BIOCHEMICAL AND NUTRITIONAL CHARACTERISTICS OF FRESH CAMEL MEAT AND TRADITIONAL PROCESSED CAMEL MEAT (*NYIRINYIRI*) ALONG THE MEAT VALUE CHAIN

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DECLARATION AND RECOMMENDATION

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I declare that this thesis is my original work and has not been presented elsewhere for an award of a degree, diploma or certificate.

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DEDICATION

I dedicate this thesis to my beloved wife Jeophita June Mwajuma who has been a great source of inspiration and encouragement in my life and also to my children Naville, Nereus, Nuella and Nirel who had to bear with an absentee father for this work to be accomplished.

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ABSTRACT

Traditional processed camel meat (*Nyirinyiri*) is a ready to eat meat product prepared traditionally from dehydrated camel meat that is deep fried in fat. The processed product is stored in the same fat and consumed little by little as required because of its long shelf life with desirable taste which pastoral households use in their diets, snack or sell for income. This study analyzed the biochemical, chemical and nutritional status of camel *Nyirinyiri* from production area in Isiolo County to urban markets including Nairobi to ascertain its safety and quality. Thirty five samples of fresh camel meat and *Nyirinyiri* were obtained from production, processing and marketing nodes of the camel *Nyirinyiri* value chain. Molds accounted for 75% at production, 55.5% at processing and 66.7% at marketing nodes with counts highest at the market (1.2 log cfu/g) and lowest at processing (0.8 log cfu/g) relative to production which was (1.0 log cfu/g). The most common mold species were *Cunninghamella* (20%) and *Syncephalastrum* (17.1%) relative to *Fusarium* (14.3%), *Alternaria* (11.4%) and *Paecilomyces* (11.4%) while *Aspergillus* (5.7%), *Penicillium* (5.7%) and *Mucor* (2.9%) were least common. Using High Performance Thin Layer Chromatography (HPTLC) and Agar Diffusion Test methods, aflatoxins B_1 and G_1 and antibiotic residues respectively, were not detected at all nodes of the value chain. The mean values for crude protein, crude lipids and free fatty acid at the different nodes of the *Nyirinyiri* value chain were significantly different at $P < 0.05\%$ level. The crude protein increased significantly ($P<0.05$) from 25.26% at production to 49.68% and 48.07% at processing and marketing respectively. There was a significant increase in crude lipids between production (1.18%) and processing (22.04%) nodes of the value chain. The same trend was exhibited at marketing to 24.01%. There was a significant increase ($P<0.05$) in free fatty acid (FFA) level from 0.2% at production to 0.73% at processing relative to 0.98% at marketing nodes of the camel *Nyirinyiri* value chain. The results indicate that camel *Nyirinyiri* is contaminated by spoilage and pathogenic molds. However, it is free from antibiotic residue. Protein fraction and fat increases along the value chain.

Key words: Molds, camel, *Nyirinyiri,* value chain

TABLE OF CONTENTS

DECLARATION AND RECOMMENDATION .... **ii**

DEDICATION .... **iii**

ACKNOWLEDGEMENT .... **iv**

ABSTRACT .... **v**

LIST OF TABLES .... **viii**

LIST OF FIGURES .... **ix**

ABBREVIATIONS .... **x**

CHAPTER ONE **1**

INTRODUCTION **1**

1.1 Statement of the problem. 3

1.2 Objective of the study 3

1.4 Hypotheses 4

1.5 Justification of the study 4

CHAPTER TWO **5**

LITERATURE REVIEW **5**

2.1 Camel meat production and handling. 5

2.2 Qualities and characteristics of camel meat 6

2.3 Indigenous knowledge meat processing 7

2.4 Occurrence and health risks of mycotoxins in meat 9

2.5 Spoilage of meat and meat products 11

2.6 Public health concerns and food safety 11

2.7 Meat compositional changes 12

CHAPTER THREE **15**

MATERIALS AND METHODS **15**

3.1 Study site 15

3.2 Mapping the camel *Nyirinyiri* value chain 15

3.3 Sampling of camel meat and *Nyirinyiri* 16

3.4.1 Isolation of molds. 16

3.4.2 Quantitative analysis of aflatoxin B_1 and G_1 17

3.4.3 Qualitative analysis of antibiotic residues 17

3.4.4 Analysis of the nutritional composition 18

3.5 Statistical analyses 19

CHAPTER FOUR **20**

RESULTS **20**

4.2 The molds isolated from fresh camel meat and N*yirinyiri* 22

4.3 Aflatoxin B_1 and G_1in camel meat and *Nyirinyiri* 25

4.4 Nutritional (Compositional) properties of *Nyirinyiri* 26

5.1 The camel meat and *Nyirinyiri* value chain 28

5.2 Microbiological characteristics of fresh camel meat and camel *Nyirinyiri* 30

5.4 Antibiotic residues 33

5.5 Compositional properties of fresh camel meat and *Nyirinyiri* 33

CHAPTER SIX **35**

CONCLUSIONS AND RECOMMENDATIONS **35**

REFERENCES **36**

APPENDIX 1 : Nyirinyiri processing questionnaire **41**

APPENDIX 2: Map of Isiolo county **44**

APPENDIX 3: Analysis of variance of the total mold count along the value chain nodes ... **45**

APPENDIX 4: Analysis of variance of the effect of processing on crude protein of camel *Nyirinyiri* along the value chain **46**

APPENDIX 5: Analysis of variance of the effect of processing on crude lipids of camel *Nyirinyiri* along the value chain **47**

APPENDIX 6: Analysis of variance of the effect of processing on free fatty acid level of camel *Nyirinyiri* along the value chain **48**

APPENDIX 7: Publication in the International Journal of Scientific & Engineering Research (ISSN 2229-5518) **49**

LIST OF TABLES

Table 1: Microbiological characteristics of fresh camel meat and camel *Nyirinyiri* obtained along the value chain. 22

Table 2: Summarized numbers and percentages of identified mold species in examined fresh camel meat and camel *Nyirinyiri* 23

Table 3: Macroscopic and microscopic characteristics of identified mold species in camel *Nyirinyiri* 23

Table 4: Variations in nutritional composition of camel *Nyirinyiri* along the value chain 27

LIST OF FIGURES

Figure 1: The meat value chain mapping results 21
Figure 2: Isolated mold genera on potato dextrose agar at $25^{O}C$ for seven days 24
Figure 3: Percent distribution of mold genera isolated samples of camel meat and *Nyirinyiri* along the value chain..25
Figure 4: HPTLC chromatograms for aflatoxins B_1 and G_1 in camel *Nyirinyiri* samples.......26

ABBREVIATIONS

AOAC	–	Association of Official Analytical Chemists.
ASAL	–	Arid and Semi-arid land.
DNA	_	Deoxyribonucleic acid.
FAO	–	Food and Agricultural Organization.
HPLC	–	High Performance Liquid Chromatography
HPTLC	-	High Performance Thin Layer Chromatography.
IFST	_	Institute of Food Science and Technology.
IKFP	-	Indigenous Knowledge Food Processing
KEBS	–	Kenya Bureau of Standards.
MRL	-	Maximum Residue Level
NGO	-	Non governmental organization
LSD	-	Least significant difference
ppb	-	Parts per billion.
Ppm	-	Parts per million.
RUFORUM	–	Regional University Forum for Capacity Building in Agriculture.
ANOVA	-	Analysis of Variance
WHO	–	World Health Organization.
KBS	-	Kenya Bureau of Statistics

CHAPTER ONE

INTRODUCTION

The dromedary camel is one of the most important domestic animals in arid and semi-arid (ASAL) regions, as it produces high quality food at comparatively low cost under extremely harsh conditions (Knoess, 1977 and Yagil, 1982). The camel has a great tolerance for high temperatures, high solar radiation and water scarcity. It can survive well on sandy terrain with poor vegetation and may chiefly consume feeds not used by other domestic species (Shalash, 1983). The camel produces animal protein at a comparatively low cost in arid zones (Tandon *et al*., 1988). Of all the animals kept in northern Kenya, camels are most adapted to the prevailing harsh environmental conditions in arid and semi-arid regions (Noor *et al*., 2012). Camels play multiple roles central to the livelihoods and culture of nomadic pastoralists in northern Kenya notably provision of milk and meat, a means of transport, and sources of income from sale of live camels and camel products. Thus, camels play an important part in the food security of communities in the ASALs of Kenya.

The population of camels in Kenya is estimated at 2,971,111 of which the greater Isiolo region in northern Kenya has an estimated camel population of 40,300 (KBS, 2010). In the northern part of Kenya, the main type of production system for camel herds is traditional nomadic system where the camel herders are continuously on the move in response to availability of grazing and water supplies. During this movement, microbial antibiotics are widely used in conventional camel production to prevent and treat microbial infection as was observed during this study. Residues of these substances may occur at unacceptable levels in edible tissues at slaughter giving rise to the potential for toxic effects in susceptible individuals. Camel meat is now increasingly commercialized and its consumption in urban areas of Kenya is growing, estimated at 5,000 metric tons per *annum* (Agri-consortium, 2003). Eastleigh in Nairobi County is the main market for camel milk and *Nyirinyiri* because majority of the inhabitants belong to the pastoral communities.

Different food products are made from camel meat by pastoralists using varied methods depending on the purpose of the product. For example in Ethiopia and northern Kenya, meat is cut into long pieces (*quanta*) smeared with powdered pepper, salted and dried by hanging above the fireplace for 5 – 7 days. This product is called *Biltong* (UNDRO, 1988). Among the Somali, strips of sun-dried meat are cut into small pieces that are fried (usually in oil with

garlic and *iliki*) and immersed in camel ghee (*kursi*). This product is referred to as *Otkacor Nyirinyiri.*

Nyirnyiri is a meat product prepared from sheep, goat or camel meat by traditional low cost technology. It is an indigenous and ready to eat dehydrated meat product that is preserved in cooking oil (Mathenge, 2005). Camel *Nyirinyiri* is prepared by cutting boneless camel meat into thin strips then sun drying the meat for 1 hour. The sun dried meat is then comminuted into small cubes and deep fried in commercial vegetable oil. It is stored in the same oil and consumed little by little as required.

These traditional foods are produced by small-scale family units and women group processors using their traditional knowledge or practices. Under these conditions, hygienic rules are not followed and quality control systems put in place during production. These traditional practices take place in a less predictable environment in which the risk of failure or food contamination is greater (Matofari *et al.*, 2007). The *Nyirinyiri* is marketed informally by the road side and inappropriately packaged into transparent polythene. These practices do not only predispose consumers to health risks such as food poisoning but also hasten spoilage of the meat by creating favorable conditions for microbial growth.

