013). Evaluation of sensory quality of calf chops: A new methodological approach. *Meat science*, 94(1), 105-114
- Fabusoro, E., and Oyegbami, A. (2009). Key Issues in Livelihoods Security of Migrant Fulani Pastoralists: Empirical Evidence from Southwest Nigeria. *ASSET: An International Journal (Series C)*, 4(2), 1-20.

- FAO (1995). *Development and Promotion of value added products*. Project Document, FAO, Rome.
- FAO (2005). *Kenya Livestock Sector Brief*. Rome, Italy, FAO Livestock Information, Sector Analysis and Policy Branch (AGAL).
- FAO (2007). *Manual on Meat Cold store Operations and Management. Agriculture and Consumer Protection*. FAO Corporate Document Repository FAO, Rome.
- FAO (2011) *Global Food Losses and Food Waste: Extent, Causes and Prevention*. Rome: FAO
- FAOSTAT (2012). Kenya Commodity Balance Sheet 1990-2009. *FAOSTAT Online Database*. Retrieved on 12/03/2014 <http://faostat.fao.org/default.aspx?lang=en>
- Fasseas MK, Mountzouris KC, Tarantilis PA, Polissiou M and Zervas G (2007). Antioxidant activity in meat treated with oregano and sage essential oils. *Food Chemistry*, 106: 1188–1194
- Faustmann, C., and Cassens, R.G. (1990), “The biochemical basis for discoloration in fresh meat: a review”. *Journal of Muscle Foods*, 1(3), 217-243
- Fernández-Ginés, J. M., Fernández-López, J., Sayas-Barberá, E., and Pérez-Alvarez, J. (2005). Meat products as functional foods: A review. *Journal of food science*, 70(2), R37-R43.
- FSAU (2001). *Food Security Analysis Unit: Pastoralists under pressure*, FAO (Food Agricultural Organization), EU (European Union)
- Gandemer, G. (2002). Lipids in muscles and adipose tissues, changes during processing and sensory properties of meat products. *Meat Science*, 62(3), 309-321.
- Garcia R and Calantone R (2002). A critical look at technological innovation typology and innovativeness terminology: a literature review. *Journal of product innovation management*, 19(2): 110-132

- García-Llatas, G., Alegría, A., Barberá, R., and Farré, R. (2011) Minerals and trace elements. In L. M. L. Nollet, and F. Toldrá (Eds.), *Handbook of analysis of edible animal by-products* (pp. 183–203). Boca Raton, FL, USA: CRC Press.
- Gheisari, H. R. and Motamedi, H (2010), Chloride salt type/ionic strength and refrigeration effects on antioxidant enzymes and lipid oxidation in cattle, camel and chicken meat, *Meat science*, 86, 377-83
- Gichure JN, Kunyanga CN, Mathi PM and Imungi JK (2016). Chemical and Sensory Attributes of Selected Meat Products from Kenyan Pastoral Communities: Case of *Nyirinyiri, Enyas, Ng'amorumoru and Olpurda*. In press.
- Gichure, J.N., Kunyanga, C.N., Mathi, P.M. and Imungi, J.K. (2015). Meat Preservation Technologies in Kenya's Pastoral Areas with Potential for Market Competitiveness Improvement. Paper presented at Conference on Policies for Competitive Smallholder Livestock Production. Gaborone, Botswana, 4-6 March 2015
- Gichure, J.N., Kunyanga, C.N., Mathi, P.M., and Imungi, J.K. (2014). The Present Status of Meat Processing and Preservation in the Pastoral Regions of Kenya. *Food Science and Quality Management*, 34, 42-50
- Gómez-Estaca, J., López-de-Dicastillo, C., Hernández-Muñoz, P., Catalá, R., and Gavara, R. (2014). Advances in antioxidant active food packaging. *Trends in Food Science and Technology*, 35(1), 42-51.
- Grillo, K. M. (2014). Pastoralism and pottery use: an ethnoarchaeological study in Samburu, Kenya. *African Archaeological Review*, 31(2), 105-130.
- Grunert KG (1997) What's in a steak? A cross-cultural study on the quality perception of beef. *Food Quality and Preference*, 8(3): 157-173.
- Guerrero-Legarreta, I and García-Barrientos, R. (2012). Thermal Technology. In *Handbook of Meat and Meat Processing*, Second Edition (pp. 523-530). CRC Press.

