HYGIENE AND MICROBIAL SAFETY OF ROADSIDE ROASTED MEAT FROM NAMAWOJJOLO AND LUKAYA FOOD MARKETS, UGANDA

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A THESIS SUBMITTED TO THE SCHOOL OF AGRICULTURE AND BIOTECHNOLOGY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF MASTER OF SCIENCE IN MEAT PRODUCTION, UNIVERSITY OF ELDORET, KENYA

2025

DECLARATION

Declaration by the Candidate

This thesis is my original work and has never been presented for the award of an academic degree in any other university and should not be copied, or reproduced in any format without written authority from the author and/or University of Eldoret.

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DEDICATION

I dedicate this work to my dear husband and the entire family for their support, endurance, and prayers while away for studies. To my grandmother and my lovely mother, thank you for the prayers. My dear brother, Kagimu Patrick, for the support and encouragement given to me while pursuing studies. Finally, to my uncle, Haji Saka Kamoga, who started this journey of education way back in the lower classes.

May God bless you all!

ACKNOWLEDGEMENTS

I acknowledge the grace of God for the opportunity of life and guidance throughout my sojourn and studies at University of Eldoret (UoE), Kenya.

I am indebted to my supervisors, Dr. Mewa, Eunice Akello and Dr. Rachuonyo, Harold Anindo from the Department of Animal Science, School of Agriculture and Biotechnology – University of Eldoret, for the encouragements, guidance, support, and advise rendered to me over the duration of my academic pursuit.

Additionally, I want to appreciate all the lecturers in Animal Science Department for their continued support and encouragement towards my academic excellence. Your contributions are highly treasured.

I wish to acknowledge the Islamic Development Bank project that awarded the scholarships to the Ugandan Government through the ministry of education and sports TVET department, of which I am a beneficiary. I am humbled and highly grateful for this special privilege and philanthropic gesture accorded to me.

To my family and friends, I am highly indebted to you for the continuous and different forms of support and encouragement towards my studies. Thank you so much.

May God Bless You All!

ABSTRACT

Roadside roasted meats provide a rich source of proteins, especially for long-distance travelers. However, there are many food-borne illnesses associated with their consumption, necessitating continuous assessment of the quality and safety. The objective of this study was to investigate hygiene and microbial safety of roadside roasted meats from two food markets of Namawojjolo and Lukaya in Uganda. Using an observation checklist and questionnaire, 90 meat vendors were observed and interviewed on compliance with standard hygiene practices. Also, a total of 89 meat samples of chicken, beef and goats' meat comprising 30 fresh (raw), 28 hot from fire and 31cold ready-to-eat meat that had been exposed to consumers for about 30 minutes, were obtained. The samples were analyzed using enriched specific media for *E. coli, Salmonella, S. aureus, Listeria* and *Campylobactor*. Descriptive analysis of the hygiene practices of the vendors in meat handling was done and scores above 70% were used to determine good hygiene practices. The study found that only 6.7% vendors had good hygiene practices and 88.9% did not store leftover meat in refrigerators. Laboratory findings revealed that bacterial contamination was higher than Uganda National Bureau of Standards (UNBS) levels. Raw samples exhibited the highest contamination across all pathogens where *S. aureus* in raw chicken (8 ± 0.56 log_{10} CFU/g) and raw goat (8 ± 0.97 log_{10} CFU/g) far exceeded the limit. Similarly, cold samples mostly matched or surpassed hot samples in contamination. For example, cold beef showed higher *Listeria* counts (5 ± 1.93 log_{10} CFU/g) than hot beef (3 ± 2.71 log_{10} CFU/g). All tested meat types showed microbial contamination above UNBS safety limits for all microbes examined which is ≤2 log_{10} CFU/g for *S.aureus* and *E.coli* or completely absent for *Salmonella*, *Lysteria* and *Campylobacter*. However, *S. aureus* was consistently the highest for all the three meat types for example 8.4 ± 9.0 log_{10} CFU/g for goat meat compared to 5.5 ± 5.7 shown for *Salmonella* in goat meat The study found that there were food safety concerns in roadside roasted meat vending, with contamination linked to poor hygiene practices and inadequate sanitation measures. Fresh/raw meat had the highest contamination levels compared to hot and cold meat, highlighting significant public health risks. There is need to sensitize vendors on food safety and hygiene plus routine health inspections of these markets.

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LIST OF ABBREVIATIONS AND ACRONYMS

CFUs:	–	Colony Forming Units
DALY:	–	Disability–Adjusted Life Year
FAO:	–	Food and Agriculture Organization
FBD:	–	Foodborne Disease
GHPs:	–	Good Hygiene Practices
Km:	–	Kilometer
LMIC:	–	Low–and Middle–Income Country
MAAIF:	–	Ministry of Agriculture Animal Industry and Fisheries of Uganda
MoH:	–	Ministry of Health of Uganda
SDGs:	–	Sustainable Development Goals
UNBS:	–	Uganda National Bureau of Standards
WHO:	–	World Health Organization

OPERATIONAL DEFINITIONS

Foodborne disease:	–	Illness caused by food contaminated with bacteria, viruses, parasites, or their toxins
Hygiene:	–	Conditions or practices conducive to maintaining health and preventing disease, especially through cleanliness.
Microbe:	–	Bacteria involved in contamination of foods
Microbial contamination:	–	Growth of undesired microbes and production of toxic molecules on foods
Quality:	–	Characteristics of meat that satisfy the needs of consumers and the sellers
Roasted meat:	–	Meat cooked by exposing it to an open fire
Safety:	–	Conditions and practices that preserve the quality in order to prevent contamination and diseases.

CHAPTER ONE:

INTRODUCTION

1.1. Background information

The World Health Organization (WHO) estimates that over 70% of diarrhea episodes result from biological or chemical contamination of food (Baidya & Rahman, 2021; Bhalla, 2019). The health challenge is associated with poor methods of food harvesting, storage/preservation, preparation, and serving/presentation which lead to contamination, adulteration, and spoilage (Momtaz et al., 2023; Uçar et al., 2016).

Diseases related to food, also popularly referred to as food-borne illnesses, constitute one of the major health problems in developing countries, especially those in sub-Saharan Africa (Bagumire & Karumuna, 2017). For instance, a recent meta-analysis of seven African countries showed an average prevalence of 34.2% of pathogens in ready-to-eat foods, which was strikingly as high as that for raw foods. The most common predisposing pathogens include *Enterobacteriaceae*, *Escherichia coli*, *Salmonella*, *Staphylococcus aureus*, and *Listeria monocytogenes* (Paudyal et al., 2017).

Roadside vending of food is widespread in the world, especially across Africa and Asia as it provides affordable, convenient, and attractive meals for many individuals, among which are travelers (Oloo & Wakhungu, 2019). Meat, as a major source of protein, is one of the most common delicacies enjoyed by travelers, as evidenced along many roads and highways in Africa and beyond, Uganda included. The common meats of choice usually comprise of beef, chicken, goat's meat, fish, and pork (Tumuhe et al., 2020); while the most common methods of preparing these meats along the roadside markets is either by roasting in open fire or deep frying. These meats are usually prepared either in makeshift or semi-permanent structures and presented mostly by semi-illiterate vendors whose main interest is earning quick cash income. This means that compliance with sanitation standards and hygiene guidelines while handling meats, is very subjective and most of the time compromised (Bagumire & Karumuna, 2019; Letuka et al., 2021).

Roadside vending of food in Uganda emerged as an option for travelers to access quick meals while in transit; however, regulation of the business is reported not to be very effective. As a result, the sanitation and hygiene practices of food handlers remain wanting, which expose travelers to unsafe meals such as roasted meats (Bagumire & Karumuna, 2019).

Poor and careless handling of food by the vendors causes contamination and food spoilage which this ends up being eaten up by hungry travelers (Kungu et al., 2021). Spoilt food is associated with food-borne diseases that are responsible for a significant number of disability-adjusted life years (DALYs), accounting for over 34% of premature deaths in children under the age of five (Hoffmann et al., 2017; Jaffee et al., 2018).

There is limited information on quality and safety of roadside roasted meats and hygiene of meat vendors in Uganda (Bagumire & Karumuna, 2017). Therefore, this study focused on hygiene practices of the meat vendors, effect of handling on microbial contamination as well as levels of contamination of the different meats vended along two major highways in Uganda. Information generated is important in bridging the paucity of available data as well as contribute to generation of policy regulations regarding quality of ready-to-eat roadside meats, specifically in Uganda.

1.2 Statement of the problem

In Uganda, roadside roasted meats, particularly those sold at highway markets such as Namawojjolo and Lukaya, serve as an important source of affordable and accessible protein for many consumers, especially travelers. Although roadside roasted meat is popular, a study by the Uganda National Bureau of Standards (UNBS) in 2018 found that 70% of roasted meat samples collected from roadside food markets were contaminated with harmful bacteria, such as *E. coli* and *Salmonella* (Nabwiire et al., 2023). This contamination can lead to food poisoning causing serious illness and even death. Food-borne illnesses are a significant public health concern worldwide resulting from consumption of unhealthy foods more so from roadside food markets. These markets are mostly unregulated, often lack proper sanitation facilities and considered high-risk environments for foodborne pathogens and contamination (Oloo & Wakhungu, 2019; Roger et al., 2015).

In Uganda, studies on the safety of roasted meat and hygiene practices of vendors are scanty and usually focus on individual parameters such as bacterial contamination (Bagumire & Karumuna, 2017), compliance to standards (Nabwiire et al., 2023), and availability of sanitation facilities in the markets (Bagumire & Karumuna, 2019). None of these studies focused on a comprehensive assessment of hygiene practices of roasted meat vendors, the quality of roadside meats served and the effect of handling on microbial safety of these roadside roasted meats served along highways.

This study therefore sought to bridge this paucity of information by assessing hygiene practices of roadside meat vendors, and the quality and safety, with specific focus on microbial contamination, of roadside meats.

1.3 Justification for the study

The food vending industry plays a very important role in meeting food requirements of travelers and local dwellers not only in Uganda but also in many developing countries across the world. However, the quality and safety of roadside vended food is usually not certain due to regulatory gaps. Uganda has food safety laws and guidelines; however, it has been noted that implementation is still wanting, leaving consumers in danger of contracting foodborne illnesses (Kankya et al., 2020).

The quality and safety of food products are essential for public health and the overall well-being of consumers (WHO, 2008). Therefore, studying meat microbial quality is essential for identifying health risks and preventing potential outbreaks of foodborne illnesses in Uganda.

Namawojjolo and Lukaya are major roadside food vending points located along busy highways, attracting large numbers of travelers daily thus their strategic position makes them key areas for intervention and food safety monitoring.

The current study thus aimed to shed light on the hygiene practices of the meat vendors and quality and safety of roasted meats in the two prominent highway roadside food markets of Namawojjolo and Lukaya in Uganda.