Water activity (a_w) levels of sheep *Nyirinyiri* ranges between 0.660 – 0.725 (Mathenge, 2005). This value supports the growth of strains of molds such as *Apergillus flavus* and *Aspergillus parasiticus.* The minimum water activity at which molds are capable of growing is 0.61 (Egan, 1984). Aflatoxins can be produced when the product is stored at a temperature of between 25°C – 30°C while exposed to oxygen. *Aspergillus flavus* produces the B type of aflatoxin which is the most potent while *Aspergillus parasiticus* produce both aflatoxin B and G. Aflatoxins are genotoxic carcinogens and are the most toxic of the mycotoxins (IFST, 2009). They have been linked to liver cancer particularly in developing countries where implicated foods are known to contain high levels of aflatoxins.

The challenges that impede women group *Nyirinyiri* processors which make them lose in quality, safety and price as well as accessing market opportunities vary in their number and significance. In northern Kenya, the harsh climate and poor infrastructure create insurmountable barriers, thus the product often varies widely in the degree of processing and this results in poorer microbiological stability and difficulty in achieving consistent quality.

Non-compliance to public health regulations, inappropriate packaging, transportation and storage of the product at ambient temperature favors the growth of mesophilic microbes. Previous studies on *Nyirinyiri* from northern Kenya concentrated on *Nyirinyiri* meat from sheep and goat (Mathenge, 2005) and there is little or no available information on camel *Nyirinyiri* meat value chain. The objective of this study was to analyze the biochemical, chemical and nutritional quality of camel *Nyirinyiri* along the value chain to ascertain the quality and safety for market acceptability to improve livelihoods of the pastoral people.

1.1 Statement of the problem.

Camel *Nyirinyiri* has been processed by pastoralists from time immemorial at domestic level for consumption or during festivals such as weddings. There have been attempts to make the product available for commercial basis especially in urban areas with the aim of improving the women pastoralist's livelihood through income security. However, there is a need to enhance market acceptability of camel *Nyirinyiri* because its main consumers in urban areas are pastoralists who have inhabited these places. Camel *Nyirinyiri* is processed in an open air environment and is also inappropriately packaged. This exposes the product to contamination by spoilage and pathogenic microorganisms from sources such as dust, soil and unclean surfaces. The storage of camel *Nyirinyiri* at room temperature favors growth of microorganisms resulting in spoilage as well as proliferation of possible pathogens especially molds that produce mycotoxins. The study conducted an analysis on microbiological (fungi), biochemical hazards and nutritional quality of camel *Nyirinyiri* along the value chain to identify constraints and possible interventions to improved safety.

1.2 Objective of the study

The overall objective is to enhance food safety, quality and market access of camel *Nyirinyiri* for consumers and for income security of the pastoral women processors

1.3 Specific objectives

i. Mapping out the camel *Nyirinyiri* value chain in Kenya.

ii. Determining the load, type and most common species of molds present in camel *Nyirinyiri.*

iii. To determine the level of aflatoxins B_1 and G_1 in camel *Nyirinyiri.*

iv. To test for antibiotic residues in camel *Nyirinyiri.*

v. To quantify the protein and fat content of camel *Nyirinyiri.*

1.4 Hypotheses

i. Camel *Nyirinyiri* is free from molds.

ii. Aflatoxins B_1 and G_1 are absent in camel *Nyirinyiri.*

iii. Camel *Nyirinyiri* is free from antibiotic residues.

iv. Camel *Nyirinyiri* processing has no effect on the protein and fat contents.

1.5 Justification of the study

The processing of *Nyirinyiri* by pastoralists dates back to many years. However, most of the published data is based on comparison of the different ways in which *Nyirinyiri* is processed and the bacteriological quality. Little has been done on the mycological, chemical and nutritional characteristics of camel *Nyirinyiri* value chain. Establishing the mycological and biochemical characteristics of the camel *Nyirinyiri* will provide information to both regulators and consumers which will promote the product from a food safety point of view. Determining the composition of camel *Nyirinyiri* will enlighten consumers on the nutritive value and thus create a shift towards their consumption. With the above benefits, more focus can be put on processing the product with an aim of enhancing market acceptability of camel *Nyirinyiri* for consumers. This would translate also to income security for the pastoral women processors.

CHAPTER TWO
LITERATURE REVIEW

2.1 Camel meat production and handling.

Camels in the area are kept in traditional herds. The camel type commonly kept is *Camelus dromedarius* and are managed in a nomadic style whereby, the herders keep moving in search of pastures and water from one area to another after a period of time. The population of camels in Kenya is estimated at 2,971,111 of which the greater Isiolo region in northern Kenya has an estimated camel population of 40,300 with a daily milk production of 50,000 litres. Camel meat is now increasingly commercialized and its consumption in urban areas of Kenya is growing, estimated at 5,000 metric tons per *annum* (Agri-consortium 2003). In the northern part of Kenya, the main type of production system for camel herds is traditional nomadic system where the camel herders are continuously on the move in response to availability of grazing and water supplies. In a more recent development, transhumant or semi-nomadic system, there is a degree of settlement experienced during the rainy season where rain fed agriculture is practiced for stable food production and the crop residues provide feed supplement for camel populations (Bakheit, 1999).

The camel meat production represents about 0.7% of the world meat production, i.e. 216,315 tons (FAO, 2006), but information is quite difficult to collect as the main part of the camel meat data comes from the informal market (Faye 2004). Camel meat in northern Kenya is an important product which serves as a source of food and income. Due to urbanization trends, camel meat is now increasingly commercialized and its consumption in urban areas of Kenya is growing, estimated at 5,000 metric tons per *annum* (Agri-consortium 2003). However, camel milk and meat value chains have been very inefficient leading to poverty levels of over 50% among pastoralists of northern Kenya compared to the national average of 46% (GoK 2009). These statistics indeed suggests that the camel sub-sector in Kenya deserves higher attention than is currently given by the government and development partners.

Camels have a low growth rate, late puberty, and long gestation time, so, the meat productivity is lower than for other ruminants. In traditional conditions, the Daily Growth Rate (DGR in g/day) for one-year camel is 190 to 310g (Faye *et al*., 2004). In more intensive conditions, it can reach 440 - 580g.Camel meat is availed through slaughter either at homes for ceremonies or due to old age and more recently for commercial market.

2.2 Qualities and characteristics of camel meat

Male camels are slaughtered when they are 1-3 or even 4-5 years old, which is considered their best age for meat production. As they grow older, their meat becomes tougher and loses quality because of old fibres and muscles (Nikmaram *et al*., 2011).Camel meat is known for its large muscular fibres and high percentage of water. It has a sweet taste because of the presence of glycogen, and its color is red or dark brown. In its general composition, camel meat is similar to beef and when the animal is 2 years old, its meat is similar to beef (Nikmaram *et al*., 2011). Young camel meat in particular is delicious and rich in nutritive elements which makes it as good as mutton. It also contains a high percentage of water compared to the meat of older camels. Recent developments make it imperative to conduct serious research on this meat because of its health and economic benefits. It is time to persuade the public to consume it because of its rich protein content and high nutritive quality; because as published statistics indicate, such consumption is still low in general (Oman Daily Observer, 2009).

The chemical composition and food value of camel meat has two qualities which distinguish it from beef and mutton: its low fat and high moisture content. Fat in camel meat amounts to 1.2 - 1.8% and in beef 4 – 8% .The figure for water is 20 %. These percentages mean that camel meat is richer than beef in protein and minerals (Oman Daily Observer, 2009). All these facts prove that not only the consumption of camel meat will lower the percentage of fat in the body, but it will lessen the intake of saturated fats connected with cardiovascular disease. Camels are better qualified than other animals to be a good source of meat especially in arid areas but also in other areas as well. Therefore we must devise methods to protect these animals and improve their production and their breeding since what genetic engineering has achieved in other animals can also be achieved in camels, especially as there are no technical obstacles to developing special breeds for meat production. People responsible for supervising and planning programs to develop animal wealth in the African continent should pay more attention to this neglected source of exploitable wealth.

Studies and medical research have proved that camel meat is superior to other kinds of meat. The camel is distinguished from other animals by the fact that the percentage of its intramuscular fat declines as the animal gets older (Bakheit, 1999). This quality, only found in camels, makes their meat less fatty, so its consumption is healthy and recommended for weight loss. And this quality also reduces the risk of cardiovascular disease and atherosclerosis since it lowers the percentage of cholesterol in the blood. Camel meat has

other medical qualities, too, like protecting against cancerous tumors, as claimed by some researchers, because it contains unsaturated fatty acids like linoleic acid which interact with other unsaturated fatty acids taken from vegetable oils to protect against cancer(Oman Daily Observer, 2009). Camel meat can also be used as a cure for exhaustion and fatigue because it contains energy needed by body cells. Such energy comprises sugar not fat, since, a camel's fat is concentrated in its hump whereas other animals store it in their muscles. In addition, camel meat contains glycogen, a carbohydrate which is easily absorbed and metabolized in the body, and is converted to glucose which activates nerve as well as other cells.

2.3 Indigenous knowledge meat processing

The arid and semi -arid land regions are less developed in terms of infrastructure hence food processing factories and refrigeration facilities are limited. Pastoralists, the major inhabitants of these areas, rely on traditional low cost appropriate technologies to process their foods such as drying (Mathenge, 2005). The oldest forms of meat preservation which are salting and drying date right back to the early man, who realized that raw meat must be quickly processed to preserve it for consumption at a later date. These two methods of meat preservation are employed by *Nyirinyiri* processors. Drying extends the shelf life of meat products by creating an unfavorable environment for microorganisms to grow through lowering the water activity. *Nyirinyiri* serves as a source of protein and is a fatty food product since it is stored in fat (Mathenge, 2005). It has a stable shelf life, reduced water activity and is good enough for eating without further hydration. The high temperatures used during deep frying dehydrate the meat hence lowering its water activity to a level that is unfavorable for the growth of many groups of spoilage microorganisms.

The art of preserving meat by deep fat frying is an old practice among the nomadic pastoralist communities of northern Kenya such as Somali, Borana, Rendile and Samburu. The method of preparation and storage varies slightly from one community to the next (Mathenge, 2005). In some communities, women prepare *Nyirinyiri* as a delicacy especially to celebrate the homecoming of the head of the household from his journey. It is also cooked during weddings and other festivals. These foods are marketed informally and this has posed growing public health concern on its safety (Matofari *et al*., 2007). These traditional foods are produced by many small-scale family units and women groups using their traditional knowledge or practices and they take place in a less predictable environment in which the risk of failure or food contamination is greater (Matofari *et al*., 2007).

