ASSESSMENT OF THE BACTERIOLOGICAL QUALITIES OF MEAT AND CONTACT SURFACES IN MARKETS IN ABIA STATE, NIGERIA

BY

IWUAGWU, UCHECHUKWU OLIVE (B.Sc., MPH)
REG. NO.: 20144920088

A DISSERTATION SUBMITTED TO THE DEPARTMENT OF PUBLIC HEALTH, POSTGRADUATE SCHOOL, FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI,
IMO STATE, NIGERIA

IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF DOCTOR OF PHILOSOPHY DEGREE (Ph.D) IN PUBLIC HEALTH (OPTION IN ENVIRONMENTAL HEALTH & SAFETY)

SEPTEMBER, 2023

CERTIFICATION

This is to certify that this work "Assessment of the bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigeria" was carried out by Iwuagwu, Uchechukwu Olive (Reg. No. 20144920088) in partial fulfilment for the award of the degree of Doctor of Philosophy (PhD) in Public Health (Environmental Health and Safety Option) in the Department of Public Health, School of Health Technology, Federal University of Technology, Owerri, Imo State.

Signature: 15/02/24

Prof. A. N. Amadi
(Project Supervisor) Date

Signature: 19/3/24

Dr. Mrs. B. O. Nworuh
(Project Supervisor 2) Date

Signature: 19/03/2024

Dr. C. C. Iwuala
(Project Supervisor 3) Date

Signature: 19/03/24

Dr U. M. Chukwuocha
Ag. Head of Department (Public Health) Date

Signature: 3/04/2024

Rev. Str. Prof. E. T. Oparaocha
Dean (School of Health Technology) Date

Signature: .....

Prof. B. O. Esonu
Dean (Post-Graduate School) Date

Signature: 05/12/2023

Prof. Godson R. E. E. Ana
Dept. of Evtal. Hlth. Sciences, UI.
(External Examiner) Date

DEDICATION

I dedicate this work to my husband Prof. Chukwumaeze Julian Iwuagwu for always being there for me; and my children - Chibuikem, Toochi and Ngozi.

ACKNOWLEDGEMENTS

I thank the Almighty God, the creator of the whole universe for seeing me through this work. I also express my profound gratitude to all who contributed immensely to the successful completion of this research. I thank my amiable Supervisor and mentor, Prof A. N. Amadi for his stern supervision and painstakingly going through the project and ensuring that I gave this work nothing but the best. My profound gratitude also goes to my Co- Supervisors Dr (Mrs.) B. O. Nworuh, Dr. (Mrs.) C. O. A. Amadi (of the blessed memory) and Dr. C. C. Iwuala; the Head of Department of Public Health - Dr. Uche Chukwuocha; the Dean, School of Health Technology (SOHT), Rev. Sr. (Prof.) E. T. Oparaocha; and my Lecturers, Prof. I.N.S. Dozie, Prof Mrs. E. A. Nwoke; Prof. (Mrs.) S. Ibe, Dr. C.O. Okereke, Mr. G.N.U. Iwuoha, Mrs. Onyi Okorie and my colleagues for their professional advice and outstanding help in the course of this Project. May God who rewards good deeds bless you all, Amen. In a special way I also remember and extend my gratitude to Prof. O. C. Abanobi of the blessed memory for all his professional advices and encouragement.

I also express my gratitude to the Dean of Postgraduate School, FUTO – Prof. B. O. Esonu and the staff of the Postgraduate School for their directives and guidance in the proper execution, compilation and presentation of this dissertation.

I thank Elder O. Ndimele and his colleagues of the Environmental Health Laboratory, College of Health Sciences, Abia State University and Prof. W. Braide of the Department of Microbiology, FUTO for assisting me with the samples collection and laboratory analysis; Dr. A. Ede, Mr. D. C. Innocent , Mr. M. Ikeanumba,, Mr. Mba Okor, Mr. U. Egbe, Mr. K. Osuji and Mrs. Nwanna Kalu for assisting me in the field work, I also acknowledge my friends – Prof. Mrs. I. P. Asiabaka, Mr. R. Omeire, Mrs. P. Rowland-Obinna and the non-teaching staff of Vice-Chancellor's Office and the Department of Public Health, FUTO for all your encouragement. I thank my husband- Prof. C. J. Iwuagwu for his financial support and encouragement; and my mother -Mrs. G. N. Okor and children for their consistent prayers and encouragement.