Information generated is very useful and critical in shaping regulation and policy formulation which are pivotal in streamlining the practices related to vending roasted meats along highways to ensure food safety and hence reduce foodborne diseases associated with roasted highway meat which is in line with Sustainable Development Goals, SDG 2 (Zero Hunger) and SDG 3 (Good Health and Wellbeing) (UN, 2015)

1.4 Significance of the study

This research is of significant benefit to many different categories of people including but not limited to consumers (general population), policy makers, regulators (standards agencies), business community and academicians. Specifically, the findings are vital for public health, education and awareness, policy and regulation, and economic impact.

a) **Public Health:** Ensuring the safety of street food in highway roadside markets is crucial for preventing foodborne illnesses and protecting public health.

b) **Economic Impact:** Foodborne illnesses can lead to significant economic losses for both consumers and vendors. Improving food safety practices can contribute to increased consumer confidence and market sustainability.

c) **Policy and Regulation:** The findings of this study can inform the development of regulations and guidelines for street food vendors, enhancing food safety standards in Uganda's highway roadside markets.

d) **Education and Awareness:** The study can serve as a basis for educating vendors and consumers about safe food handling and the importance of food safety.

1.5 Objectives

1.5.1 Broad objective

Generally, the study sought to investigate quality and safety measures of roadside roasted meats in Uganda with the overall goal of highlighting gaps that may contribute to curbing health challenges arising from foodborne illnesses.

1.5.2 Specific objectives

1) To assess hygiene practices applied in preparation and vending of roadside roasted chicken, beef and goat meat in Namawojjolo and Lukaya food markets, Uganda.

2) To determine the effect of handling, roasting and vending on microbial contamination of roadside roasted chicken, beef and goat meat from Namawojjolo and Lukaya food markets.

3) To evaluate the effect of meat type on levels of microbial contamination of roasted meats along the roadside food markets of Namawojjolo and Lukaya Highway Food Markets in Uganda.

1.5.3 Hypotheses

Null Hypotheses

1. (Ho): Hygiene practices used by vendors in preparation and vending of roadside roasted meats from Namawajjolo and Lukaya food markets are not significantly poor.

2. (Ho): Handling, roasting and vending of roadside meats have no significant effect on the microbial load of ready-to-eat roasted meats from Namawajjolo and Lukaya food markets, Uganda.

3. (Ho): There is no significant difference in levels of microbial contamination of the different roasted meat types from Namawojjolo and Lukaya roadside food markets, Uganda.

Alternative hypotheses

1. (H1): Hygiene practices used by vendors in the preparation of roadside roasted meats from Namawajjolo and Lukaya markets are significantly poor.

2. (H1): Handling, roasting and vending of roadside meats have a significant effect on the microbial load of ready-to-eat roasted meats from Namawajjolo and Lukaya food markets, Uganda.

3. (H1): There is a significant difference in levels of microbial contamination of the different roasted meat types from Namawojjolo and Lukaya roadside food markets, Uganda.

CHAPTER TWO:

LITERATURE REVIEW

2.0 Overview of roadside food markets

The most common means of transport in Uganda is by road, characteristically involving long-distance travel with frequent stop-overs, usually at roadside food markets. This implies that customers in these food markets include all sorts of travelers like in-country travelers, tourists, and those crossing to nearby countries like Kenya, Tanzania, Rwanda, the Democratic Republic of Congo and South Sudan (Namusoke, 2022; Oloo & Wakhungu, 2019). It is worth noting that despite the informal nature of these roadside food markets, they significantly contribute to the availability of food which is very vital for food security as outlined in SDG 2 (WHO, 2018).

Travelers, more so those going for long distances by road, such as truck drivers, often have stop-overs in different places, mainly to eat, drink, and refresh. Such stopovers attract businesses that offer goods and services to these travelers, and food vending is one of the most prominent enterprises (markets). The most commonly served foodstuff in these markets are fast foods like roasted and deep-fried meats, usually served with chips (Katende, 2021). In Uganda, the most characteristic foods include roasted plantain (popularly known as *Gonja*), roasted meats, chips, roasted cassava, roasted maize and peanuts, drinks (like soda, juice, and water), and chapatti, among others (Namusoke, 2022). Vendors usually obtain their merchandise from subsistence farmers from the surrounding villages, slaughterhouses, and other unsolicited suppliers (Tumuhe et al., 2020).

Figure 1: **Vendors surrounding a traveler's car at Namawojjolo Market (Photo by Daily Monitor – (Katende, 2021)**

Roadside food markets are very common in Uganda, being found almost along every major road but one conspicuous feature of these markets is the nature of the structures. There are hardly any permanent structures but mostly temporary or makeshift structures (Oloo & Wakhungu, 2019).

Vendors in these roadside food markets are mostly illiterate or semi-illiterate and are usually low-income earners who cannot afford high-end equipment and materials for the safe preparation of ready-to-eat foodstuff. Because of the aforementioned, the most common means of food preparation in these markets is roasting using charcoal stoves (locally known as *sigiri*) and deep frying using improvised frying pans and this is always done in the open-air along the roads (Jeffer et al., 2021; Kasozi et al., 2018). Relatedly, the vendors typically run and flock around the vehicles that stop at these markets with their merchandise as shown in Figure 1 above, which may exacerbate exposure of the food (ready-to-eat meats) items to various forms of contamination (Katende, 2021).

2.1 Common hygiene practices in handling and roasting meat

Quality and safety of different meats should be ensured by different hygiene measures right from slaughtering procedures, processing practices, storage/chilling arrangements (including fresh meat, ready-to-eat, and leftovers), preparation or cooking, and up to serving to the consumer (Bhalla, 2019). Some of these practices are directly to the personal hygiene of the meat vendors (and/or those who roast), sanitation facilities in the market such as proper waste disposal facilities, availability of storage facilities, and compliance with the guidelines on meat handling (Momtaz et al., 2023).

Good Hygiene Practices (GHPs) generally include personal hygiene, cleaning and sanitization, temperature control, proper storage and prevention of cross contamination between raw and ready to eat meats (San Onofre et al., 2021).

Personal hygiene in meat handling entails washing hands thoroughly for at least 20 seconds with soap and water before and after handling meat to remove any potential contaminants, cleaning between fingers and under nails, avoiding touching the face, hair, or any other body parts while handling meat to prevent cross-contamination (Yüksel & Günay, 2023a).

Regular cleaning and sanitization of all equipment, utensils, and surfaces are vital to prevent the growth and spread of bacteria. All surfaces, cutting boards, knives, and utensils used for handling raw meat should be thoroughly cleaned with hot, soapy water after each use. Sanitizing with approved disinfectants further ensures the elimination of any remaining bacteria. It is also important to clean and sanitize kitchen countertops, sinks, and other areas that come into contact with raw meat (Holah, 2014; Okpala & Ezeonu, 2019; YÜKSEL & GÜNAY, 2023b).

Typically, temperature of the raw meat during storage must be maintained at about 0 - 4 ^{0}C to prevent microbial contamination (Sulieman et al., 2023). It is important to promptly refrigerate raw meat after purchase or use. During roasting, meat should be cooked to the recommended internal temperature to ensure that all harmful bacteria are destroyed. Using a food thermometer is highly recommended to accurately measure the internal temperature of the meat (San Onofre et al., 2021; Sulieman et al., 2023). This implies that meat vendors are obliged to have freezers and reliable source of electricity; however, such amenities are rarely available in these roadside food markets (Okpala & Ezeonu, 2019).

Reports show significant levels of non-compliance to Food Safety Guidelines in many of these roadside food markets owing to poor sanitation, hygiene, and handling practices (Jeffer et al., 2021; Kankya et al., 2020). For example, an analysis of Food Safety Management Systems in the Beef Meat Processing and Distribution Chain in Uganda found that most slaughter houses did not have functional cooling facilities yet butcher shops, supermarkets and other small scale meat vendors sourced meat from these slaughter houses (Jeffer et al., 2021). Relatedly, a situational analysis of food safety control system in Uganda found that there were hardly sufficient handwashing facilities in most markets in the country and roadside food markets are no exception (Kankya et al., 2020).

2.2 Safety of Roadside Ready- to -Eat meats

Although meat is highly nutritious, the way in which it is harvested, stored, prepared, transported and served affects its safety attributes (Forsythe, 2020). Different contaminants including microbes, chemicals, heavy metals and sometimes poor-quality preservatives pose safety issues to meat products in general (Das et al., 2019; Forsythe, 2020).

Roadside ready-to-eat meats are specifically more susceptible to having safety problems due to the nature of market set up in terms of infrastructure, method and extent of preparation, mode of delivery to customers, hygiene standards of vendors (mostly semi-illiterates), enforcement and adherence to guidelines and the unsolicited nature of supply of raw meat and ingredients (Jeffer et al., 2021).

Roadside meat and ingredients are often prepared in a hurry, without observing good hygiene and sanitation measures for instance, they often lacking proper washing facilities and refrigeration for storage (Siluma et al., 2023). Such conditions may lead to microbial contamination and spread of foodborne illnesses to the consumers (Balali et al., 2020). Chemical contamination from motor vehicle exhaust gases is also a concern and, in some cases, roadside meat may even be substituted with unconventional and potentially harmful meats, such as rat, cat, or dog meat (Kasozi et al., 2018).

Similarly, the lack of reliable sources of electricity and the urge for quick cash, roadside vendors sometimes use unconventional means to prepare the meat. For example, a recent study in Nigeria showed that there were elevated levels of heavy metals, particularly lead and copper, in roasted goat meat due to use of old tyres as fuel. The levels of heavy metals were found to be higher than the acceptable limits of the Food and Agricultural Organization, FAO (Joseph et al., 2024).

Moreso, the meat maybe found to be half cooked which not only affects the appetite but is also a potential route of transmission of zoonotic diseases like brucellosis and typhoid to consumers (Mugagga, 2021).

2.3 Potential microbial contamination of meats roasted along roadside markets

Microbial contamination of roasted meat may occur at different levels of the food supply chain, ranging from production/slaughter of sick animals (such as chicken having typhoid), contamination during slaughter, transportation, storage, roasting and even while serving to the final consumer (Anihouvi et al., 2013).

Transport from slaughter houses to storage/roasting places along roadside markets is crucial if microbial contamination is to be prevented; however, in Uganda, most roadside vendors do not usually afford standard means of transport instead many times meat, especially beef, is transported on motor cycles just tied without covering (Nabwiire et al., 2023).

Besides transport, storage is another issue that poses a significant opportunity for microbial contamination due to the kind of infrastructure available in these roadside markets which are usually makeshift in nature (Jeffer et al., 2021; Namusoke, 2022).

Poor storage of meat leads to cross-contamination which is a significant concern when handling raw meat. It is essential to prevent the transfer of bacteria from raw meat to other surfaces or cooked food. This can be achieved by ensuring separate storage of raw and cooked meat, using different utensils for each, and avoiding contact between raw meat and ready-to-eat foods (Nagarajan et al., 2018). Use of separate cutting boards, utensils, and dishes for raw and ready-to-eat meat, washing kitchen utensils after each use, and washing raw meat reduces risk of harmful bacteria and prevent spread of foodborne illnesses (Kisaakye et al., 2020). However, such utensils are rarely available in these roadside food markets (Kasozi et al., 2018).