In Africa, meat from cattle, sheep and goats is preserved through drying, smoking, salting (Katz and Weaver, 2003) and use of honey which all use the principle of removal of water from the product to increase shelf life. Removal of water helps prevent the growth of spoilage and pathogenic microorganisms and prevents chemical reactions that lead to spoilage of the food. Dehydrated meats have a long shelf life and are not open to spoilage unless rehydrated. All handling and storage methods are therefore primarily concerned with minimizing microbial contamination and retarding microbial growth and activity. Modern methods of preserving meat include the use of high temperature e.g. canning, low temperature e.g. chilling, freezing and pasteurization, drying, use of radiation and the use of chemical preservatives.

In Ethiopia and northern Kenya, among the pastoralists, meat that is cut into long pieces (*quanta*) is smeared with powdered pepper, salted, and dried by hanging above the fireplace for 5 - 7 days (UNDRO, 1988). Among the Somali, dried meat (*otkac*or *nyirinyiri*) is prepared from camel meat (*hilibgel*). Strips of sun-dried meat are cut into small pieces that are fried (usually in oil with garlic and *iliki*) and immersed in camel ghee (*subag*). *Nyirnyiri* can keep for several months and is usually eaten with tea or honey (Katz and Weaver, 2003). Camel *Nyirinyiri* is prepared by deep frying comminuted camel meat in fat and preserving the product in fat.

2.4 Occurrence and health risks of mycotoxins in meat

Although mycotoxin contamination of food commodities is a global problem, the developed world through the application of modern agricultural practices and legislatively regulated food processing and marketing system have greatly reduced exposure in these populations (Oyero and Oyefolu, 2010). The contrary is the case in developing countries where populations live largely on commodities from local markets where regulations relating to mycotoxin control and consumer protection rarely exist; even when they are available they are not strictly enforced. As a result, mycotoxins presence in food represents a constant health risk for man.

Aflatoxins have been recognized as significant contaminants by the agricultural production community since the 1960s and control strategies have mostly eliminated harmful exposures in developed countries (Guo, 2000). The application of these strategies in developing countries is difficult, given differences in technology, agriculture, and trade practices, as well as other issues contributing to occurrence of aflatoxins and incidence of exposure. Consequently, over 5 billion people in developing countries worldwide are at risk of chronic exposure to aflatoxins through contaminated foods (IFST, 2009).One of the world significant mycotoxins are aflatoxin, toxins produced by three species of molds. *Aspergillus flavus* produces the B type of aflatoxin, and other two species (*Aspergillus parasitic* and *Aspergillus nomius*) produce both aflatoxins B and G.

Mycotoxins occur widely in nature and are produced by filamentous fungi. Organisms producing them can develop in the foods at any stage in the food chain from farm to fork. They may be present in the food as a result of the organism growing and producing the toxin or they enter the food chain by a more indirect route, for example in milk from animals that have consumed contaminated feed. Developing economies are at particular risk of contamination as moist, warm climatic conditions favor mould growth, while adequate control and good storage may be difficult to achieve (IFST, 2009).

Human intake of mycotoxins occurs mainly from plant-based foods and from animal derived foods such as milk and milk products and certain fermented meat-based products (Bennett and Klich, 2003). While over 300 mycotoxins have been identified, about 20 have been shown to occur naturally in foods and feeds at significant levels and frequency to be of a food safety concern (Smith *et al*., 1994). The majority of these toxins are produced by fungi of the genera, *Aspergillus, Penicillium* and *Fusarium*. The most commonly occurring mycotoxins include aflatoxins (B_1,B_2,G_1G_2,M_1), Ochratoxin A, patulin, citrinin and sterigmatocystin. The

aflatoxin problem has been reported to be more serious in tropical and subtropical regions of the world where climatic conditions of temperature and relative humidity favor the growth of *Aspergillus flavus* and *Aspergillus parasiticus*. Aflatoxins are genotoxic carcinogens and are the most toxic of the mycotoxins (IFST, 2009). They have been linked to liver cancer particularly in developing countries where implicated foods are known to contain high levels of aflatoxins. It is not possible to determine the threshold levels below which aflatoxins have no effect and therefore no Tolerable Daily Intake (TDI) levels have been recommended (IFST, 2009). However, it is recommended that concentrations of aflatoxins in food should be reduced to the lowest levels achievable.

The occurrence of aflatoxins is associated with certain environmental factors hence the extent of contamination will vary with geographic location, agricultural and agronomic practices, and the susceptibility of commodities to fungal invasion during pre-harvest, harvesting, storage and/or processing periods. Aflatoxins have received greater attention than any other mycotoxins because of their demonstrated potent carcinogenic effect in susceptible laboratory animals and their acute toxicological effects in humans (IFST, 2009). As it is realized that absolute safety is never achieved, many countries have attempted to limit exposure to aflatoxins by imposing regulatory limits on commodities intended for use as food and feed. Recent reports indicate significant levels of aflatoxins in feeds and farm products marketed in East African Countries (WHO, 1990). For instance, animal feeds and milk from urban centres in Kenya were found to be laden with aflatoxin B_1 and M_1 respectively, with 55% of the feeds and 31% of the milk samples exceeding the WHO/FAO limits of 5ppb and 0.05µg/kg (FAO/WHO, 1990, 1992), respectively.

Aflatoxins bind to macromolecules, especially nucleic acids and nucleoproteins. Their toxic effects include mutagenesis due to alkylation of DNA, carcinogenesis, teratogenesis, reduced protein synthesis, and immunosuppression. Reduced protein synthesis results in reduced production of essential metabolic enzymes and structural proteins for growth. The liver is the principal organ affected. High doses of aflatoxins result in severe hepatocellular necrosis; prolonged low dosages result in reduced growth rate and liver enlargement. The various control strategies to prevent the growth of mycotoxigenic fungi as well as to inhibit mycotoxin biosynthesis include pre-harvest (resistant varieties, field management and use of biological and chemical agents), harvest management, and post-harvest (improving of drying and storage conditions and the use of natural and chemical agents) (Kabak *et al*., 2006).

Throughout the world, there are many advisory bodies concerned with food safety, including the World Health Organization (WHO), Codex Alimentarius Joint Expert Committee for Food Additives and Contaminants (JECFA) and the European Food Safety Authority (EFSA). They regularly assess the risk from mycotoxins and advice on controls to reduce consumer exposure.

2.5 Spoilage of meat and meat products

The rate of microbial spoilage of meat varies widely depending on (i) initial microbial contamination,(ii) temperature, (iii) pH, (iv) presence of oxygen, (v) presence of nutrients, and (vi) presence of inhibitory substances, including carbon dioxide. The most common forms of spoilage of raw meat take place slowly, and considerable growth of microorganisms can occur without detracting from the eating quality of the meat. When it eventually becomes apparent, spoilage takes the form of souring or slime production on the surfaces, which is readily recognized by the typical consumer before the meat becomes unsuitable for consumption. Alternative less common spoilage takes the form of putrefaction and produces offensive odors and flavors associated with the breakdown of nitrogen-containing substances (Hannan, 1985).The most important factors in handling fresh meat are speed of handling, control of temperature, and good hygiene conditions. Slaughter practices are required to minimize both physical and microbiological contamination of carcasses. Integrated hygiene control along the meat production line could therefore be the processor's most effective approach to increasing the storage life of these products (Smulders, 1995).

2.6 Public health concerns and food safety

The routes by which veterinary drugs make it into human food trace a disturbing portrait of how large dairy farms operate. Sick animals are given medications to help them recover, but if it appears an animal will die, it's often sold to a slaughterhouse as quickly as possible, in time to kill it before it dies(Kambarage *et al*., 2004). That way, the farmer can recoup some of his investment in the animal. In such cases, medications may be consumed along with the meat. Cooking meat destroys pathogens, but not chemical residues, which heat may actually breakdown into components that are more harmful to consumers (Bakheit, 1999). Antimicrobial substances, commonly referred to as antibiotics, are widely used in conventional animal production to prevent and treat bacterial infection. The use of antibiotics may be therapeutic, in treatment of current infections in animals, prophylactic, to prevent the

occurrence of infections, or as feed additives (limited, specific compounds) to improve performance (O'Keeffe *et al*., 2001).

Surveys carried out in Kenya (Kang'ethe *et al*., 2005) have reported residue levels in raw milk samples ranging from 1% to 36%. These high levels pose a health risk for the following reasons: a) certain antibiotics may lead to allergic reactions in sensitized individuals, b) development of antibiotic resistant bacteria populations amongst mastitis pathogens or intestinal microflora of calves and humans after ingestion of milk containing residues of antibiotics. Antibiotic residues in milk are illegal when above maximum residue limits (MRL's). MRL's have been established to ensure public safety. MRL is the maximum concentration of a residue resulting from the use of a veterinary drug, expressed in ppm or ppb that is legally permitted or recognized as acceptable in or on food. Ordinary heat treatment does not destroy fully the activity of most antibiotics, thus residual activity may be present even in boiled milk posing a health hazard. There are two areas of particular concern with regard to use of antibiotics in animal production. Firstly, residues of these substances may occur at unacceptable levels in edible tissues at slaughter giving rise to the potential for toxic effects in susceptible individuals. Secondly, their widespread use in agriculture may contribute to the development of resistant strains of bacteria (O'Keefe *et al*., 2001).

Animals that do not respond to treatment are slaughtered and consumed in the household, die and are buried, sold off quickly to butchers before they die or are thrown away after death. Meats from sick animals sold to butchers find their way into the market and human food chain despite the risks (Kambarage *et al*., 2004). Most farmers in developing countries do not often care about withdrawal periods in treated animals (Keyyu *et al*., 2003) and cows are usually treated and milked at the same time in the morning before being let out to graze (Awumbila and Bokuma, 1994). Drug residues in meat and milk are therefore likely to be higher in livestock products produced by smallholder rural farmers and herdsmen.