- Guillet, M., and Rodrigue, N. (2009). Shelf Life Testing Methodology. In G. L. Robertson (Ed.), *Food Packaging and Shelf Life: A Practical Guide* (pp. 31-53). CRC Press.
- Gulati, R. (1998). Alliances and network. *Strategic Management Journal*, 19(4): 293–317
- Han, B., and Bischof, J. C. (2004). Direct cell injury associated with eutectic crystallization during freezing. *Cryobiology*, 48(1), 8-21.
- Han, J. H. (2009) Food Safety and Innovative Food Packaging, in *Microbiologically Safe Foods* In Heredia, H., Wesley, I. and García, S.(Ed), John Wiley & Sons, Inc., Hoboken, NJ, USA.
- Han, J. H. (2009) Food Safety and Innovative Food Packaging, in *Microbiologically Safe Foods* (eds Heredia, H., Wesley, I. and García, S.), John Wiley & Sons, Inc., Hoboken, NJ, USA.
- Heinz, G., and Hautzinger, P. (2009). *Meat processing technology for small to medium scale producers*. FAO.
- Henard DH and Szymanski DM (2001). Why some new products are more successful than others. *Journal of Marketing Research*, 38: 362-375.
- Henchion, M., and McIntyre, B. (2010). From transactions to relationships: the care of the Irish beef chain. In C. Fischer, and M. Hartmann (Eds.), *In Agri-food chain relationships*. CAB International. ISBN-13: 9781845936426.
- Hess, M., (2008). Governance, value chains and networks: an afterword. *Economy and Society*, 37 (3): 452–459.
- Holley, R.A., and Patel, D. (2005). Improvement in shelf-life and safety of perishable foods by plant essential oils and smoke antimicrobials. *Food Microbiology*, 22(4), 273-292.
- Honikel, K. O. (2008). The use and control of nitrate and nitrite for the processing of meat products. *Meat science*, 78(1), 68-76.

- Hsieh, Y. H., and Ofori, J. A. (2011). Food-grade proteins from animal by-products. Their usage and detection methods. In L. M. L. Nollet, and F. Toldrá (Eds.), *Handbook of analysis of edible animal by-products* (pp. 3–11). Boca Raton, FL, USA: CRC Press.
- Hubbard, L. J., and Farkas, B. E. (2000). Influence of oil temperature on convective heat transfer during immersion frying. *Journal of Food Processing and Preservation*, 24(2), 143-162.
- Huff-Lonergan E and Lonergan SM (2005) Mechanisms of water-holding capacity of meat: The role of postmortem biochemical and structural changes. *Meat Science*, 71: 194–204
- ISO (2006). International Organization for Standardization. Sensory analysis–Methodology–Ranking. EN ISO, 8587, 2006.
- ISO (2009). Animal and vegetable fats and oils - *Determination of acid value and acidity*. ISO 660:2009
- Issanchou S (1996). Consumer expectations and perceptions of meat and meat product quality. *Meat Science*, 43: 5-19.
- Janjai, S., and Bala, B. K. (2012). Solar drying technology. *Food Engineering Reviews*, 4(1), 16-54.
- Jiménez-Colmenero, F. (2007). Healthier lipid formulation approaches in meat-based functional foods. Technological options for replacement of meat fats by non-meat fats. *Trends in Food Science and Technology*, 18(11), 567-578.
- Jimenez-Colmenero, F., Carballo, J., and Cofrades, S. (2001). Healthier meat and meat products: their role as functional foods. *Meat Science*, 59(1), 5-13.
- Juárez, M., Aldai, N., López-Campos, O., Dugan, M., Uttaro, B. and Aalhus, J. (2012) *Beef Texture and juiciness*. In *Handbook of Meat and Meat Processing*. CRC Press, Taylor & Francis Group