Additionally, most highway roadside food markets are located in places far from towns or peri-urban areas, which are usually characterized by unreliable sources of clean water. Many times, even when meat is washed properly, it is done using dirty water that could be infested with pathogens or disease-causing vectors (Alum et al., 2016).

A study in Benin found that beef samples collected from roadside barbecue sites had high levels of microbial contamination, including potential pathogens like E. coli, Salmonella, and Staphylococcus aureus. This was attributed to lack of adequate hygiene and food safety practices (Sina et al., 2019). Similarly, several studies have shown significant levels of microbial contamination in roasted meats especially in developing countries (Birgen, 2019). Some of these studies are summarized in **Table 1** below.

Looking specifically at Uganda, noncompliance to standards has been documented and non-conformity to international limits of chemical and microbial contamination was noted in some studies (Bagumire & Karumuna, 2017; Kungu et al., 2021).

Table 1: Microbial contamination of meat products from different countries

Country	Meat Type	Hazard	Unsafe, %	Standard of reference	Reference
Nigeria	Beef	Total viable count	98 %	International standard	(Grace Delia, 2015)
India	Pork	Enterobacteriaceae	89 %	International standard	(Fahrion et al., 2014)
Kenya	Chicken	E. coli/coliform counts	76%	International standard	(Odwar et al., 2014)
Rwanda	Beef	Total aerobic count	100 %	European Microbiological standards (2.5 log CFU)	(Niyonzima et al., 2013)
	Poultry import	S. aureus	0.2 %	European Union	(Jansen et al., 2018)
Germany	Turkey meat import	S. aureus	0%	European Union	

2.4 Foodborne diseases

Foodborne diseases (FBDs) can be defined as any illness that results from ingesting foods or beverages that are either contaminated or naturally harmful and usually manifest through acute gastrointestinal infections (Grace Delia, 2017; WHO, 2018). They are a major public health concern globally to varying degrees in developed and developing countries. Recent estimates indicate that foodborne diseases account for 33 million years of healthy lives lost (DALYs), with 600 million cases and 420,000 deaths. Notably, about 30% of deaths from foodborne diseases occur among children under five years of age (Kankya et al., 2020; WHO, 2015).

The contaminants are usually microorganisms basically Bacteria, Viruses, and Fungi, natural poisons from organisms (toxins) as well as chemicals and other harmful substances (WHO, 2015). However, microbial contamination is the most common cause of many of the foodborne diseases (Ciekure et al., 2016).

Norovirus, *Campylobacter*, *Salmonella*, *Escherichia coli* and *Listeria* are some of the common food pathogens associated with improper handling and undercooking of foods by vendors, in food service establishments or at home (Pattabhiramaiah & Mallikarjunaiah, 2023). Foods like meat, poultry, eggs, and dairy are frequently implicated means of transmission. Also, toxins from *Clostridium botulinum*, *Staphylococcus aureus* and chemicals like pesticides or heavy metals cause food poisoning (Gupta & Gupta, 2020; Pattabhiramaiah & Mallikarjunaiah, 2023). Symptoms range from mild gastroenteritis to life-threatening neurological, hepatic or renal syndromes. Children, elderly and immunocompromised groups are at high risk (WHO, 2015).

In Uganda, there are documented outbreaks of foodborne diseases such as the cholera outbreak in Kampala in January 2019, plus other prior outbreaks documented (Bwire et al., 2021; Eurien et al., 2021). In 2015, there was an outbreak of typhoid fever in Kampala with over 10,000 cases reported and it was attributed to street vended beverages, especially juices (Murphy et al., 2017). There are many other reported cases of food borne illnesses in Uganda such as Brucellosis and anthrax (Kisaakye et al., 2020).

Generally, data relating to FBDs has been explored by different studies (Grace Delia, 2015; Kankya et al., 2020); however, there are limited location specific studies particularly of roadside food markets in regard to roasted meats (Oloo & Wakhungu, 2019).

2.5 Summary and Research Gap

The literature indicates that roadside-roasted meats in Uganda and similar low- and middle-income settings are frequently handled under suboptimal hygiene conditions and often exhibit significant microbial contamination. In informal highway markets like (Namawojjollo and Lukaya), vendors typically lack basic necessities for good hygiene and sanitation such as refrigerators, running water and handwashing facilities. This creates ample opportunities for cross-contamination and bacterial proliferation since the vendors rarely implement recommended good hygiene practices.

Some studies in sub-Saharan Africa reported reasonable counts of *E. coli*, *Salmonella*, *Staphylococcus aureus*, *Listeria*, and other bacteria in street-vended meats which was affirmed by a UNBS report which found that 70% of sampled street roasted meats were contaminated with *E. coli* and *Salmonella*.

In Uganda, studies relating to microbial safety, hygiene and behavior of meat vendors are scanty and there are few location-specific studies of hygiene and safety in roadside-roasted meats. The relationship between on-site handling practices and the microbial safety of ready-to-eat meats vended at roadside food markets remains inadequately documented.

This study directly addresses that gap by assessing both the hygiene practices of vendors and the microbial safety of different meat types at two major highway markets (Namawojjolo and Lukaya). By simultaneously observing vendor behavior and measuring bacterial loads in raw, hot-roasted and ready-to-eat meats, it provides the comprehensive evidence that earlier studies have lacked. This integrated approach thus fills the identified research void and informs targeted interventions to improve the safety of roadside-vended meats.

CHAPTER THREE:

METHODOLOGY

3.0 Introduction

This section covers methods that were used to achieve the set objectives and it is divided into sections such as; study setting, study design, study population, sample size, sampling procedure, selection criteria, data collection, data quality control, data analysis, and ethical considerations.

3.1 Study setting/site

The study was conducted in two purposively selected roadside markets of Namawojjolo along Kampala-Jinja and Lukaya along Kampala-Masaka Highways. The two food markets were selected because they are strategically located and have a high population of ready-to-eat food vendors.

Namawojjolo is found in Nama, Mukono District in Central Uganda about 33 km East of Kampala City and 11 km away from Mukono. It is located at a GPS reading of N 0°23'3, E 32°50'18 and altitude of 1123 m above sea level along Kampala-Jinja Highway which is the main route linking the capital city (Kampala) to the Eastern parts of Uganda and those traveling to Kenya by road. This makes it a very busy road with heavy traffic and many travelers make stopovers at Namawojjolo Market to get already prepared food items.

Lukaya is located in Kalungu District, along the Kampala-Masaka Highway, approximately 107 km from Kampala and 27 km from Masaka Town in Central Uganda at a GPS reading of 0°09'03.0"S, 31°52'28.0"E. Kampala-Masaka Highway leads to the Southern and Western parts of Uganda and further links to Rwanda and the Democratic Republic of Congo (DRC) borders. Each of these two markets has a total population of between 300-400 vendors each who are involved in the sale of different foods daily (Bagumire & Karumuna, 2017).

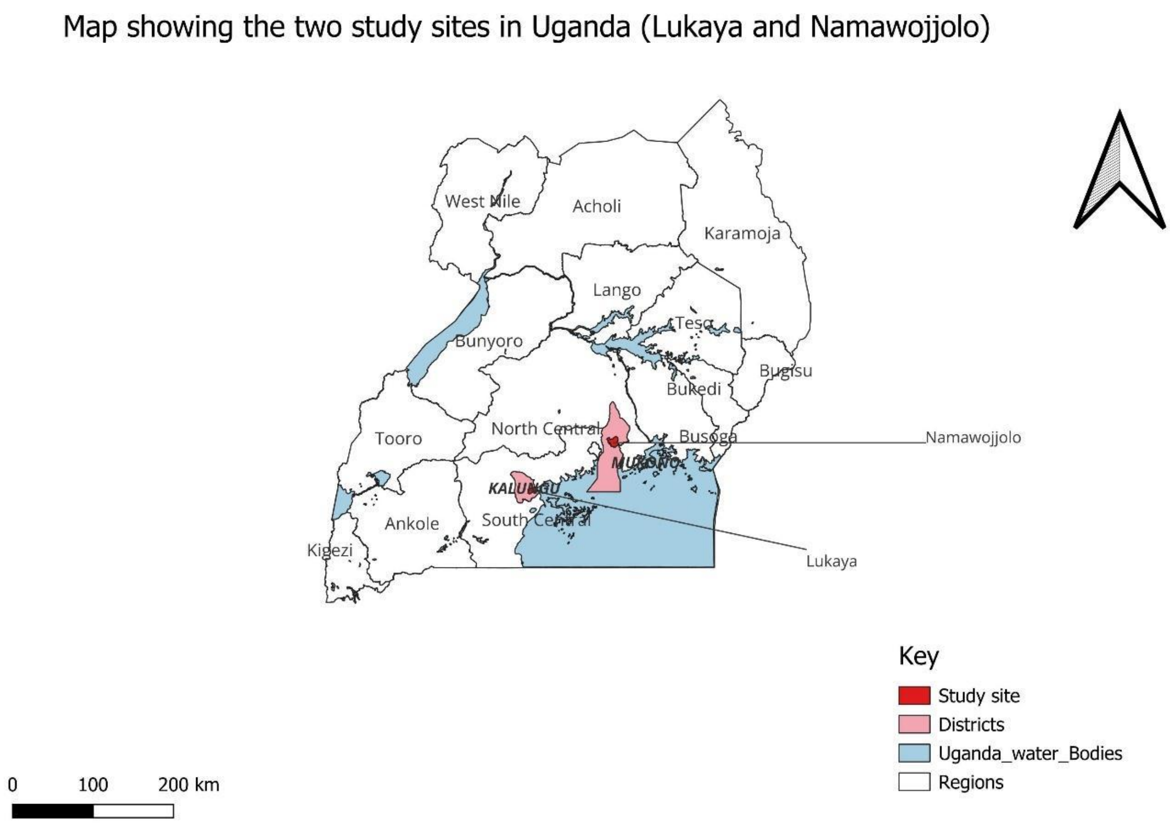

Figure 2: Map of Uganda showing the two study sites of Namawojjolo and Lukaya Food Markets

3.2 Study design

A cross-sectional study design that was both observational (for the vendor hygiene assessment) laboratory-based (for microbial analysis). A qualitative research approach was used to collect data on hygiene practices of the meat vendors in both Namawojjolo and Lukaya Food Markets (objective one). A completely randomized design was used to assess the effect of handling roasting, and vending on the microbial safety of roadside meats as well as the effect of meat type (chicken, beef and goats' meat) on the level of microbial contamination (objectives two and three).

3.3 Study population

The study population comprised of vendors of roadside roasted (ready-to-eat) meats along the highway markets of Namawojjolo and Lukaya. Samples of the roadside roasted ready-to-eat meats were purchased from selected meat vendors of the two markets of Namawojjolo and Lukaya for microbial laboratory analysis.

3.3.1 Selection criteria

3.3.2 Inclusion criteria

All vendors who prepare and sell at least one of the three types of meat (beef, chicken, or goat meat) to travelers in Namawojjolo and Lukaya roadside food markets were targeted. Three meat categories (beef, chicken, or goat's meat) were sampled.