2.7 Meat compositional changes

The purpose of many food processing techniques is to slow down or prevent deleterious changes occurring in food materials. These changes are often caused by contaminating microorganisms or by chemical reactions among natural components of food tissues. These changes can also be caused by simple physical occurrences such as dehydration (Cheftel *et al*., 1997). Heating muscular tissues causes extensive changes in its appearance and physical

properties. These changes are dependent on the time-temperature conditions imposed during processing. Alpha-Actin is the most heat labile muscle protein, becoming insoluble at 50°C. The heavy and light chains of mammalian myosin become insoluble at about 55°C and actin at between 70°C –80°C (Cheftel *et al.*, 1997). Myoglobin also undergoes denaturation during heating. The susceptibility of the haem pigment to oxidation in the denatured protein is much greater than in the undenatured myoglobin. On heating, therefore, red meat generally turns brown due to the formation of the oxidized pigment, hemin.

Severe heating of meat brings about further changes in proteins and free amino acids with production of some volatile products. Sulfur-containing compounds produced include: hydrogen sulfide, mercaptans, sulfides and disulfides as well as aldehydes, ketones, alcohols and volatile amines. The nutritional values of these amino acids can thus be reduced. Lipid components may also breakdown into volatile products such as aldehydes, ketones, alcohols, acids and hydrocarbons. Some of these volatile compounds contribute to the flavor and aroma of cooked meat(Cheftel *et al.*, 1997). It is well known that raw meat has a serum-like or blood-like flavor, which on heating is altered to produce compounds that impart a full, rich flavor. The conditioning of postmortem muscle causes this cooked flavor to be richer and stronger as the post-rigor muscle becomes tenderized. Most of the compounds responsible for taste and "meaty" flavor consist of a reducing sugar (usually glucose), a source of amino acids and peptides, and a taste enhancer (e.g., inosinic acid; Baines and Mlotkiewicz, 1984).

Lipid oxidation is a major factor that limits the shelf life of dehydrated muscle tissue. Lipid oxidation results in undesirable flavors that make the animal tissue unacceptable. Destruction of oxidisable nutrients such as essential fatty acids, some amino acids and some vitamins; oxidation of haem pigments and protein cross-linking are effects of lipid oxidation. Production of fatty acids during meat storage, for example by the action of lipases or phospholipases can cause off-flavors. They can also interact with contractile proteins and denature them. Oxidation products of fatty acids, including free radicals can interact with protein causing their insolubilisation, by intermolecular cross-linking, thereby decreasing water-holding ability and increasing muscle toughness (Pearson and Dutson, 1990).

Non-enzymatic browning can also take place. The carbonyl source for this reaction includes glucose, phosphorylated sugar derivatives and other aldehydes and ketones. Amine groups for this reaction come mainly from free amino acids or the e-amino groups of lysine residues.

The resultant maillard reaction leads to formation of dark pigments and decreased nutritive value of amino acids and proteins. Moreover, when sugars react with proteins, the physical properties of protein change resulting in a toughening or hardening of the texture. Non-enzymatic browning can also lead to desirable changes in flavors some of which are typical of cooked meats.

CHAPTER THREE
MATERIALS AND METHODS

3.1 Study site

The study was carried out in Isiolo County, situated in the Eastern part of Kenya (appendix 2).The county is a semi-arid to arid region covering 25,336 square kilometers, most of which is composed of lowland areas receiving between 150 - 650mm mean annual rainfall. There are two rainy seasons in most years (April-June and October-December) and annual rainfall ranges from 150 to 650mm. Day time temperatures vary from 12°C - 28°C. The most predominant type of vegetation is shrubs and acacia plant species that are well adapted to the high temperatures. Camels are the most abundant livestock species in this area, with camel milk and meat production being an important income earning opportunity for the pastoral households. The human population as of 2009 was established at 143,294 of which Isiolo North constitutes 100,176 while Isiolo South 43,118 (KBS). Out of the total population a portion of approximately 62,374 live in the urban areas while the rest reside in the rural areas. It is amongst the ten least populated counties in Kenya.

3.2 Mapping the camel *Nyirinyiri* value chain

The value chain mapping was conducted in two phases; a) an initial basic map after the collection of initial data illustrating participants and functions using a semi structured questionnaire, and b) adjusted mapping, which was conducted following additional interviews. The actors along the camel *Nyirinyiri* value chain were interviewed to assess camel meat handling and processing practices. Additional information was obtained through survey. Three women group processors were identified, who through a focus group discussion were able to describe the production of camel *Nyirinyiri* as well as demonstrate the same. The information provided included; mapping the flow of product, the volume of product and mode of transportation, as well as the geographical flow of the product. The information obtained from the focus group discussion was used as the basis for formulating the value chain. The functions were determined which included the following elements;

- Input supply
- Production
- Transport
- Processing
- Marketing

These elements were used to organize key information about the role of actors in the value chain.

3.3 Sampling of camel meat and *Nyirinyiri*

Using simple random sampling, a total of eight fresh camel meat samples weighing 250g each were obtained at production represented by four butcheries slaughtering camels within Isiolo town. At processing, a total of eighteen *Nyirinyiri* samples weighing approximately 500g were collected from five different processors selected randomly from the women group stakeholders. Similarly, a simple random sampling was applied in obtaining samples at marketing where a total of nine samples weighing 500g each were obtained from nine *Nyirinyiri* vendors within Nairobi's Eastleigh market. The sampling yielded a total of 35 (eight fresh camel meat and twenty seven camel *Nyirinyiri*) samples at different nodes along the value chain. Sampling at marketing node was subject to availability of the product at from the vendors and each sample was taken in duplicate. Samples were aseptically placed into sterile glass containers, maintained at $5^{o}C$ – $10^{o}C$ in a cooler box using ice packs for laboratory analysis within a period of 6 hours.

3.4 Laboratory analysis of the samples for molds, antibiotic residues and nutritional composition

3.4.1 Isolation of molds.

The plate count method was used to determine the load and type of molds present in the camel *Nyirinyiri* product. Dilutions of Buffered Peptone Water (10^{-1} up to 10^{-3}) were pour-plated on Potato Dextrose Agar. 1ml from each dilution bottle was pipetted and poured into each duplicate sterile Petri dish. This involved preparing 15-20 ml of the media (39g of Potato Dextrose Agar in 1000 ml distilled water) and sterilizing at $121^{0}C$ for 15 minutes then cooled to $50^{o}C$. The pH was then adjusted to 3.5 by aseptically adding sterile 10% tartaric acid to inhibit bacterial growth. The media and the sample were mixed gently and incubated at room temperature for 7 days. All colonies were counted and colony forming units/gram (cfu/g) calculated by multiplying the average number of colonies by the reciprocal of the dilutions. Successive hyphae tip were transferred until pure cultures of each fungus was obtained. The fungi were identified by their cultural and morphological features (Benson,2001) using a microscope. Visual examination of the colony was used to reveal important data concerning color, texture, diffusible pigments, growth zones, aerial and

submerged hyphae growth rate, colony topography, and macroscopic structures such as ascocarps and sclerotia.

3.4.2 Quantitative analysis of aflatoxin B_1 and G_1

The meat was ground using a motor and pestle. Approximately 5g of ground meat were accurately weighed into a glass – stoppered flask and 20 ml of a mixture of methanol and water (17:3) added. The mixture was shaken vigorously by mechanical means for 30 minutes and filtered on a Whatman filter paper. The first 5 ml of the filtrate were discarded and the next 4 ml portion collected. The filtrate was transferred to a separating funnel upon which 4 ml of sodium chloride solution (5g of sodium chloride in 50 ml of water) and 2.5ml of hexane were added and shaken for 1 minute. The layers were allowed to separate and the lower aqueous layer transferred to a second separating funnel. This aqueous layer was extracted twice, each time with 2.5 ml of methylene chloride, by shaking for 1 minute. The layers were allowed to separate each time. The lower organic layer was separated and the combined organic layers collected into a 50 ml conical flask. The organic solvent was evaporated on a water bath. The remaining extract was transferred to an appropriate sample tube and evaporated to dryness on a water bath. The residue obtained was dissolved in 200 µl of acetonitrile and shaken by mechanical means.

Preparation of aflatoxin standards B_1 and G_1

Accurately weighed standard solutions containing 0.05 µg/ml aflatoxin B_1 and G_1 (Sigma) in a mixture of chloroform and acetonitrile (9.8:0.2) were prepared. The sample after preparation was transferred into 1ml auto sampler vials. 10µl of the sample was applied onto the lower edge of the plate. The sample was developed in a 10ml developing solvent of Chloroform, acetone, water (140:20:0.3) v/v/v in an automatic development chamber saturated for 20 minutes. A developing distance of 70mm from the lower edge of the plate was allowed and the plate dried for 5 minutes in a stream of cold air. The plates were then examined under UV at 366°nm.

3.4.3 Qualitative analysis of antibiotic residues

Samples were screened for antibiotic residues using the four plate test according to Heitzman, 1994 (Agar diffusion method). *Bacillus subtilis*, which was sensitive to the antibacterial substances was inoculated into Muller Hinton agar medium (Oxoid) in a petri dish. The medium was adjusted to pH 6.0, 7.2 and 8.0 using 0.1N sodium hydroxide and 0.1N

hydrochloric acid and then autoclaved. Sterile petri dishes were filled with 15 ml of the prepared culture medium and a sterile 7mm diameter cork borer was used to create disc shaped meat samples of 2mm thickness which were applied to the surface of the agar medium using surface plating method. The medium was then seeded with *Bacillus subtilis* in test agar pH 6.0, pH 7.2 and pH 8.0. Plates containing *Bacillus subtilis* pH 6.0 were to detect in particular beta – lactam and tetracycline residues. Plates containing *Bacillus subtilis* pH 7.2 and *Bacillus subtilis* pH 8.0 were to detect sulfonamides e.g sulfamethoxazole and aminoglycoside residues respectively. Positive controls were set up with 1mg/ml of Penicillin, Chloramphenicol and Tetracycline. The agar plates were incubated at 30°C for 18 hours. A positive sample was indicated by a complete inhibition of growth in an annular zone not less than 2mm wide. Less than 2mm of inhibitory zone indicated negative result.

3.4.4 Analysis of the nutritional composition

The determination of the nutritional compositions of crude protein and fat content were according to AOAC (2000) protocols.

Crude protein AOAC 2000

Crude protein was determined using the macro-kjeldhal method in which 0.1 grams of the sample, concentrated sulphuric acid and a selenium tablet (catalyst) were digested at 430^{0}C for 3 hours in a digester. The digest was cooled to room temperature and distilled into 20ml of 0.1N HCl containing a mixed indicator of 0.1% methyl red and 0.5% phenolphthalein. The resultant distillate was titrated against 0.1N NaOH solution. The titre obtained was used to calculate percent crude protein content using the following formula;

$\% \ P = V \times N \times 14 \times C \times 100 / 1000 \times S$

Where: P is the % protein by weight.

