

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING
AND ENTREPRENEURIAL DEVELOPMENT**

**MICROBIAL QUALITY OF KUMASI ABATTOIR COMPANY LIMITED
MEAT AT RETAIL OUTLETS AT KEJETIA MARKET, GHANA**

ASANE MILLECHOR

2025

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BY

ASANE MILLECHOR

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A thesis submitted to the Department of Public Health Education of the Faculty of Environment and Health Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development in partial fulfilment of the requirements for the award of a Master of Philosophy Degree in Public Health.

MAY, 2025

DECLARATION

Candidate's Declaration

I hereby declare that this thesis, except for quotations and references contained in published works which have been duly acknowledged, is the result of my own original work and that no part of it has been presented for another degree at this university or elsewhere.

Candidate's Name: **ASANE MILLECHOR**

Signature

Date.....

Supervisor's Declaration

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on thesis supervision laid down by the Akenten Appiah-Mensah University of Skills Training Entrepreneurial Development.

Principal Supervisor's Name: **DR. KOFI SEKYERE BOATENG**

Signature

Date

Co-Supervisor's Name: **DR. DENIS DEKUGMEN YAR**

Signature

Date

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I owe a debt of gratitude to the Almighty God for giving me the strength, insight, and aptitude to undertake this project. I am also highly grateful to my principal supervisor, Dr. Kofi Sekyere Boateng, for his constructive criticisms, guidance, and endurance and for taking the pains to read through this work. To you, I say, may the good lord God richly bless you. I am equally grateful to my Co-supervisor, Dr. Denis Dekugmen Yar, for his immense support and contribution to completing this work.

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DEDICATION

This thesis is dedicated to the Almighty God, my beloved parents, Mr. Dari Millechor, and Mrs. Adwoa Dari and siblings.

TABLE OF CONTENT

DECLARATION	i
ACKNOWLEDGEMENT	ii
DEDICATION	iii
TABLE OF CONTENT	iv
LIST OF TABLES	x
LIST OF FIGURES	xi
LIST OF ABBREVIATIONS	xii
ETHICAL CLEARANCE	xiii
APPROVAL LETTER FROM THE STUDY SITE	xiv
ABSTRACT	xv
CHAPTER ONE	1
INTRODUCTION	1
1.1 Background of the Study	1
1.2 Problem Statement	3
1.3 Study Objectives	3
1.3.1 Specific objectives.....	3
1.4 Research Hypothesis	4
1.5 Significance of the study	4
1.6 Scope of the Study.....	4

1.7	Limitations of the Study	5
1.8	Organization of the Study	5
CHAPTER TWO.....		6
LITERATURE REVIEW		6
2.1	Introduction	6
2.2	Description of an Abattoir	6
2.2.1	Sanitation and Hygienic Practice in Abattoir	7
2.2.2	Facilities, hygienic practices and their challenges in abattoirs	8
2.3	Global Situation on Foodborne Disease Outbreaks	9
2.4	Common Microorganisms in Meat and Meat Products	11
2.5	Sources of meat contamination	11
2.6	Gram-Negative Bacteria Associated with Meat Spoilage.....	15
2.6.1	Enterobacteriaceae	15
2.6.2	Campylobacter spp	17
2.6.3	Hafnia alvei	18
2.6.4	Pseudomonas spp	19
2.6.5	Enterobacter spp	20
2.6.6	Serratia spp	21
2.6.7	Citrobacter freundii	22
2.6.8	Proteus vulgaris	23

2.7	The Gram-positive Bacteria Associated with Meat Spoilage	24
2.7.1	Bacillus cereus.....	24
2.7.2	Listeria monocytogenes.....	25
2.7.3	Staphylococcus aureus	26
2.7.4	Staphylococcus epidermidis	28
2.7.5	Brochothrix spp	29
2.7.6	Enterococcus	30
2.7.7	Escherichia coli	31
2.8	Post-Slaughter Carcass Handling	32
2.9	Hazard Analysis Critical Control Points in the Meat Processing.....	34
2.10	Meat distribution chains	35
2.11	Stages affecting the Technological and Microbiological Quality of Meat	37
2.11.1	Transportation and Storage	39
2.11.2	Characteristics of meat van for transportation	41
2.11.3	Packaging	42
2.12	Display of Fresh Meat	43
2.13	Challenges during Meat Distribution	44
CHAPTER THREE		47
METHODOLOGY		47
3.1	Introduction	47

3.2	Study area.....	47
3.2.1	Kumasi Abattoir	48
3.3	Research design.....	49
3.4	Source of data.....	49
3.5	Population and sample size	50
3.6	Inclusion and Exclusion Criteria	50
3.7	Sampling Procedure	50
3.8	Data Collection Tools.....	51
3.9	Procedure for Data Collection.....	51
3.9.1	Data Collection from the Participants	51
3.9.2	Collection of Meat Samples	51
3.10	Laboratory Methods and Analysis	52
3.10.1	Media preparation	52
3.10.2	Sample Preparation	52
3.10.3	Inoculation and counting of bacteria colonies.....	52
3.10.4	Inoculation and estimation of Escherichia coli	53
3.10.5	Inoculation and estimation of Salmonella sp. and Shigella.....	53
3.10.6	Inoculation and estimation of Staphylococcus sp.	54
3.11	Quality control.....	54
3.12	Data analysis	54
3.13	Ethical Considerations.....	55

CHAPTER FOUR	56
RESEARCH FINDINGS AND DISCUSSIONS	56
4.1 Introduction	56
4.2 Socio-demographic characteristics of respondents	56
4.2.1 Response rate.....	56
4.2.2 Demographic information of butchers	56
4.3 Meat handling practices employed by handlers and transporters in Kumasi Metropolis	57
4.3.1 Observed Meat Handling Practices at the Abattoir	57
4.2.2 Meat handling and transportation practices among butchers	59
4.4 Microbial contaminants on meat samples before and after transportation.....	61
4.5 Number of infected butchers' meat and microbial counts on different	
culture media before and after transportation	63
4.6 Knowledge and awareness of butchers regarding meat hygiene and	
Safety and possible factors influencing meat contamination	65
4.6 Discussions of Findings	67
4.6.1 Meat handling practices employed by handlers and transporters	67
4.6.2 Microbial contaminants on meat samples before and after transportation.....	71
4.6.3 Knowledge and Awareness of Butchers Regarding Meat Hygiene	
and Safety	75

CHAPTER FIVE	79
SUMMARY KEY FINDINGS, RECOMMENDATIONS AND	
CONCLUSIONS	79
5.1 Summary of the key findings and contribution to knowledge.	79
5.2 Conclusion.....	80
5.3 Recommendations	81
5.4 Further research study	81
REFERENCES	82
APPENDICE	113

LIST OF TABLES

Tables		Pages
Table 4.1	Demographic information of butchers.....	57
Table 4.2	Summary of Observed Meat Handling Practices at the Abattoir.....	58
Table 4.3	Carcasses handling practices among butchers transporting to the market.....	60
Table 4.4	Mean Microbial Count on Different Culture Media Before Transportation.....	61
Table 4.5	Mean Microbial Count on Different Culture Media After Transportation.....	62
Table 4.6	Bacterial Isolates from Meat Samples Before and After Transportation.....	63
Table 4.7	Descriptive Statistics of Log-Transformed Microbial Counts.....	64
Table 4.8	Bacterial Group-Specific Trends before and after Transportation.....	65
Table 4.9	Knowledge and Awareness of Butchers Regarding Meat Hygiene and Safety.....	66
Table 4.10	Factors Influencing Meat Contamination (Using "No" as Reference).....	67

LIST OF FIGURES

Figures		Pages
Figure 3.1	Map of Kumasi showing the Kumasi Abattoir and other butcheries within the city.....	48
Figure 4.1	Transportation methods and Rates	59

LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
BPW	Buffered Peptone Water
Cfu	Coliform forming unit
FAO	Food and Agricultural Organisation
FDA	Food and Drug Authority
GSA	Ghana Standards Authority
HACCP	Hazard Analysis and Critical Control Points
HBM	Health Belief Model
HIV	Human Immunodeficiency Virus
ICMSF	International Commission on Microbiological Specifications for Foods
LMICs	Low Middle Income Countries
MOFA	Ministry of Food and Agriculture
MoH	Ministry of Health
MAP	Modified Atmosphere Packaging
SD	Standard deviation
SPSS	Statistical Package for Social Sciences
EU	The European Union
WHO	World Health Organisation

ETHICAL CLEARANCE



Kwame Nkrumah
University of Science
and Technology, Kumasi

College of Health Sciences
SCHOOL OF MEDICINE AND DENTISTRY

COMMITTEE ON HUMAN RESEARCH, PUBLICATION AND ETHICS

Our Ref: CHRPE/AP/831/24

12th August 2024

Mr. Asane Millechor
Department of Public Health Education
Akenten Appiah - Menka University of
Skills Training and Entrepreneurial Development
MAMPONG-KUMASI.

Dear Sir,

LETTER OF APPROVAL

Protocol Title: *“Microbial Quality of Carcasses along the Supply Chain from the Kumasi Abattoir Company Limited to Meat Retail Outlets at the Kejetia Market, Ghana.”*

Proposed Site: *Kumasi Abattoir Company Limited and Kejetia Market..*

Sponsor: *Mr. Yimpo Dari.*

Your submission to the Committee on Human Research, Publications, and Ethics on the above-named protocol refer.

The Committee reviewed the following documents:

- A notification letter of 25th March 2024 from the Kumasi Abattoir Company Limited (study site) indicating approval for the conduct of the study at the facility.
- A Completed CHRPE Application Form.
- Participant Information Leaflet and Consent Form.
- Research Protocol.
- Questionnaire

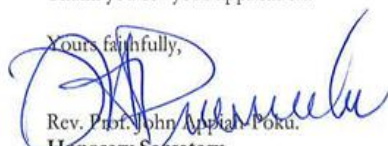
The Committee has considered the ethical merit of your submission and approved the protocol. The approval is for a fixed period of one year, beginning **12th August 2024** to **11th August 2025** renewable thereafter. The Committee may, however, suspend or withdraw ethical approval at any time if your study is found to contravene the approved protocol.

Data gathered for the study should be used for the approved purposes only. Permission should be sought from the Committee if any amendment to the protocol or use, other than submitted, is made of your research data.

The Committee should be notified of the actual start date of the project and would expect a report on your study, annually or at the close of the project, whichever one comes first. It should also be informed of any publication arising from the study.

Thank you for your application.

Yours faithfully,


Rev. Prof. John Appiah Poku.
Honorary Secretary
FOR: CHAIRMAN

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APPROVAL LETTER FROM THE STUDY SITE

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KACL/ADM.56/057/24

25th March, 2024.

The Head of Department,
AAMUSTED
Department of Public Health Education,
Mampong Ashanti.

Attention: Rev. Dr. Dennis Dekugmen Yar

Dear Sir,

APPROVAL TO UNDERTAKE RESEARCH WORK

We acknowledge receipt of your letter dated 12th March, 2024 and have the pleasure to inform you that the **Mr. Asane Millechor** an Mphil Public Health Student has been accepted to undertake his research work with this Company.

He will be attached to the **Production Department** and would be required to abide by the **Rules & Regulations** of this Company.

We do hereby confirm that he will receive all the assistance he requires to enable him achieve his goal.

Yours faithfully,

ELIZABETH AHLIJAH
H.R. MANAGER

cc: Managing Director
Production Manager

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ABSTRACT

Meat contamination during handling and transportation poses serious public health risks. This study assessed butchers' knowledge, meat handling practices, and microbial quality of meat before and after transportation from the Kumasi abattoir to the Kejetia market. A cross-sectional study involving 20 butchers was conducted, and meat samples were analyzed for microbial contamination using MacConkey Agar, Mannitol Salt Agar, and Salmonella-Shigella Agar. Approximately 85 % of butchers understood the importance of washing their hands before handling meat, while on 30 % were aware of and understood the need to follow guidelines for temperature control. Meanwhile, only 35 % were aware of the recommended temperature for storing meat. Meat handling practices were suboptimal, as 70 % of respondents used commercial taxis for transportation, and all (100 %) failed to maintain proper temperature control. Microbial analysis showed increased bacterial loads after transportation. Before transportation, bacterial counts on MacConkey Agar (MCA) for *E. coli* ranged from (log 2.69) to (log 5.46), while those on Mannitol Salt Agar (MSA) for *staphylococcus spp.* ranged from (log 4.18) to (log 5.49). The highest bacterial load was recorded in SSA at (log5.51, $P<0.05$). After transportation, MCA ranged from (log 3.53) to (log 5.97), while MSA ranged from (log 4.64) to (log 6.18). The highest count on SSA was (log 6.96). All media showed statistically significant increases in microbial counts after transportation ($P<0.05$). SSA exhibited the most significant mean log difference (+1.55). For MCA, the mean log difference was (0.84). MSA demonstrated a more minor but significant increase, suggesting moderate to high levels growth of *Staphylococcus Spp.* Improper handling and transportation of meat contributed to microbial contamination. Targeted interventions, including training programs and enhanced transportation methods, are necessary to mitigate contamination risks and safeguard public health.

CHAPTER ONE

INTRODUCTION

1.1 Background of the Study

Meat is an excellent source of protein in human diets and sometimes exhibits high-quality variations due to intrinsic and extrinsic factors (Font-i-Furnols & Guerrero, 2024). Due to its nutrient composition, meat is a primary food source globally (Pal et al., 2018). In Africa, particularly West Africa, meat is widely consumed because it contains high levels of protein and vitamins, including vitamins A and B12, which are not found in plant sources (Schonfeldt et al., 2013).

Meat production involves slaughter and dressing, both of which significantly influence the microbial load of meat (Chiles & Fitzgerald, 2018). Several processes ensure safe and high-quality meat production in abattoirs and slaughterhouses, which are then made available to consumers (Njoga et al., 2023). Despite the implementation of these processes such as Good Manufacturing Practices (GMP) and Hazard Analysis and Critical Control Points (HACCP) to ensure safety sanitary conditions, carcasses produced at abattoirs are susceptible to microbial contamination, mainly when transported to market outlets for sale (Gashe, 2022). Carcasses produced under poor sanitary conditions are vulnerable to contamination by pathogenic microorganisms such as *Escherichia coli*, *Staphylococcus aureus*, *Campylobacter spp.*, *Salmonella spp.*, and *Brucella spp.* (Mpundu et al., 2019).

One critical step in the slaughter process that affects meat quality is evisceration, during which microbial contamination can occur through improper handling or equipment (Van Zyl, 2022). In Ghana, the meat processing and trade industries involve both formal and

informal sectors. The formal sector, which operates from abattoirs, is responsible for inspecting and approving meat for consumption by meat inspectors. However, it is vital to note that visual inspection by meat inspectors does not adequately detect the microbiological threats posed by bacteria (Alvseike et al., 2018). Once approved, the meat is distributed to retailers for sale to consumers (Van Zyl et al., 2018). The transportation types, modes, and procedures for transporting carcasses from the abattoirs to market outlets pose a significant threat to microbial contamination (Rani et al., 2023). Handling and transportation of meat post-slaughter contribute significantly to microbial contamination. During transportation from abattoirs to market outlets, meat may be exposed to unsanitary surfaces and poor environmental conditions that increase the microbial load (Zwirzitz et al., 2020; Mpundu et al., 2019). This is particularly concerning at retail points like the markets, where high demand and limited cold chain infrastructure may worsen contamination risks (Nastasijević et al., 2017).

Although meat contamination by microbes like *E. coli*, *Salmonella*, and *Staphylococcus aureus* has been reported globally (Hudson & Lockless, 2022; Kinyua, 2024; Galán-Relaño et al., 2023), there is limited literature on the microbial quality of meat specifically from Kumasi Abattoir Company Limited and how it changes from production to retail at Kejetia market. This gap necessitates a scientific investigation to determine the microbial quality of meat before and after transportation, assess handling practices, and evaluate butchers' knowledge and awareness regarding meat hygiene and safety standards. This study therefore aimed to investigate the microbial quality of meat at the abattoir and the market outlet to understand the sources and extent of meat contamination.

1.2 Problem Statement

Although attempts are made in most abattoirs to follow regulations designed to protect consumer health, the issue of meat hygiene and safety during processing and handling remains a challenge (Adzitey et al., 2020). The meat industry, particularly the Kumasi Abattoir Company Limited, transports carcasses to markets and retailers. Butchers typically rely on private transportation, such as old taxis and tricycles. The transportation of carcasses via these private means compromises the microbial quality of carcasses along the supply chain. This increases the risk of meat contamination and concerns regarding microbial quality and safety. Although several studies have assessed the microbial quality of meat in Ghana (Asati et al., 2024; Ababa et al., 2019; Ali et al., 2021; Ntanga, 2013), there is limited literature on the microbial quality of carcasses along the supply chain in the Kumasi Metropolis. Therefore, this study aimed to determine the microbial quality of carcasses along the supply chain from Kumasi Abattoir to retail outlets in the Kumasi Metropolis.

1.3 Study Objectives

The primary objective of this study was to determine the microbial quality of meat transported from Kumasi Abattoir Company Limited to meat retail outlets at the Kejetia market in the Kumasi Metropolis.

1.3.1 Specific objectives

- i. To assess the meat handling practices employed by handlers and transporters in Kumasi Metropolis.
- ii. To determine the microbial contaminants on meat samples before and after transportation to the market.

- iii. To assess Knowledge and Awareness of Butchers Regarding Meat Hygiene and Safety Standards.

1.4 Research Hypothesis

Null Hypothesis: There is no significant difference in meat contamination from the abattoir to meat retail outlets at the Market.

Alternate Hypothesis: There is a significant difference in meat contamination from abattoirs to retail outlets at the Market.