- Karpinska, M., Borowski, J., and Danowska-Oziewicz, M. (2001), The use of natural antioxidants in ready-to-serve food. *Food Chemistry*, 72, 5-9
- Karre, L., Lopez, K., and Getty, K. J. (2013). Natural antioxidants in meat and poultry products. *Meat science*, 94(2), 220-227.
- Kim, Y. N. (2011). Vitamins. In L. M. L. Nollet, and F. Toldrá (Eds.), Handbook of analysis of edible animal by-products (pp. 161–182). Boca Raton, FL, USA: CRC Press
- Kirkbride, M. and Grahn, R. 2008. Survival of the fittest: pastoralism and climate change in East Africa. *Oxfam Policy and Practice: Agriculture, Food and Land*, 8(3), 174-220.
- Kisembe, S. W., Muliro, P. S., Matofari, J. W., and Bebe, B. O. (2017). An Evaluation of Nutritional Quality of Traditionally Processed Camel Meat (Nyirinyiri): Value Chain Assessment and Recommendations. *International Journal of Nutrition and Food Sciences*, 6(4), 172.
- KNBS (2010). 2009 Kenya Population and Housing Census, *Kenya National Bureau of Statistics*, Nairobi. Available at: <http://www.knbs.or.ke>. Accessed June 19, 2013.
- Koohmaraie M (1996). Biochemical factors regulating toughening and tenderization processes of meat. *Meat Science*, 43: 193–201.
- Krokida, M. K., Oreopoulou, V., and Maroulis, Z. B. (2000). Water loss and oil uptake as a function of frying time. *Journal of Food Engineering*, 44(1), 39-46.
- Kruska, R.L., Reid, R.S., Thomson, P.K., Henninger, N. and Kristjanson, P.M., (2003). Mapping Livestock oriented agricultural production systems for the developing world. *Agricultural Systems*, 77(1), 39-63.
- Labuza, T. P., and Altunakar, B. (2007). Water activity prediction and moisture sorption isotherms. In Gustavo V. Barbosa-Cnovas, Anthony J. Fontana, Jr., Shelly J. Schmidt, Theodore P. Labuza (Ed.) *Water activity in foods: fundamentals and applications*, 109-154.

- Latorre M.A., Lazaro R., Valencia D.G., Medel P, Mateos G.G. (2004). The effects of gender and slaughter weight on the growth performance, carcass traits, and meat quality characteristics of heavy pigs. *Journal of Animal Sciences*, 82: 526–33.
- Lee, K. T. (2010). Quality and safety aspects of meat products as affected by various physical manipulations of packaging materials. *Meat science*, 86(1), 138-150.
- Leroy, F., and Degreef, F. (2015). Convenient meat and meat products. Societal and technological issues. *Appetite*, 94, 40-46.
- Lewa A. Katunge (2010): Evaluation of Animal Health Care Delivery Systems in Selected Areas of Kenya.- Phd thesis, University of Nairobi.
- Leygonie, C., Britz, T. J., and Hoffman, L. C. (2012). Impact of freezing and thawing on the quality of meat: Review. *Meat science*, 91(2), 93-98.
- Leygonie, C., Britz, T. J., and Hoffman, L. C. (2012). Impact of freezing and thawing on the quality of meat: Review. *Meat science*, 91(2), 93-98.
- Lindqvist, A. K., and Verba, T. (2009). *Overview of drylands development communication initiatives in Africa*. Chicago
- Lokuruka, MN. 2006. Meat is the Meal and Status is by Meat: Recognition of Rank, Wealth, and Respect through Meat in Turkana Culture, *Food and Foodways: Explorations in the History and Culture of Human Nourishment*, 14:3-4, 201-229
- Lues, J. F. R. and van Tonder, I. (2007). The occurrence of indicator bacteria on hands and aprons of food handlers in the delicatessen sections of a retail group. *Food control*, 18(4), 326-332.
- Lungu, B., Ricke, S. C., and Johnson, M. G. (2009). Growth, survival, proliferation and pathogenesis of *Listeria monocytogenes* under low oxygen or anaerobic conditions: A review. *Anaerobe*, 15(1), 7-17.