TABLE OF CONTENTS

LIST OF TABLES

TABLES:

LIST OF FIGURES

FIGURE

LIST OF PLATES

PLATES:

ABSTRACT

Microbial contamination of meat comes from several sources including during cutting, handling and processing of the meat. This study was carried out to determine the sanitation and hygiene practices of meat handlers and assess the bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigeria. This research involved the use of Hazard Analysis Critical Control Point (HACCP) checklist and Walk-through inspection to determine the sanitation and hygiene practices of meat handlers. Also, microbiological analyses of red and white meat; water and contact surfaces were used to determine the microbial qualities of the environmental media. A total of 425 meat samples were randomly collected from 425 meat handlers in Abia State. Furthermore, seventy eighty (78) samples comprising twenty (20) water samples and fifty eight (58) swabs from meat contact surfaces were used to establish the bacteriological quality of the water samples and meat contact surfaces. The multistage simple random sampling technique through balloting was employed to determine communities/markets for the study. Samples for the study were collected and analyzed using standard microbiological techniques such as culturing; and the bacteria were enumerated and identified using biochemical tests. Results showed that the total mean percentage score for the harmonized HACCP checklist was 24.66 ± 6.08% and falls far below the HACCP Good Hygiene Practises (SOPs) minimal pass mark of 40%. At critical control points, the mean percentage HACCP scores were 22.51 ± 4.70% for meat transportation; 20.99 ± 5.87% for meat storage; 27.97 ± 5.30% for personal hygiene; 26.30 ± 5.65% for cleaning and sanitation; 20.44 ± 4.81% for pest control; 26.13 ± 5.09% for waste disposal and 21.58 ± 4.89% for staff competency and training. 87.00% of the meat samples analysed using nutrient agar had bacterial growth. The mean bacterial loads of the red and white meat samples on nutrient agar plates were 2.33 x 10^6, 1.99 x10^5 and 2.73 x10^5 cfu/g; and 1.81 x 10^5, 1.73 x 10^5 and 2.20 x 10^6 cfu/g for Umuahia, Aba and Ohafia zones respectively. The prevalent bacterial isolates include *Staphylococcus* sp (78.80%), *Bacillus* sp (73.17%), *Enterococcus* sp (64.00%), *Escherichia coli* (62.11%), *Salmonella* sp (62.11%), *Klebsiella* sp (51.29%), *Micrococcus sp* (44.94%) and *Campylobacter* sp (43.52%). SPSS analysis using the one way ANOVA showed no significant difference (P>0.05) in bacteria isolated from markets in the three Senatorial Zones of the State. *Staphylococcus* sp was isolated in 61.11% of the tables, 50.00% of vehicles, 41.67% of knives and 46.32% of water; *Salmonella* sp was isolated in 47.22% of the tables, 36.11% of vehicles, 30.56% of knives and 43.85% of water; *Bacillus* sp was isolated in 41.67% of the tables, 44.44% of vehicles, 33.33% of knives and 23.70% of water; *Campylobacter* sp was isolated in 27.78% of the tables, 25.00% of vehicles, 30.56% of knives and none in water. There was no significant difference (P>0.05) in bacteria isolated from the contact surfaces and water from the markets in the three zones of the State. The poor HACCP compliance in meat handling (during transportation, storage, personal hygiene and sanitation practices etc) as observed in this study and indicated by the low mean percentage HACCP checklists score of 24.66 ± 6.08% could have contributed in the contamination of the meat carcasses resulting in the observed high mean bacterial loads from the meat samples. Thus, the bacteriological quality of meat in markets in Abia State could be said to be poor due to the recorded high mean bacterial load counts and the isolation of Indicator bacteria such as *E, coli, Salmonella and Campylobacter* from the studied meat samples. The presence of *E. coli* in the studied meat samples is an indicator of feacal contamination and a red alert for the Public health sector. It is recommended among others that meat should be properly cooked before consumption; and meat handlers should undergo proper training and regularly update their knowledge of meat safety.