1.5 Significance of the study

The study's findings are important for practitioners and the meat industry. The study outcomes would serve as a valuable resource for policymakers to consider establishing regulations and formulating and implementing them to ensure meat safety. It would also provide evidence-based information that would inform policy directions. The study would contribute to the existing empirical literature on food or meat contamination and advance academic knowledge. It would help practitioners make informed decisions. The findings of this study would also guide policy and practice in hygienic food management and its implementation across various areas in the country. The adoption recommendation from this study is along with the appropriate measures to mitigate the debilitating effects of foodborne diseases and illnesses on the population.

1.6 Scope of the Study

The primary focus of the research was on the microbial quality of carcasses along the supply chain from the Kumasi Abattoir Company Limited (KACL) to Meat Retail Outlets at the Kejetia Market in the Kumasi Metropolis, Ghana. Thus, this research has

limited the theoretical framework to the most relevant aspects of research on the microbial quality of meat during transportation. Geographically, the research was limited to the Kumasi Metropolis.

1.7 Limitations of the Study

While the study provides valuable insights, it also has some limitations. First, the study was conducted only in Kumasi, focusing on meat from a single abattoir to a single market. The results may not apply to other areas or abattoirs with different conditions. Second, the number of meat handlers, transporters, and butchers may not accurately represent the entire meat supply chain. A more extensive and varied group could give more substantial results. Additionally, the study was conducted during a specific time, and the level of bacteria in meat can fluctuate with the seasons due to variations in temperature and humidity. This means the findings may not accurately reflect what happens throughout the year. The study only examined certain bacteria, which may omit other microbial contaminants.

1.8 Organization of the Study

This study is organized into five main chapters. Chapter 1 contains the background, problem statement, significance of the study, specific objectives, research questions, and the organization of the study. Chapter 2 includes an introduction, a theoretical and empirical review of the existing literature, and a conceptual framework. Chapter 3 presents an introduction, research design, study area, research method, data sources, target population, research instruments, data gathering procedures, inclusion and exclusion criteria, and data analysis instruments. Chapter 4 focuses findings and discussions and Chapter 5 presents on summary, conclusion, and recommendations.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter is divided into two major sections. The first section reviews the global situation of foodborne disease outbreaks, and the second part examines the literature on meat contamination and the effects of significant transportation means, as observed in Ghana, by different authors.

2.2 Description of an Abattoir

Abattoirs are a community service unit that are intended to offer wholesome, safe, and healthy meat as well as a clean environment for slaughter and surveillance of animal illnesses and public health hazards (Ekpunobi et al., 2024). Certain precondition programs must be taken into account when operating an abattoir in order to offer the fundamental operating and environmental conditions required for the production of safe meat. According to Regina et al. (2017), these precondition programs consist of standard operating procedures (SOP), good manufacturing practices (GMP), and good hygiene practices (GHP).

In most abattoirs, operating facilities, sewage and waste disposal systems, potable water supply, cold storage system, staff and worker restrooms, changing rooms, and showers are all lacking in the majority of abattoirs (Akpabio et al., 2015). This frequently results health risks by contaminating the carcass during slaughter processes and by releasing waste and effluents into the environment and water without proper supervision. According to Ovuru et al. (2024), modern abattoirs must have a sufficient and consistent

supply of drinkable water in addition to facilities for the treatment and disposal of both liquid and solid waste.

2.2.1 Sanitation and Hygienic Practice in Abattoir

According to WHO (2018), sanitation is the process of preventing human contact with waste dangers in order to ensure good health. According to Chand et al. (2020), sanitation is the creation and implementation of policies aimed at safeguarding the general public's health or disposing of garbage. Hygiene, on the other hand, refers to circumstances and behaviors that support health maintenance and stop the development of disease (WHO, 2010). Since hygiene issues are linked to improper animal processing as well as slaughter, the lack of drinkable water supplies, the state of public infrastructure, and the unsanitary conditions of these abattoirs pose major health risks to the general public (Gashe, 2022). Strict attention to hand-washing practices and the wearing of gloves will minimize the risk from personnel (Alshagrawi, & Alhodaithy, 2024).

Sanitation and cleanliness are essential to the process of slaughtering and meat handling, and they ought to be taken into account when slaughterhouses are being planned and built. Furthermore, hygienic procedures should be taught and understood by males who slaughter animals, clean up after themselves, and load and unload cargo (Birhanu Seifu et al., 2017). The facility will be permanently contaminated to a very high degree in cases when cleaning and disinfection are not feasible (Twum, 2015). The majority of employees don't understand the fundamental value of personal hygiene, which leaves processed goods open to serious contamination from dust, insects, mice, flies, and other debris. Meat must be treated hygienically since it is a very perishable meal, but unsanitary

processing methods frequently create an environment that is favorable to the growth of numerous harmful germs (Gashe, 2022).

After slaughter, hygienic care of carcasses is essential to avoiding contamination and guaranteeing the safety of the meat for human use. This is essential because, the meat will spoil and consumers will become ill if hygienic procedures are not followed throughout any food handling procedures. This is because pathogenic and spoiling microorganisms will come into touch with food and use it as a source of nutrients to grow (Gashe, 2022). According to Fasanmi et al. (2018), inadequate hygiene measures have been found to be a significant factor in foodborne outbreaks caused by carcass contamination.

2.2.2 Facilities, hygienic practices and their challenges in abattoirs

Abattoirs in most developing countries including Ghana, have unsanitary slaughterhouses that encourage the proliferation of harmful microbes (Ovuru et al., 2024). A significant environmental and public health concern is the contamination of carcasses with animal wastes (such as blood or feces) and the resulting water (Stanley et al., 2016). Lack of sanitary inspectors, adequate waste disposal facilities, and drinkable water are common features of many African abattoirs. There is typically a paucity of necessary equipment and infrastructure (Nigussie et al., 2025). Generally, clean and unclean areas are not separated, and procedures like HACCP that can lower dangers are not used. Due to the lack of motorized or manual hoists, animals are frequently killed and disemboweled on the ground. Animals are often slaughtered and eviscerated on the floor because of the absence of mechanical or manual hoists. This is a major source of contamination (Yemane, & Mekelle, 2016).

The abattoir draws mice, flies, and other insects that can spread the disease to people, as well as domestic and wild carnivores (Gashe, 2022). The facilities used to transport and store meat are insufficient and unsanitary. Waste accumulation that has a negative influence on the environment is caused by inadequate disposal technologies and expensive waste management costs (Singh & Kaur, 2024). Officha et al. (2018) reported that the abattoir's environmental effects included water, soil, and air pollution; a dirty environment; obstructions in drainage systems; and the health effects of flies.

2.3 Global Situation on Foodborne Disease Outbreaks

Foodborne disease outbreaks remain a major global public health concern, affecting both developed and developing countries. According to Saad et al. (2018), foodborne illnesses are among the most prevalent health issues in the world today. The World Health Organization (WHO, 2020) estimates that over 30 % of individuals in developed countries suffer from foodborne illnesses each year. These illnesses range in severity but collectively contribute significantly to the global burden of disease.

Further statistics provided by the WHO (2021) indicate that globally, there are between 3 to 5 billion cases of diarrhoeal disease annually, with approximately 1.8 million deaths attributed to the consumption of contaminated food and water, including meat products. This underlines the serious threat that unsafe food poses to health, particularly in resource-limited settings where access to clean water and food safety interventions is limited. Moreover, WHO (2022) reported that around 2 million cases of food poisoning are documented each year, predominantly in developing nations where sanitation, hygiene, and regulatory enforcement may be weak or inconsistent.

In addition, the WHO (2020) highlighted that foodborne illnesses cause approximately 420,000 deaths globally each year. Notably, children under five years old account for

40% of these deaths, emphasizing their vulnerability. It was also reported that one in every ten people worldwide falls ill after consuming contaminated food. These alarming figures demonstrate the persistent and widespread nature of foodborne diseases and the urgent need for improved food safety measures worldwide.

In Ghana, while national legislation on food safety is well-established, enforcement remains a significant challenge due to limited resources and infrastructure. Key institutions such as the Ghana Standards Authority (GSA) and the Food and Drugs Authority (FDA) are mandated to oversee food safety standards and public education. However, the frequency of foodborne disease outbreaks and instances of enteric bacterial contamination in street foods across the country suggest that existing food safety systems are not yet fully effective (Monney et al., 2013).

Salas (2011) estimated that food poisoning affects approximately 5.8 million people annually in Ghana, indicating a high public health burden. According to Ferron et al. (2019), factors such as low public health literacy, weak health policies, widespread poverty, and under-resourced health systems contribute significantly to the prevalence of foodborne diseases. A more recent study by Boateng (2022) found bacterial contamination in various sources including food, meat, vendors, and preparation environments, further reinforcing the concern about food hygiene practices.

Nigusse and Kumie (2022) and Rane (2021) observed that meat transportation practices also contribute to contamination risks. In many instances, meat is transported in vehicles that are not adequately cleaned or disinfected, leading to microbial contamination during transit.

2.4 Common Microorganisms in Meat and Meat Products

Microorganisms that play a key role in meat hygiene include, moulds, bacteria, helminths, viruses, and bacteria, with bacteria being the most significant concern. Parasites generally pose little risk when meat is adequately inspected or when effective parasite control measures are implemented. *Salmonella*, *Listeria monocytogenes*, *Clostridium perfringens*, *Yersinia enterocolitica*, *Bacillus cereus*, *Vibrio parahaemolyticus*, *Staphylococcus aureus*, *Escherichia coli*, and *Campylobacter* are the most prevalent bacterial pathogens in beef products (Biswas et al., 2011). Fresh meat and poultry frequently include *Campylobacter* spp., *Escherichia coli*, and *Salmonella* spp., (Zhao et al., 2018).

In meat samples from retail establishments, Ali et al. (2021) identified a range of foodborne pathogens, including *Shigella* species, *Salmonella enteritidis*, *Listeria* spp., and *Escherichia coli* O157:H7. Additionally, *Staphylococcus* and *Shigella* spp. were detected on meat-handling equipment. Additionally, Soyiri et al. (2018) found *Escherichia coli*, *Clostridium perfringens*, *Bacillus cereus*, and *Staphylococcus aureus* were found in butchers' beef samples. Faecal coliforms, particularly *Escherichia coli*, are commonly used as reliable indicators of faecal contamination from warm-blooded animals (Yousuf et al., 2018).

2.5 Sources of meat contamination

Meat is considered spoiled when it becomes unfit for human consumption due to physical, chemical, or biological deterioration (Anas et al., 2019). Several factors contribute to meat spoilage, including improper handling, exposure to excessive heat and air, or conditions that trigger undesirable chemical reactions or microbiological

contamination (Addis, 2015). These unfavorable conditions can occur at any stage, from slaughter to storage, and even during retail handling. However, the most common and significant cause of spoilage remains the growth of bacteria and the subsequent production of their metabolic by-products (Rawat, 2015). These microorganisms degrade the quality of meat, making it unsuitable for consumption by altering its texture, taste, and safety.

According to Zamudio (2017), spoiled meat and its by-products are generally rendered inedible due to the development of undesirable characteristics, such as off-putting odours and unpleasant flavours. Nonetheless, consumers may also reject meat based on visible or sensory changes like abnormal discoloration, bloated or gas-filled packaging, sourness, and surface slime, which indicate microbial activity and chemical changes in the meat. These indicators, although useful, are not always reliable as meat may still contain harmful pathogens without showing any visible signs of spoilage, making it particularly dangerous for public health. This silent threat underlines the importance of rigorous microbial testing and proper food safety measures.

Microorganisms responsible for meat spoilage and contamination can enter the meat either before or after the animal is slaughtered (Addis, 2015). According to Odeyemi et al. (2020), contamination may occur endogenously while the animal is still alive, especially if it is infected with pathogenic organisms. In such cases, the meat can serve as a medium for the transmission of several diseases. Endogenously contaminated meat can transmit a wide range of zoonotic and foodborne illnesses such as anthrax, bovine tuberculosis, brucellosis, salmonellosis, listeriosis, trichinosis, and taeniasis (Rahman et al., 2020). These illnesses pose serious public health concerns, especially in communities

where meat inspection systems are under-resourced or inconsistently applied. However, many of these conditions can be detected and managed through thorough meat inspections, which are designed to identify signs of infection or disease before the meat reaches consumers.

More commonly, contamination occurs after slaughter, making it exogenous in nature. This exogenous contamination is often due to the introduction of bacteria or fungi during the meat handling and processing stages (Bayantassova et al., 2022). For instance, Abebe et al. (2020) pointed out that bacteremia, or the presence of bacteria in the bloodstream of slaughtered animals, could lead to contamination if proper dressing procedures are not followed. After slaughter, the intestines, particularly the large intestine, contain a high bacterial load that can contaminate meat if the carcass is improperly eviscerated or not cleaned adequately (Rani et al., 2017). Inadequate bleeding and poor dressing techniques, especially in informal settings, exacerbate this risk.

According to Waldman et al. (2020), contamination may also occur due to unsanitary slaughterhouse practices. For example, powered knives and other cutting tools that are not regularly sterilized between uses can serve as vectors for bacterial transfer from one carcass to another. This highlights the need for strict adherence to sanitation protocols and routine equipment sterilization. Post-slaughter handling in the abattoir also presents multiple points of contamination. To minimize microbial risks, strict hygienic measures must be applied to avoid contact between the meat and potential contaminants such as hides, soil, washing water, poorly sanitized tools, and even the clothing or hands of personnel (Gashe, 2022). Failure to adhere to such protocols introduces a range of pathogenic bacteria onto the meat surface. These include fecal streptococci, *Shigella* spp.,

Salmonella spp., *Escherichia coli*, *Proteus*, *Staphylococcus albus*, *Staphylococcus aureus*, *Clostridium welchii*, and *Bacillus cereus*, all of which can pose severe health risks when ingested.

Soil-based bacteria like *Clostridium botulinum*, which humans may carry or that may be present in contaminated environments, are particularly dangerous due to their toxin-producing ability (DeFlorio et al., 2021). These bacteria not only break down the meat but also release toxins that can cause foodborne illnesses such as food poisoning, gastrointestinal infections, and in some cases, life-threatening conditions like botulism (Akinsemolu et al., 2024). The toxic compounds released by these microbes often persist in the meat and can survive even after cooking.

Although thorough cooking typically destroys most microorganisms, some bacteria produce heat-resistant toxins or spores that may remain viable even after standard cooking procedures. In such cases, the consumption of contaminated meat may still lead to infection or intoxication. Fortunately, the natural microflora in the human digestive tract often provides some level of defense against these pathogens. However, this defense is not always sufficient, particularly in immunocompromised individuals (Anderson et al., 2017).

Zhang et al. (2023) emphasized the importance of rapid and accurate spoilage detection methods to prevent losses at various stages of the meat supply chain, including production, distribution, storage, and retail. Although traditional microbiological testing methods remain the gold standard for assessing freshness, spoilage, and safety, they are often labor-intensive and time-consuming. Similarly, sensory evaluation techniques, while useful, are subjective and often slow. As an alternative, recent studies have

demonstrated the effectiveness of analyzing chemical compounds associated with microbial spoilage (Ribes et al., 2018). These indicators can be used to detect spoilage at earlier stages than traditional methods allow.

Technological advancements have significantly improved the detection of spoilage organisms (Saini et al., 2021). Modern diagnostic tools such as electronic noses, biosensors, and fluorescence spectroscopy offer faster and more accurate alternatives for identifying contamination and spoilage. These tools can detect volatile compounds and fluorescence signatures associated with microbial growth (Kumar et al., 2024). Furthermore, molecular techniques such as polymerase chain reaction (PCR) and next-generation sequencing now allow for the rapid identification and quantification of specific spoilage organisms (Borch et al., 2019).

2.6 Gram-Negative Bacteria Associated with Meat Spoilage

2.6.1 Enterobacteriaceae

Gram-negative bacteria with polar flagella and motility make up the *Enterobacteriaceae* family. Under both aerobic and anaerobic conditions, these bacteria proliferate efficiently on conventional media, typically within 24 hours at an incubation temperature of 37°C. Their nutritional requirements are minimal, and many species can thrive in synthetic media utilizing simple carbon sources such as glucose (Hiaider et al., 2022). This adaptability enhances their ability to survive and multiply in various environmental niches, including food products. Biochemically, most members of this family are oxidase-negative and have the capacity to reduce nitrate to nitrite. Exceptions to this biochemical profile include certain species of *Erwinia* and *Yersinia*, which may exhibit unique metabolic pathways. The name *Enterobacteriaceae* is derived from their

widespread presence in the intestines of humans and animals, where they may exist as commensals or pathogens (Barko et al., 2018). Beyond the gastrointestinal tract, some members of this bacterial family are also isolated from natural environments such as soil and water, and can be found parasitizing various plants and animals (Hormaeche & Edwards, 2019).

Numerous studies have explored the classification of Enterobacteriaceae, focusing on distinguishing glucose-fermenting Gram-negative bacilli from non-fermenters (O'Hara & Miller, 2017). This distinction is crucial in clinical diagnostics and food safety surveillance, especially in identifying potential spoilage organisms in meat and other perishable foods. Identification of these bacteria has traditionally relied on commercial diagnostic kits, which include both manual and automated systems. However, some species remain difficult to classify using conventional biochemical and phenotypic techniques, particularly outside of well-equipped reference laboratories (Váradi et al., 2017).

To address these limitations, molecular techniques such as 16S ribosomal DNA (rDNA)-based sequencing have emerged as reliable alternatives for species-level identification (Michel et al., 2017). These genetic methods offer greater specificity and sensitivity, especially in complex microbial environments such as those encountered in spoiled meat. Consequently, the role of *Enterobacteriaceae* in meat spoilage is increasingly recognized, necessitating advanced detection and control strategies in meat processing and preservation (Mladenović et al., 2021).