3.3.2 Exclusion criteria

Vendors who did not speak and understand English or Luganda languages. This is because the study tools were written in English and Luganda, which are the commonly used languages for business in the two markets.

Vendors who had not operated the meat business in the area for at least one month, those who were below eighteen years old, and those who did not consent to participating in the study were left-out.

3.4 Study materials and apparatus

70% ethanol (disinfectant)
Surgical blades, Kitchen knife, Ziplock bags
Cool box, Sterile gloves
Weighing scale, Laboratory marker, Freezer
Meat samples (e.g., chicken, beef)
Sterile equipment: pipettes, beakers, Petri dishes, and test tubes
Incubator with controlled temperature
Sterile water

Sterile stomacher bags or blenders or motor and pestle

pH meter

Incubator (capable of anaerobic conditions or microaerophilic environment)

Colony counting equipment

Dilution tubes (for serial dilutions)

Buffered Peptone Water (BPW)
Plate count Agar
Selenite Cysteine Broth (SCB)
Xylose Lysine Deoxycholate (XLD) agar
Mannitol Salt Agar (MSA)

Chromogenic agar plates (such as CHROMagar ECC or Brilliance E. coli/Coliform Agar)

Campylobacter Agar Base

Sheep Blood (defibrinated)

Campylobacter Supplement (an antibiotic like vancomycin)

Listeria Oxford Medium Base (LOM)

Oxford Supplement (FD071)

Inoculation loops or sterile swabs

3.5 Sample size

The sample size was calculated differently for the different objectives. Objective one was calculated using the Kish-Leslie formula for an infinite population and adjusted with the modified Kish-Leslie using an approximate number of meat vendors in the two markets (section 3.5.1). The sample size for objectives two and three was on the other hand approximated based on literature as in section 3.5.2 below

3.5.1 Sample size for the number of vendors/stalls (objective one)

This was calculated using the Kish-Leslie (1965) formula for sample size determination:

$N = Z^2P\ (1- P)/d^2$ Where;

N = desired sample size;

Z = standard normal value corresponding to 95% confidence interval (1.96);

P = expected compliance of the vendors with the standard guidelines on hygiene.

Since the compliance was uncertain, a 50% estimate was used since no previous study gave the proportion of interest (and yet 50% would give the maximum sample size) and

1-P = the probability of vendor population that complies with the guidelines

[(1-0.50) = 0.50]

d = level of precision/tolerable sampling error (5% was used since our value of P is >10%)

$N = (1.96^2 \times 0.5 \times 0.5)/\ (0.05^2) = 384$ vendors which was then scaled down to the expected number of meat vendors (n).

n (adjusted sample size) = N/ [1+ (N-1)/K] which is the modified Kish Leslie formula for a finite population. K = estimated total number of meat vendors in both Namawojjolo and Lukaya Highway Food Markets (approximately 118 meat vendors).

n = 384 / [1+ ((384-1)/118)] = 90 meat vendors that were considered for the survey. This number was proportionately divided into the two markets giving Lukaya food market 46 participants and

Namawojjolo 44 participants who were interviewed in each market.

3.5.2 Samples for laboratory analysis (objectives two and three)

Considering some similar studies on microbial contamination of different foods (Bagumire & Karumuna, 2017; Mwove, 2023) a total of 89 samples were bought for laboratory assessment for microbial analysis and these were sampled as detailed in **Table 2** below. Proportionate sampling, was used to determine the meat sample sizes due to variability in meat types and numbers available in the different markets. Most vendors were found to be selling chicken followed by beef and very few sold goat meat therefore proportionate sampling gave the numbers shown in **Table** 2. Also, there was no goat meat in Namawojjolo hence more chicken samples were bought in Namawojjolo in place of goat meat.

Table 2: Categories and number of meat samples purchased from the two roadside food markets for the determination of microbiological contamination

Category of meat		**Namawojjolo**	**Lukaya**	**Total**
Raw/fresh	Chicken	11	06	17
	Beef	04	05	09
	Goat meat	00*	06	06
Sub-total (raw meat samples)		**15**	**17**	**32**
Roasted (ready-to-eat)	Chicken	16	12	28
	Beef	08	10	18
	Goat meat	00*	11	11
Sub-total (roasted meat samples)		**24**	**33**	**57**
Grand total		**39**	**50**	**89**

*There was no goat's meat in Namawojjolo Food Market

3.6 Data collection procedure

As shown in **Table 2** above, a total number of 89 samples were bought from both markets and a total number of 90 vendors were interviewed. Convenience consecutive sampling was used to select participants to be interviewed. Convenience consecutive sampling involves selecting participants in a sequence, one after the other until the desired sample size is reached. This was used to collect data for objective one while purposive sampling was used to select vendors from whom samples were randomly bought for objectives two and three.

3.6.1 Hygiene practices of the meat vendors

This was done using an observational checklist combined with a semi-structured questionnaire (Appendix I). The checklist was used to capture information on storage and handling facilities for raw meat, personal hygiene of the vendor, equipment cleanliness, food preparation area, interaction with the customer (such as handling of money), and management of waste.

The semi-structured questionnaire was used to capture information on participant demography, knowledge of the guidelines, knowledge of foodborne diseases, and way of presenting roasted meat to the customers.

3.6.2 Sample collection for laboratory analysis

Samples of beef, chicken, and goat meat were bought from randomly selected vendors who had been previously interviewed for objective one. The raw samples were bought from randomly selected vendors who accepted however, ready-to-eat samples were bought using a simulated client to avoid bias by the vendor.

The samples were packed in zipper-lock polythene bags, sealed off, put in a cool box (at a temperature of 2°C) and transported to the laboratory on the same day for microbial analysis. Laboratory analysis was done on five common microbes which were *Escherichia coli*, *Salmonella*, *Staphylococcus aureus*, *Campylobacter*, and *Listeria*. This was done at the Agricultural Biotechnology Laboratory of Makerere University, housed in the Department of Agricultural Production.

Total Plate Count was also done to determine the level of microbial contamination of the different types of meat for the five microbes.

3.6.3 Microbial analysis for objectives two and three

a) Quantifying *Salmonella* using enrichment and selective culture of Buffered Peptone Water (BPW), Selenite Cysteine Broth (SCB), and Xylose Lysine Deoxycholate (XLD) agar.

The meat sample was weighed (5 g) and placed into a sterile motor then homogenized using a pestle in 45 mL of Buffered Peptone Water (BPW). The mixture was shaken thoroughly for 2 minutes to release bacteria from the sample into the BPW. The homogenized sample was incubated in BPW at 37°C for 24 hours to enable recovery of any stressed *Salmonella* cells. After 24 hours, 1 mL of the homogenized sample was added to 9 mL of Selenite Cysteine Broth (SCB) and incubated at 42°C for 24 hours to suppresses competing flora thereby promoting the growth of Salmonella. After incubation in SCB, 6 dilutions were done from which 0.05 mL of the enriched broth was spread onto Xylose Lysine Deoxycholate (XLD) agar plates and then incubated at 37°C for 24 hours. After incubation, the number of Salmonella appeared as black colonies on XLD plates which were counted and quantification was based on colony-forming units (CFU) per gram of meat given by the formula;

CFU/g = (Number of colonies × Dilution factor) / (Sample inoculated/ volume plated)

b) Quantifying *Staphylococcus aureus* in meat using Mannitol salt agar and white egg

The meat sample was weighed (5g) and placed into a sterile motor then homogenized thoroughly using a pestle in 45 ml of Buffered Peptone Water (BPW). Serial dilutions of the homogenized sample was performed to reduce bacterial concentration, facilitating accurate quantification. This was done starting with a 1:10 dilution (e.g., 1 mL sample to 9 mL diluent) and proceeding to further dilutions as needed. Using a sterile pipette, a small volume (0.05 mL) was transferred from each dilution onto separate MSA plates and the sample was spread evenly across the agar surface using a sterile spreader. The plates were incubated at 37°C for 24 hours. Staphylococcus aureus colonies appeared as yellow clusters. Plates with 30-300 colonies were selected and colonies on these were counted. The number of CFUs per gram of meat was calculated as:

CFU/g = (Number of Colonies × Dilution Factor)/ (Plated Volume)

c) Quantify *E coli* in meat using chromogenic agar

The meat sample was weighed (5g) and placed into a sterile motor then homogenized thoroughly using a pestle in 45 ml of BPW to make a 1:10 dilution. Six dilutions of the homogenized sample were made. Using a sterile pipette, 0.05 mL was taken from the homogenized sample and spread on the chromogenic agar plate. The Chromogenic agar plates were incubated upside down at 37°C for 24 hours after which the plates were observed for distinctly colored colonies. The blue colonies were counted specifically as *E. coli*. To get the CFU per gram, the number of colonies was multiplied by the dilution factor of the original meat sample and divided by the plated volume.

d) Quantifying Campylobacter in meat using *Campylobacter* Agar Base and defibrinated Sheep Blood

Campylobacter agar base was weighed and 37g added to one liter of distilled water in a sterile flat-bottomed flask. The mixture was gently heated to facilitate dissolving after which the agar base was allowed to cool to 50°C. Defibrinated sheep blood (10% v/v) was added to the cooled agar base and mixed gently, then Campylobacter supplement was added and mixed to ensure even distribution of the supplement in the medium. The prepared medium was then autoclaved at 121°C for 15 minutes and allowed to cool to 50°C before pouring. The agar was poured into sterile Petri dishes and allowed to solidify at room temperature.

The meat sample was homogenized in BPW, six dilutions were made and each plate was inoculated with 0.1 mL of diluted sample. The inoculum was spread evenly across the surface of the agar and the plates incubated in a controlled environment of 5% O_2, 10% CO_2, and 85% N_2 at 42°C for 48 hours. After incubation, plates were examined for blue colonies and counted.

e) Quantification of Listeria in meat using *Listeria* Oxford Medium (LOM) and Oxford supplement (FD071).

The meat sample was weighed where 5g was placed into a sterile motor then homogenized using a pestle in 45 mL of BPW 2 minutes to create a uniform suspension. Serial dilutions of the homogenized sample were prepared and for each dilution, 0.05 mL was transferred onto Listeria Oxford Media (LOM)plates. Different dilutions were spread on separate plates and the Oxford supplement (FD071) was added to the LOM at a concentration of 1% (v/v) before inoculating. The plates were incubated at 30°C for 24 hours and after incubation, the plates were examined for typical Listeria colonies. The number of Listeria colonies on each plate were counted and recorded for each dilution to determine the concentration of Listeria in the original meat sample. The number of Listeria per gram of meat was calculated using the formula:

CFU/g = (Number of Colonies × Dilution Factor)/ (Plated Volume)

The microbial load was compared with recommended microbiological reference criteria for acceptable limits as described (Ciekure et al., 2016). Uganda National Bureau of Standards (UNBS) guidelines US EAS 84-1 -Meat grades and meat cuts specification Part 1: Beef grades and cuts and US EAS 953 -Dressed poultry specification

3.6.4 Total plate count using Plate Count Agar

The total plate count (TPC) was done to give a summary of the microbial analysis results. The Plate Count Agar (PCA) was weighed according to the manufacturer's instructions (23.5 g per 1 liter of distilled water). The PCA powder was then dissolved in the appropriate volume of distilled water and heated gently while stirring to fully dissolve the medium. The medium was dispensed into bottles and autoclaved at 121°C for 15 minutes. After autoclaving, the media was allowed to cool to 45°C before pouring into sterile Petri dishes where 20 ml of PCA was poured into each dish and the plates allowed to solidify.