Keywords: Bacteriological quality, Meat, Contact surfaces, HACCP, Meat handlers, markets, Sanitation, Hygiene Practices

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Meat is a key component of food and it is rich in protein, mineral, vitamins and oil (Ashwathi, 2017; Cheesbrough, 2000). Meat could be defined as the various tissues of animal origin and include beef from cattle, pork from pigs, mutton from sheep, poultry from chickens, ducks and turkey (Ashwathi, 2017). Fish, seafood, insects and snails are excluded here (Ranjitka *et al*., 2016). A recent publication by Food Agricultural Organization (FAO, 2020), defined meat as animal flesh that is eaten as food. It is a good source of protein and amino acid (consisting of about 15 to 20 per cent of protein); iron; fat, zinc, B-vitamins, phosphorus etc. Meat supply protein which is of paramount importance as it is connected with the immune mechanism of the body; needed for building, repair and maintenance of body tissues; maintenance of osmotic pressure; and the synthesis of certain substances like antibodies, plasma proteins, haemoglobin, enzymes, hormones and coagulation factors (Balaban & Rasooly, 2010; Parks, 2007).

However, this high nutrient, mineral and water contents of meat amongst other factors, predispose meat and meat products to microbial proliferations; resulting in their quick spoilage and contamination by microorganism (Bryant *et al.,* 2014). With a high water content of about 75%, Fresh meats are among the most perishable foods (Friis, 2007). Lulietto *et al.,* (2015); Doulgeraki *et al.,* (2012) and Dave and Ghaly, (2011) reported that meat is one of the most perishable foods and is a good medium for microbial growth due its high nutrient and water contents, moderate pH and inherent chemical and enzymatic activities.

Thus, in order to ensure the wholesomeness, safety and quality of meat being sold to the public, various management procedures and guidelines for food and meat safety regulation nationally and internationally had been introduced. This is of paramount public health concern considering the continued global emergence and re-emergence of food borne diseases. Some of these internationally recommended meat/food safety protocols are the Codex Alimentarius Commission CAC - Good Hygiene Practices (GHPs) and Hazard Analysis Critical Control Point (HACCP) - based Standard Operating Procedures (SOPs). The HACCP approach is use to investigate the processes and procedures/management practices that contribute to bacterial contamination, growth and survival; and to identity points where control measures could be applied to prevent or eliminate the bacteriological hazards or reduce them to acceptable levels. (HACCP B (2015) in meat plants).

Meat handlers in Nigeria like their counterparts in other developing countries are yet to come to terms with these meat safety management protocols. Okeudo (2017) and Ehiri *et al.,* (2001) reported that animals slaughtering and carcass handling in Nigeria also fall short of acceptable international standards; and that fresh meat sold to the public is contaminated from contact surfaces such as retail and slaughter slabs; dirty wheel barrows and car boots during transportation; openly displayed in the market and are examined with dirty hands by meat sellers and buyers with flies perching on them etc.

Meat gets contaminated by microorganisms from external source during cutting, handling and processing of the meat - mainly from the skin and the intestinal tract of the animal. (Jhalka *et al.,* 2014). Meat contamination could also occur during refrigeration if the proper cooling temperature is not maintained (Larsson & Orsini, 2014). Some of the important bacteria that have been implicated in meat contamination and spoilage include: *Salmonella, Staphylococcus,*

Campylobacter, *Escherichia coli*, *Enterobacter*, *Micrococcus*, *Bacillus*, *Clostridium*, *Streptomyces*, etc (Wolk, 2016).

Food borne illness posed a significant public health challenges, and the prevention of food borne disease is an essential function of both public and environmental health (Frumkin, 2010). Given the widespread impact of foodborne illness on people's health, economies, and food systems amongst others; researchers from all over the world are committed to figuring out ways to increase food safety on a variety of levels. This has resulted in researches on food safety practices and food handling lately (Havelaar *et al.,* 2015). I intend to use HACCP-Good Hygiene Practices (GHPs) protocol for the assessment of meat hygiene and safety and then carry out bacteriological qualities assessment of meat and meat contact surfaces in markets in Abia State.