V = Number of ml of hydrochloric acid solution used in titration (titre).

N = Normality of the hydrochloric acid solution.

C = Conversion factor (6.25 for meat).

S = Weight in grams of the sample.

Determination of fat content (AOAC 2000)

Fat content was determined by the Soxhlet method using petroleum ether as the solvent. A weighed sample of 10 grams was placed in an extraction thimble in triplicate and closed with fat free cotton- wool. The fat was extracted for 8 hours on a heating mantle. The solvent was

then evaporated and the fat dried in an oven set at 80°C for 30 minutes. It was cooled in a descicator and weighed. The crude fat content was calculated by the formula:

% Crude lipids = Weight of residue/Original weight of sample × 100

Determination of the free fatty acids followed

Free fatty acid (AACC 2004)

Free fatty acid was determined by mixing together 50ml ether and 50ml alcohol (95%). An indicator, 1 ml phenolphthalein solution was added and neutralized with 0.1N Sodium Hydroxide solution. To this neutral solvent, 7g of *Nyirinyiri* was added and titrated with aqueous Sodium Hydroxide while shaking constantly until a pink color persisted for 15 seconds. Free fatty acid was calculated using the following formula:

% Free fatty acid = ml × N × F × 100/ Sample weight × 1000

Where ml = Volume of Sodium Hydroxide solution required.

N = Normality of Sodium Hydroxide solution.

F = Equivalent weight of free fatty acid in which results are to be expressed (usually expressed as % oleic acid and equivalent weight is 282)

3.5 Statistical analyses

Data collected were subjected to analysis of variance (ANOVA) using SAS program version 9.1. The least significant difference (LSD) was used for mean separation.

CHAPTER FOUR
RESULTS

4.1 Mapped value chain

Figure 1 shows results of the mapped camel *Nyirinyiri* value chain from Isiolo county where camels are produced to marketing centres in Nairobi's Eastleigh market where *Nyirinyiri* is sold.

In the northern part of Kenya, the main type of production system for camel herds is the traditional nomadic system where the pastoralists are continuously on the move in response to availability of grazing and water supplies. In this system, drugs, as was observed, were administered to sick camels without professional help and meat from sick animals sold to butchers could find its way into the market and human food chain despite the risks.

The camels are bought by butcher owners who on particular days of the week slaughter them at the public abattoir for purposes of selling the meat at their respective butcheries. The slaughter house was identified to be the production point of the value chain. Camels were slaughtered in an open environment on a concrete floor with poor drainage. The facility also lacked free flowing water. However, the slaughter process was done in presence of a public health officer who would later inspect the meat prior to transportation. The meat traders transport the carcase to the butcheries on donkey driven carts by road. The women group processors often acquire the raw material for camel *Nyirinyiri* from these butchers and process it into *Nyirinyiri* using low cost technology (drying and frying).Processing involved a combination of cutting the meat into thin strips, sun-drying, dicing the meat and finally deep frying in cooking oil. Camel *Nyirinyiri* after processing was either sold locally or packaged in plastic containers and transported to Nairobi's Eastleigh market by road, where it is sold by the road side in an open air environment. It was from this mapping that the three nodes of the value chain (production, processing and marketing) were identified as critical control points and subsequently made the nodes of sampling to ascertain the safety.

Figure 1: The meat value chain mapping results

4.2 The molds isolated from fresh camel meat and N*yirinyiri*

Of the thirty five samples of fresh camel meat (eight) and *Nyirinyiri (*twenty seven) collected along the meat value chain (eight at production, eighteen at processing and nine at marketing), the mold count was highest at the market node (1.2 log cfu/g) and lowest at processing node (0.8 log cfu/g) relative to production (1.0 log cfu/g) as indicated in table 1. The total viable count (TVC) and *Coliform* counts were highest at production (5.5 log cfu/g and 2.6 log cfu/g) respectively and lowest at processing (3.9 log cu/g and 1.3 log cfu/g) respectively relative to marketing (4.8 log cfu/g and 2.2 log cfu/g) respectively.

Table 1: Microbiological characteristics of fresh camel meat and camel *Nyirinyiri* obtained along the value chain.

Value chain node	Samples (n)	T.V.C log cfu/g	Coliform log cfu/g	Molds log cfu/g
Production(Fresh meat)	8	5.5^{a}	2.6^{a}	1.0^{a}
Processing (*Nyirinyiri*)	18	3.9^{b}	1.3^{b}	0.8^{a}
Marketing (*Nyirinyiri*)	9	4.8^{c}	2.2^{c}	1.2^{a}

Means in the same column followed by the same superscript are not significantly different ($p< 0.05$)

Table 2: Summarized numbers and percentages of identified mold species in examined fresh camel meat and camel *Nyirinyiri*

Mold species	Production (n = 8)		Processing (n = 18)		Marketing (n = 9)		Total	
	No	%	No.	%	No.	%	No.	%
Syncephalastrum	1	12.5	4	22.2	1	11.1	6	17.1
Paecilomyces	1	12.5	3	16.6			4	11.4
Aspergillus			1	5.5	1	11.1	2	5.7
Penicillium			2	11.1			2	5.7
Mucor			1	5.5			1	2.9
Alternaria			4	22.2			4	11.4
Cunninghamella	1	12.5	4	22.2	2	22.2	7	20
Fusarium	1	12.5	4	22.2			5	14.3

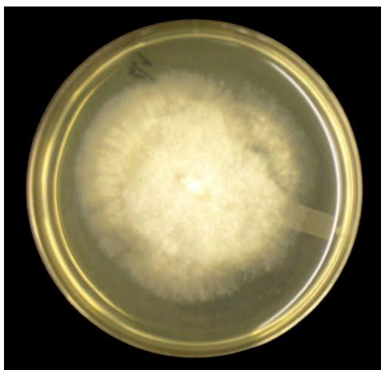
No. is the number of positive samples% were calculated in relation to the total number of examined samples

Table 3: Macroscopic and microscopic characteristics of identified mold species in camel *Nyirinyiri*

Value chain nodes	Cultural and morphological characteristics	Inference
Production processing and marketing	A zygomycete; sporangiophores bear rod-shaped sporangioles, each containing a row of spherical spores.	*Synephalasctrum*
	Variants of yellow, orange, red, and purple colonies; sickle-shaped macroconidia.	*Fusarium*
	Yellowish-brown; elliptical microconidia.	*Paecilomyces*
	Pinkish-white, elliptical microconidia.	*Cunninghamella*
	Bluish-green; brush arrangement ofphialospores.	*Penicillium*
	Bluish-green with sulfur-yellow areas on the surface.	*Aspergillus*
	Dark greenish-black surface with gray periphery; black on reverse side; chains of macroconidia.	*Alternaria*
	A zygomycete; sporangia with a slimy texture; spores with dark pigment.	*Mucor*

A. *Alternaria* **B.** *Aspergillus* **C.** *Cunninghamella* **D.** *Fusarium*

E. *Penicillium* **F.** *Paecilomyces* **G**. *Syncephalastrum*



H. *Mucor*

Figure 2: Isolated mold genera on potato dextrose agar at 25°C for seven days

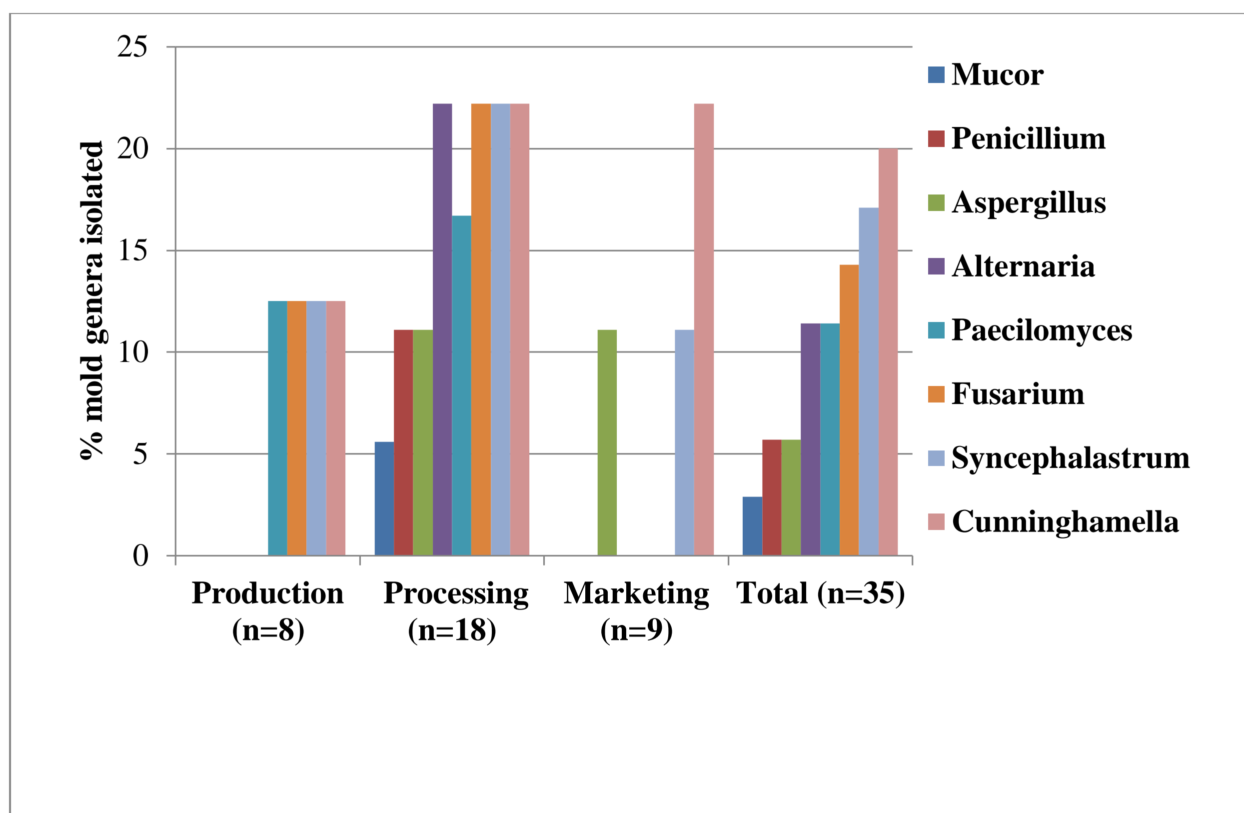
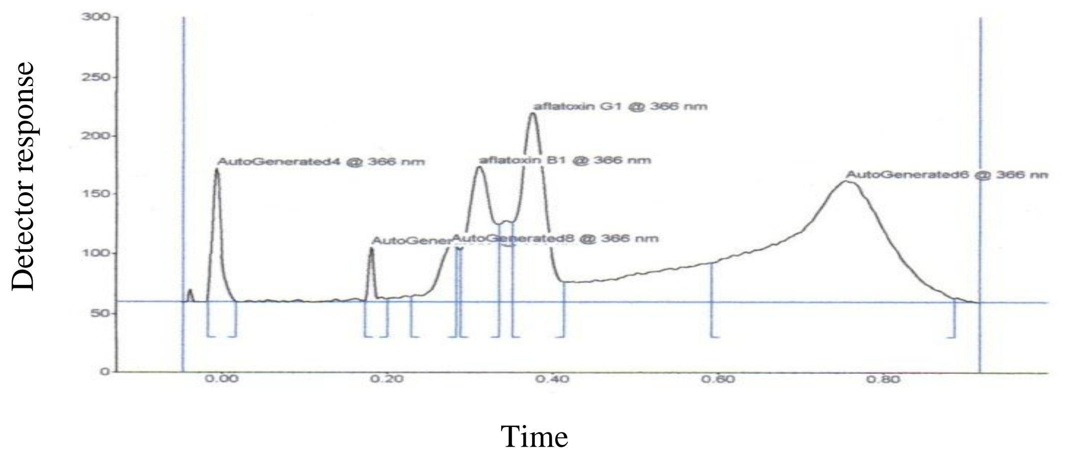