The meat sample was weighed (5g) aseptically and placed into a sterile stomacher bag. Sterile peptone water (45ml) was added to make a 1:10 dilution then the sample was homogenized using a stomacher for 2 minutes to obtain a uniform suspension. To the first test tube, 1ml of the homogenized sample was added and 9ml of the diluent then vortexed to mix thoroughly. Serial dilutions were then performed by transferring 1 mL from the previous dilution into the next test tube containing 9 mL of diluent, creating further dilutions (e.g., 10^{-2}, 10^{-3}, etc.). From each selected dilution (e.g., 10^{-3} and 10^{-4}), 0.05 ml was transferred onto a sterile PCA plate then 20 ml of molten PCA poured onto the sample. The plate was swirled gently to mix the sample and the medium and the plates were allowed to solidify. The solidified plates were inverted to prevent condensation from dripping onto the agar surface and they were incubated at 35°C for 24 hours. After incubation, the plates with 30–300 colonies were counted, the colony count for each plate was recorded and TPC was expressed in CFU/g of the meat sample.

3.7 Data quality control

The survey checklist and questionnaire was pretested in Zigoti, a market with a similar setup to those under study and ten (10) vendors were used to test the tools.

Close supervision of the data collection process was done to ensure completeness and accuracy of the data collected before leaving the field. The activity was first done in one market (Namawojjolo) then the team proceeded to the other (Lukaya). Also, after data entry, data cleaning was done before analysis to minimize errors in data.

Laboratory data was read thrice and averages taken to minimize errors in reading.

The questionnaire was translated to Luganda (the most common dialect for conducting business in the study areas) by a language expert and translated back to English as a check.

3.8 Validation and reliability of the instruments/tools

All materials and equipment used in the laboratory were calibrated. All reagents used were of analytical grade and were tested against standards to ensure their quality before use in the experiments. All experiments were conducted under the guidance of an experienced microbiology laboratory technician (or technologist).

3.9 Data analysis

Scored hygiene checklists from direct vendor observations were compiled and parameters scored as binary or categorical variables (Yes/No, Good/Satisfactory/Poor)

Descriptive statistical analysis was performed by calculating percentages, frequencies, and means of vendors following each specified hygiene practice. Total hygiene scores were computed for each vendor and compared across locations.

For comparison, statistical tests were conducted to compare the different microorganisms. Analysis of variance (ANOVA) was conducted where assumptions of homogeneity of variances were assessed using both Levene's test and Bartlett's test. Levene's test was used to evaluate whether the variances across groups were equal by testing the null hypothesis that group variances are equal. Bartlett's test, which assumes normally distributed data, served as a secondary check for homoscedasticity.

One-way ANOVA was performed to determine whether there were statistically significant differences in mean microbial counts between the treatment groups. The F-statistic and associated p-values were reported. Forvariables with significant differences ($p < 0.05$), *Bonferroni-adjusted post hoc* was used to identify specific group differences for the two markets. The analysis was conducted using Stata version14.

3.10 Ethical considerations

The interviews were conducted among adults using questionnaires. There were no samples or body parts collected from the study participants so there is negligible physical and emotional harm to the participants. The participants' informed consent was sought and direct participant identifiers eliminated from the data collection tools in order to ensure confidentiality and anonymity of the information. Administrative clearance was sought from the management of the markets before commencing data collection.

3.11 Study limitations

The study did not assess the hygiene practices at the slaughterhouses. This may directly affect the conclusions made especially about the raw (unprocessed) meats. This was minimized by correlating the microbial analysis results with hygiene practices as noted by the checklist and questionnaire data.

Observation bias could affect the recording of hygiene behaviors if vendors altered practices consciously when they noticed that they are being observed. This was catered for by triangulation of data from the observation, self-reported information (collected by questionnaire) and laboratory analysis of samples.

3.12 Outcomes

Datasets of hygiene practices on storage, roasting, serving, and personal hygiene by e vendor were generated. Microbial contamination profiles of some samples randomly bought from different vendors in the two roadside markets were made after laboratory analysis.

CHAPTER FOUR:

RESULTS

4.1 General findings from the study

The study involved 90 meat vendors of beef, chicken, and goat, where the majority were males and more than half were operating from Lukaya. The majority sold chicken and beef but generally, sanitation practices were found to be poor.

Also, most samples were found to have hygiene related pathogenic microbes in quantities beyond the acceptable limits according to Uganda National Bureau of Standards.

4.1.1 Characteristics of the study participants

The study involved 90 participants where most (51.1%) were vendors from Lukaya. Majority of the vendors were males 89 (98.9%) and most (34.4 %) practiced muslim religion. A greater proportion (92.2%) of the participants stayed in the area where they work from, most of them (75.6%) were married with 51.1% having attained secondary school as shown in **Table 3**.

Table 3: Demographic attributes of meat vendors from Namawojjolo and Lukaya Food Markets, Uganda

Variables	Frequency	Percentages
Site		
Namawojolo	44	48.9
Lukaya	46	51.1
Sex		
Male	89	98.9
Female	1	1.1
Religion		

Catholic	29	32.2
Protestant	21	23.3
Pentecostal	8	8.9
Muslim	31	34.4
Others	1	1.1
Marital status		
Single	22	24.4
Married	68	75.6
Stay in area of work		
No	7	7.8
Yes	83	92.2
Highest level of Education		
No education	4	4.4
Primary	40	44.4
Secondary	46	51.1

4.1.2 Characteristics of business/stalls of roadside roasted meat vendors along Namawojjolo and Lukaya Food Markets, Uganda.

Out of the 90 participants, more than half (53.3%) of the participants owned the business of vending meat, where majority (96.7%) were sharing the fire place for roasting the meat, and most (72.2%) carried out both roasting and selling activities simultaneously. Majority (55.5%) sold chicken meat whereas beef and goat meat was sold by 36.7% and 7.8% of the vendors respectively and half (50%) sourced the meat directly from farmers. Additionally, more than half (62.2%) of the participants reported having licensed their business operations as shown in **Table 4**.

Table 4: Description of work-related factors of meat handling, preparation and vending along Namawojjolo and Lukaya Food Markets, Uganda

Variables	Frequency	Percentages
Owner operator		
No	42	46.7
Yes	48	53.3
Shared fireplace		
No	3	3.3
Yes	87	96.7
Labour division		
Seller only	4	4.4
Roaster only	21	23.3
Both roast and seller	65	72.2
Meat category		
Chicken	50	55.5
Beef	33	36.7
Goats’ meat	7	7.8
Source of meat		
Farmers	45	50
Butcher	32	35.6
Middlemen	13	14.4
Business License		

No	34	37.8
Yes	56	62.2
Complaints from customers		
No	57	63.3
Yes	33	36.7
Types of stalls		
Semi-Permanent	40	44.4
Permanent	44	48.9
Improvised	6	6.7

4.2 Sanitation and hygiene practices of roadside roasted meat vendors

Sanitation practices were majorly assessed based on presence/absence or cleanliness of different items used. This included cleanliness of containers (utensils), storage facilities, hand -washing facilities, waste disposal facilities and cleanliness of the roasting area. Similarly, personal hygiene practices were assessed based on cleanliness of the apron, fingernails, covering the hair, wearing jewelry, and hand-washing among others.

4.2.1 Personal hygiene practices among meat vendors of Namawojjolo and Lukaya Food Markets, Uganda

Among the 90 participants, most of them (75.6%) wore aprons while working and among them a high number (85.3%) wore clean aprons. However, only 42 (46.7%) of the vendors had their hair covered. Results indicated that only (46.7%) of the vendors had their hair covered but majority 82 (91.1%) had short and clean fingernails with most of them (88.9) not wearing jewelry while working. Most vendors (93.3%) reported washing hands with soap and almost all of them (98.9%) reported washing hands after the toilet as shown in **Table 5**.

Table 5: Personal hygiene practices among meat vendors of Namawojjolo and Lukaya Food Markets, Uganda.

Variables	Frequency	Percentages
Wearing Apron while working		
No	22	24.4
Yes	68	75.6
Are Aprons clean		
No	10	14.7
Yes	58	85.3
Hair covered while working		
No	48	53.3
Yes	42	46.7
Finger nails short and clean		
No	8	8.9
Yes	82	91.1
Wearing any jewelry		
No	80	88.9
Yes	10	11.1
Wash hands with soap		
No	6	6.7
Yes	84	93.3
Wash hands with soap after visiting the toilet		

No	1	1.1
Yes	89	98.9
Hygiene and sanitation Practices*		
Poor-Practices	84	93.3
Good-Practices	6	6.7

*Practices were given scores and computed for each vendor; scores above 70% were taken as good hygiene practices

4.2.2 Sanitation practices among meat vendors of Namawojjolo and Lukaya Food Markets, Uganda.

Very few 29 (32.2%) of the participants kept meat in clean containers, far less 5 (5.6%) stored utensils on clean shelves and a meagre 4 (6.7%) had meat roasting areas that were clean and free from dust and spider webs. Most 84 (93.3%) of the vendors stored raw meat separate from ready-to- eat meat while very few (11.1%) stored left over ready-to-eat meat in refrigerator and few 34 (37.8%) had stalls without rodents. Most (97.8) had hand washing facility at the toilet, also most (63.3%) had waste disposal containers where over half (53.3%) used dust bins as waste disposal containers. (**Table 6**).

Table 6: Sanitation measures practices by meat vendors of Namawojjolo and Lukaya Food Markets, Uganda

Variables	**Frequency**	**Percentages**
Keeping ready-to-eat meat in clean container:		
No	61	67.8
Yes	29	32.2
Utensils are stored in clean shelf/cup-board		
No	85	94.4

Yes	5	5.6
Raw meat stored separately from ready-to-eat one:		
No	6	6.7
Yes	84	93.3
Left over ready-to-eat meat stored in refrigerator:		
No	80	88.9
Yes	10	11.1
Hand washing facilities in toilet:		
No	2	2.2
Yes	81	97.8
Availability of waste disposal container:		
No	33	36.7
Yes	57	63.3
Categories of waste disposal container:		
Dust-bin	48	53.3
Sacks	14	15.6
Others (pits, rubbish heap, and open field)	35	38.9
Presences of insects and rodents:		
No	34	37.8
Yes	56	62.2
Clean (free from dust, spider webs) meat roasting area:		
No	86	93.3

Yes	4	6.7

4.2.3 Knowledge on hygiene and sanitation measures of meat vendors from Namawojjolo and Lukaya Food Markets, Uganda

Of the 90 roadside roasted meat vendors who participated, more than half 57 (63.3%) reported having received training on food safety, hygiene and sanitation measures; where majority 73 (81.1%) had knowledge of food borne diseases, including contamination 55/90 (75.3%), and unhygienic handling of food items 44/90 (60.3%). Additionally, results indicated that contamination of food occurs due to unhygienic hands 77/90 (85.6%), working environment 60/90 (66.7%), unclean utensils 44/90 (48.9%), using contaminated water 15/90 (16.7%) and exposure to insects and rodents 30/90 (33.3%) as shown in **Table 7**.