2.6.2 *Campylobacter spp*

Campylobacter is a microaerophilic, anaerobic, and Gram-negative bacterium that typically exhibits a spiral or curved rod-shaped morphology. It is known for its fastidious growth requirements and sensitivity to environmental stress, which complicates its detection and cultivation in standard laboratory settings. Numerous *Campylobacter* species are suspected or confirmed to be associated with human gastrointestinal disorders, often transmitted through contaminated food or water sources (Skirrow, 2019). According to Skirrow (2019), the majority of human campylobacteriosis cases are attributed to *Campylobacter jejuni* and *Campylobacter coli*, which are recognized as the primary pathogenic species. In several Western countries, the incidence rate of campylobacteriosis has surpassed that of *Salmonella*-related foodborne illnesses, marking it as a significant public health issue (Aarø et al., 2024). Among the main reservoirs, poultry and poultry-derived products play a central role in the transmission of *Campylobacter* to humans, acting as crucial vectors for the disease (Evans, 2018). In developing countries, however, the burden of campylobacteriosis may be underestimated due to the limited availability of effective and sensitive diagnostic tools. This leads to underreporting and gaps in epidemiological data, hampering efforts to assess the true scale of the infection (Trachoo, 2020).

The primary mode of transmission is through the consumption of contaminated animal-derived food products, particularly undercooked meat, unpasteurized milk, and untreated water (Butzler & Oosterom, 1991). The symptoms of *C. jejuni*-induced gastroenteritis commonly include diarrhoea which may become bloody in later stages alongside vomiting, abdominal cramps, and fever (Gabberth et al., 2023). The illness typically resolves within 7 to 10 days after infection, with symptoms generally appearing 2 to 7

days following exposure. While many cases are self-limiting, antimicrobial treatment is recommended in severe cases, with erythromycin and tetracycline being the most effective antibiotics (Blaser et al., 2016).

2.6.3 *Hafnia alvei*

Hafnia alvei is a facultatively anaerobic, Gram-negative bacterium that belongs to the *Enterobacteriaceae* family. It is recognized for its ability to survive and grow in low-oxygen conditions, which makes it particularly relevant in the context of food packaging and storage (Ramos-Vivas et al., 2022). This microorganism has been linked to gaseous spoilage in chub-packed ground beef and other meat products stored in modified-atmosphere or vacuum-sealed environments (Legrand et al., 2020). Under these conditions, *H. alvei* is capable of producing hydrogen sulfide and gas accumulation beneath the packaging film, leading to bloating and unpleasant odours in meat products (Hanna et al., 2017). Kennedy et al. (2016) reported that *H. alvei* can thrive in vacuum-packed, chilled beef, further emphasizing its adaptability to refrigerated storage conditions.

Al-Mazrouei et al. (2024) found that *H. alvei* was present in 47% of aerobically packaged retail ground beef samples, indicating a notable prevalence of this bacterium in commercial meat products. Its frequent detection in beef is likely attributed to its natural presence in slaughtered cattle. Maciak (2019) identified the organism in 21% of examined cattle tissues, including muscle, lymph nodes, and internal organs, suggesting that contamination may occur during the slaughter or meat processing stages.

While the presence of *H. alvei* in retail beef is well-documented, its specific role in the spoilage of ground beef sold in retail settings remains underexplored. This limited research attention is possibly due to the bacterium's relatively poor competitive ability against aerobic spoilage bacteria in oxygen-rich packaging environments, where it may not dominate microbial activity (Singh, 2017). Nevertheless, its significance cannot be overlooked, particularly in vacuum-sealed or low-oxygen packaging conditions, where it is more likely to flourish.

In addition to its role in food spoilage, *H. alvei* has also been isolated from a variety of animal hosts (Sharma et al., 2017). It is suspected of causing gastrointestinal disorders in humans, such as gastroenteritis (Reina, 2018), and has been associated with a range of clinical conditions, including pneumonia and other opportunistic infections, particularly in immunocompromised individuals (Klapholz et al., 2018). These findings highlight the importance of monitoring *H. alvei* not only as a spoilage organism but also as a potential public health concern.

2.6.4 *Pseudomonas spp*

The primary bacteria responsible for meat spoilage belong to the *Pseudomonas* genus, which are strict aerobes (Pellissery et al., 2020). These microorganisms are among the most common and significant spoilage agents, particularly in refrigerated meat products. *Pseudomonas* species play a major role in producing the foul odours associated with spoiled meat (Stanborough et al., 2018). This occurs when the bacteria break down proteins in the substrate into amino acids, which are then further degraded into volatile compounds such as unpleasant-smelling amines, esters, and organic acids (Greer, 2019).

These metabolic by-products are largely responsible for the offensive smells and undesirable taste associated with spoiled meat.

Members of the *Pseudomonas* genus are Gram-negative, rod-shaped, aerobic bacteria equipped with polar flagella, which contribute to their motility and colonization efficiency (Anzai et al., 2020). *Pseudomonas aeruginosa*, one of the most well-known and widely studied species, is an opportunistic pathogen capable of adapting to a wide range of environments. It can infect both humans and animals, making it a potentially zoonotic pathogen capable of crossing species barriers (Moradali et al., 2017). Its presence in food processing environments raises both spoilage and public health concerns, particularly in immunocompromised individuals.

It is well established that *Pseudomonas* species contribute to spoilage even under low-temperature storage conditions (Meng et al., 2017). Psychrotrophic strains thrive in chilled environments, which allows them to dominate the microbial flora of refrigerated meat. Specific psychrophilic species are known for targeting various food products: *P. fragi* is commonly associated with spoilage in dairy products; *P. dantrolene* is known to cause musty odours in eggs; while *P. microlens* and *P. lundensis* have been identified as major spoilage organisms in fish, pork, cheese, and milk (Denissem et al., 2022). Their metabolic versatility and resistance to cold make them particularly difficult to manage in the cold chain of meat and perishable food storage.

2.6.5 *Enterobacter spp*

Enterobacter spp. are Gram-negative, motile, rod-shaped bacteria that typically possess peritrichous flagella, which aid in their movement and colonization (Salimiyan et al.,

2020). These bacteria are commonly found in food due to their ability to grow at various temperatures and adapt to a wide range of nutritional conditions (Mladenović et al., 2021). Their metabolic flexibility allows them to survive in diverse environments, including meat processing and storage facilities.

In meat products, *Enterobacter spp.* contribute to spoilage by producing off-flavours, gas, and slime as a result of protein and carbohydrate breakdown during metabolism (Akinsemolu & Onyeaka, 2024). These changes affect the sensory quality of meat and reduce its market value. Research has shown that *Enterobacter spp.* are frequently isolated from raw and processed meats, especially when hygiene and storage conditions are poor (Mladenović et al., 2021; Akinsemolu & Onyeaka, 2024). Their ability to grow at refrigeration temperatures makes them important spoilage organisms that require careful monitoring in the meat supply chain.

2.6.6 *Serratia spp*

Serratia spp. are Gram-negative bacteria classified under the Enterobacteriaceae family. These organisms are known for their distinctive enzymatic activity, which includes the production of DNase, gelatinase, and lipase enzymes that contribute to their pathogenicity and spoilage potential (Giri et al., 2018). These enzymes enable the degradation of nucleic acids, proteins, and lipids, which can lead to undesirable changes in meat and other food products.

Serratia spp. are environmentally versatile and have been widely detected in a variety of habitats. They are commonly found in water, soil, and plants, and have also been isolated from insects, animals, and humans (Singleton & Sainsbury, 2020). Their broad environmental distribution and adaptive capacity allow them to colonize food surfaces

and thrive in processing environments, especially under conditions of inadequate sanitation.

2.6.7 *Citrobacter freundii*

Citrobacter freundii is an aerobic, Gram-negative bacterium that typically appears as a long, rod-shaped organism measuring between 1 and 5 micrometres in length. Most *C. freundii* cells are motile due to the presence of multiple flagella, although non-motile strains have also been reported (Wang et al., 2020). This organism is commonly found in a variety of natural environments, including soil, water, and sewage. It is also present in food products and is part of the intestinal microbiota of both humans and animals (Whalen & Mully, 2020).

Although *C. freundii* is often a harmless environmental bacterium, it is considered an opportunistic pathogen capable of causing a wide range of infections (Hidayatullah et al., 2020). It is particularly associated with nosocomial infections and has been implicated in bloodstream infections, urinary tract infections, and respiratory tract infections, especially in immunocompromised individuals (Singh et al., 2021). These infections often arise in clinical settings where the bacterium can exploit weakened host defences. According to Whalen and Mully (2020), *C. freundii* accounts for approximately 29 % of all opportunistic infections, emphasizing its public health significance. Furthermore, its presence in food and water sources has raised concerns regarding its potential role in foodborne illness, particularly when hygiene practices are inadequate (Wang et al., 2020; Singh et al., 2021; Akinsemolu & Onyeaka, 2024).

2.6.8 *Proteus vulgaris*

Proteus vulgaris is a Gram-negative, rod-shaped bacterium that is classified as chemoheterotrophic, meaning it obtains its energy through the oxidation of organic compounds. The cells typically measure between 0.4 to 0.6 micrometres in diameter and 1.2 to 2.5 micrometres in length. *P. vulgaris* is motile due to the presence of peritrichous flagella, which enable it to move effectively in liquid environments (O'Hara et al., 2017; Todar, 2020).

This bacterium is commonly found in a range of environments including soil, contaminated dust, water, raw or uncooked meat, and the gastrointestinal tracts of animals and humans (Cheesbrough, 2019). Its ability to survive in diverse habitats makes it a frequent contaminant in food products, particularly meat, where improper handling and storage can lead to its proliferation.

Although *Proteus* species are best known for causing urinary tract infections, especially in catheterized patients, they are also capable of causing more serious infections such as wound infections and abscesses (O'Hara et al., 2017). Among the species, *P. mirabilis* is responsible for approximately 90 percent of infections and is most often associated with cases in the general community. In contrast, *P. vulgaris* is more commonly isolated from nosocomial or hospital-acquired infections, making it a significant concern in clinical settings where immunocompromised individuals are at higher risk (Cheesbrough, 2019; Todar, 2020).

2.7 The Gram-positive Bacteria Associated with Meat Spoilage

2.7.1 *Bacillus cereus*

Bacillus cereus is a spore-forming, Gram-positive, aerobic, rod-shaped bacterium that is widely distributed in the environment, particularly in air, soil, and water (Claus & Berkeley, 2016). Its spores are highly resistant to adverse conditions, allowing the organism to survive common food processing methods and persist on food-contact surfaces. *B. cereus* is recognized as a significant spoilage microorganism, particularly in red meat and meat-based products (Nel et al., 2018). Its ability to grow under aerobic conditions and form endospores contributes to its resilience in food production and storage environments.

A study conducted by Mosupye and Von Holg (2019) confirmed the widespread presence of *B. cereus* in both raw and cooked food items, including meat. Its prevalence in food is of particular concern due to its role in food spoilage and foodborne illness. In meat products, managing microbial contamination is critical to maintaining product quality and ensuring food safety (Jo et al., 2020). Proper sanitation practices during the pre-slaughter, slaughter, and post-slaughter phases are essential to minimize contamination risks and ensure the hygienic handling of meat products (Satin, 2020).

During slaughter, meat is exposed to numerous potential sources of contamination, including the animal's skin, intestinal content, slaughtering equipment, and the surrounding environment, all of which can introduce *B. cereus* spores into the meat (Lawrie, 2016). Once introduced, the bacterium can survive cooking processes and become particularly problematic in cooked and processed meat products. *B. cereus* is more frequently found in processed products such as ground beef and cooked meats than

in raw meat, likely due to cross-contamination and the favorable growth conditions offered by post-processing storage environments (Mosupye & Von Holg, 2019).

This bacterium is also known for causing two distinct forms of foodborne illness: an emetic form, which results in nausea and vomiting, and a diarrhoeal form, characterized by abdominal cramps and watery diarrhoea following the consumption of contaminated food (Nelms et al., 2017). The severity and onset of symptoms vary depending on the quantity of toxin ingested and the susceptibility of the host.

2.7.2 *Listeria monocytogenes*

According to Farber and Peterkin (2019), *Listeria monocytogenes* is a rod-shaped, facultatively anaerobic, Gram-positive, non-spore-forming, motile bacterium that is catalase positive and oxidase negative. It is widely regarded as a serious foodborne pathogen with the potential to cause listeriosis, a condition that can lead to severe complications such as meningitis, septicaemia, and miscarriage, particularly in vulnerable groups including pregnant women, the elderly, and immunocompromised individuals. This organism is considered a major threat to food safety and is commonly identified in a variety of foods, particularly those of animal origin (Whalen & Mully, 2020).

Significant outbreaks of listeriosis have been directly linked to the consumption of contaminated animal-based food products such as meat and dairy (Dos Reis et al., 2022). *Listeria monocytogenes* has been isolated from both raw and cooked meats, highlighting its ability to survive and thrive in diverse environmental and food-processing conditions (Osek & Wieczorek, 2023). Although its presence in raw meat is well-documented, research on its growth patterns in such products has produced varying results. Factors

such as the pH level of the meat, temperature, tissue type, and the presence of competing microflora are known to significantly influence its proliferation (Farber & Peterkin 2019).

Ideally, *Listeria monocytogenes* should be completely absent in cooked meat products. Thermal processing practices, including heating meat for at least two minutes at temperatures of 70 degrees Celsius or slightly above, are generally effective in destroying the bacterium (Osek et al., 2022). Nevertheless, many laboratory studies on *Listeria* survival have used artificially high inoculum levels ranging from 10^7 to 10^8 colony-forming units per gram, which are not representative of realistic contamination scenarios (Boyle et al., 1990). These studies may overestimate the bacterium's heat resistance and fail to reflect actual risks in commercial food environments.

While heat-stressed *Listeria* cells can become more resistant when exposed to sublethal temperatures for short periods, this condition usually occurs under specific and uncommon circumstances. In typical raw meat samples, contamination levels are much lower, often under 100 colony-forming units per gram (Sheridan et al., 2019). Under such conditions, standard cooking procedures are generally sufficient to eliminate the pathogen and ensure food safety (Claus & Berkeley, 2016).

2.7.3 *Staphylococcus aureus*

Staphylococcus aureus is a bacterium capable of producing strains that generate a highly heat-resistant toxin, which is a major cause of human foodborne illness. This type of illness, commonly referred to as staphylococcal food poisoning, occurs when food becomes contaminated with enterotoxins produced by *S. aureus*. Contamination often

results from improper handling and occurs especially when food is left at ambient temperatures for extended periods (Walls, 2017).

Foods that are frequently handled during preparation and not properly refrigerated are commonly associated with outbreaks of staphylococcal food poisoning (Argaw & Addis, 2015). The enterotoxin produced by *S. aureus* is highly stable and retains its toxicity even after exposure to typical cooking temperatures. As such, cooking or reheating food may destroy the bacteria themselves but will not eliminate the already-formed toxin (Grispoldi et al., 2021).

A variety of cooked food items, including tuna, ham, poultry, egg-based dishes, and mixed salads such as potato or macaroni salad, are particularly vulnerable. These are often displayed at room temperature for long durations, such as in restaurant windows or on buffet counters, creating ideal conditions for *S. aureus* to grow and produce toxins (Marathe, 2024).

Additionally, ready-to-eat foods prepared under unhygienic conditions and stored at room temperature are of significant concern (Makinde et al., 2020). This includes many street foods that are often prepared early in the day and left unrefrigerated for hours before consumption. In such cases, the time lapse between preparation and consumption plays a critical role in the risk of intoxication. Mensah et al. (2018) observed that in many informal food vending environments, such as street food settings, meals are typically cooked in the morning and kept at room temperature throughout the day, heightening the risk of toxin development and foodborne illness.

2.7.4 *Staphylococcus epidermidis*

Staphylococcus epidermidis is a Gram-positive, coagulase-negative coccus that is naturally present as part of the normal human flora, particularly on the skin and mucous membranes (Tektook et al., 2018). Although it is typically non-pathogenic in healthy individuals, *S. epidermidis* functions as an opportunistic pathogen and can cause infection when the host's immune system is compromised or when it gains access to normally sterile body sites (Becker et al., 2018). It is one of the most significant causes of nosocomial infections, especially in patients with indwelling medical devices (Nilsson et al., 2018).

This organism is well known for its ability to form resilient biofilms on medical equipment such as prosthetic joints, catheters, and heart valves, which makes infections challenging to treat and often resistant to antibiotics (Pietrocola et al., 2022). *S. epidermidis* has been linked to a range of clinical conditions, including endocarditis of both native and prosthetic heart valves, urinary tract infections, osteomyelitis, bacteremia, and peritonitis (Nilsson et al., 2018).

Although *S. epidermidis* is not commonly associated with foodborne illness, its presence in meat or other food products can indicate contamination due to improper food handling, particularly from human contact or unsanitized surfaces (Becker et al., 2014). In food processing environments, especially those lacking stringent hygiene practices, *S. epidermidis* may serve as a marker of poor sanitary conditions rather than a primary pathogen. Nevertheless, its ability to survive on surfaces and in biofilms suggests that its presence should not be overlooked, especially when dealing with vulnerable populations (Viana et al., 2025).

2.7.5 *Brochothrix spp*

Brochothrix is a Gram positive, non-spore forming, facultative anaerobic bacterium that predominantly inhabits meat, which serves as its primary ecological niche (Stanborough, 2018). It is recognized as one of the principal spoilage organisms associated with fresh and processed meat products. The organism is particularly well adapted to meat environments, with glucose, abundant in meat tissues, serving as a primary energy source that supports its growth and metabolic activity (Gill, 2016).