- Mahroum, S., Atterton, J., Ward, N., Williams, A., Naylor, R., Hindle, R. and Rowe, F. (2007). Rural Innovation. National Endowment for Science, Technology and the Arts (NESTA), London.
- Makokha S., Witwer M., Monroy L., (2013). Analysis of incentives and disincentives for live cattle in Kenya. Technical notes series, MAFAP, FAO, Rome.
- Mancini, R. and Hunt, M. (2005) Current research in meat colour. *Meat Science*, 71, 100–121.
- Mandal, P. K., Rao, V. K., Kowale, B. N., and Pal, U. K. (1999). Utilization of slaughter house blood in human food. *Journal of Food Science and Technology*, 36, 91–105.
- Mataragas, M., Skandamis, P., Nychas, G. J. E., and Drosinos, E. H. (2007). Modeling and predicting spoilage of cooked, cured meat products by multivariate analysis. *Meat science*, 77(3), 348-356.
- McAfee, A, McSorley, E, Cuskelly, G, Moss, B, Wallace, J, Bonham, M and Fearon, A. (2010). Red meat consumption: An overview of the risks and benefits. *Meat Science*, 84, 1–13.
- Meilgaard, M., Civille, G. V., and Carr, B. T. (1999). Sensory evaluation techniques. Boca Raton, FL: CRC Press LLC.
- Melton , S. L. (1990). Effects of feeds on flavor of red meat: A review. *Journal of Animal Science* 68 : 4421 – 4435 .
- Metaxopoulos, J., Mataragas, M., and Drosinos, E. H. (2002). Microbial interaction in cooked cured meat products under vacuum or modified atmosphere at 4 C. *Journal of applied microbiology*, 93(3), 363-373.
- Miller, R.K., Moeller, S J, Goodwin, R N, Lorenzen, C L and Savell, J.W. (2000), ‘Consistency in meat quality’, International Congress of Meat Science and Technology, 46, 566–580.

- Min, S. C., Kim, Y. T., and Han, J. H. (2009). Packaging and the Shelf Life of Cereals and Snack Foods. In G. L. Robertson (Ed.), *Food Packaging and Shelf Life: A Practical Guide* (pp. 339-352). CRC Press.
- Mohamed, A., Jamilah, B., Abbas, K. A., and Abdul Rahman, R. (2008). A review on lipid oxidation of meat in active and modified atmosphere packaging and usage of some stabilizers. *Journal of Food, Agriculture and Environment*, 6 (3 and 4), 76–81.
- MOLD (2010): An overview of livestock sub-sector in Kenya. Perspectives, opportunities and innovations for market access for pastoral producers. Accessed at <http://africa.procasur.org/wp-content/uploads/downloads/2012/02/An-Overview-of-Livestock-Sectorin-Kenya--State-of-Art-document-copia.pdf>. Ministry of Livestock, Kenya.
- Mor-Mur, M., and Yuste, J. (2010). Emerging bacterial pathogens in meat and poultry: an overview. *Food and Bioprocess Technology*, 3(1), 24-35.
- Neath, K. E., Del Barrio, A. N., Lapitan, R. M., Herrera, J. R. V., Cruz, L. C., Fujihara, T., Muroya, S., Chikuni, K., Hirabayashi, M. and Kanai, Y. (2007). Difference in tenderness and pH decline between water buffalo meat and beef during postmortem aging. *Meat Science*, 75(3), 499-505.
- Nieuwenhuizen, W. F., Weenen, H., Rigby, P., and Hetherington, M. M. (2010). Older adults and patients in need of nutritional support: review of current treatment options and factors influencing nutritional intake. *Clinical nutrition*, 29(2), 160-169.
- O'Bryan CA, Crandall PG, Ricke SC, Olson DG. (2008). Impact of irradiation on the safety and quality of poultry and meat products- A review. *Critical Review of Food Science and Nutrition*, 48: 442–457.