Figure 3: Percent distribution of mold genera isolated samples of camel meat and *Nyirinyiri* along the value chain.

From the fresh camel meat and *Nyirinyiri* samples examined, the most common mold species (Figure 3) were *Cunninghamella* (20%) and *Syncephalastrum* (17.1%) relative to *Fusarium* (14.3%), *Alternaria* (11.4%) and *Paecilomyces* (11.4%) while *Aspergillus* (5.7%), *Penicillium* (5.7%) and *Mucor* (2.9%) were least common. All these species were present in *Nyirinyiri*samples from the processing node while *Nyirinyiri* samples from marketing had only *Cunninghamella, Aspergillus* and *Syncephalastrum* species. *Paecilomyces, Fusarium, Syncephalastrum* and *Cunninghamella* were isolated in the fresh camel meat samples (production node), each at a level of 12.5%.

4.3 Aflatoxin B_1 and G_1in camel meat and *Nyirinyiri*

The HPTLC chromatograms of standard aflatoxin B_1 and aflatoxin G_1 and that of a camel *Nyirinyiri* sample are shown in figure 4. In this study eight fresh camel meat samples at production, eighteen camel *Nyirinyiri* at processing and nine at marketing were analyzed for aflatoxins B_1 and G_1 contamination by HPTLC. None of the samples had a positive result of contamination with both aflatoxins B_1 and G_1as indicated by the chromatogrms.



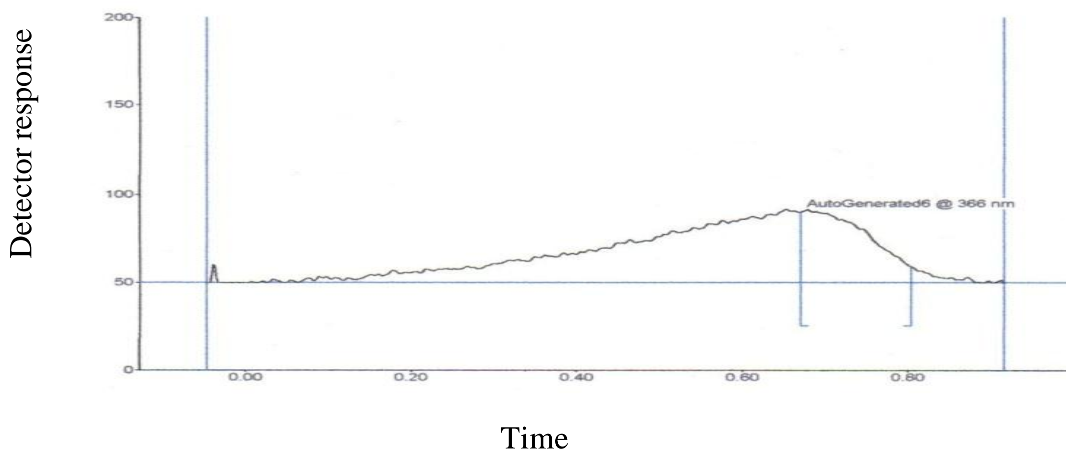


Figure 4: HPTLC chromatograms for aflatoxins B_1 and G_1 in camel *Nyirinyiri* samples

4.4 Nutritional (Compositional) properties of *Nyirinyiri*

Table 4 shows that the means for crude protein, crude lipids and free fatty acid are different along the value chain (P<0.05).

Table 4: Variations in nutritional composition of camel *Nyirinyiri* along the value chain

Property (%)	Nodes of the value chain		
	Production (N=8)	Processing (N=18)	Marketing (N=9)
Crude protein	25.26 ± 0.71^{a}	49.68 ± 1.91^{b}	48.07 ± 0.94^{c}
Crude lipids	1.18 ± 0.05^{a}	22.04 ± 4.74^{b}	24.01 ± 0.99^{c}
Free Fatty Acid (as % (OA).	0.2 ± 0^{a}	0.73 ± 0.11^{b}	0.98 ± 0.12^{c}

Means in the same row followed by the same superscript are not significantly different ($p< 0.05$)

CHAPTER FIVE

DISCUSSIONS

5.1 The camel meat and *Nyirinyiri* value chain

At production, the meat for commercial market was slaughtered at a public slaughterhouse in the open air and the environment within the slaughter house including air movement, walls, floor, utensils, hide and intestinal contents of the slaughtered camels were considered the main source of fungal contamination to camel carcasses. The slaughter houses were not properly constructed and the camels were mainly slaughtered on a slab floor with poor blood drainage and waste disposal. There was lack of fresh water supply at the abattoir. The molds that were isolated at the production node of the value chain (*Cunninghamella spp, Syncephalastrum spp, Fusarium spp* and *Paecilomyces spp*.) could be attributed to this environment. The high mycological contamination levels at this node may be connected with the wide distribution of environmental contaminants as well as lack of good hygiene practices in meat processing.

Camel meat after slaughter was mainly transported from slaughter slabs to butcheries using donkey drawn carts. However, the carts lacked seamless joints and were not dust proof hence offering difficulty in cleaning. This was evident by the observed hidden corners within the carts floor. The cart displayed in (Figure 1) was waiting in preparation for loading of the carcass at the abattoir with its lid wide open while the donkeys grazed. Because of the climatic conditions and lack of cold storage facilities it is virtually impossible to keep meat fresh for any length of time.

The entire *Nyirinyiri* processing was done in an open air environment and therefore exposing the product to microbial contamination especially the air-borne molds. The women processors rarely dressed up in clean attire while doing the processing and there was lack of free flowing water to be used for rinsing utensils as well as hands. This too could serve as a source of contamination. It was also observed that the stripped meat was sun- dried on the same hanging line used for their clothes. The drying of the meat takes advantage of existing natural factors such as temperature, humidity and air movement, which is the oldest method of food preservation to reduce the water activity of the meat as well as facilitate the dicing process of the meat prior to deep frying. Based on observation and organoleptic test, the product may vary in the degree of drying and processing time. This was manifested by color and texture of the *Nyirinyiri*. Light brown color with a very soft texture signified inadequate

dehydration. This implies that the product has a high water activity which can support microbial proliferation hence reducing its shelf life.

Chemically, camel meat contains more moisture than veal. The protein content of the camel meat (25.26%) is significantly greater and intramuscular fat (1.18%) is significantly lower than veal (Kadim *et al*., 2008). The processing of *Nyirinyiri* meat by deep frying the camel meat is essential to achieve a palatable and safe product. However, heat treatment can lead to undesirable modifications, such a decrease in nutritional value (mainly due to vitamin and mineral losses) and changes in the fatty acid composition due to lipid oxidation (Rodriguez-Estrada *et al*., 1997).

Fresh camel meat was sold from butchers designated at different locations within Isiolo town. All the butchers sampled from lacked refrigeration facilities implying that fresh camel meat was exposed to ambient temperatures for long hours hence the risk of microbial (fungal) proliferation. The ambient temperatures ranged from 12°C - 28°C which are ideal for growth of mesophiles such as *Cunninghamella species*. *Nyirinyiri* was sold besides the road (Figure 1) in an open environment hence exposing the product to contamination with fungi from air. It was dispensed from a plastic bucket using a plastic mug and the packaging was done in clear polythene papers. These practices did not only predispose consumers to health risks but also hastened spoilage of the meat by re-contamination every time it is dispensed and also the ambient temperature of about 25°C provides a conducive environment for growth of mesophilic organisms such as *Aspergillus* and *Paecilomyces.* This observation was in agreement with (Matofari *et al*., 2007) who reported that these foods are marketed informally and this has posed growing public health concern on its safety. Eastleigh in Nairobi County is the main market for camel milk and *Nyirinyiri* because majority of the inhabitants belong to pastoral communities. In this study, the mapping of the value chain assisted in obtaining information related to *Nyirinyiri* processing and also to understand the practices towards reducing hazards, as well as increasing safety.

5.2 Microbiological characteristics of fresh camel meat and camel *Nyirinyiri*

Table 1 shows the incidence of total viable count (TVC), *Coliforms* and molds in the fresh camel meat and camel *Nyirinyiri* sampled along the value chain. The presence of coliforms along the value chain suggests important microbiological sanitary indicators, which emphasizes hygiene in processing and handling of the *Nyirinyiri* product. At production, coliforms are attributed to the environment (slaughter and transportation) while their presence at processing and marketing nodes could be attributed to post process contamination or extended shelf life. Total Viable Count (TVC) is defined as the total number of microorganisms able to grow in an oxygenated or aerobic environment. It is one of the most common tests applied to indicate the microbial quality, not safety, of food. The significance of TVC can vary according to the type of food product and the processing it has received.