Under anaerobic conditions, *Brochothrix* produces mainly lactic acid along with small quantities of volatile compounds, resulting in only a faint off odour and minimal spoilage characteristics. However, under aerobic conditions, especially in exposed or loosely packaged meat, it produces a variety of strong smelling metabolites (Wang et al., 2025). These include acetoin, acetic acid, isobutyric acid, isovaleric acid, and their corresponding aldehydes and alcohols, which contribute to the development of unpleasant odours and flavours associated with spoiled meat (Ryan & Ray, 2018). This metabolic flexibility allows *Brochothrix* to grow under both oxygen rich and oxygen poor environments, making it a significant colonizer in a wide range of meat storage scenarios (Stanborough, 2018).

The bacterium's optimal growth temperature ranges between 20 to 25°C, although it can grow at lower temperatures, making it especially relevant to meat products stored under refrigeration. Its preferred pH level is around 7.0, though it is capable of growing within a pH range of 5 to 9, which covers the typical pH levels found in fresh meat (Gill, 2016). *Brochothrix thermosphacta* is the most common species associated with meat spoilage and is frequently isolated from chilled, vacuum packed, or modified atmosphere

packaged meat and poultry products. It is also found in irradiated meats and plays a key role in spoilage, especially in prepacked or retail displayed meats stored at low temperatures (Ryan & Ray, 2018).

2.7.6 *Enterococcus*

Enterococcus is a Gram-positive, facultative anaerobic coccus that typically appears as pairs (diplococci) or short chains. This morphological arrangement makes it difficult to distinguish from *Streptococcus* species based on physical characteristics alone (Ahmed, 2020). *Enterococcus* species are non-spore forming, catalase-negative (except in the presence of peroxidase), and can grow in harsh environments such as high salt concentrations, bile, and a wide pH range. Their ability to tolerate extreme environmental conditions makes them resilient contaminants in food systems (García-Solache & Rice, 2019). Among the various species of *Enterococcus*, *E. faecalis* accounts for approximately 90–95% of clinical and commensal isolates, while *E. faecium* makes up about 5–10% (Gilmore et al., 2019). These two are predominant in the gastrointestinal tracts of humans and animals and are considered normal gut flora. However, other species such as *Enterococcus casseliflavus*, *E. durans*, and *E. raffinosus* have also been isolated from clinical cases and food sources, albeit at lower frequencies (Lee et al., 2022).

Although they are often harmless as gut commensals, *Enterococcus* species can become opportunistic pathogens under favourable conditions, especially in immunocompromised individuals or those undergoing prolonged antibiotic treatment (Sangiorgio, et al., 2024). They are frequently associated with nosocomial infections, including urinary tract infections, endocarditis, bacteremia, and intra-abdominal infections, which are particularly difficult to treat due to their growing resistance to multiple antibiotics

(Kalode, & Patil, 2023). The emergence of vancomycin-resistant enterococci (VRE), particularly strains of *E. faecium*, poses a serious challenge to hospital infection control programs globally. In the context of food safety, *Enterococcus* species are important indicators of fecal contamination in meat and meat products, reflecting poor hygienic practices during slaughtering, processing, or packaging (Mladenović, et al., 2021). Their presence in food can also be attributed to cross-contamination through contact with unclean equipment, surfaces, or handlers.

Furthermore, *Enterococcus* species are known for their ability to form biofilms on surfaces and to survive routine sanitation procedures in food processing facilities, making them persistent contaminants. Their capacity for horizontal gene transfer also enables them to share resistance genes with other bacteria, further complicating treatment and containment (Abebe, 2020).

2.7.7 Escherichia coli

Certain strains of *Escherichia coli*, such as *enterohemorrhagic E. coli* (EHEC) and *enterotoxigenic E. coli* (ETEC), are responsible for foodborne outbreaks (Vila et al., 2016). Contaminated raw or undercooked meat, unpasteurized milk, and fresh produce have been implicated in *E. coli* infections. *Escherichia coli*, commonly known as *E. coli*, encompasses both harmless commensal strains and pathogenic variants responsible for severe foodborne illnesses (Liu et al., 2020). Among the pathogenic strains, *enterohemorrhagic E. coli* (EHEC) and *enterotoxigenic E. coli* (ETEC) pose significant public health risks and have been associated with foodborne outbreaks. *Escherichia coli* infections in humans normally result from the consumption of contaminated foods that are present in the food chain. The predilection site of the bacteria is primary in the

intestinal tract and excreted in feces and transmitted through consumption of raw meat due to improper slaughtering. Most *E. coli* strains do not cause diseases and are part of the normal flora of the intestinal tract of animals and humans but detection of *E. coli* in foods intended for human consumption shows poor sanitary and hygiene during production, processing, transportation, or preparation (Kim et al., 2023).

2.8 Post-Slaughter Carcass Handling

To ensure high standards of hygiene, minimize unnecessary animal cruelty, and prevent the spread of disease, abattoirs are governed by regulations (Grandin & Smith, 2023). The methods of slaughter and carcass handling are crucial for meat products' quality and shelf life. Chulayo and Muchenje (2019) argue that poor meat quality reflects poor carcass quality. Technological aspects of meat quality, such as colour, PH, marbling, tenderness, flavour, and juiciness (Bredahl et al., 2018; Muchenje et al., 2019), significantly impact both meat quality and profitability if negatively affected (Grunert et al., 2022).

With growing consumer demand for high-quality meat, various methods have been employed to enhance meat quality, including breeding (Hermesch, 2018), feeding strategies, nutrition, and improving animal welfare during transport and slaughter (Muchenje et al., 2020). Post-slaughter practices also play a significant role in determining meat quality, affecting profitability, consumer acceptance, and functional properties of the meat (Zhao et al., 2018). These treatments include handling after slaughter, processing, chilling, transport, and other factors.

Following exsanguination, post-slaughter handling starts in the abattoir and continues through the processing, storage, and transportation of the meat before reaching the final customer (Grandin & Smith, 2023). During this time, irreversible quality losses, particularly in hygienic quality, can occur due to improper slaughtering and carcass handling (FAO, 2021). Poor handling, which compromises quality and shelf-life, may also pose health risks to consumers. Therefore, maintaining hygiene throughout slaughter and meat handling is crucial, as initial contamination can accelerate meat deterioration, especially at ambient temperatures (De Vos van Steenwijk, 2024).

Qualified meat inspectors monitor and inspect carcasses post-slaughter. Carcasses that pass inspection are stamped and certified as safe for consumption (Nabwiire, 2023). However, in Ghana's abattoirs, carcasses are primarily inspected visually, with checks for bruises and disease signs in internal organs, while microbiological assessments are rarely performed (Akansale, 2019). Few abattoirs conduct microbial assessments; when they do, it is not daily; the veterinary department occasionally performs random inspections. The European Union (EU) guidelines recommend that total aerobic bacteria and total coliforms in meat should not exceed 5.0 and 2.5 log cfu/g, respectively (Kostoglou et al, 2023). Any carcass that fails inspection is considered unsafe for human consumption and is removed from the market, often resulting in significant economic losses for the meat industry due to condemned carcasses (Alton et al., 2019).

After slaughter, carcasses are placed in a freezer for 24 hours at 4°C to prevent rigor mortis and inhibit microbial growth (Brown et al., 2020). The chilling process impacts carcass quality by reducing microbial growth on the surface, as warmer temperatures promote microbial proliferation. Immediate chilling similarly reduces evaporative

weight loss, improves lean colour, enhances water-holding capacity, and minimizes the development of pale, soft, exudative meat—factors that can negatively affect meat quality (Adzitey & Nurul, 2018). Finally, the chilling period influences enzyme activity, which is temperature-dependent (Adzitey & Nuda, 2019).

2.9 Hazard Analysis Critical Control Points in the Meat Processing

Hazard analysis critical control points: A quality management system that manages the physical, microbiological, and chemical risks of food production in order to effectively and efficiently ensure farm-to-table food safety (Motarjemi & Warren, 2023). Rather than attempting to detect and manage contamination after it has already happened, this prevention-based system adopts a proactive stance by identifying the main risks and control points where contamination can be avoided, reduced, or eliminated throughout the entire food production process (Berendonk et al., 2015).

The HACCP system can be used at all stages of a food chain, from food production and preparation processes including packaging, distribution (Awuchi, 2023). Hazard analysis, critical control point identification, critical limit setting for each critical control point, critical control point monitoring requirements, corrective action setting, procedures for making sure the HACCP system is operating as intended, and recordkeeping procedures are all part of each processing step (Kim & Yim, 2016).

The practical steps and procedures that make up good hygiene practice (GHP) include: restoring the processing environment to its initial state (disinfection or sanitation programs); maintaining the efficient operation of buildings and equipment (maintenance programs); and preventing cross-contamination during manufacturing (usually involving people, surfaces, the air, and the segregation of raw and processed products) (Surono,

2024). GHP and the use of the HACCP system in abattoirs for the processing and killing of animals. Preventing, eliminating, or lowering the prevalence and concentrations of germs harmful to humans is the aim of using the GHP and HACCP systems in slaughterhouse operations (Ahmed, 2023).

2.10 Meat distribution chains

The meat distribution chain refers to the complete and systematic process involved in delivering meat to consumers, starting from the transportation of live animals to slaughterhouses and ending with the retail display of processed meat products Rani et al. (2017). As outlined by Rani et al. (2017), this sequence encompasses all the logistical and processing activities that convert live animals into consumable meat for market outlets. The process begins on farms, where livestock such as cattle, goats, sheep, and poultry are raised under various husbandry systems. These animals are then transported, often over long distances, to slaughterhouses or abattoirs, where they are humanely killed, dressed, and processed into carcasses and meat cuts suitable for human consumption (Verma, et al., 2022).

From slaughterhouses, the meat enters another critical phase of the supply chain involving transportation, storage, and distribution to wholesalers, retailers, restaurants, and local market vendors (Kayikci et al., 2020). Key actors in this chain include animal farmers, breeders, livestock traders, stockers, feedlot operators, abattoir workers, processors, packers, cold chain managers, retailers, and food service providers (Brauckmüller, 2023). Each of these stakeholders plays a vital role in ensuring that the meat remains safe, fresh, and of high quality throughout its journey from the farm to the consumer's plate.

A fundamental objective of the distribution process is to minimize microbial contamination and spoilage, thereby preserving the freshness, taste, and visual appeal of meat products (McDonald & Sun, 2019). Since meat is highly perishable due to its high moisture and protein content, it provides a favorable environment for the growth of spoilage and pathogenic microorganisms if not properly managed. As emphasized by Bhandari et al. (2023), strict hygiene and sanitation, along with continuous temperature control, are necessary throughout the distribution stages to ensure food safety and reduce the risk of foodborne illnesses.

Consumers often judge meat quality based on intrinsic characteristics such as tenderness, juiciness, pH, marbling, flavor, and most importantly, color (Glitsch, 2020). Color is the first visual indicator consumers use to assess freshness, and it plays a significant role in influencing purchase decisions. According to Faustman and Cassens (2017), meat color is determined primarily by the pigment myoglobin, which reacts with oxygen to form oxymyoglobin, giving meat a bright red appearance. However, exposure to air over extended periods can lead to the oxidation of oxymyoglobin into metmyoglobin, which gives the meat a brownish hue that is often associated with spoilage (Bekhit, et al., 2019). To avoid such deterioration, oxygen exposure must be limited, and temperature must be carefully regulated throughout the meat distribution chain.

Temperature control is perhaps the most critical factor in ensuring the shelf life and microbial safety of meat. As reported by Nychas et al. (2018), the distribution of meat under chilled or refrigerated conditions significantly extends its shelf life and reduces the rate of microbial spoilage. Cold chain logistics, which include refrigerated vehicles and storage facilities, are essential components of meat distribution. Interruptions in this cold

chain such as inadequate refrigeration during transportation or poor temperature monitoring can result in the rapid proliferation of harmful bacteria like *Salmonella*, *Listeria monocytogenes*, and *Escherichia coli* (Niyonzima, 2015).

Moreover, inefficient meat handling during loading and unloading, unclean transportation containers, and improper retail display practices can all contribute to cross-contamination and meat spoilage (Supian, 2018). To mitigate these risks, regulatory frameworks such as Hazard Analysis and Critical Control Points (HACCP) and Good Distribution Practices (GDP) have been established to enforce best practices in meat handling and logistics (FAO, 2020).

2.11 Stages affecting the Technological and Microbiological Quality of Meat

The overall quality and safety of meat products are significantly influenced by various interconnected stages from slaughter to retail (Rebezov et al., 2024). These stages include slaughterhouse procedures, hygienic handling, transportation, storage, and packaging. Each stage plays a crucial role in preserving the technological properties of meat such as tenderness, texture, pH, and color, as well as in maintaining microbiological integrity to prevent spoilage and foodborne illnesses (Rosenvold & Andersen, 2023; Lawrie & Ledward, 2014).

One of the most essential components of meat preservation is temperature regulation, particularly during storage and transportation (Banerjee et al., 2018). Improper refrigeration facilitates microbial proliferation, especially by psychrotrophic bacteria capable of growing at low temperatures, such as *Listeria monocytogenes* and *Pseudomonas spp.* (Yalew et al., 2024). Effective cold chain management, by

maintaining temperatures between 0°C and 4°C, is therefore fundamental in slowing enzymatic activity and inhibiting the multiplication of spoilage organisms (Taormina, 2021).

Another critical factor is the hygienic conditions maintained during and after slaughter. Cross-contamination may result from unclean equipment, contact surfaces, handlers' clothing, and improper hand hygiene (Ebert, 2018). Poor sanitation practices during the slaughtering and butchering process significantly increase the microbial burden of meat (Adzitey et al., 2020). Studies have shown that bacteria such as *Escherichia coli*, *Salmonella spp.*, and *Staphylococcus aureus* are commonly introduced at this stage, particularly in cases where Good Hygienic Practices and Hazard Analysis Critical Control Points protocols are not rigorously enforced (Ali et al., 2021).

The duration of storage also influences both microbial and sensory qualities of meat (Gómez et al., 2020). Even when refrigerated properly, meat stored beyond its shelf life may undergo protein denaturation, color fading, and the development of undesirable odors. These biochemical and microbiological changes may not always be detectable by consumers but can pose health risks (Sheng & Wang, 2021).

Packaging methods are equally important in preserving meat quality during distribution. Techniques such as vacuum packaging and Modified Atmosphere Packaging help reduce oxygen exposure, thus limiting the growth of aerobic spoilage organisms (Kandeepan & Tahseen, 2022). However, any compromise in packaging integrity, such as improper sealing or physical damage, combined with temperature abuse during handling, can render these methods ineffective and lead to rapid spoilage (Thomas, 2019).

At the retail level, poor handling practices such as prolonged exposure to light and air, lack of refrigeration, and multiple points of contact all contribute to increased microbial loads (Mahunu et al., 2024). According to Faustman and Cassens (2017), visual characteristics, especially meat color, are vital indicators that affect consumer choices. When meat is displayed under inadequate storage conditions, its quality deteriorates quickly and poses a higher risk of contamination (Glitch, 2020; Mensah et al., 2018). Ensuring meat quality throughout the supply chain requires strict adherence to hygiene and safety protocols at every stage (Jo et al., 2020). Stakeholders including slaughterhouse workers, transporters, vendors, food safety officers, and retailers must collaborate to implement proper monitoring systems and best practices. This coordinated effort is essential not only for preserving meat quality but also for protecting consumer health and reducing foodborne disease risks (WHO, 2020).

2.11.1 Transportation and Storage

Transportation plays a crucial role in the movement of live animals and meat products from farms to abattoirs, retail outlets, and ultimately consumers (Brauckmuller, 2023). Efficient and hygienic transport is essential for maintaining meat quality, safety, and shelf life. According to Rejeb (2018), the direct transport of meat products to retail outlets often represents a weak point in the distribution chain, where temperature abuse and contamination risks are most likely to occur.

Carcasses should ideally be chilled before transportation in order to inhibit microbial activity and slow the process of spoilage (Okpala, & Korzeniowska, 2023). However, many small and medium-sized abattoirs, particularly in low-resource settings, lack adequate refrigeration facilities. As a result, carcasses are often transported without prior

chilling, exposing them to elevated ambient temperatures during transit and increasing the risk of bacterial proliferation (Richardson et al., 2019).

Poor handling practices during transportation further compromise meat quality and safety. Richardson et al. (2019) emphasize that one of the major challenges in meat transport is maintaining the correct temperature throughout each stage of the cold chain. These stages include palletization, staging, loading, unloading, and storage. Any failure in this sequence can break the cold chain, providing favourable conditions for bacteria such as *E. coli*, *Listeria monocytogenes*, and *Salmonella* to multiply rapidly. This highlights the need for well-insulated and temperature-controlled vehicles and strict adherence to cold chain protocols.

Temperature is a critical determinant of meat quality, even after the product reaches the retail cabinet. As Koutsoumanis and Taoukis (2022) explain, refrigeration slows bacterial growth, while freezing can completely halt microbial activity. Consistently lowering the temperature reduces the potential for spoilage by making the meat environment less favourable for microbial survival and reproduction (Owusu-Apenten & Vieira, 2022).

Apart from microbial safety, temperature also significantly influences the visual and sensory attributes of meat, including colour and appearance. Research by Dawson and Richardson (2023) shows that meat stored at refrigerated temperatures between 2 and 5 degrees' Celsius experiences substantial changes in colour and overall quality. Maintaining the desirable bright red colour of oxymyoglobin on the meat surface requires proper temperature management, especially during prolonged storage. If not managed correctly, lipid oxidation can occur, leading to undesirable colour changes and off-flavours (Zhao et al., 2018). In addition, the oxidation and oxygenation processes within

meat are closely tied to temperature exposure. Fluctuations in temperature can accelerate oxidative reactions and discoloration, ultimately reducing product appeal and marketability.