Table 7: Knowledge on hygiene and sanitation measures in meat handling, preparation and presentation by meat vendors of Namawojjolo and Lukaya Food Markets, Uganda

Variables	Frequency	Percentages
Obtained training on food safety measures:		
No	33	36.7
Yes	57	63.3
Have knowledge on food borne diseases:		
No	17	18.9
Yes	73	81.1
Identified causes of food borne disease:		
Contamination with germs	55	75.3
Contamination with chemicals	14	19.2

Unhygienic food	44	60.3
Food from inappropriate sources	12	16.4
Pathways leading to transmission of food borne illnesses:		
Contaminated water	8	8.9
Vectors	37	41.1
Others (cold food, half roasted meat, sick animals)	11	12.2
Know sources of food contamination:		
Unhygienic hands	77	85.6
Unhygienic working environment	60	66.7
Unclean utensils	44	48.9
Using contaminated water	15	16.7
Exposure to insects and rodents	30	33.3
Store ready-to-eat meat in separate containers:		
No	2	2.2
Yes	88	97.8
Knowledge on right temperature for storing fresh meat		
I don't know	32	35.6
Below 2^{o}C	5	5.6
between 2-60^{o}C	47	52.2
above 60^{o}C	6	6.7
Knowledge on how personal hygiene prevents food borne disease:		
No	6	6.7

Yes	84	93.3
Knowledge on safe/hygienic food presentation practices to customers		
No	89	98.9
Yes	1	1.1
Use of packaging materials in food handling/storage:		
Paper bag	71	78.9
Transparent polythene	5	5.6
Both paper bag and polythene	14	15.5

4.3 Effect of handling, roasting and vending on microbial contamination of roadside roasted meats

Assessment of the critical points of microbial contamination of ready-to-eat meats during handling before roasting, during roasting and vending was done and compared to Uganda National Bureau of Standards (UNBS) safety limits (**Table 8**). Samples labelled "cold" refer to the ready-to-eat roasted meat samples that had been exposed to customers for at least 30 minutes, while "hot" refers to the ready-to-eat roasted meats that were direct from fire and "raw" refers to fresh raw samples ready to be put on fire.

All samples exceeded UNBS limits for *S. aureus*, E. *coli* levels surpassed the limit (≤ 2 $\log_{10}$ CFU/g) in 7 out of 9 samples, with only hot chicken (3 ± 2.44) and cold goat (4 ± 1.98) nearing compliance. Generally, raw samples exhibited the highest contamination across all pathogens, for instance, *S. aureus* in raw chicken (8 ± 0.56 $\log_{10}$ CFU/g) and raw goat (8 ± 0.97 $\log_{10}$ CFU/g) far exceeded the limit. Similarly, cold samples mostly matched or surpassed hot samples in contamination. For example, cold beef showed higher *Listeria* counts (5 ± 1.93 $\log_{10}$ CFU/g) than hot beef (3 ± 2.71 $\log_{10}$ CFU/g) as shown in **Table 8**.

Table 8: Effect of handling on microbial contamination (log_{10} CFUs/g) of different meats presented as mean±SD

Treatment / Pathogen	Raw	Hot	Cold	UNBS limit (log_{10} CFU/g)
S. aureus	7.63±0.92	6.23±0.69	6.10±0.89	2
E. coli	4.70±2.49	4.07±1.78	3.90±2.08	2
Salmonella	4.27±2.75	4.07±1.78	2.60±2.60	Absent
Listeria	6.10±1.45	3.57±2.34	4.57±2.03	Absent
Campylobacter	5.57±3.05	3.80±2.93	3.27±3.01	Absent

Using log_{10} CFUs/g (**Figure 3**), for all pathogens assessed, raw meat samples consistently exhibited the highest levels of contamination, while cold samples showed intermediate levels of contamination, but higher than hot samples, which consistently displayed the lowest microbial counts among the three treatments.

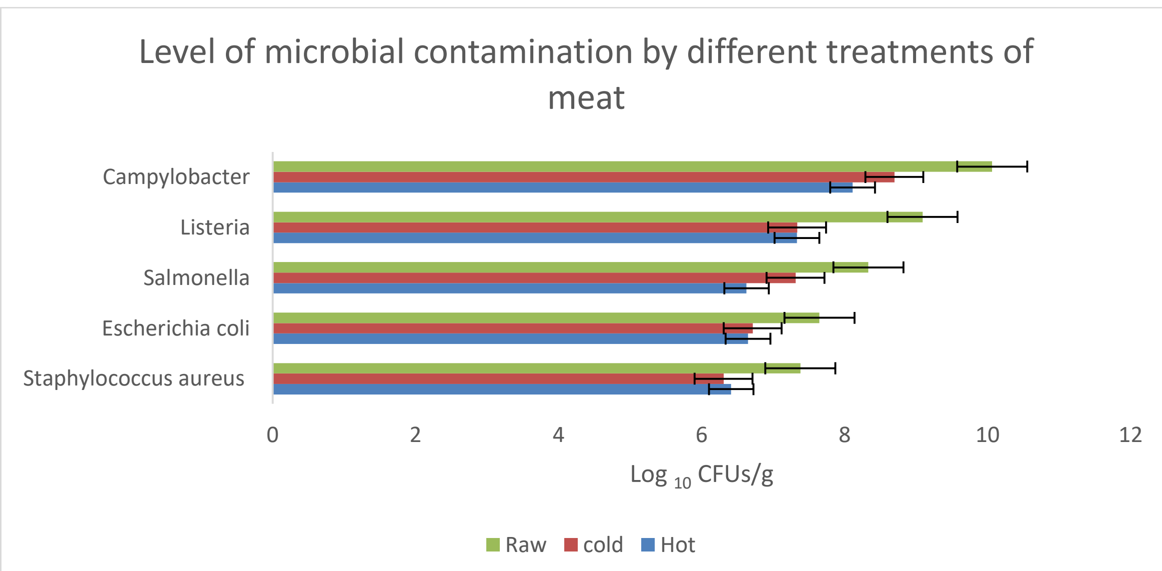

Figure 3: Levels of microbial contamination according to treatment for roadside roasted meats of Namawojjolo and Lukaya food markets.

4.4 Effect of meat type on levels of microbial contamination of different roadside roasted meats

All tested meat types (beef, chicken, and goat) showed microbial contamination far above UNBS safety limits for all microbes examined which is ≤2 log_{10} CFU/g for *S.aureus* and E.coli or completely absent for *Salmonella*, *Lysteria* and *Campylobacter*. However, S. aureus was consistently the highest for all the three meat types for example 8.4 ± 9.0 log_{10} CFU/g for goat meat compared to 5.5 ± 5.7 shown for *Salmonella* in goat meat as shown in **Table 9**. Similarly, **Figure 4** shows that chicken and goat reached up to ten units for *S. aureus*.

Table 9: Effect of Meat Type on Levels of microbial contamination (log_{10} CFUs/g) on Raw and Ready-to-Eat Roasted (Hot and Cold) Meats

Types of Meat	Beef	Chicken	Goats	Limit (UNBS)
S. aureus (log_{10} CFUs/g)	8.3 ± 8.8	7.7 ± 8.0	8.4 ± 9.0	2
E. coli (log_{10} CFUs/g)	5.9 ± 6.4	5.7 ± 6.1	5.9 ± 6.3	2
Salmonella (log_{10} CFUs/g)	5.4 ± 5.5	5.6 ± 5.7	5.5 ± 5.7	Absent
Listeria (log_{10} CFUs/g)	6.5 ± 6.7	6.5 ± 6.7	6.2 ± 6.6	Absent
Campylobacter (log_{10} CFUs/g)	6.7 ± 7.6	7.3 ± 7.7	7.0 ± 7.5	Absent

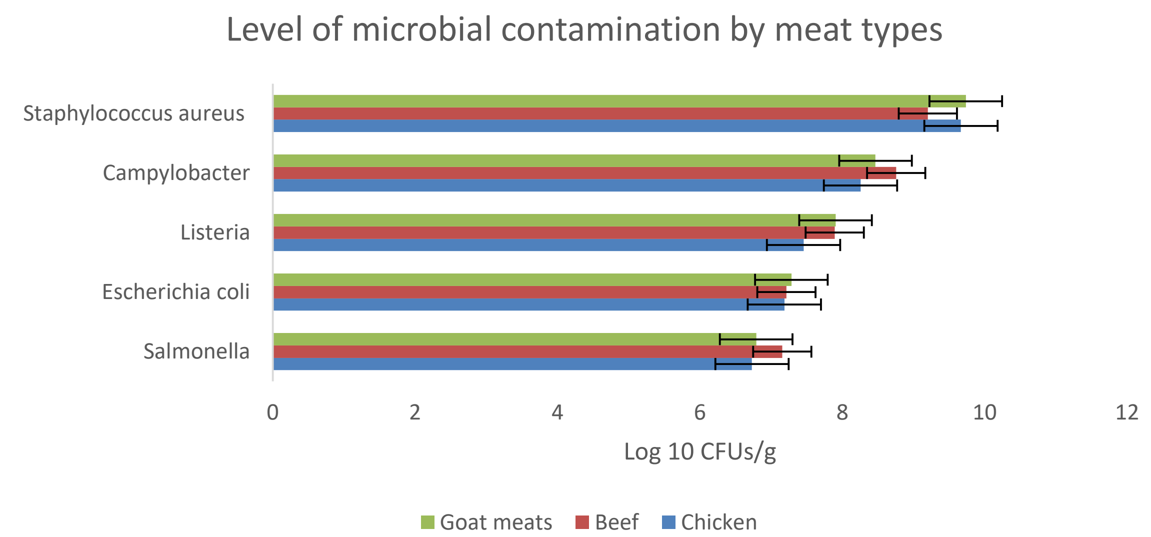

Figure 4: Levels of microbial contamination according to meat type for roadside roasted meats of Namawojjolo and Lukaya food markets.

4.5 Levels of microbial contamination of different roadside roasted meats by total plate count

Of the 89 meat samples analyzed for microbial contamination using total plate count, only five samples (5.8%) were found to be contaminated. Among these, three samples (60%) originated from Lukaya, while two (40%) were from Namawojjolo as shown in **Table 10**. However, this difference in contamination by site was not statistically significant (p = 0.965), indicating that the likelihood of contamination occurring was similar between the two locations.

In contrast, contamination was significantly associated with meat treatment type (p = 0.002). All five contaminated samples were raw chicken, and none of the roasted meat samples showed contamination. The low p-value (0.002) indicates that there is only a 0.2% probability that this observed association between contamination and meat treatment is due to chance, thus providing strong evidence that raw or fresh meat, particularly raw chicken, was significantly more likely to be contaminated than roasted meat.