There was a significant reduction in TVC and *Coliforms* from 5.5 log cfu/g and 2.6 log cfu/g respectively at production to 3.9 log cfu/g and 1.3 log cfu/g respectively at the processing node. This could be attributed to the effect of heat during deep frying which resulted in destruction of the microorganisms. There was a significant increase in the TVC and *Coliforms* (4.8 log cfu/g and 2.2 log cfu/g) respectively at the marketing node. This could be attributed to post process contamination and/or extended shelf life of the product. However, processed ready to eat meat products are considered unsatisfactory if the TVC and *Coliforms* exceed 5.0 cfu/g and 3.0 cfu/g respectively.

Table 1 shows the incidence of molds in the fresh camel meat and *Nyirinyiri* sampled along the value chain. At the production stage of the value chain, presence of molds could be attributed to unhygienic handling practices of the meat post slaughter. The camel slaughter house is open and camels were slaughtered in the open air. Spores of molds are present in the air and dust in the environment. Fresh water and energy supply to the slaughter slab were absent. Most of the environmental microorganisms including the fungal spores, bacterial spores and *Coliforms* are likely to contaminate the meat at the slaughter level. This may explain why molds of *Cunninghamella, Paecilomyces, Fusarium* and *Syncephalastrum spp* were dominant at the meat slaughter place (production) as is indicated in figure 4.

Camels were slaughtered in the open air. Spores of molds are always present in the environment and they enable the molds to survive even in extreme conditions (Mizakova *et al*., 2002). The slaughter took place on a cemented slab floor, so the meat is soon contaminated with dust and dirt. However, hanging racks were available for hanging up the

cuts. Lack of electricity coupled with unreliable supply of potable water often made it difficult to clean and disinfect the slaughterhouse and equipment and dispose of offal and effluent. This means there is a very high risk of contamination of the meat. Cold storage rooms were also unavailable. In general, the conditions during the production of meat products (ambient temperature, relative humidity, air circulation) are suitable for the development of filamentous fungi.

The decrease in mold count from 1.0 log cfu/g at production to 0.8 log cfu/g at the processing node (Table 1) of the value chain may be attributed to the heat treatment of the cooking oil (approximately 170°C) used in processing of *Nyirinyiri.* Temperature tolerance is strongly tied to the amount of water so that wet heat is much more effective at damaging spores than dry heat. The effects of heat on molds are related to the chemical reactions within the fungal cells. For optimum growth, temperatures must be in a range that allows the most efficient progression of the chemical reactions necessary for growth. As temperatures progress above the optimum temperature, the chemical reactions occur less efficiently, and growth slows. Eventually, the temperature can reach a point where growth stops, and cell components begin to be actually damaged by the heat. Enzymes are proteins that change structurally when heated to their limit of tolerance. Likewise, membranes, which contain lipids, change in structure, and their function of protecting and regulating the internal environment of the cell becomes compromised. *Penicillium* spore death in water occurs at 54.4^{o}C for 30 minutes (Burge, 2006).

The incidence of all the eight species of molds at this node (figure 3) was attributed to post process contamination as well as storage of the product at ideal temperatures for proliferation of molds. Soon after processing the *Nyirinyiri* was left to cool in the open air and packaged containers that do not offer satisfactory sealing. The prevalence of all the eight species of molds at processing could be attributed to the storage temperature (room temperature) of *Nyirinyiri* which favor the proliferation of the organisms.

The increase in load of molds at the marketing stage to 1.2 log cfu/g up from 0.8 log cfu/g (Table 1) at processing node of the value chain could be due to an inadequate process of drying resulting in a high water activity within the whole product or only on the surface of the product. In such cases, the spores can germinate, and the potentially toxigenic filamentous fungi can produce toxic metabolites in form of aflatoxins, endangering the consumer’s health.

Nyirinyiri was sold in open air environments besides the road hence exposing the product to contamination by mold spores present in the air and suitable temperatures for mold growth. Most fungi e.g Penicillium and Fusarium are mesophilic and have growth optima within the temperature range of (18 - 22°C). Nyirinyiri is marketed informally and no standards have been developed for it hence growing public health concern on its safety (Matofari et al., 2007). The packaging of Nyirinyiri in polythene papers or plastic containers that cannot be cleaned well is a risk to the consumers. These practices did not only predispose consumers to health risks but also hasten spoilage due to re-contamination during dispensing and the ambient temperatures of about 25oC are ideal for the proliferation.

Spores of molds are always present in the environment and they enable the molds to survive even in extreme conditions. Therefore, it is practically impossible to eliminate them from food (Mizakova *et al.,* 2002). The conditions during the production of dried meat products (ambient temperature, relative humidity, air circulation) are suitable for the development of filamentous fungi. Exposure of the camel *Nyirinyiri* to atmospheric conditions during marketing subjects it to increased water activity. *Cunninghamella* species which was predominant at marketing requires high water activity for growth and have a rapid growth habit relative to other molds.

5.3 Aflatoxin B_1 and G_1 in camel *Nyirinyiri.*

Lack of detection of aflatoxins B_1 and G_1 could be attributed to the absence or a low microbial load of aflatoxin forming species (*Apergillus flavus* and *Aspergillus parasiticus*) as well as unfavorable conditions for the production of aflatoxins in the meat and meat product. The main causes for the growth of molds in dehydrated meat products include an inadequate process of drying, resulting in a high water activity within the whole product or only on the surface of the product, as well as inadequate packaging and storage at ambient conditions (25°C – 28°C) which favors proliferation of spoilage and pathogenic fungi most of which are mesophilic. Microorganisms need water to grow, and as water content is reduced, growth rates are reduced due to reduced metabolic water. The water activity required for growth of fungi ranges between 0.65 – 0.85.*Aspergillus species* grow at a water activity level of 0.65 (IFST, 2009). When water activity is high, the spores germinate, and the potentially toxigenic ones can produce toxic metabolites endangering the consumer’s health. The impact of mycotoxins on human and animal health is well understood and to obtain a clear view on food products it is worthy to carry out the best sensitive and accurate method of analysis

because aflatoxinB_1 is recognized as a potent toxic carcinogenic substance (Ramos and Hernandez, 1997).

5.4 Antibiotic residues

Antibiotic residues along the *Nyirinyiri* meat value chain were absent at all nodes as was revealed by the microbial inhibition test which is a qualitative test. This could be attributed to the fact that the antibiotics were either absent in the samples or were at such low levels that could not be detected by microbial inhibition assay. In the former case, it implies that withdrawal period was observed after administering antibiotics. However, a more sensitive method such as HPLC (high performance liquid chromatography) could have been used since it is capable of quantifying even at very low levels. Drugs or their metabolites left over in the body after their administration for a longer time are termed as residues (Jabar *et al*., 2013). After the treatment of infected on consumption may cause potential human health hazards. So it is worthwhile to take preventive measures against the residues by establishing their withdrawal period from edible products.

5.5 Compositional properties of fresh camel meat and *Nyirinyiri*

The crude protein increased significantly ($P<0.05$) from 25.26% at production to 49.68% and 48.07% (Table 4) at processing and marketing respectively. There was a significant increase in crude lipids between production (1.18%) and processing (22.04%) nodes (Table 3) of the value chain. However, the increase at marketing (24.01%) was not significant. There was a significant increase ($P<0.05$) in free fatty acid (FFA) level from 0.2% at production to 0.73% at processing relative to 0.98% at marketing nodes of the value chain. At production node, determinations were done on wet weight basis (mass per 100g of wet material) while at processing and marketing nodes on dry weight basis (mass per 100g of dried material).

Change in crude protein across the value chain

In table 4 the crude protein increases along the value chain. This can be attributed to the heat processing using cooking oil that is employed during *Nyirinyiri* preparation. The protein percentage increases in cooked meat than raw, because of reduced weight (Casey, 1992). This indicates that processing camel meat into *Nyirinyiri* improves (due to concentration wet weight basis to dry weight basis) the percentage protein of the product thus increasing nutrient density. Heat – induced changes in protein solubility relate to changes in water-holding capacity of the meat (Morphy and Marks, 1999). The water content within the meat

myofibrils in the narrow channels between the filaments changes as the meat shrinks within the tissue matrix. Cook out due to moisture loss from a cut serves to increase the protein fraction (Casey, 1992). *Nyirinyiri* is thus a protein dense food.

Crude lipids

There was a significant increase (P<0.05) in crude lipids between production and processing nodes of the value chain (table 4). This could be attributed to absorption of cooking oil during the processing. Camel *Nyirinyiri* was prepared by deep frying in oil and when frying food, the hot frying fat that penetrated into it, replaced part of the water it contained. When fat penetrates a food, it may selectively modify the composition of the food. The uptake of absorbed oil in food ranges in percentage from 4 – 14% of the total weight, depending on the food and the type of the frying medium (Andrikopoulos *et al*., 2003). At marketing these values were also expected since *Nyirinyiri* is a meat product preserved in fat.

Free Fatty Acid (as % oleic acid)

Table 4 indicates that **t**here was a significant increase (P<0.05) in free fatty acid (FFA) level from 0.2% at production to 0.73% at processing relative to 0.98% at marketing node of the value chain. Free fatty acid test was done to monitor the extent of hydrolysis of camel *Nyirinyiri* lipids. The increase in FFA from 0.2% at production to 0.73% at processing could be attributed to the effect of myoglobin and fats when brought into intimate contact with one another in meat. Their coupled reaction will contribute to rancidity and discoloration. During cooking, both haem-bound and non-haem iron released from the latter accelerate lipid oxidation. At the processing node, the result was expected since the water present in the meat interacted with the oleic acid causing hydrolytic reactions which resulted in larger amounts of free fatty acids such as diacylglycerol, monoacylglycerol and glycerol. The increase in FFA at processing from 0.73% to 0.98% at marketing could be attributed to fat hydrolysis as storage period increases. Fats undergo changes through oxidative deterioration which is of two kinds (autoxidation and photo-oxidation). These processes lead to similar, but not identical, unstable allylichydroperoxides which decompose to volatile short-chain molecules (mainly aldehydes) resulting in the production of off-odors and taste, loss of nutritive value, and perhaps the production of toxic substances (Gunstone, 2008).These compounds have low but differing threshold levels so that only small quantities are necessary to produce their undesirable effects. Table 4 indicates that the FFA value did not lie between the 1.2 - 2.1% limit which is reported by Pearson (1968a) to be the minimum limit for odor to be acceptable.