2.11.2 Characteristics of meat van for transportation

Vehicles used to transport meat from slaughterhouses to retail outlets can serve as significant sources of contamination, primarily due to improper cleaning and inadequate coverage, which allow dust, insects, and flies to come into contact with the meat (Ntanga et al., 2023). Alternative modes of transportation, such as motorbikes and bicycles, are also linked to contamination problems, especially in regions where proper vans and trucks are unavailable (Chepkemoi et al., 2021). Furthermore, the absence of suitable cleaning facilities for these vehicles has contributed to high levels of microbial contamination (Ntanga et al., 2023).

The various stages of meat transportation from cold storage to retail outlets and finally to consumer refrigerators are critical for ensuring the quality and safety of the meat (Lulietto, 2023). Maintaining consistent temperatures within the transport vehicles is a significant factor in this process, as fluctuations can negatively affect the meat. To maintain proper chilling, vehicles must be equipped with reliable refrigeration systems that function throughout the transportation process. It is also essential to prevent the intrusion of heat caused by hot weather, poor insulation, or air leaks. Addressing these issues is key to maintaining optimal conditions during transit.

Regulations governing transport equipment and temperature control for beef transportation have become more stringent, particularly for intra-European shipments of

refrigerated foods (Mian, & Chaudry, 2018). One of the most vulnerable stages in the beef distribution chain is the transport phase, whether from the slaughterhouse to the butcher or from the retail shop to the consumer's refrigerator. However, there is limited published data on this specific aspect (Rani et al., 2023).

2.11.3 Packaging

The quality and shelf-life of fresh meat are significantly influenced by its original quality, storage conditions, and packaging parameters (Zhao et al., 2018). Packaging is crucial in protecting the meat during transportation and distribution (Silayoi & Speece, 2017). It is essential in the food industry as it offers protection from environmental factors, serves as a marketing tool, and provides consumers with information on how to use the product (Yam et al., 2019). For fresh meat, packaging helps prevent contamination, supports enzymatic activity that enhances tenderness, delays spoilage maintains the red colour of meat (oxymyoglobin or cherry red) during retail display, and minimizes weight loss (Ahmed, et al., 2018). However, packaging only preserves the existing quality of the meat, so it is important to ensure the meat is of good quality before packaging. This process helps delay spoilage by controlling the contributing factors (Schumann, & Schmid, 2018).

The development and design of packaging are key to extending the shelf-life of food products. Proper material and technology selection help maintain product freshness and quality throughout storage, transportation, and distribution. Packaging, when combined with refrigeration, can further slow microbial growth, thereby enhancing the effectiveness of preservation. Knowledge of packaging options and their impacts is vital, as they significantly affect food product quality (Brody, 2017).

Various packaging systems have different characteristics and uses, ranging from overwraps for retail displays to Vacuum packing and modified atmosphere packaging (MAP) for long-term display (Reyes, 2022). MAP systems utilize gases such as carbon dioxide, nitrogen, and oxygen to replace the typical environment with a gas mixture tailored to the type of food (Czerwiński et al., 2021). McMillin et al. (2019) define MAP as removing or replacing the gases surrounding the product before sealing it in vapor-barrier materials. This process helps prevent deterioration, including off-flavours, discoloration, odours, texture changes, nutrient loss, pathogenic growth, and other issues (Yam et al., 2020). According to Davies (2019), some of the key benefits of MAP are its ability to increase meat shelf-life, maintain quality, and reduce loading frequency. While bacterial spoilage, appearance deterioration, and exudate loss are significant challenges in storing chilled meat, MAP helps maintain an appealing red meat colour for consumers (Ismail, & Huda, 2024). Vacuum packaging, on the other hand, is primarily used to prevent oxidation, shrinkage, colour changes, and the growth of aerobic spoilage organisms (Tyuftin, & Kerry, 2023).

2.12 Display of Fresh Meat

The colour of meat plays a crucial role in shaping consumer perceptions of its freshness and quality (O'Grady et al., 2020). As meat comes into contact with oxygen, its colour changes due to the transformation of myoglobin pigments. It starts as purple deoxymyoglobin, shifts to red oxymyoglobin, and eventually turns brown as metmyoglobin forms (Calnan et al., 2018). Retailers face difficulties maintaining an appealing colour, particularly if the meat remains on display for extended periods. Plastic packaging allows consumers to view the meat in an attractive, hygienic, and convenient manner (Renerre & Labadie, 2017). Alternatively, meat can be displayed unwrapped in

chilled cabinets that control humidity to minimize drying, typically providing a shelf-life of one to two days.

Meat packaging methods vary. Over-wrapped packaging with the standard permeable film initially gives the meat a red colour but leads to oxidation and browning after a short time. This packaging typically extends the shelf-life to one to two days (Liu et al., 2017). Modified Atmosphere Packaging (MAP), which seals meat in trays with high-oxygen environments, can extend the shelf-life to seven to ten days while keeping the red colour longer. However, the meat eventually turns brown (Richardson et al., 2019). Vacuum packaging, which excludes air, preserves the purple-red colour of meat and can extend its shelf-life to ten days, provided it is stored at temperatures below 3 °C (Peck et al., 2020).

Regarding bacterial growth, bacteria are classified based on their optimal temperature ranges: mesophiles grow between 10–45 °C, psychrophiles grow between 0–28 °C, and psychrotrophs grow between 10–45 °C but at a slower rate from 0–10 °C. While mesophiles do not thrive below 10 °C, psychrotrophic bacteria, particularly *Pseudomonas*, can grow at temperatures as low as 0 °C. Lower storage temperatures help slow bacterial growth, thereby extending the shelf-life of meat (FAO, 2021).

2.13 Challenges during Meat Distribution

The distribution of meat presents numerous challenges, particularly concerning its microbiological safety and technological quality. Meat is highly susceptible to microbial contamination due to its composition, which includes approximately 75% water along with essential metabolites such as amino acids, peptides, nucleotides, and simple sugars.

These components create an ideal environment that supports rapid microbial growth (Lawrie, 2017).

Spoilage in fresh meat begins immediately after slaughter and is driven by both microbial activity and biochemical reactions. Although the internal organs of healthy animals are typically sterile, external parts such as the skin, hooves, and intestines contain large populations of bacteria (FAO, 2021). During slaughter, these microorganisms can be transferred to meat through several processes including skinning, scalding, evisceration, dressing, and handling. Cross-contamination often occurs via contact with contaminated tools, surfaces, equipment, and the hands of butchers (Ovuru et al., 2024).

Even after slaughter, bacterial contamination continues to affect meat during cutting, packaging, transportation, and retail display (Velebit et al., 2021). One of the most effective ways to slow down bacterial growth is by storing meat at low temperatures. Refrigeration significantly reduces microbial metabolism, while freezing can halt microbial activity entirely (Liang et al., 2021). However, environmental conditions such as temperature fluctuations during distribution can allow dormant microorganisms to reactivate and multiply. Zwirzitz et al. (2020) explain that bacteria may pause growth under harsh conditions and resume once the environment becomes favorable again.

Spoilage not only threatens food safety but also leads to economic losses. These effects may not always be visible in the early stages, but as spoilage progresses, meat exhibits discolouration, off-putting odours, and the formation of surface slime—factors that influence consumer rejection (Nychas et al., 2022). According to McDonald and Sun (2019), meat is highly perishable and becomes unsafe if not properly stored, processed,

packaged, or distributed. Once spoilage sets in, the product is no longer suitable for human consumption (Bradeeba & Sivakumaar, 2018).

Temperature and pH are critical in determining microbial spoilage rates. High ambient temperatures can accelerate bacterial growth, while maintaining cold chain conditions can extend the shelf life of meat significantly (Nethra et al., 2023). Likewise, the pH of meat influences the activity of spoilage bacteria. Koutsoumanis et al. (2021) noted that meat with a pH closer to 6.0–6.5 is more vulnerable to microbial contamination, compared to meat with lower pH values. Lawrie (2017) emphasized that pH monitoring is a valuable tool for predicting spoilage and estimating shelf life.

CHAPTER THREE

METHODOLOGY

3.1 Introduction

This chapter encompasses the background of the study area, research design, target population, inclusion and exclusion criteria, instrument for data collection, sampling procedure and sample size, source of data, quality control, ethical consideration, and how the data was collected and analyzed.

3.2 Study area

The study occurred in the Kumasi Metropolis, one of the 30 districts in the Ashanti Region of Ghana. It is located 250–300 meters above sea level and lies between latitudes 6.35°N and 6.40°S and longitudes 1.30°W and 1.35°E. Bosomtwe District is to the south, Asokore Mampong and Ejisu-Juaben Municipality are to the east, Kwabre East and Afigya Kwabre Districts are to the north, and Atwima Kwanwoma and Atwima Nwabiagya Districts are to the west of the Metropolis. It is located approximately 270 km north of the national capital, Accra, covering an area of about 214.3 square kilometres, which constitutes around 0.9 per cent of the region's total land area. Nevertheless, it houses about 36.2 % of the region's population. Kumasi emerged as the new Asante State's capital, formed through several city-states' voluntary union. The British Colonial Authority reinstated the Asanteman Traditional Council, the governing body of the old Asante Kingdom, in 1935, designating Kumasi as its seat. However, political power remained with the British Colonial Government based in Accra (Kudoda, 2019).

The Kumasi Abattoir is one of the facilities in developing countries where animals are brought locally and internationally from farms after long journeys. Cattle intended for

slaughter at the Kumasi Abattoir are transported from various regions in Ghana, such as Yeji in Brong Ahafo and northern Ghana, as well as from neighbouring countries like Burkina Faso and Mali. The abattoir is located at latitude 6°39'36.6"N and longitude 1°36'15.4"W in Kumasi, with the butchers distributing the meat within the city.

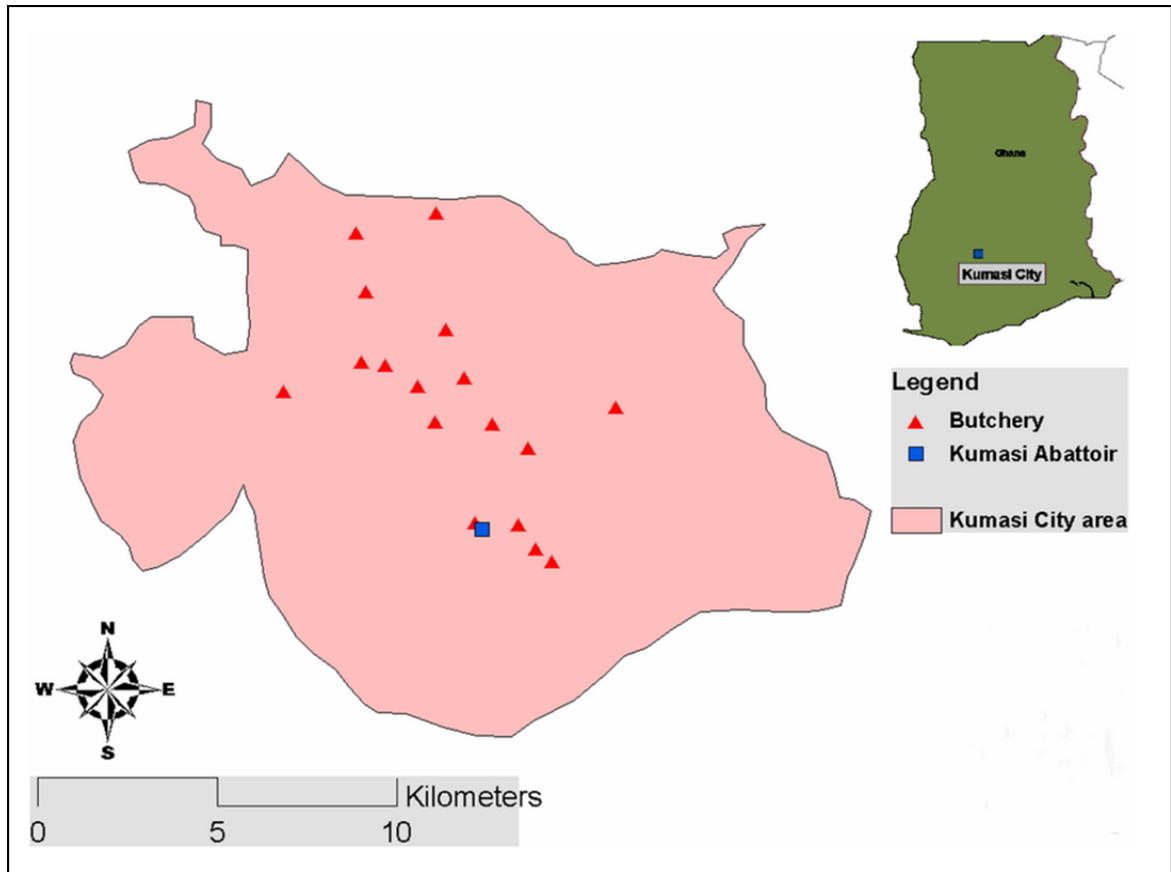


Figure 3.1: Map of Kumasi showing the Kumasi Abattoir and other butcheries within the city (Source: Ghana Statistical Service, GIS)

3.2.1 Kumasi Abattoir

The Kumasi Abattoir Company Limited was founded in 1997 with funding from the Government of Ghana and the Canadian International Development Agency (CIDA), beginning operations in 1998. Located approximately 150 meters from the abattoir is a cattle market, which features kraals for housing animals while they are sold, along with a holding pen for cattle awaiting slaughter. This holding pen, situated about 10 meters from the slaughterhouse, keeps cattle overnight until the following morning when they

are processed. There is also a lairage intended for resting animals prior to slaughter. Nearby, about 100 meters from the slaughterhouse, are a non-functional waste treatment plant and an abandoned fish pond. While the Kumasi Abattoir handles various animals, including cattle, pigs, sheep, and goats, for processing and packaging for the Ghanaian market, this study focuses solely on cattle. Initially, the abattoir had a daily slaughter capacity of 200 cattle, 100 pigs, and 250 sheep and goats. The facility has since been redesigned, allowing for an increased capacity of up to 400 cattle per day by converting one of the sheep and goat slaughter lines into an additional cattle line and adding a singeing platform.

3.3 Research design

This study adopted a cross-sectional survey research design to determine the microbial quality of meat from the Kumasi Metropolis to meat retail outlets at the Kejetia market in the Kumasi Metropolitan Assembly. The study used a quantitative data collection procedure, where meat samples from the Abattoir to meat retail outlets were aseptically collected before and after transportation for bacterial counts. Observations were employed to gather information on the meat handling practices of meat handlers both at the abattoir and during transportation to the market.

3.4 Source of data

The study used primary data from a questionnaire to elicit information from the butchers who transport their meat from the abattoir to the meat retail outlets at the Kejetia market. Bacterial counts from collected meat samples before and after transportation to the retail points were also used in the study.

3.5 Population and sample size

The study was restricted to the Kejetia market. The target population for this study consisted of butchers who transported their meat or carcasses along the supply chain from the Kumasi abattoir company limited to meat retail outlets at the Kejetia market. The total number of butchers taking the meat from the abattoir to the meat retail outlets at the Kejetia market were 20. All butchers conveying carcasses to the markets were included in the study due to their small number. According to Sharma (2017), a study where the entire population is studied gives complete accuracy and no sampling bias. This promoted the acquisition of comprehensive information from respondents.

3.6 Inclusion and Exclusion Criteria

The study included individual butchers selling meat at the Kejetia market who were actively transporting their meat from the abattoir and willingly agreed to participate. Those butchers selling in other markets or areas and transporting meat from the abattoir to different locations were excluded, as were butchers at Kejetia who were not directly involved in transporting their meat from the abattoir.

3.7 Sampling Procedure

Meat samples were collected from all 20 butchers before and after transportation along the supply chain from the abattoir to the retail outlet at Kejetia market. These samples were placed in sterile plastic bags and labelled according to the sampling locations (Abattoir and Kejetia Market) before being sent to the Department of Theoretical and Applied Biological, at Kwame Nkrumah University of Science and Technology (KNUST) in Kumasi, Ashanti region, for bacteriological analysis.

3.8 Data Collection Tools

An observational checklist was employed to ascertain the meat handling and storage practices during the transportation of meat and the possible risk factors contributing to carcass contamination along the supply chain from the abattoir to retail meat outlets. This was used to record various factors and conditions such as handling practices, transportation conditions, vehicle cleanliness, packaging and storage, time and duration, environmental hygiene and sanitation, employee hygiene and sanitation, and meat condition, among others, to identify potential risks and areas for improvement about microbial contamination of meat. The instrument was meant to cover every aspect of the study, which helped to achieve the purpose of the study.

3.9 Procedure for Data Collection

3.9.1 Data Collection from the Participants

The observation gathered information on meat handling and storage practices employed at the abattoir during processing and the butchers during transportation along the supply chain. Throughout the study, observations were made on transporting carcasses to meat retail outlets at the Kejetia Market. This involved accompanying butchers during their daily activities and recording their practices.

3.9.2 Collection of Meat Samples

Meat samples were collected using aseptic techniques and placed into sterile zip bags. The samples were obtained by purchasing from the butchers. They were stored in an ice chest at 0°C and promptly transported to the Microbiological Laboratory for analysis. This was crucial for preserving the viability and integrity of the bacteria during transit to the laboratory. A total of 40 meat samples were taken for the microbial analysis.