Table 10: Results for total plate count for the different meat categories and treatments.

Variables	Contamination n=5	Not Contaminated n=84	P-value
Site			
Lukaya	3(60.0%)	50(60.9%)	0.965
Namawojolo	2(40.0%)	32(39.1%)	
Meat categories			
Beef	0(0%)	27(32.9%)	0.058
Chicken	5(100%)	37(45.2%)	
Goat	0(0%)	18(21.9%)	
Meat treatments			
Raw/fresh	5(100%)	26(31.7%)	0.002

Roasted	0(0%)	56(68.3%)	
Roasted Meat treatments			
Cold	0(0%)	28(47.5%)	0.004
Hot	0(0%)	27(45.8%)	
Others (spiced chicken)	1(100%)	4(6.8%)	

Further analysis showed that the biggest proportion (45%) of the contaminated samples had an average of 3 CFUs/g (Log_{10} TPC) while very few (3%) reached an average of 6 CFUs/g (log_{10}TPC) as shown in **Figure 5** below.

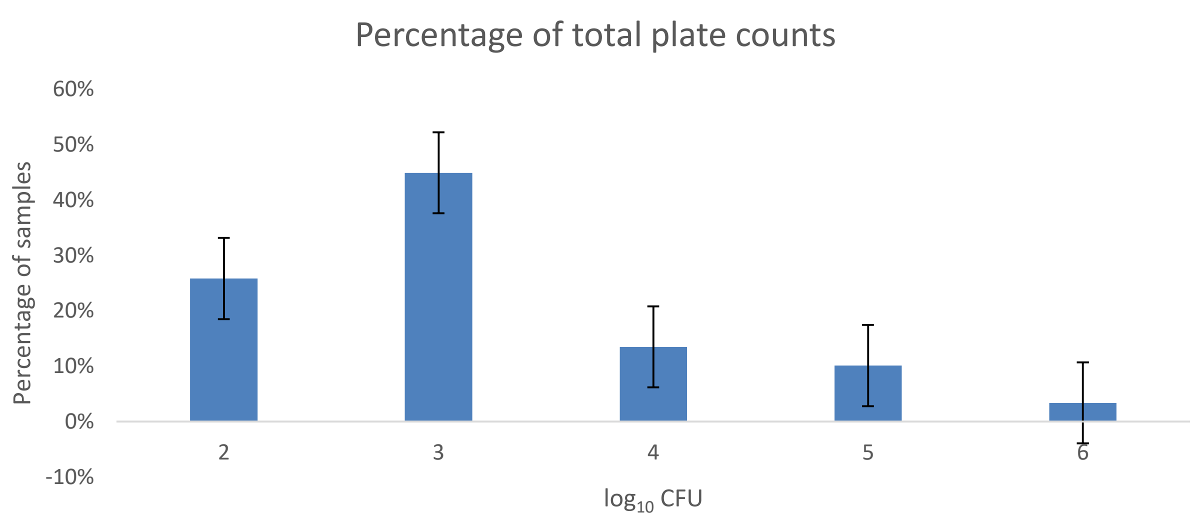

Figure 5: Proportion of contaminated meat samples from Namawojjolo and Lukaya food markets

4.6 Comparison of levels of microbial contamination according to the market.

Based on location, *Staphylococcus aureus* was found to have contaminated all the meat samples from both markets, *E. coli* and *Campylobacter* were mostly found to have contaminated meat from Lukaya 43/53 (81.1%) and 37/53 (84.9%), respectively. While *Listeria* and *Salmonella* were mostly found to have contaminated meat from Namawojolo 32/36 (88.9%) and25/36 (69.4%) respectively, as shown in **Table 11**.

Table 11: Proportion of contaminated samples according to area of work for roadside roasted meats of Namawojjolo and Lukaya food markets.

	Staphylococcus aureus		Escherichia coli		Campylobacter		Listeria		Salmonella	
Location	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc	Freq	Perc
Lukaya	53	100	43	81.1	37	69.8	45	84.9	36	67.9
Namawojolo	36	100	27	75	25	69.4	32	88.9	25	69.4

Levene's and Bartlett's tests confirm equal variances, meaning ANOVA assumptions hold because all the p-values were above 0.05 thus showing equal variance among the meat samples. The ANOVA test showed that there was a significant difference in the average CFUs of Staphylococcus aureus of Lukaya and Namawojolo were (p = 0.0092) was less than 0.05. Furthermore, the *Bonferroni post-hoc* test confirms that Lukaya has a significantly higher bacterial load of Staphylococcus aureus than Namawojolo (p = 0.009) **Table 12**.

Table 12: Comparison of Location (Lukaya and Namawojolo)

	Levene test			**ANOVA**		**Bartlett's test**		**Bonferroni Post Hoc**	
Micro-organisms	**Wo**	**df**	**P-value**	**F-statistic**	**P-value**	**X^2 value**	**P-value**	**Mean difference**	**P-value**
Staphylococcus aureus	1.03	1, 87	0.31	7.1	0.01	0.08	0.782	-29.64	0.009
Escherichia coli	0.051	1, 87	0.82	2.23	0.14	0.01	0.924	-9.39	0.139
Salmonella	0.166	1,	0.68	0.04	0.84	0.05	0.816	-1.39	0.841

		87							
Listeria	0.082	1, 87	0.78	0.98	0.32	0.00	0.989	6.73	0.324
Campylobacter	1.306	1, 87	0.20	0.73	0.40	0.59	0.441	-7.04	0.397

CHAPTER FIVE:

DISCUSSION OF RESULTS

5.1 Hygiene and safety measures practiced by roadside meat vendors along Namawojjolo and Lukaya Highway Food Markets.

The study involved 90 vendors of beef, chicken, and goat meat where majority were males and operated their own businesses. Some of the best hygiene practices include wearing clean aprons while working, keeping short and clean fingernails as well as washing hands with soap. However, sanitation practices were poor since very few kept ready-to-eat meat in clean containers and many vendors did not store utensils on clean shelves. Very few understood proper meat storage temperatures and practices like covering food when presenting to customers.

5.1.1 Personal hygiene practices of roadside roasted meat vendors of Namawojjolo and Lukaya food markets.

Most roadside meat vendors wore aprons while working, with the majority keeping them clean. This is a sign of good personal hygiene and can be attributed to the need to attract customers. These findings are similar to a study conducted on Highway markets in Uganda, which showed a relatively high score of 2.5/3 for the hygiene of aprons (Bagumire & Rollanda, 2017).

The study revealed that very few vendors covered their hair yet it is important in food handling since it can carry bacteria, dust, and sweat, that would contaminate the food. Covering hair also provides a professional appearance, reassuring customers about food safety. The findings in this study showed fewer vendors covering their hair compared to findings of a study conducted in Nigeria that reported 53.9% covering their hair (Chukuezi, 2010).

Most of the vendors maintained short and clean fingernails which reduced the risk of cross-contamination and prevented the spread of harmful bacteria like *Salmonella* and *E. coli* from hands to food. Furthermore, it also improved handwashing effectiveness making it easier to clean hands properly, as bacteria and debris were not trapped under them. These findings are consistent with a study done is south Africa that revealed the importance of keeping finger nails short and clean (Rohith, 2021).

5.1.2 Sanitation practices of roadside roasted meat vendors of Namawojjolo and Lukaya food markets.

Generally, the sanitation practices were poor, especially in Lukaya where very few of the vendors maintained clean roasting areas, and also very few stored utensils on clean shelves, indicating poor adherence to sanitation standards. A similar study reported low conformity to recommended sanitation conditions among roadside meat vendors due to inadequate facilities (Bagumire & Rollanda, 2017; Soon, 2019).

5.1.3 Food Safety knowledge of roadside roasted meat vendors of Namawojjolo and Lukaya food markets.

Only 5.6% of vendors correctly identified temperatures below 2°C to be safe for storing fresh meat or critical for slowing bacterial growth. Similarly, only 11.1% used refrigeration while storing meat. The findings are similar to a study in Nigeria where only 18% of street vendors knew the correct meat storage temperatures (Chukuezi, 2010)

Whilst some vendors reported having received training on food safety from various Non-governmental Organizations (NGOs) and having licensed businesses, they had no certificates with them. Despite the low education levels, 63.3% reported receiving food safety training and 81.1% demonstrated knowledge of foodborne diseases. However, practices like sharing the fireplace, can be sources of cross-contamination indicating a gap between awareness and implementation. This gap between knowledge and practice is consistent with finding from other studies that attribute such discrepancies to economic pressures and lack of regulatory enforcement (Oolo and Wakhungu 2019).

5.2 The effect of handling on microbial contamination of roadside roasted meats of Namawojjolo and Lukaya food markets.

The study analyzed a total of 89 meat samples, comprising 55 roasted meat samples (61.8%) and 34 raw meat samples (38.2%). Among the ready-to-eat samples, 29 (32.6%) were categorized as "cold" (exposed to customers for at least 30 minutes), while 26 (29.2%) were "hot" (freshly prepared from fire). The microbial analysis revealed serious contamination levels for the different pathogenic bacteria.

All meat samples (100%) were contaminated with *S. aureus*, indicating its presence in both sampling markets. Additionally, the majority of samples showed contamination with Listeria (86.5%), Escherichia coli (78.7%), Campylobacter (69.7%), and Salmonella (68.5%).

These results are consistent with previous findings that reported significant bacterial contamination in ready-to-eat meats from Ugandan highway markets, underscoring the systemic nature of food safety issues in informal meat vending sectors across the country (Bagumire & Karumuna, 2017). However, the results contradict a study in Egypt that reported 68% of the RTE samples being free from *S. aureus* compared to only 24% of the raw samples (Hogoo, 2020). Also, another similar study reported complete destruction of S. aureus by cooking at 80^0C (Montanari et al., 2015).

The presence of different pathogens on raw meat samples has been attributed to contamination from bad slaughtering techniques, unhygienic abattoirs, mishandling of the animal, and unhygienic containers (Hogoo, 2020).

Statistical analysis using ANOVA and *Bonferroni post-hoc* tests confirmed significant differences in *S. aureus* contamination levels between the two locations ($p = 0.0092$), with Lukaya samples showing significantly higher bacterial loads. These geographical variations may reflect differences in vendor practices, environmental conditions, or source materials between the two markets. The higher *S. aureus* load in Lukaya suggests potentially less hygienic handling practices among vendors in this location, which aligns with findings from (Loukieh et al., 2018) who identified handling practices as a critical factor in microbial safety of street foods.

Despite roasting being expected to reduce microbial loads, ready-to-eat meats showed substantial contamination. This supports findings in Lebanon, where it was observed that cooked street foods were susceptible to post-processing contamination due to unhygienic handling and storage (Loukieh et al., 2018). Similarly, in Bangladesh, (Noor, 2016) reported high prevalence of *E. coli* and *S. aureus* in common street foods, which was attributed to persistent fecal and human-derived contamination pathways.