- Ockerman, H. W., and Basu, L. (2004). By-products. In W. Jensen, C. Devine, and M. Dikemann (Eds.), *Encyclopedia of meat sciences* (pp. 104–112). London, UK: Elsevier Science Ltd.
- Offer G and Cousins T. (1992). The mechanism of drip production formation of 2 compartments of extracellular-space in muscle postmortem. *Journal of the Science of Food and Agriculture*, 58: 107–116.
- Ofori, J. A., and Hsieh, Y. H. P. (2011). Blood-derived products for human consumption. *Revelation and Science*, 1, 14–21.
- Ogunsola OO and Omojola AB Qualitative Evaluation of Kilishi Prepared from beef and Pork. *Afr. J. Biotech.*, 2006; 7(11): 1753-1758.
- Ohene - Adjai , S. , M. Ellis , F. McKeith , and S. Brewer (2003). Effects of chilling rate and location within muscle on the quality of ham and loin muscles. *Journal of Muscle Foods*, 14 (2): 107 – 118 .
- Oloo, J. E. O. (2010). Food safety and quality management in Kenya: An overview of the roles played by various stakeholders. *African Journal of Food, Agriculture, Nutrition and Development*, 10 (11).
- Olson, J. (2006). Implications of trends in land use change for livestock systems evolution in East Africa: Lessons from the LUCID Project.
- Otieno, D., Omit, J., Waiyaki, N., and Miencha, F. (2008). *Determinants of Kenya's Beef Export Supply*. KIPPRA Discussion Paper No. 85.
- Oz, F., and Kaya, M. (2011). Heterocyclic aromatic amines in meat. *Journal of food processing and preservation*, 35(6), 739-753.
- Page, J.K., Wulf, D.M., Schwotzer, T.R. (2001). A survey of beef muscle color and pH. *Journal of Animal Sciences*, 79:678–87.

- Parfitt, J., Barthel, M., and Macnaughton, S. (2010). Food waste within food supply chains: quantification and potential for change to 2050. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554), 3065-3081.
- Pavanello, S (2010). Livestock Marketing in Kenya-Ethiopia Border Areas – A Baseline Study. Overseas Development Institute, Humanitarian Policy Group (HPG) Working Paper. Assessed on <http://www.odi.org.uk/sites/odi.org.uk/files/odi-assets/publications-opinion-files/6054.pdf>
- Pearson, D. (1976). *The chemical analysis of foods*. Churchill Livingstone, Edinburgh London and New York, Seventh Edition
- Peng, W., Xing-lian, X. and Guang-hong, Z. (2009). Effects of Meat and Phosphate Level on Water-Holding Capacity and Texture of Emulsion-Type Sausage During Storage *Agricultural Sciences in China*, 8(12), 1475-1481
- Pereira-de-Abreu, D. A., Cruz, J. M., and Paseiro-Losada, P. (2012). Active and intelligent packaging for the food industry. *Food Reviews International*, 28(2), 146-187.
- Pérez-Elortondo, F., Ojeda, M., Albisu, M., Salmerón, J., Etayo, I., and Molina, M. (2007). Food quality certification: An approach for the development of accredited sensory evaluation methods. *Food Quality and Preference*, 18(2), 425-439.
- Petit, T., Caro, Y., Petit, A. S., Santchurn, S. J., and Collignan, A. (2014). Physicochemical and microbiological characteristics of biltong, a traditional salted dried meat of South Africa. *Meat science*, 96(3), 1313-1317.
- PKF Consulting Ltd. (2005). Meat Production in Kenya. Kenya Export Processing Zones Authority. Nairobi, Kenya. Retrieved from <http://www.epzkenya.com/UserFiles/File/MeatIndustry.pdf> last assessed 17/09/2013
- Porter ME (2008). *Competitive advantage: Creating and sustaining superior performance*. Simon and Schuster