3.10 Laboratory Methods and Analysis

3.10.1 Media preparation

Media preparation and microbial identification through colony morphology and biochemical methods followed Oxoid standard protocols. The reagents used included Phosphate Buffer Solution (PBS), Plate Count Agar (Oxoid, England), MacConkey Agar (Oxoid, England), Salmonella-Shigella Agar, and Mannitol Salt Agar (Oxoid, England). MacConkey Agar was utilized for culturing and isolating Gram-negative bacteria, Salmonella-Shigella Agar was for differentiating and isolating *Salmonella* and *Shigella* spp., and Mannitol Salt Agar was for isolating *Staphylococcus aureus* (Sagar A., 2019).

3.10.2 Sample Preparation

Meat samples were collected under aseptic conditions. Ten (10) grams of each meat sample were added to 10 ml of Buffered Peptone Water (BPW) to create an initial dilution (stock solution), followed by further dilution using 5 ml of BPW as the diluent. An antiseptic pipette was used to transfer 1 ml of aliquots from each dilution, which were labelled accordingly and the various bacteriological microbes were subsequently isolated.

3.10.3 Inoculation and counting of bacteria colonies

Following the sample preparation, an antiseptic pipette was used to inoculate 1 millilitre of the prepared sample onto the appropriate agar plates for culturing. The inoculum was carefully streaked on the agar to ensure even distribution. The types of agar used in this study included MacConkey Agar (MA), Shigella-Salmonella Agar (SSA), and Mannitol Salt Agar (SMA). After inoculation and streaking, the plates were incubated at the

specified temperatures. The bacterial colonies were then enumerated using the pour plate method and a colony counter.

3.10.4 Inoculation and estimation of *Escherichia coli*

Escherichia coli was isolated and quantified using the MacConkey Agar (MA) pour plate method. Serial dilutions of 10^{-1} , 10^{-2} , 10^{-3} , & 10^{-4} were prepared. Ten (10) grams of each carcass sample were weighed, placed in 90 millilitres of peptone water, and then treated in a pulcifier for 15 seconds. One millilitre of aliquots from each dilution (10^{-1} , 10^{-2} , 10^{-3} , & 10^{-4}) was inoculated into Petri dishes containing prepared MA. The plates were incubated at 35°C for 24 hours. After incubation, pink colonies indicating *E. coli* were counted and recorded using a colony counter.

3.10.5 Inoculation and estimation of *Salmonella sp.* and *Shigella*.

Serial dilutions of 10^{-1} , 10^{-2} , 10^{-3} , & 10^{-4} were prepared to serve as diluents. Ten (10) grams of each meat sample were weighed and mixed with 90 millilitres of peptone water, then treated in a pulcifier for 15 seconds. Ten (10) millilitres of Buffered Peptone Water (BPW) was prepared and placed in a universal bottle, into which the serial dilutions of each sample were added. This mixture was then incubated at 37°C for 24 hours. Subsequently, 0.1 millilitres of the BPW sample were transferred into 10 millilitres of Selenite broth in the universal bottle and incubated at 44°C for 48 hours. A streak from the broth was then transferred onto SS Agar and incubated at 37°C for 37 hours. The expected indicators of *Salmonella* and *Shigella* were black colonies and cream colonies on the SS Agar, respectively. In this experiment, only *Shigella* was detected, indicating the absence of *Salmonella*.

3.10.6 Inoculation and estimation of *Staphylococcus* sp.

Staphylococcus sp. was isolated and counted using the Salt Mannitol Agar (SMA) pour plate method. Serial dilutions of 10^{-1} , 10^{-2} , 10^{-3} , & 10^{-4} were prepared as diluents. Ten grams of each meat sample were weighed and added to 90 millilitres of peptone water, then treated in a pulcifier for 15 seconds. One millilitre aliquot from each dilution (10^{-1} , 10^{-2} , 10^{-3} , & 10^{-4}) was inoculated into Petri dishes containing prepared SMA. The plates were incubated at 37°C for 24 hours. After incubation, yellow colonies indicative of *Staphylococcus* were counted and recorded as the *Staphylococcus* count using a colony counter.

3.11 Quality control

Quality control measures were taken during the analysis to confirm the accuracy of the results. In every analytical batch, all samples were analyzed separately with serial dilutions to ensure accuracy.

3.12 Data analysis

Raw data from microbial analysis were then entered into a Microsoft Excel 2016 spreadsheet and transformed into log₁₀ for normal distribution. SPSS version 20 was also used to analyze data gathered using observation and questionnaire into percentages. A t-test was conducted to compare the means of bacterial counts obtained from the meat samples to check if there was a significant difference at (P=0.05). The results were presented in graphs and tables.

3.13 Ethical Considerations

Before the study was undertaken, written permission was sought from the Kumasi Abattoir Company Limited and the Kejetia Butchers Association. Ethical approval was obtained from the Committee on Human Research, Publications, and Ethics at the Kwame Nkrumah University of Science and Technology (KNUST-CHRPE/AP/831/24). Consent was also sought from individual butchers.

CHAPTER FOUR

RESEARCH FINDINGS AND DISCUSSIONS

4.1 Introduction

This chapter presents the results of the data gathered from participants at Kumasi-Kejetia. The results are presented in four major categories: butcher socio-demographic characteristics, handlers and transporters' meat handling practices in minimizing microbial contamination, and the microbial loads on meat before and after transportation from Kumasi abattoir to the Kejetia market.

4.2 Socio-demographic characteristics of respondents

4.2.1 Response rate

The study targeted all 20 butchers transporting meat from Kumasi Abattoir Company Limited (KACL) to the Kejetia market with a 100 % response rate. This ensured a broad view of butchers' knowledge and opinions regarding microbial contamination of meat transported from the Kumasi abattoir to Kejetia market.

4.2.2 Demographic information of butchers

Table 4.1 shows that 30 % of respondents were between 30 and 40, 41 and 50, and above 60. All the respondents were males (100 %), and 60 % were Muslims, whereas 50 % had no formal education. Meanwhile, 30 % had basic education, 55 % had worked for more than 20 years in the meat retailing business, and 15 % had worked between 1 and 4 years.

Table 4. 1: Demographic information of butchers

Variable	Frequency (n)	Percentage (%)
Age		
<30 years	2	10
30-40 years	6	30
40-50 years	6	30
>60 years	6	30
Sex		
Male	20	100
Female	0	0
Religion		
Christian	8	40
Islam	12	60
Traditionalist	0	0
Level of Education		
No formal education	10	50
Basic Education	6	30
SHS/SSS	4	20
Tertiary Education	0	0
Years in Work		
1 - 4 years	3	15
5 - 10 years	5	25
11 - 20 years	6	30
Above 20 years	6	30
Marital Status		
Married	14	70
Single	6	30

(Source: Field Survey, 2024.)

4.3 Meat handling practices employed by handlers and transporters in Kumasi Metropolis

This section presents results for objective 1, which assesses meat handling practices employed by handlers and transporters to minimize microbial contamination.

4.3.1 Observed Meat Handling Practices at the Abattoir

Table 4.2 presents the results on the observed meat handling practices employed by handlers at the abattoir.

Table 4.2: Summary of Observed Meat Handling Practices at the Abattoir

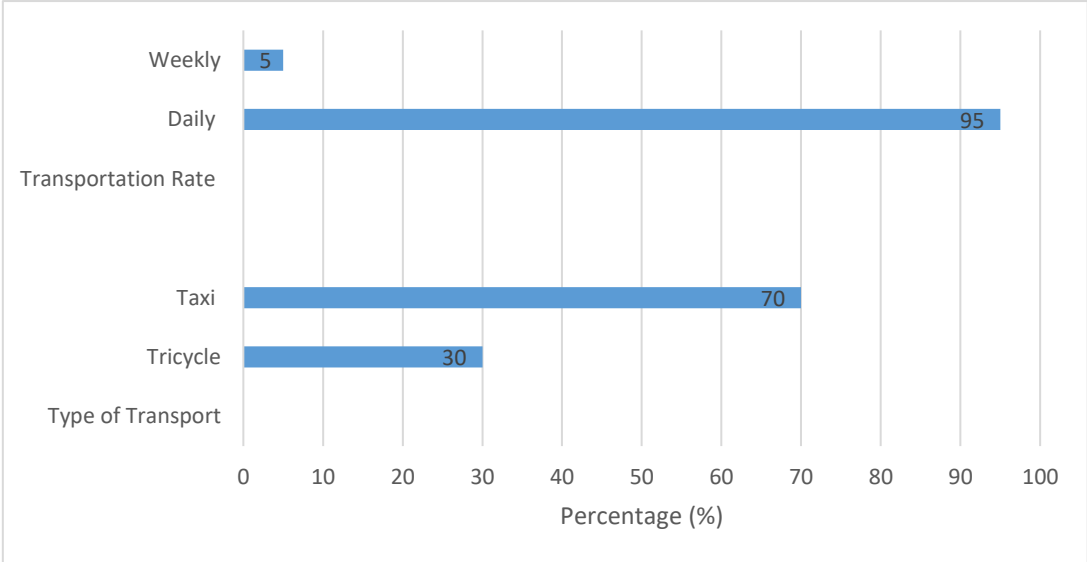
Meat Handling Practice	Observation	Issues Identified
Daily Cleaning of the Abattoir	The abattoir was cleaned daily after the end of the day's work.	Inconsistent cleaning practices and insufficient drainage system.
Anti-mortem and Post-mortem Inspections	Conducted by veterinary officers on animals and carcasses.	No issues were identified; inspections were appropriately conducted.
Carcass Handling (Rails vs. Floor)	Carcasses were placed on rails to minimize contamination; some were found on the floor in pools of blood.	Cross-contamination risk due to carcasses being placed on the floor.
Use of Protective Clothing by Butchers	Some butchers did not wear protective clothing (e.g., hair restraints).	Lack of protective gear increases contamination risk.
Sterilization of Equipment	Butchers did not work with sterilized equipment or disinfect the dressing area.	Increased risk of contamination due to lack of sterilization.
Exposure to Flies	Carcasses were exposed to flies without proper storage conditions (e.g., chilling room).	Risk of contamination by flies, no proper chilling facilities.
Spitting, eating in meat handling areas	Butchers were observed eating and spitting outside the carcass handling and processing areas.	No risk of contamination of carcasses at the abattoir through food or spits.
Waste Management	Poor waste management with a heap of animal waste close to the abattoir, producing foul odours.	Improper waste disposal and hygiene.
Support for Chilling Carcasses	Most butchers opposed chilling carcasses before transportation to the market.	Lack of support for proper storage methods, increasing contamination risk during transport.
Footwear and Protective Clothing for Butchers	Butchers entered the carcass dressing area without changing footwear or wearing protective clothing.	Increased risk of contamination from footwear and lack of personal protection.

(Source: Field Survey, 2024.)

Table 4.2 showed several important aspects that contribute to the overall hygiene and safety of the meat processing environment. Daily cleaning was conducted, and proper veterinary inspections were carried out on animals and carcasses. However, issues related to inadequate hygiene, protective clothing, and storage practices were identified. Carcasses were occasionally found on the floor, and butchers did not consistently use protective gear or sterilize equipment.

4.2.2 Meat handling and transportation practices among butchers

Figure 4.1 presents results on the transportation rates and methods, and table 4.3 presents the meat handling practices employed by butchers along the transportation chain to the market outlet.



(Source: Field Survey, 2024.)

Figure 4.1 Transportation Methods and Rates

Figure 4.1 shows that 95 % of the butchers transported their carcasses/meat from the KACL to a market outlet daily, and 70 % employed the services of a commercial taxi. Meanwhile, 30 % of them relied on tricycles for carting carcasses to the markets.

Table 4. 3: Carcasses handling practices among butchers transporting to the market

Checklist/Observation	Yes (%)	No (%)
Use appropriate transports to cart carcasses to sale outlets.	0	100
Wear the proper PPE while conveying carcasses to the market outlet.	30	70
Use proper equipment to handle carcasses conveying to market outlets.	0	100
Meat exposed to flies during transportation.	0	100
Use proper storage containers and materials for carting meat carcasses.	0	100
Carcasses are stored at correct temperatures while conveyed to markets.	0	100
Carcasses are exposed to weather during transportation.	100	0
Disinfect the meat-holding areas before loading the meat.	50	50
Wear a hair net while transporting carcasses to the markets.	0	100
Carcasses are placed directly on the transport floor.	0	100
Carcass exposed to dust during transportation	0	100
Carcasses are adequately chilled to 5° before loading into transport.	0	100
Carcasses exposed to weather during transportation	100	0

Source: Field Survey, 2024.

Table 4.3 showed that, all the butchers (100 %) did not use the correct transportation to cart carcasses, and 30 % used the appropriate PPEs, whereas all (100 %) of them exposed the carcasses to flies, did not use the proper containers, exposed carcasses to the weather, and did not store the carcasses at the right temperature while transporting to the market. Half (50 %) of them disinfected the carcass-holding areas before loading the meat, all (100 %) of them did not put on hair net while transporting carcasses to the markets, had their meat placed directly on the floor of the transport, had their meat free from dust particles during transportation, never had their carcasses adequately chilled to 5° before loading into transport, and had their carcasses exposed to weather during transportation.

4.4 Microbial contaminants on meat samples before and after transportation

Tables 4.4 and 4.5 presents the microbial load of meat samples collected from butchers before and after transportation respectively using MacConkey Agar (MCA), Mannitol Salt Agar (MSA), and Salmonella Shigella Agar (SSA).

Table 4.4 Mean microbial count on different culture media before transportation

Butchers	MCA (cfu/ml)	Log	MSA (cfu/ml)	Log	SSA (cfu/ml)	Log
1	7.90×10 ⁴	4.89	1.50×10 ⁴	4.17	9.00×10 ⁴	4.95
2	3.40×10 ³	3.57	2.60×10 ⁴	4.41	2.30×10 ⁵	5.36
3	4.90×10 ²	2.69	3.60×10 ⁴	4.55	0.00×10 ⁰	0.00
4	2.40×10 ³	3.38	4.50×10 ⁴	4.65	9.00×10 ⁴	4.95
5	3.40×10 ³	3.53	6.20×10 ⁴	4.79	2.30×10 ⁵	5.36
6	2.90×10 ⁵	5.46	3.00×10 ⁵	5.48	6.50×10 ⁴	4.81
7	2.90×10 ⁴	4.46	5.60×10 ⁴	4.75	9.00×10 ⁴	4.95
8	7.90×10 ³	3.89	4.40×10 ⁴	4.64	3.20×10 ⁵	5.51
9	1.20×10 ⁵	5.07	2.80×10 ⁴	4.44	1.30×10 ⁵	5.11
10	2.30×10 ⁴	4.36	6.00×10 ⁴	4.78	2.30×10 ⁵	5.36
11	4.50×10 ⁴	4.65	8.40×10 ⁴	4.92	1.60×10 ⁴	5.20
12	6.10×10 ⁴	4.78	3.90×10 ⁴	4.59	2.30×10 ⁵	5.36
13	3.50×10 ⁴	4.54	3.50×10 ⁴	4.54	1.60×10 ⁴	4.20
14	4.5×10 ⁴	4.65	3.10×10 ⁴	4.49	2.30×10 ⁵	5.36
15	6.50×10 ⁴	4.81	3.60×10 ⁴	4.55	6.60×10 ⁴	4.82
16	8.80×10 ⁴	4.94	1.50×10 ⁴	4.17	0.0×10 ⁰	0.00
17	1.00×10 ⁴	4.00	5.90×10 ⁴	4.77	4.00×10 ⁴	4.60
18	1.00×10 ⁴	4.00	1.20×10 ⁵	5.07	9.00×10 ⁴	4.95
19	3.90×10 ⁴	4.59	3.10×10 ⁴	4.49	2.30×10 ⁴	4.36
20	1.90×10 ⁴	4.27	1.70×10 ⁴	4.23	4.00×10 ⁴	4.60

MCA= MacConkey Agar, MSA=Mannitol Salt Agar, SSA=Salmonella Shigella Agar, Log=logarithm, cfu/ml= Coliform forming unit/millilitres.

Table 4.5: Mean Microbial Count on Different Culture Media After Transportation

Butchers	MCA (cfu/ml)	Log	MSA (cfu/ml)	Log	SSA (cfu/ml)	Log
1	3.50×10 ⁵	5.54	5.7×10 ⁴	4.76	2.30×10 ⁵	5.36
2	3.80×10 ³	3.53	5.5×10 ⁴	4.74	2.30×10 ⁵	5.36
3	5.70×10 ⁴	4.76	7.8×10 ⁴	4.89	9.00×10 ⁵	5.95
4	2.80×10 ⁵	5.45	4.4×10 ⁵	5.64	3.20×10 ⁵	5.51
5	1.90×10 ⁵	5.28	1.5×10 ⁵	5.17	2.30×10 ⁵	5.36
6	9.40×10 ⁵	5.97	3.0×10 ⁵	5.48	2.30×10 ⁵	5.36
7	6.70×10 ⁴	4.83	2.2×10 ⁵	5.34	9.10×10 ⁶	6.96
8	4.00×10 ⁵	5.60	6.4×10 ⁴	4.80	3.20×10 ⁵	5.51
9	8.00×10 ⁵	5.90	4.8×10 ⁴	4.68	3.50×10 ⁵	5.54
10	1.90×10 ⁵	5.28	3.1×10 ⁵	5.49	2.30×10 ⁵	5.36
11	3.40×10 ⁵	5.53	3.1×10 ⁵	5.49	4.10×10 ⁵	5.61
12	2.40×10 ⁵	5.38	4.3×10 ⁵	5.63	3.20×10 ⁵	5.51
13	5.40×10 ⁵	5.73	9.1×10 ⁴	4.96	3.20×10 ⁵	5.51
14	6.40×10 ⁵	5.81	9.9×10 ⁴	5.00	6.60×10 ⁵	5.82
15	3.80×10 ⁵	5.58	1.7×10 ⁵	5.23	3.20×10 ⁵	5.51
16	1.70×10 ⁵	5.23	2.2×10 ⁵	5.34	2.30×10 ⁵	5.36
17	1.40×10 ⁵	5.15	1.8×10 ⁵	5.26	9.00×10 ⁵	5.95
18	3.60×10 ⁵	5.56	1.5×10 ⁶	6.18	3.20×10 ⁵	5.51
19	4.00×10 ⁵	5.60	4.2×10 ⁵	5.62	3.20×10 ⁵	5.51
20	4.00×10 ⁵	5.60	3.2×10 ⁵	5.51	2.30×10 ⁵	5.36

MCA= MacConkey Agar, MSA= Mannitol Salt Agar, SSA= Salmonella Shigella Agar, Log=logarithm, cfu/ml= Coliform forming unit/ millilitres.