5.3 Levels of microbial contamination of different roadside roasted meats of Namawojjolo and Lukaya food markets.

Out of the 89 samples analyzed, 43 were chicken (comprising 48.3%), 28 were beef, and 18 were goat meat. *S. aureus* was mostly found in chicken and goat meat, *Campylobacter* and *Salmonella* were more in beef, *Listeria* was more in beef and goat, while *E. coli* was present in almost equal proportions in all the different types of meat. These findings are consistent with a study in South Africa, which considered microbial profiles of different types of meat (beef, pork, and mutton) at different stages of the distribution chain. *E. coli* was found in almost the same quantities in all the different meat types (Rani et al., 2023). Similarly, in Bangladesh, a study (Noor, 2016) reported high prevalence of *E. coli* and *S. aureus* in common street foods, which was attributed to persistent fecal and human-derived contamination pathways.

The current study's findings of *Campylobacter* (69.7%) and *Salmonella* (68.5%) are notably higher than those reported in some similar studies. For instance, (Miraz et al., 2024) found lower Campylobacter prevalence in Bangladeshi street foods, suggesting potentially higher risks in the Ugandan context.

Furthermore, a similar study in Kenya showed that poultry products often harbor higher *Campylobacter* loads compared to red meats, while beef may be more susceptible to *E. coli* contamination due to slaughterhouse practices. The physical and biochemical properties of different meat types (pH, water activity, fat content) can significantly influence microbial growth patterns. Additionally, different meat types typically undergo varying handling procedures from slaughter to vending point, potentially introducing different contamination risks (Mwove, 2023).

CHAPTER SIX:

CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

Some personal hygiene practices are well upheld in preparation and vending of roadside roasted meats in Namawojjolo and Lukaya food markets, Uganda. However, there exists clear gap between knowledge and sanitation practices applied, posing potential risks on food contamination.

There was a higher presence of different pathogens on raw meat compared to the roasted meat samples, although they were all above UNBS limits.

All the different types of meat were contaminated with all the five pathogens in almost equal proportions and all above the UNBS limits.

6.2 Recommendations

There is need for stricter regulatory enforcement requiring food safety certification as well as sensitization on food handling and storage temperatures.

Authorities should enforce sanitation standards by ensuring clean roasting areas, proper waste disposal, and safe storage for utensils and meat to prevent cross-contamination.

Local governments and NGOs should support vendors by providing safe, convenient and consistent sources of meat to ensure the microbial safety of the different meats.

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APPENDICES

APPENDIX I: QUESTIONNAIRE AND CHECKLIST

An investigation on the Quality and Safety of Roadside Roasted Meats from Namawojjolo and Lukaya Food Markets, Uganda.

Questionnaire number: ___________________ Date _________________

Site (market) ☐ Namawojjolo ☐Lukaya

A. Background information of the respondent

1. Age of respondent: ____
2. Sex of respondent ☐Male ☐Female
3. Nationality of respondent: ☐Ugandan ☐non-Ugandan (specify): _____________________
4. Religious background of respondent ☐Muslim ☐Catholic ☐Protestant

   ☐SDA ☐Pentecostal ☐Other (specify): _____________

5. Marital status of respondent ☐Single ☐Married
6. If single in 5), which of these categories does respondent fall in?

☐Never married ☐Divorced ☐Widow/widower

7. Do you live with in Namawojjolo/Lukaya? ☐Yes ☐No

8. If no in 7, how far do you live from this market (Km): ______________________________
9. Respondent's highest education level. (*Tick one that best applies*):

☐ Never been to school

☐ Primary school (specify class in which you ended): ______________________

☐ Secondary school (specify class in which you ended): ____________________

☐ Post-secondary school certificate

☐ Diploma ☐Degree ☐Other (specify): _____________________

10. How long have you been doing this business (roasting and selling meat)? _______________

B. Characteristics of the business/stall

11. Do you own this business or you work for someone? ☐Yes ☐No

12. How many vendors use this stall? __________________

13. Do you share the fire place used for roasting the meat? ☐Yes ☐No

14. If yes in 13, how many people use that fire place/roasting place? ______

15. Do you roast and sell the meat yourself or there are people who help in selling?

☐I roast and sell myself ☐I only roast and other people sell

☐I roast and also sell ☐I don't roast, I only sell

16. Which type of roasted meat do you sell? (Tick all that apply)

☐Beef ☐Chicken ☐Goats' meat ☐others (specify)__________________

17. Where do you get your meat from? (Please list all the sources of supply such as butcheries, direct from a farmer, a solicited supplier, etc.)

____

____

18. How often do you roast in a day? ☐I roast once ☐I roast throughout the day

☐I roast more after selling what I roasted first ☐I don't roast, I just get from those who roast

19. What do you use for roasting? ____

20. Is this business licensed? ☐Yes ☐No

21. If yes in 20, who licensed you? ____

22. Have you ever received any complaints from customers about the quality of your meat?

☐Yes ☐No

If yes in 22, can you briefly describe the complaint? ______________________________

____

23. Type of stall? ☐Permanent ☐Semi-permanent ☐Makeshift/improvised

C. Sanitation facilities and general cleanliness

24. Wearing outer garments/gown/apron while working? ☐Yes ☐No

25. If "yes in 24" is outer garment/gown/apron clean? ☐Yes ☐No

26. Is the hair covered while working? ☐Yes ☐No

27. Finger nails short trimmed and clean? ☐Yes ☐No

28. Wearing any jewelry or ring on hand while working? ☐Yes ☐No

29. Used soap/ detergent for washing dishes? ☐Yes ☐No

30. Used hot water for washing dishes? ☐Yes ☐No

31. Wash their utensils using three washing compartments? ☐Yes ☐No

32. Wash his/her hands with soap and water before working with food? ☐Yes ☐No

33. Wash his/her hands with soap and water after visiting a latrine? ☐Yes ☐No

34. Ready-to-eat meat is kept in a clean container? ☐Yes ☐No

35. Ready-to-eat meat is covered properly protecting it from dust and exhaust gases of passing vehicles? ☐Yes ☐No

36. Utensils are stored in well-arranged manner in shelf or cupboard? ☐Yes ☐No

37. Raw meat is stored in an area separate from ready-to-eat meat? ☐Yes ☐No

38. Left over ready- to- eat meat is stored in refrigerator? ☐Yes ☐No

39. If "No" in 38, where do you store left-over meat? ____________________________________

40. Source of water ________________________

41. Availability of toilet facility? ☐Yes ☐No

42. If "yes" in 40, is there a hand washing facility with water at the toilet? ☐Yes ☐No

43. Is there a container for solid waste? ☐Yes ☐No

44. Type of solid waste storage

☐Dust bin ☐Barrel ☐Sack ☐other (specify)____________________

45. Means of wastewater disposal (like from hand washing basin, and dishwashing)

☐open space/field ☐ septic tank ☐Latrine ☐ Storm water drainage

☐ Seepage pit (a small pit dug around) ☐other (specify)________________________

46. Existence of insects and rodents in the establishment ☐Yes ☐No

47. The meat roasting area is free from dust, spider webs and smoke particles ☐Yes ☐No

D. Awareness of safety information

48. Have you received any training on food safety? ☐Yes ☐No

49. If yes where? ____

50. Have you ever heard about food borne diseases? ☐Yes ☐No

51.If yes what causes food borne diseases? Tick all that apply

☐Contamination with germs ☐ Contamination with chemicals ☐Unhygienic food handling

☐ food from unapproved sources ☐ Anger of God ☐other (specify)___________________

52. How are food borne diseases transmitted? Tick all that apply

☐Contaminated food ☐ Contaminated hands of consumers

☐ Contaminated hands of those who prepare and serve food ☐ Contaminated water

☐ Vectors (such as houseflies) ☐other (specify)_____________________________

53. What contaminates food? Tick all that apply

☐Contact with unhygienic hands ☐ Unhygienic working environment

☐ Unclean utensils ☐ Using contaminated water

☐ Exposure to insects and rodents ☐other (specify)____________________________________

54. Raw meat and roasted (ready-to-eat) meat must always be kept in separate containers?

☐Yes ☐No

55. What is the right temperature for storing fresh meat?

☐ Below 5^0C ☐ Between 5-60^0C ☐ Above 60^0C ☐ I do not know

56. Good personal hygiene prevents food borne disease

☐ Yes ☐ No ☐ I do not know

E. Presentation of roasted meat to customers

57. Do you cover the roasted meat as you present it to the customers?

☐Yes ☐No

58. If yes in 57 above, what material do you use for covering roasted meat before presenting it to the customer?

☐Transparent polythene ☐ Aluminum foil ☐ Clean cloth

☐other (specify)____________________________________

59. Do you pack the roasted meat before handing it over to the customers?

☐Yes ☐No

60. If yes in 59 above, what material do you use for packing roasted meat before giving to the customer?

☐Transparent polythene ☐ Aluminum foil ☐Paper bag

☐other (specify)____

61. If No in 59 above, how do you present meat to your customers?

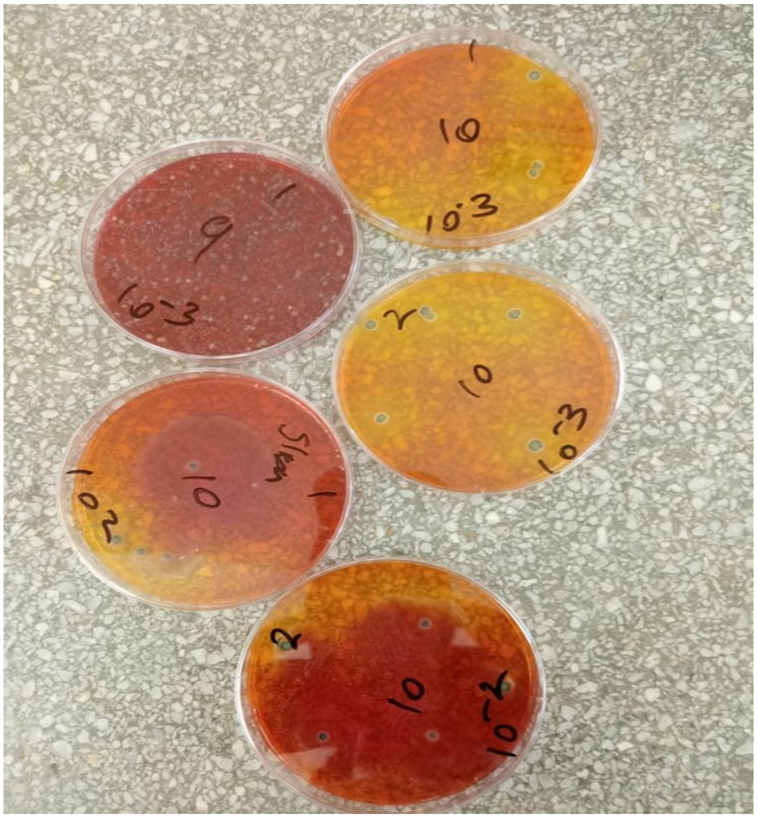
____

____

62. Where do you get the packing material from? ______________________________

____

FIELD AND LABORATORY PHOTOS

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