- Rahman, M.S., Salman, Z., Kadim, I.T., Mothershaw, A., Al-Riziqi, M.H., Guizani, N., Mahgoub, O., Ali A. (2005). Microbial and physico-chemical characteristics of dried meat processed by different methods. *International Journal of Food Engineering*, 1(2):1–14.
- Ratti, C. (2001). Hot air and freeze-drying of high-value foods: a review. *Journal of food engineering*, 49(4), 311-319.
- Rendueles, E., Omer, M. K., Alvseike, O., Alonso-Calleja, C., Capita, R., and Prieto, M. (2011). Microbiological food safety assessment of high hydrostatic pressure processing: A review. *LWT-Food Science and Technology*, 44(5), 1251–1260.
- Resurreccion, A. V. A. (2003). Sensory aspects of consumer choices for meat and meat products. *Meat Science*, 66(1), 11-20.
- Rich K., Ross R., Baker A. and Negassa, A. (2011). Quantifying value chain analysis in the context of livestock systems in developing countries. *Food Policy* 36: 214–222.
- Robbins , K. , Jensen. J., Ryan, K., Homco-Ryan, C., McKeith, F. and Brewer, S. (2003). Consumer attitudes towards beef and acceptability of enhanced beef. *Meat Science*, 65 (2): 721 – 729 .
- Rota, A and Sidahmed, A. (2010). IFAD’s Livestock Position Paper Livestock planning, challenges and strategies for livestock development in IFAD. Rome. <https://www.ifad.org/documents/10180/bcb2e5dd-ad6b-4a5d-a23b-6031d5f99303>
- Rota, A. and Sperandini, S. (2009). Value chains, linking producers to the markets, in Livestock Thematic Papers: Tools for project design. IFAD, Rome. <http://www.ifad.org/lrkm/factsheet/valuechains.pdf>
- Russell, B. C., McAlister, G., Ross, I. S., and Pethick, D. W. (2005). Lamb and sheep meat eating quality-industry and scientific issues and the need for integrated research *Australian Journal of Experimental Agriculture*, 45, 465–467.

- Rutten (2013) What economic theory tells us about the impacts of reducing food losses and/or waste: implications for research, policy and practice. *Agriculture and Food Security* 2:13
- Saguay, I. S., and Dana, D. (2003). Integrated approach to deep fat frying: engineering, nutrition, health and consumer aspects. *Journal of food engineering*, 56(2), 143-152.
- Salvá, B. K., Fernández-Diez, A., Ramos, D. D., Caro, I., and Mateo, J. (2012). Chemical composition of alpaca (*Vicugna pacos*) charqui. *Food chemistry*, 130(2), 329-334.
- Satterthwaite D, McGranahan G and Tacoli C (2010).Urbanization and its implications for food and farming. *Philosophical Transactions of the Royal Society of London B: Biological Sciences*, 365(1554): 2809-2820.
- Schwanke S, Ikins WG, Kastner C and Brewer MS (1996). Effects of liquid smoke on lipid oxidation in a beef model system and restructured roasts. *Journal of Food Lipids*, 3: 99–113.
- Scollan, N., Hocquette, J. F., Nuernberg, K., Dannenberger, D., Richardson, I., and Moloney, A. (2006).Innovations in beef production systems that enhance the nutritional and health value of beef lipids and their relationship with meat quality, *Meat science*, 74(1), 17-33.
- Shahidi , F. (1994). Flavor of meat and meat products — An overview. In Flavor of Meat and Meat Products, F. Shahidi (ed). London : Blackie Academic and Professional .
- Shahidi, F. and Wanasundara, U. N. (2002).Methods for measuring oxidative rancidity in fats and oils.*Food lipids: chemistry, nutrition and biotechnology*, 387-403.
- Sharma, A., Chen, C. R., and Lan, N. V. (2009). Solar-energy drying systems: A review. *Renewable and sustainable energy reviews*, 13(6), 1185-1210.
- Singh, G., Kiran, S., Marimuthu, P., Isidorov, V., and Vinogorova, V. (2008).Antioxidant and antimicrobial activities of essential oil and various oleoresins of *Elettaria cardamomum* (seeds and pods).*Journal of the Science of Food and Agriculture*, 88(2), 280-289.