Tables 4.4.and 4.5 revealed that, the mean bacterial count on MCA before transportation, ranged from 4.9×10² cfu/ml (log 2.69) to 2.9×10⁵ cfu/ml (log 5.46). On MSA, bacterial counts varied between 1.5×10⁴ cfu/ml (log 4.18) and 3.1×10⁵ cfu/ml (log 5.49). The highest microbial load recorded on SSA, with a peak value of 3.2×10⁵ cfu/ml (log 5.51), while some samples recorded no growth. After transportation, the microbial load was

generally increased across all culture media. The mean microbial count on MCA ranged from 3.4×10^3 cfu/ml (log 3.53) to 9.4×10^5 cfu/ml (log 5.97). On MSA, bacterial counts ranged from 4.3×10^4 cfu/ml (log 4.64) to 1.5×10^6 cfu/ml (log 6.18). The highest microbial count was observed on SSA (9.1×10^6 cfu/ml, log 6.96), indicating significant bacterial growth during transportation.

4.5 Number of infected butchers' meat and microbial counts on different culture media before and after transportation

The number of butchers with contaminated meat and microbial counts both before and after transportation to the market outlets are presented in tables 4.6 and 4.7 respectively.

Table 4.6: The number of butchers with infected meat

Culture Media	Bacteria Isolates	Infected Meat Samples	Infected Meat Sample
		before transportation (Frequency)	after transportation (Frequency)
MCA	<i>E. coli</i>	20	20
MSA	<i>Staphylococcus</i> spp.	20	20
SSA	<i>Shigella</i> spp.	18	20

MCA=MacConkey Agar, MSA= Salt Agar, SSA=Salmonella-Shigella Agar, E. coli=Eschericia coli, Staph. Spp=Staphylococcus species.

Table 4.6 indicated that all meat samples were contaminated with *E. coli* and *Staphylococcus spp* both before and after transportation. In contrast, for *Shigella*, 18 meat samples were contaminated before and 20 samples after transportation.

Table 4. 7: Log-Transformed Microbial Counts

Medium	Target Bacteria	Time	Mean log (cfu)	p-value	Mean Log Difference (After – Before)	Explanation
MCA	<i>E. coli</i>	Before	4.69	0.001	0.84	Poor temperature control during transit likely promoted gram-negative growth.
		After	5.53	0.001		
MSA	<i>Staph. spp.</i>	Before	4.75	0.014	0.64	Human handling during transportation may have introduced <i>Staphylococcus</i> .
		After	5.39	0.014		
SSA	<i>Shigella</i>	Before	4.04	0.001	1.55	Significant pathogen growth suggests inadequate sanitation during transit.
		After	5.59	0.001		

MCA=MacConkey Agar, MSA= Mannitol Salt Agar, SSA=Salmonella-Shigella Agar, Log=logarithm, cfu/ml= Coliform forming unit/millilitres, P-value=probability value, E. coli=Eschericia coli, Staph. Spp=Staphylococcus species.

Table 4.7 revealed that the Log-transformed microbial counts increased across all media after transportation. For MCA, mean log counts rose from 4.69 to 5.53, indicating a marked increase in gram-negative bacteria. MSA showed a moderate rise in mean counts from 4.72 to 5.39 while SSA exhibited high variability before transportation likely due to zero-adjusted values (Butchers 3 and 16). After correcting for these zeros, SSA counts increased significantly post-transportation (mean log = 5.59).

Table 4.7 further revealed that all media showed statistically significant increases in microbial counts after transportation ($P < 0.0167$ after Bonferroni correction). SSA exhibited the most significant mean log difference (+1.55, $P < 0.05$). MSA demonstrated a more minor but significant increase ($P < 0.05$), suggesting moderate growth of *Staphylococcus spp* (Table 4.5).

MCA-selected gram-negative bacteria (*E. coli*) surged from 7.9×10^4 to 3.5×10^5 cfu/ml. MSA-targeted *Staphylococcus spp.* doubled (2.6), likely due to human contact during

handling. SSA-specific pathogens (*Shigella*) increased significantly ($P<0.05$), indicating potential contamination risks during transportation.

4.6 Knowledge and awareness of butchers regarding meat hygiene and Safety and possible factors influencing meat contamination

Tables 4.8 and 4.9 presents the results on the levels of consciousness of butchers on the subject of meat hygiene and safety respectively and possible factors influencing meat contamination.

Table 4.8: The consciousness of butchers regarding meat hygiene

Statement	Yes (%)	No (%)
Understand the importance of washing hands before handling meat	85	15
Use gloves while handling meat	70	30
Know the recommended temperature for storing meat ($\leq 5^{\circ}\text{C}$)	35	65
Are you aware of the risks associated with cross-contamination	50	50
Disinfect tools and equipment before using them	65	35
Know how to recognize spoiled meat	55	45
Have formal training on meat hygiene and safety	60	40
Are familiar with proper storage methods for meat	70	30
Follow guidelines for temperature control during transport	30	70
Use hair restraints while handling meat	65	35
Keep meat away from flies during storage and transport	55	45

Source: Field Survey, 2024

Table 4.8 revealed that most butchers (85 %) understood the importance of handwashing before handling meat, and 70 % the importance of using gloves during meat handling. In terms of meat storage, only (35 %) were aware of the correct temperature for storing meat ($\leq 5^{\circ}\text{C}$), while (70 %) knew the proper storage methods. Despite this, only (30 %) understood temperature control guidelines during transportation. Half of the butchers (50 %) were aware of cross-contamination risks, whereas (65 %) understood the need to disinfect their tools and equipment regularly before using them. More than half (60 %) received formal training in meat hygiene. Regarding environmental factors, (54 %) understood the reasons behind keeping meat away from flies during storage, but (65 %) understood the use and the reasons behind the use of hair restraints, indicating gaps in protective measures during meat handling.

Table 4.9: Factors Influencing Meat Contamination (Using "No" as Reference)

Independent Variable	Odds Ratio (OR)	95 % CI for OR	P-value
Knowledge of Hygiene (Yes vs No)	2.5	1.2 - 5.3	0.014
Hygiene Training (Yes vs No)	1.8	1.0 - 3.2	0.032
Use of PPE (Yes vs No)	1.4	0.8 - 2.5	0.271
Hand-washing Practice (Regular vs Irregular)	3.2	1.5 - 6.9	0.003
Years of Experience (Years)	0.9	0.7 - 1.1	0.214
Storage Conditions (Yes vs No)	0.6	0.3 - 1.2	0.136
Use of Gloves (Yes vs No)	1.6	1.0 - 2.6	0.046
Cleaning Tools after Use (Yes vs No)	2.1	1.2 - 3.7	0.015
Regular Inspection of Meat (Yes vs No)	1.7	1.0 - 3.1	0.04

Source: Field Survey, 2024

The analysis showed that several factors affected whether butchers handled meat without bacterial contamination. Butchers who knew about hygiene were 2.5 times more likely

to avoid contaminating the meat (P=0.014). Similarly, butchers who had received hygiene training were 1.8 times more likely to keep the meat clean (P=0.032). Butchers who washed their hands regularly were 3.2 times more likely to prevent contamination (P=0.003). Using gloves also helped, with butchers being 1.6 times more likely to avoid contamination (P=0.046).

4.6 Discussions of Findings

4.6.1 Meat handling practices employed by handlers and transporters

According to Hudson and Lockless (2022), meat handling conditions are crucial for food safety and quality. It involves temperature control, cross-contamination prevention, personal hygiene, packaging and storage. The meat handling and transportation practices observed in this study revealed significant shortcomings that were likely to contribute to microbial contamination of meat. The findings of the study showed that majority of the butchers transporting meat from the Kumasi abattoir to their retailing centers was an everyday activity. This was to ensure the availability of meat to consumers at all time. This corroborates with the study of Rani et al. (2023), who opined that the marketing of meat and meat products are daily basis business that ensures daily slaughter and transportation of meat from abattoirs to market centers.

Also, it was observed that majority of the butchers constituting 70 % (14) relied on closed vehicles to transport their meat from the abattoir to the retailing centers. Examples of closed vehicles utilized by these butchers were commercial taxis. Again, 30 % (6) of the butchers also transported their meat products from the Kumasi abattoir to the retailing centers through open vehicles normally a tricycle. Upon further inquiries, participants explained that using commercial taxi and a tricycle were easiest means of transportation

to bring meat from the abattoir to the market. However, Richardson et al. (2019) maintained that refrigerator vans are specific design to transport meat and meat products from slaughter houses to retailing points. This is to maintain cold chain of meat to control bacterial growth and increase.

Further, it was also observed that half (50 %) of the butchers did not sanitize the meat holding areas in the vehicles before loading the meat. This had the tendency to increase micro-organism contamination during the transportation as vehicles might already be contaminated with bacterial. All the butchers (100 %) had their meat exposed to hot temperatures during transportation and wrapped with a rubber which had the tendency to exacerbate the growth of micro-organism contaminations. As opined by Cesar (2018), exposure of animal carcass to high temperatures provides favorable conditions for microbial growth and increase.

Another most notable finding was non-compliant transportation methods. Specifically, all the butchers in this study (100 %) relied on taxis and tricycles for transporting carcasses to the market instead of meat vans. This practice exposes meat to environmental contaminants such as dust, flies, and the weather, all known to increase the risk of contamination. Similar findings have been reported in other studies from low-resource settings. For instance, in Ethiopia, meat transported without proper refrigeration or in open vehicles was found to have increased bacterial contamination (Mwashuuya et al., 2018). Similarly, in Greece, the use of open trucks for transporting meat was linked to the proliferation of harmful bacteria like *Salmonella* and *E. coli* (Kostoglou et al., 2023). These studies reinforce the observation in this research that improper transport methods significantly contribute to microbial contamination.

Another critical issue identified in this study was the lack of temperature control during transportation. None of the butchers stored carcasses at the recommended temperature of $\leq 5^{\circ}\text{C}$, essential to minimize pathogenic bacteria growth. When they were further asked why they did not prefer chilled meat, they mentioned that their customers preferred their meat fresh instead of the chilled one.

This lack of refrigeration was linked with the post-transport surge in bacterial count as there was a statistically significant increase in microbial counts after transportation ($P < 0.0167$ after Bonferroni correction). This finding is consistent with studies conducted in other countries. In Kenya, for example, the absence of chilling facilities in slaughterhouses and vehicles was associated with increased bacterial load, particularly *E. coli* and *Salmonella* (Njoga et al., 2023). This was in line with the findings of (Banerjee et al., 2016), who concluded that unrefrigerated transportation and poor storage conditions increased the prevalence of *E. coli* and other pathogens in meat products. These studies further support the conclusion that improper meat handling and lack of refrigeration are key factors contributing to bacterial contamination.

Personal protective equipment (PPE) was another area where the butchers in this study fell short. Only 30 % of the butchers used appropriate PPE, such as gloves and aprons, during meat transportation. PPE is essential to reduce the risk of contamination during meat handling, as it acts as a barrier between the handler and the carcass. Similar trends have been reported in other studies, where gloves and aprons were found to reduce microbial contamination significantly. For instance, a study conducted in Egypt found that butchers who wore gloves and aprons during meat handling had lower bacterial contamination levels than those who did not (Kanko et al., 2023). Also according to a

related study by Sani and Siow Sani (2014) meat handlers were observed not to be using gloves. However, Addison (2015) found that a much greater proportion of food handlers wore aprons, hair caps, and gloves, which runs counter to the findings of this investigation. The fingertips are susceptible to contamination from microorganisms including *Salmonella* and *Escherichia coli*. All food handlers should wash their hands before handling food, according to Addison (2015). The low use of PPE in this study suggested that a lack of awareness or resources may hinder the improvement of hygiene practices in meat handling. Contrary to this study's finding, Chepkemai et al. (2015) discovered that, over the course of their daily job at the abattoir, 70% of butchers in Nairobi and 82% of those in Isiolo Counties, respectively, did not wear protective gear. Since protective equipment is supposed to restrict contamination from workers' bodies, this is a good practice that can help reduce meat contamination.

Furthermore, the study highlighted the poor waste management practices at the abattoir, which likely contributed to the overall contamination risk. Animal waste was found near the abattoir, and the foul smell further indicated inadequate waste disposal procedures. This is consistent with findings from other studies showing poor waste management in slaughterhouses as a significant risk factor for contamination. These conditions at the abattoir tend to introduce and exacerbate the increase of microorganisms in animal carcasses. These conditions are similar to the findings of Anim-Larbi et al. (2017) at the Obuasi abattoir, where the researchers observed a heap of animal waste close to the abattoir with free contact of flies to the animal carcass. These conditions are avenues for microbial contamination on animal carcasses. Again, in a study conducted in Uganda, inadequate waste management practices in abattoirs were linked to high contamination levels in meat products (Ayalew et al., 2015). Proper waste management, including the

disposal of animal waste and the maintenance of clean environments, is critical to reducing the risk of contamination.

The findings from this study emphasized the need for improvement in meat handling practices, particularly in the transportation and storage of meat. The use of appropriate transport vehicles with refrigeration facilities, as well as the use of PPE by butchers, is essential to reduce the risk of contamination. Additionally, better waste management practices at abattoirs are necessary to minimize microbial risks. Policymakers and stakeholders in the meat industry should prioritize these areas to ensure the safety of meat products and protect public health.

4.6.2 Microbial contaminants on meat samples before and after transportation

The study showed that raw meat sold in retail settings was highly vulnerable to microbial contamination. These results are similar to those of Olu Taiwo et al. (2021) and (Adjei et al. (2022), who discovered that the majority of the beef sold was contaminated with harmful bacteria in Accra and Ashaiman, Ghana, respectively. Studies from China, Ethiopia, Pakistan, and Nigeria have all reported similar results (Asati et al., 2024). Microbes can contaminate meat at several points in time, including during processing, shipping, and slaughter. To protect public health from the dangers of food-borne bacterial diseases, it is imperative to enhance the chain of handling and processing meat (Kanko et al., 2023). For the meat industry, microbial populations in meat provide a serious problem (Komba et al., 2012).

The microbial analysis in this study showed a significant increase in bacterial contamination after meat transportation. All meat samples were contaminated with *E.*

coli and *Staphylococcus spp* both before and after transportation. In contrast, for *Shigella*, 18 meat samples were contaminated before and 20 samples after transportation. Salmonella-Shigella Agar (SSA) had the highest contamination level, with a peak value of 9.1×10^6 exceeding cfu/ml (log 6.96). This high bacterial count meant that meat was at a high risk of carrying foodborne pathogens, which could cause serious health problems. *E. coli* and *Shigella* indicated faecal contamination, often linked to poor hygiene and unsanitary conditions during handling and transportation.

One of the key findings in this study was the rise in *Staphylococcus spp.* after transportation. The results showed an increase from 1.5×10^4 cfu/ml (log 4.18) and 3.1×10^5 cfu/ml (log 5.49) before the meat was transported to 4.3×10^4 cfu/ml (log 4.64) to 1.5×10^6 cfu/ml (log 6.18) after the transportation. The increase in *Staphylococcus* showed a significant difference at ($P > 0.05$). This suggests that human handling contributed to additional contamination. The increase in *Staphylococcus* contamination may have risen from using unapproved vehicles and the prevailing conditions used to transport the meat (WHO, 2021). Hudson and Lockless (2022) reported that contamination of *Staphylococcus* occurs easily in commercial vehicles used to transport meats due to the bacterial reliance and frequent presence on human skin, making it easy to spread on contaminated surfaces. Poor hygienic conditions of vehicles used to transport meat at warmer temperatures remain a factor in increasing *the Staphylococcus* contamination after transportation. Similar results have been reported in studies from Ethiopia, where butchers and meat handlers without proper protective clothing were found to introduce *Staphylococcus aureus* contamination into the meat (Feben et al., 2018; Tamir et al., 2021). In both studies, researchers found that a lack of proper handwashing and the use of unclean equipment significantly increased bacterial loads.

Another major factor contributing to microbial contamination was the absence of refrigeration during meat transportation. Many butchers in this study did not store their meat under proper cooling conditions before reaching the market. Studies from Nigeria and Kenya also observed that meat transported without refrigeration had significantly higher microbial counts than meat stored at low temperatures. Cold storage helps slow bacterial growth, reducing the risk of contamination (Chepkemoi, 2016). However, refrigeration was unavailable or not used consistently by butchers and meat traders in many low-resource settings. Also, this study observed that meat was often exposed to inappropriate temperatures, and other environmental contaminants during transportation. These findings are similar to a study in Ghana, where researchers found that transporting meat in unapproved vehicles led to increased contamination from airborne microbes and insects due to insufficient vans (Sulley, 2006).