CHAPTER SIX
CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

- The processing and marketing of camel *Nyirinyiri* in an informal way exposes the product to hazards especially of microbiological origin thus compromising the safety.
- The study established that both spoilage and pathogenic molds were present in the camel *Nyirinyiri*. Due to the fact that pathogenic molds were present, the whole product is unsafe for consumption.
- Camel *Nyirinyiri* is free from aflatoxin. However, the presence of other mold species suggests that the product could contain other mycotoxins such as ochratoxins. These findings indicate that there may be a risk of human exposure to mycotoxins through consumption of camel *Nyirinyiri*.
- Although antibiotic residues were absent, the microbial inhibition assay is not a reliable test and therefore there is need to use a more sensitive equipment such as HPLC. The microbial inhibition test was used as an alternative because the HPLC in the laboratory where the analysis was done was not functional and due to the time frame allocated, it was not possible to access a functional HPLC.
- Processing of camel meat to *Nyirinyiri* has a positive effect on the nutritional quality. The processing improves the nutrient composition especially the protein and fat thus making it nutrient dense.

6.2 Recommendations

- Camel *Nyirinyiri* as a dried meat product has a promising future if policies can be developed and adopted to guide this informal meat value chain as well as marketing the product to enlighten the general public of its health benefits.
- Educational programs and training courses are recommended to the meat handlers, processors and marketers to sensitize on hygienic conditions to be maintained in the production, storage and distribution of the meat product including appropriate packaging.

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APPENDIX 1

NIRINYIRI PROCESSING QUESTIONNAIRE

PRODUCTION STAGE

Pre-slaughter

1. Are the animals under any treatment (Farmer)?

2. What is the withdrawal period before slaughter (Farmer)?

3. Is the camel inspected before slaughter (slaughter man)?

Observation checklist

Value chain actors

Health status of the camel

Presence of veterinary officers

Post-slaughter

4. Is the meat inspected?

5. Do you clean your hands before slaughter?

Observation

Value chain actors

Personnel hygiene

Environmental hygiene

Means of transport and hygiene

PROCESSING STAGE

6. Where do you obtain the meat from?

7. Do you wash your hands before processing?

8. What equipment do you use for processing?

9. What products do you make from camel meat?

10. How are they prepared?

11. Where do you obtain the processing water from?

12. How do you package the product?

13. Where and how do you store the product?

Observation checklist

Personnel hygiene during processing

Environmental hygiene

Packaging material

Storage environment/hygiene

MARKETING STAGE

Observation checklist

Exposure to high temperature

Unhygienic trading environment

Consumer Survey

14. Do you consume the product *Nyirinyiri*?

15. Where do you obtain the product (Market or household)?

16. How do you store the product in the house?

17. What do you like about *Nyirinyiri*?

18. How long does *Nyirinyiri* keep to your liking?

19. What don't you like about *Nyirinyiri* (concerns, spoilage, improvement)?

Observation checklist

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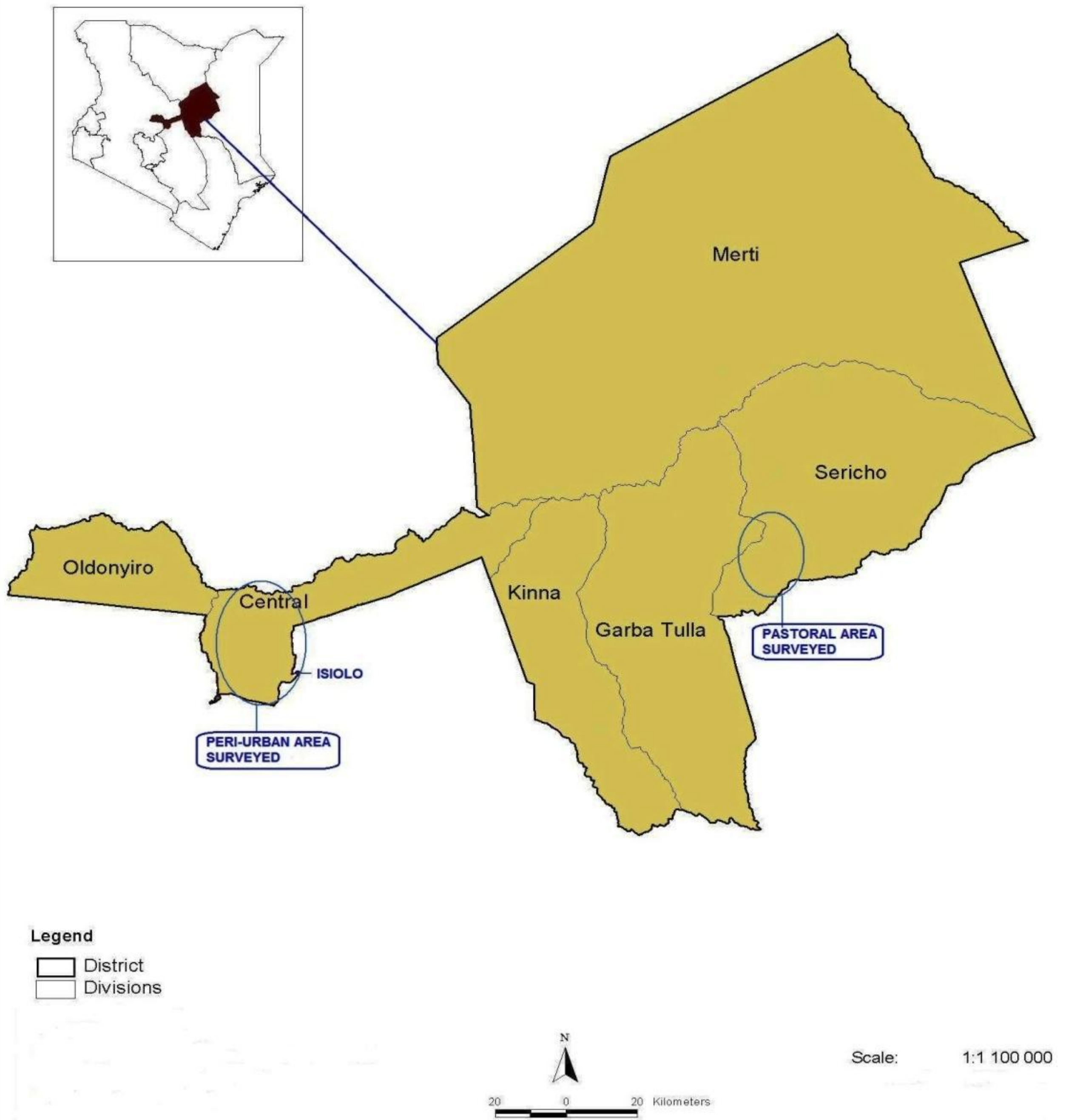
APPENDIX 2



Map of Isiolo county

APPENDIX 3

Appendix 3: Analysis of variance of the total mold count along the value chain nodes

Dependent variable: Mold count

Effect; VC		Estimate	Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Marketin	Processi	0.4167	0.2336	32	**1.78***	0.0840	Tukey-Kramer	0.1912
Marketin	Producti	0.1736	0.2780	32	**0.62***	0.5368	Tukey-Kramer	0.8079
Processi	Producti	-0.2431	0.2431	32	-1.00	0.3250	Tukey-Kramer	0.5824

*Figures in bold face show significant differences at $p \leq 0.05$

APPENDIX 4

Appendix 4: Analysis of variance of the effect of processing on crude protein of camel *Nyirinyiri* along the value chain

Dependent Variable; Crude protein

Effect; VC	Estimate	Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Marketin Processi	-1.6167	0.6136	32	-2.63	0.0129	Tukey-Kramer	0.0335
Marketin Producti	22.8042	0.7303	32	**31.23***	< .0001	Tukey-Kramer	<.0001
Processi Producti	24.4208	0.6386	32	**38.24***	<.0001	Tukey-Kramer	<.0001

*Figures in bold face show significant differences at $p \leq 0.05$

APPENDIX 5

Appendix 5: Analysis of variance of the effect of processing on crude lipids of camel *Nyirinyiri* along the value chain

Dependent variable: Crude lipids

Effect; VC		Estimate	Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Marketin	Processi	1.9722	1.4254	32	**1.38***	0.1760	Tukey-Kramer	0.3612
Marketin	Producti	22.8361	1.6965	32	**13.46***	<.0001	Tukey-Kramer	<.0001
Processi	Producti	20.8639	1.4836	32	**14.06***	<.0001	Tukey-Kramer	<.0001

*Figures in bold face show significant differences at $p \leq 0.05$

APPENDIX 6

Appendix 6: Analysis of variance of the effect of processing on free fatty acid level of camel *Nyirinyiri* along the value chain

Dependent variable: Free fatty acid

Effect; VC	Estimate	Error	DF	t Value	Pr > |t|	Adjustment	Adj P
Marketin Processi	0.2556	0.04049	32	**6.31***	<.0001	Tukey-Kramer	<.0001
Marketin Producti	0.7833	0.04819	32	**16.26***	<.0001	Tukey-Kramer	<.0001
Processi Producti	0.5278	0.04214	32	**12.52***	<.0001	Tukey-Kramer	<.0001

*Figures in bold face show significant differences at $p \leq 0.05$

APPENDIX 7

Appendix 7: Publication in the International Journal of Scientific & Engineering Research (ISSN 2229-5518)

SAFETY OF PASTORAL PROCESSED CAMEL MEAT (*NYIRINYIRI*) FOR CONSUMERS ASCERTAINED FROM MICROBIOLOGICAL QUALITY

Stephen W. Kisembe, Patrick S. Muliro, Joseph W. Matofari, Bokeline O. Bebe.

ABSTRACT-This study determined the load, type and most common species of molds in 35 samples of fresh camel meat and *Nyirinyiri* obtained at different nodes along the value chain. Molds were detected in the samples: 75% at production, 55.5% at processing and 66.7% at marketing nodes with counts highest at the market (1.2 log cfu/g) and lowest at processing (0.8 log cfu/g) relative to production (1.0 log cfu/g). The most common mold species were *Cunninghamella* (20%) and *Syncephaalastrum* (17.1%) relative to *Fusarium* (14.3%), *Alternaria* (11.4%) and *Paecilomyces* (11.4%) while *Aspergillus* (5.7%), *Penicillium* (5.7%) and *Mucor* (2.9%) were least common. The study established that both spoilage and pathogenic molds were present in the camel *Nyirinyiri* and therefore the product could be unsafe for human consumption due to the risk of *mycotoxins.* However, there is room for improved hygiene standards along the camel *Nyirnyiri* value chain.

Key words: Camel, molds, *Nyirinyiri*, processing, species, value chain