- Singh, R. and Singh, N. (2005). Quality of packaged foods. In J. H. Han (Ed.), *Innovations in food packaging* (pp. 22–24). Amsterdam: Elsevier Academic Press.
- Singh, R. P., and Anderson, B. A. (2004). The major types of food spoilage: an overview. In *Understanding and measuring the shelf-life of food*, 3-23. Woodhead Publishing Limited
- Sosa-Morales, ME, Orzuna-Espiritu, R, and Velez-Ruiz, JF. (2006). Mass, thermal and quality aspects of deep-fat frying of pork meat, *Journal of Food Engineering*, 77, 731–738
- Stabinsky, D., and Brush, S. B. (2007). *Valuing local knowledge: indigenous people and intellectual property rights*. Island Press.
- Steenkamp JEM and van Trijp HCM. (1996). Quality guidance: a consumer-based approach to food quality improvement using partial least squares. *European Review of Agricultural Economics*, 23(2): 195-215.
- Tajkarimi, M. M., Ibrahim, S. A., and Cliver, D. O. (2010). Antimicrobial herb and spice compounds in food. *Food control*, 21(9), 1199-1218.
- Tateo, F., Caseiro, G., Orlandi, A. and Giovanditto, S. (1995) Food flavors: generation, analysis and process influence. London: Elsevier Science, 1995
- Teshome, J., and Bayissa, Z. (2014). A Literature Review Report on Understanding the Context of People Transitioning out of Pastoralism (TOPs) in Ethiopia. *Addis Ababa: Haramaya University*.
- Thompson, R. (2015). Red meat and bowel cancer risk – how strong is the evidence? *World Cancer Research Fund*. Last accessed on 16th August, 2016
<http://www.wcrf.org/int/blog/articles/2015/10/red-meat-and-bowel-cancer-risk-how-strong-evidence>

- Tiwari, U., Gunasekaran, M., Jaganmohan, R., Alagusundaram, K., and Tiwari, B. K. (2011). Quality characteristic and shelf life studies of deep-fried snack prepared from rice brokens and legumes by-product. *Food and bioprocess technology*, 4(7), 1172-1178.
- Toldrá, F., and Reig, M. (2011). Innovations for healthier processed meats. *Trends in Food Science and Technology*, 22, 517–522
- Toth, L., and Potthast, K. (1984). Chemical aspects of the smoking of meat and meat products. *Advances in food research*, 29, 87-158.
- Troy, D.J. and Kerry, J.P. (2010). Consumer perception and the role of science in the meat industry, *Meat Science*, 86, 214–226.
- Velasco, V., and Williams, P. (2011). Improving meat quality through natural antioxidants. *Chilean journal of agricultural research*, 71(2), 313.
- Véronique, C. (2008). Bioactive packaging technologies for extended shelf life of meat-based products. *Meat science*, 78 (1), 90-103.
- Vestergaard, M., Oksbjerg, N., Henckel, P. (2000). Influence of feeding intensity, grazing and finishing feeding on muscle fibre characteristics and meat colour of semitendinosus, Longissimus dorsi and supraspinatus muscles of young bulls. *Meat Science*. 54:177–85.
- Vitrac, O, Dufour, D, Trystram, G and Raoult-Wack, AL. 2002. Characterization of heat and mass transfer during deep-fat frying and its effect on cassava chip quality. *Journal of Food Engineering*, 53, 161–176.
- Wanyoike, F., Kaitibie, S., and Omore, A. O. (2009). Can small-scale actors earn higher returns from improved quality and safety of animal products? *Unpublished manuscript*
- Weber, J., Bochi, V. C., Ribeiro, C. P., Victório, A. D. M., and Emanuelli, T. (2008). Effect of different cooking methods on the oxidation, proximate and fatty acid composition of silver catfish (*Rhamdia quelen*) fillets. *Food Chemistry*, 106(1), 140-146.