The high levels of *Shigella* contamination in this study was alarming, as these bacteria are responsible for serious foodborne infections. *Shigella* contamination may have increased due to using unapproved vehicles and the prevailing conditions for transporting the meat. Jeremiah & Gibson (2021) opined that *Shigella* is notable for spreading quickly even with minimal exposure to contaminated vehicles used to carry food or waste without proper containment. In warmer conditions, as is typical with vehicles used by butchers to transport their meats, coupled with poor hygienic conditions of the vehicles, the growth rate and the number of *Shigella* were promoted. This finding resonates with the WHO report (2021) on food-borne disease outbreaks, which stated that transporting meat in unregulated vehicles with multi-purpose use exposes the meat to microbial contamination at the risk of disease outbreak.

Also, similar studies in Western Nigeria found that *Shigella*-contaminated meat caused food poisoning outbreaks due to poor meat handling (Akinro, 2009). In these countries, improper meat inspection and inadequate hygiene practices were linked to an increased risk of gastrointestinal diseases among consumers. The findings of this study highlighted the urgent need for better meat handling and transportation practices. Proper use of personal protective equipment (PPE), regular handwashing, cleaning of tools, and refrigerated transport could significantly reduce microbial contamination. Studies from Ethiopia have shown that when these measures are enforced, there will be little or no contamination by micro-organisms, whether bacteria, yeasts, moulds, viruses, or protozoa (Osama and Gehan, 2011). Training butchers and meat handlers on food safety and ensuring strict hygiene regulations could significantly reduce the risks associated with contaminated meat.

Further, it was noted that the mean count of *E. coli* bacterial contamination on the carcass before transportation to the market outlet significantly increased ($P < 0.05$). This increase in *E. coli* may be due to unapproved vehicles and the prevailing conditions for transporting meat from the Kumasi abattoir to the market centre, typically taxis and tricycles. According to Aworh et al. (2021), *E. coli* bacteria can survive on surfaces, and food and animal handlers and other passengers can spread *E. coli*, which can contaminate transported meat. Inadequate hygiene practices and exposure of meat to high temperatures were favourable conditions for *E. coli* bacteria to increase rapidly. This corroborates Azad et al. (2019) assertion that bacteria are found to increase exponentially at higher temperatures and in poor hygienic environments.

Finally, the loading of the carcasses may have contributed to the increase in their microbial contamination. These aligns with the study by (Kilgannon et al., 2019) which revealed that the contamination levels of *E. coli* on all meat kinds were greater ($P < 0.05$) between the loading and off-loading points. Beef increased between 4.7 and 4.9 log cfu/cm². The best explanation for these finding was that workers handled the carcasses carelessly when loading and unloading, failing to wear protective gear. This may have led to microbial cross-contamination because the carcasses were placed on the workers' shoulders as they were being loaded from the chiller rooms to transport vehicle.

4.6.3 Knowledge and Awareness of Butchers Regarding Meat Hygiene and Safety

The study determined the microbial quality of meat transported from the Kumasi abattoir to the Kejetia market. According to an observational research by Ansari-Lari et al. (2010), food handlers with excellent knowledge demonstrated food safety in their operations, whereas those with insufficient understanding did not. The results of this survey showed that participants knew enough about food safety. Given that all of the respondents confirmed they had food safety certifications, their extensive training in the subject may be responsible for their high level of awareness.

Furthermore, much like the findings from South Africa, Yakubu et al. (2013) found that in a Northern Nigerian state of Kano, there was an increase in the level of meat handling personal hygiene knowledge of butchers. The high level of meat hygiene knowledge of the butchers in this study could be due the fact that they do receive formal training as the findings of this study showed. One tactic to raise knowledge of food safety procedures is

thought to be food handler training, which will help food handlers and institutions in the long run (Gaungoo & Jeewon, 2013).

The results of this study however indicated several key areas where butchers' knowledge and practices regarding meat hygiene and safety fell short. Despite the relatively high awareness of the importance of handwashing (85 %), the practice of using gloves (70 %) and maintaining proper temperature control (35 %) during storage and transportation was less common. This highlights a gap between knowledge and practice, consistent with previous studies showing that while food handlers may be aware of hygiene protocols, they often fail to implement them due to a lack of resources, time, or training (Dlomo, 2019).

Similarly, the results of this study are consistent with studies conducted in Ethiopia by Tokuç et al. (2009) and Yenealem et al. (2020), who found that although those in charge of handling meat were aware of the need of personal hygiene procedures, they did not follow through on them. Yenealem et al. (2020), however clarified that this is the reality of the majority of underdeveloped nations, such as Ghana, where a lack of basic facilities occasionally causes appropriate knowledge not to correspond with practice. The current study's findings, however, go counter to prior research that found that food handlers in Africa lacked adequate awareness of food safety (Tamiru et al., 2022). According to the World Bank Global Index LMIC List 2020, a scoping analysis (Wallace et al., 2020) carried out in all LMICs (except from Nigeria) revealed that just 9 (20%) of 45 publications described suppliers as having sufficient food safety knowledge.

The findings on hygiene training (60 %) of butchers having formal training and regular tool disinfection (65 %) suggest a low formal education in meat hygiene, making it a critical issue. Previous research has demonstrated that proper training significantly influences the likelihood of food handlers adhering to hygiene practices (Stephen, 2019). Butchers without proper training may not fully appreciate the risks associated with poor hygiene practices, resulting in contamination risks. Regarding storage practices, the low percentage (35 %) of butchers being aware of the temperature control guidelines during transportation and the recommended temperature for storing meat was concerning. This result aligned with studies by Mahunu et al. (2024), which found that improper temperature control is a significant factor in the proliferation of foodborne pathogens, particularly in developing regions where resources and infrastructure for cold storage may be limited.

The issue of cross-contamination was another critical aspect. While half of the butchers (50 %) were aware of the risks of cross-contamination. This moderate level of knowledge runs regarding cross-contamination among butchers runs counter to the findings of Asare (2020), which showed that slaughterhouse butchers had very little general knowledge of cross-contamination when handling meat. Only 30% of them were found to have high knowledge of cross-contamination, while 70% had low knowledge. However, this result is consistent with that of Faith (2015), who discovered that butchers in South Africa possessed a good degree of understanding of the procedures involved in handling meat. According to this study, the butchers' moderate level of knowledge of cross-contamination when handling meat may possibly be attributed to their generally moderate level of education.

The study further revealed that, 65 % understood the reasons behind regularly disinfecting their tools and equipment. This gap between knowledge and practice is a common challenge in food safety. This may be due to insufficient training or inconvenience for one part of these butchers. Studies by Pilling et al. (2009) have highlighted that while food handlers are often aware of cross-contamination risks, the lack of consistent disinfection practices stems from insufficient training or perceived inconvenience. However, butchers' awareness of environmental factors, such as keeping meat away from flies (55 %) and using hair restraints (65 %), showed room for improvement. This reflected broader challenges in maintaining a clean working environment, as demonstrated in studies by Barnes et al. (2024), where inadequate environmental controls were identified as a major contributor to contamination in food handling. The use of hair restraints, in particular, is a simple yet effective measure that reduces the risk of contamination, yet it was not widely known and practiced by butchers in this study.

In conclusion, while butchers in this study exhibited some awareness of meat hygiene principles, the gap between knowledge and practice was substantial. This disparity was consistent with findings from other regions and underscores the need for more comprehensive training programs and better enforcement of hygiene practices to improve food safety. A combination of formal training, resources for protective equipment, and strict monitoring of hygiene practices could significantly reduce the risks associated with meat handling in this setting.

CHAPTER FIVE
SUMMARY KEY FINDINGS, RECOMMENDATIONS AND
CONCLUSIONS

5.1 Summary of the key findings and contribution to knowledge.

This study determined the microbial quality of meat transported from the Kumasi abattoir to the Kejetia market.

In terms of meat handling practices, the study revealed that:

- i. None of the butchers used appropriate vehicles for transporting meat products and most of them relied on closed vehicles to move meat from the abattoir to retail centres.
- ii. None of the butchers chilled their meat before transportation, and many did not wear protective clothing.
- iii. At the abattoir, some slaughtered carcasses were found on the floor in pools of blood.
- iv. Some butchers entered the dressing area without protective clothing or failed to change footwear and carcasses were often exposed to flies.
- v. Waste management was poor, with heaps of animal waste near the abattoir emitting foul odours.

Regarding microbial growth for both before and after transportation, the study revealed that:

- i. There was an increase in load across all media.
- ii. MCA counts ranged from 4.9×10^2 cfu/ml (log 3.53) to 9.4×10^5 cfu/ml (log 5.97).
- iii. MSA, counts ranged from 4.3×10^4 cfu/ml (log 4.64) to 1.5×10^6 cfu/ml (log 6.18).
- iv. The highest load was recorded on SSA (9.1×10^6 cfu/ml, log 6.96), showing substantial bacterial growth.

In terms of butchers' knowledge and awareness of meat safety the study revealed that:

- i. Most butchers were informed about food safety practices.
- ii. Majority (85 %) of the butchers acknowledged the need for handwashing.
- iii. Most (70 %) butchers understood the need to use gloves.
- iv. More than half (65 %) of the butchers recognized the importance of disinfecting tools.

5.2 Conclusion

Meat handling practices employed by handlers and transporters were generally substandard. All butchers relied on taxis and tricycles instead of approved meat vans, exposing meat to dust, flies, and high temperatures. Furthermore, refrigeration was generally absent during transportation, with carcasses not stored at the recommended temperature of $\leq 5^{\circ}\text{C}$. The limited use of personal protective equipment and poor waste management around the abattoir also played a critical role in contamination.

Microbial analysis of meat samples taken after transportation showed a significant rise in bacterial load. The mean microbial load of $<10^4/\text{g}$ on meat samples was classified as high compared to the permissible limit of the Ghana Standards Authority. Also, the study recorded significant microbial contamination, including increased levels of *E. coli*, *Staphylococcus spp.*, and *Shigella*, posing serious public health risks. These increases were primarily attributed to the unhygienic conditions of transport vehicles, lack of temperature control, and exposure to environmental contaminants.

Most butchers demonstrated basic awareness of hygiene practices such as handwashing and regular tool disinfection, however, implementing other crucial safety practices like gloves and observing correct temperature control was low. Only 35 % of butchers knew

the recommended storage temperatures for meat. The limited formal training in meat hygiene further highlights the need for structured capacity-building programs.

5.3 Recommendations

This study makes the following recommendations:

- Ministry of Food and Agriculture (MOFA) should Provide butchers with regular food safety and hygiene training programs to improve meat handling practices and reduce contamination risks.
- Kumasi city authorities should implement infrastructure improvements, such as better waste management systems at abattoirs and designated transport vehicles, to reduce contamination at the source.
- Food Safety Authorities should establish a regular monitoring and testing framework for meat quality at various stages, including post-transportation, to ensure consumer safety.
- The abattoir authorities should ensure proper sanitation by butchers at the abattoir and during transportation to the market to avoid contaminating the environment with microorganisms.

5.4 Further research study

Studies should be conducted to check the microbial quality of carcasses along the supply chain from the abattoirs, not only in Kumasi metropolis but throughout the country, to meat retail outlets in other markets.

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APPENDICE

AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING

AND ENTREPRENEURIAL DEVELOPMENT

FACULTY OF ENVIRONMENTAL HEALTH EDUCATION

**QUESTIONNAIRE ON MICROBIAL QUALITY OF KUMASI ABATTOIR
COMPANY LIMITED MEAT AT RETAIL OUTLETS AT KEJETIA MARKET,
GHANA**

Dear respondents,

This research seeks to study the microbial quality of carcasses along the supply chain from the Kumasi abattoir company limited to meat retail outlets at the Kejetia market, Ghana. You happen to be one of my respondents on the issue. You are assured that all information shared with me will be treated as confidential. This interaction will take about 10 minutes of your time. Do I have your permission to continue?

Yes No

Participant Study ID-----

Date of Data collection: -----

Microbial Quality of Carcass – Kumasi Abattoir to Kejetia Market	
<i>Socio-Demographic Characteristics</i>	
1.	What is your current age in years? 1. <input type="checkbox"/> < 30 2. <input type="checkbox"/> 30 to 40 3. <input type="checkbox"/> 41 to 50 4. <input type="checkbox"/> 51 to 60 5. <input type="checkbox"/> > 60
2.	Sex 1. <input type="checkbox"/> Male 2. <input type="checkbox"/> Female
3	What is your religion? 1. <input type="checkbox"/> Christian 2. <input type="checkbox"/> Islam 3. <input type="checkbox"/> Traditional 4. <input type="checkbox"/> Other

4.	Marital status 1. <input type="checkbox"/> single 2. <input type="checkbox"/> married 3. <input type="checkbox"/> divorce 4. <input type="checkbox"/> widow/widower
5.	Level of education 1. <input type="checkbox"/> No formal education 2. <input type="checkbox"/> Basic (Primary/JHS/JSS) school 3. <input type="checkbox"/> SHS/SSS 4. <input type="checkbox"/> Tertiary
6.	How long have you been doing this work? 1. <input type="checkbox"/> 0 - 4 years 2. <input type="checkbox"/> 5- 10 years 3. <input type="checkbox"/> 11 - 20 years 4. <input type="checkbox"/> Above 20 years
7.	Do you belong to any organization as far meat selling is concern?
Carcasses transportation Methods and Rates	
8.	How often do you transport meat products? 1. <input type="checkbox"/> Everyday 2. <input type="checkbox"/> Twice a week 3. <input type="checkbox"/> Once a week 4. <input type="checkbox"/> Based on customers' demand 5. <input type="checkbox"/> Others, specify.....
10.	What type of vehicle do you usually use to transport meat products? 1. <input type="checkbox"/> Freezer vans 2. <input type="checkbox"/> Refrigerated trucks 3. <input type="checkbox"/> Tricycle (Abobboyyaa) 4. <input type="checkbox"/> Taxi 5. <input type="checkbox"/> Others, specify.....
Knowledge and Awareness of Butchers Regarding Meat Hygiene and Safety	
	Responses
1.	Understand the importance of washing hands before handling meat 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
2.	Use gloves while handling meat 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
3.	Know the recommended temperature for storing meat ($\leq 5^{\circ}\text{C}$) 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
4.	Are you aware of the risks associated with cross-contamination 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
5.	Disinfect tools and equipment before using them 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
7.	Know how to recognize spoiled meat 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
8.	Have formal training on meat hygiene and safety 1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
9.	Are familiar with proper storage methods for meat 1. <input type="checkbox"/> Yes

		2. <input type="checkbox"/> No
10.	Follow guidelines for temperature control during transport	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
11.	Use hair restraints while handling meat	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
12.	Keep meat away from flies during storage and transport	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING
AND ENTREPRENEURIAL DEVELOPMENT
FACULTY OF ENVIRONMENTAL HEALTH EDUCATION
ON THE MEAT HANDLING PRACTICES THROUGH TRANSPORTATION
FROM THE ABATTOIR TO MEAT RETAIL OUTLETS AT THE KEJETIA
MARKET, KUMASI METROPOLIS.**

To be filled by the researcher

Participant Study ID-----

Date of Data collection: -----

MICROBIAL QUALITY OF CARCASS – KUMASI ABATTOIR TO KEJETIA MARKET		
	Observational checklist on meat handling and storage practices employed by butchers during transportation.	Responses
1.	Use appropriate transports to cart carcasses to sale outlets.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
2.	Wear the proper PPE while conveying carcasses to the market outlet	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
3.	Use proper equipment to handle carcasses conveying to market outlets.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
4.	Meat exposed to flies during transportation	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
5.	Use proper storage containers and materials for carting meat carcasses.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
7.	Carcasses are stored at correct temperatures while conveyed to markets.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
8.	Carcasses are exposed to weather during transportation.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
9.	Disinfect the meat-holding areas before loading the meat	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
10.	Wear a hair net while transporting carcasses to the markets.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
11.	Carcasses placed directly on the floor of the transport.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
12.	Carcass exposed to dust during transportation	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
13.	Carcasses adequately chilled to 5° before loading into transport.	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
14.	Carcasses exposed to weather during transportation	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No

**AKENTEN APPIAH-MENKA UNIVERSITY OF SKILLS TRAINING AND
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MICROBIAL QUALITY OF CARCASS – KUMASI ABATTOIR TO KEJETIA MARKET		
	Observational checklist on meat handling and storage practices employed at the abattoir.	Responses
1.	Is there a daily cleaning of Abattoir before and after slaughtering process?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
2.	Is there any anti-mortem inspection by an authorised Veterinary Officer on the animal before slaughter?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
3.	Is there any post-mortem inspection by an authorised Veterinary Officer on the carcass?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
4.	Does the facility possess adequate cold storage facilities for the storage of raw meat?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
5.	Is Chilling done as soon as possible after washing and dissecting carcass?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
7.	Are Carcasses on rails and without touching floors/walls to prevent cross contamination?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
8.	Do the carcasses and offal come into contact with floors, walls or soiling during dressing and evisceration?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
9.	Is the meat kept in the chiller for the appropriate days before it is transported to the retail outlet?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
10.	Do all butchers who enter any part of the slaughtering facility wear suitable, clean protective clothing and footwear?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
11.	Do butchers wear Hair restraints, for both head and facial hair in cutting and dressing areas	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
12.	Is the meat exposed to flies during preparation?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
13.	Do butchers and workers wash their hands with soap/detergent before and after touching the meat?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
13.	Spitting, eating, chewing and the use of tobacco observed in meat handling areas	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
15.	Do butchers use aprons/white coats and or head covers and other protective clothing during slaughtering and preparation process?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
16.	Is the waste management at the abattoir good?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No
17.	Are the Carcasses cleansed or washed with portable water?	1. <input type="checkbox"/> Yes 2. <input type="checkbox"/> No