- Wellard-Dyer, K. (2012). *Pastoralism in the Horn of Africa: Diverse livelihood pathways*. Future Agricultures Consortium Secretariat, University of Sussex, Brighton
- WHO.(2003). Diet, nutrition and the prevention of chronic diseases. WHO Technical Report Series 916. Geneva: WHO Library Cataloguing publication Data.
- Wulf, D.M., O'Connor, S.F., Tatum, J.D., Smith, G.C. (1997). Using objective measures of muscle color to predict beef longissimus tenderness. *Journal of Animal Sciences*. 75:684–92.
- Yang, H. S., Kang, S. W., Joo, S. T., and Choi, S. G. (2012). Effects of salt concentration and drying time on the quality characteristics of pork jerky during dehydration. *Korean Journal for Food Science of Animal Resources*, 32(3), 285-292.
- Zegeye, A. (1999) A note on the influence of heat treatment, salting and smoking on the acceptability of camel meat products, *Meat Science*, 1999; 53(4): 217-219
- Zhang, W., Xiao, S., Samaraweera, H., Lee, E. J., and Ahn, D. U. (2010). Improving functional value of meat products. *Meat Science*, 86, 15–31
- Zhou, G.H. Xu, X.L., and Liu, Y. (2010). Preservation technologies for fresh meat – A review. *Meat Science*, 86, 119–128
- Ziaifar, AM, Achir, N, Courtois, F, Trezzani, I and Trystram, G. 2008. Review of mechanisms, conditions, and factors involved in the oil uptake phenomenon during the deep-fat frying process, *International Journal of Food Science and Technology*, 43, 1410–1423

Annex 1: Focus Group Discussion Guide

Questions for Focus Group Discussions (Knowledgeable people in pastoral communities)

1. Which livestock is mostly consumed in this area?
2. What do you slaughter the animal and how is meat handled immediately after slaughter?
3. How do you preserve your raw meat?
4. Describe the products in question 3 (appearance, taste, smell)?
5. How do you store the meat products you describe in question 3?
6. What is the shelf life of these products?
7. Where do you sell your products?
8. What challenges do you experience during preservation of meat?

Processing (Veterinary/ livestock extension officers in the County offices)

1. Are you aware of any meat products made by the different communities in this County? If aware, which products are made?
2. Which communities prepare the mentioned products?
3. How are the mentioned products made?
4. How are the mentioned products stored? What is the shelf-life of these products during storage?
5. Are the mentioned products marketed outside the regions or are they made just for subsistence?
6. What are the challenges faced by the communities in marketing these products?

Annex 3: Sensory analysis score sheet

Rank the following products using the following 7-points likert scale based on your preference.

- 7 = Like very much
- 6 = Like moderately
- 5 = slightly like
- 4 = neither like nor dislike
- 3 = slightly dislike
- 2 = Dislike moderately
- 1 = extremely bad.

After each sample, rinse your mouth with the water provided.

Evaluate without tasting

Sensory parameters	625	170	468	029
Colour				
Appearance				
Ease of scoping				
Preference based on oiliness				
Preference based on size of meat particles				

Now sniff and/ or taste to evaluate

Sensory parameters	625	170	468	029
Odour				
Taste				
Chewiness				
Overall acceptability				

Any other comment: _____