1.2 Problem Statement

It is generally believed that microbial contamination of meat comes from external sources during cutting, handling and processing of the meat. According to several publications, poor meat handling and management practices (in the storage, transportation and processing etc) at variance with internationally recognized standards as observed in some States in Nigeria have been implicated in meat contamination resulting in food poisoning and food borne diseases outbreaks (Olubunmi *et al.,* 2017; Azuamah *et al.,* 2018; Grace, 2015; Frumkin, 2010; Joseph, 2017; Iro *et al.,* 2020). Some of these practices include non-adherence to internationally recommended standards such as the CAC - Good Hygiene Practices (GHPs) and HACCP - based Standard Operating Procedures (SOPs). It is reported that about 75 million cases of food poisoning and 5000 deaths occur annually in USA; with contaminated animal flesh accounting for 70% of the food poisoning (Saenz *et al.,* 2007; Tegegne, 2017; PETA, 2010). Nigeria like

other developing countries does not have accurate information on the prevalence and impact of food borne diseases; however, it is an established fact that diarrhea – the most common manifestation of food borne diseases is a major cause of sickness and death in the country. Contaminated meat/food is important cause of illness and death globally; and food borne diseases impede socioeconomic development by straining health care systems; contributing to decrease in workers' productivity; loss in school days; reduce family income as huge sums of money are spent on medical bills; causing pains and suffering and early death (WHO, 2015; Iro *et al.,* 2020). These grave public health implications occasioned by increased mortality and morbidity resulting from meat/food-borne diseases could be averted if internationally recognized food safety system such as HACCP- SOPs and GHP are incorporated in the meat management by meat handlers in Nigeria. I undertook this study due to the magnitude of problem of poor meat safety hygiene practices and carcass handling in Nigeria which fall short of acceptable international standards with its presumed compromise in the quality of fresh meat being sold to the public.

1.3 Objectives of the Study

General Objective

The general objective of this study was to assess the bacteriological qualities of meat and contact surfaces in selected markets in Abia State, Nigeria.

Specific Objectives

The specific objective are to determine the:

(i) Sanitation and hygiene practices of meat sellers in markets in Abia State, Nigeria.

(ii) Bacterial loads and isolates of red meat from markets in Abia State, Nigeria.

(iii) Bacterial loads and isolates of white meat from markets in Abia State, Nigeria.

(iv) Bacterial loads and isolates on meat contact surfaces - knives, cutting table tops and boots of transport vehicles used by meat handlers and water sources in markets in Abia State, Nigeria.

(v) To compare the burden of bacterial isolates from meat being sold in the markets in the three Senatorial zones in Abia State.

1.4 Research Questions

(i) What are the sanitation and hygiene practices of meat handlers in markets in Abia State, Nigeria?

(ii) What are the bacterial loads and isolates of red meat from markets in Abia State, Nigeria?

(iii) What are the bacterial loads and isolates of white meat from markets in Abia State, Nigeria?

(iv) What are bacterial loads and isolates on on meat contact surfaces - knives, cutting table tops and boots of transport vehicles used by meat handlers and water sources in markets in Abia State, Nigeria?

(v) Are there any differences in the bacterial burdens and isolates from meat being sold in markets in the three Senatorial zones in Abia State?

1.5 Research Hypotheses

HO_1: There is no significant difference in the bacterial loads and isolates from red meat sold in markets in the three Senatorial zones in Abia State.

HO_2: There is no significant difference in the bacterial loads and isolates from white meat sold in markets in the three Senatorial zones in Abia State.

HO_3: There is no significant difference in the bacterial loads and isolates from the contact surfaces and the water sources in the markets in the three Senatorial zones in Abia State.

1.6 Justification for the Study

I decided to assess the bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigeria because of the magnitude of the problem of poor sanitation and hygiene practices in meat handling in Nigeria which (even though not well documented) fall short of acceptable international standards; and which may result in the contamination of fresh meat sold to the public and possible food borne diseases outbreaks (which has been on the increase lately) (EFSA & ECDPC, 2022; Havelaar *et al.*, 2015)

This study will

- Provide a baseline data for which stake holders (governmental and non-governmental agencies, policy makers, corporate organizations and food hygienists) will use when planning for programmes in promoting good meat safety and hygiene practices among meat handlers.

- Knowledge of the point of contamination will guide health officers and stake holders on areas to focus on when organizing health promotion interventions/control measures.

- Generally improve the performance of meat handlers in the meat value chain and contribute to the improvement of Public Health in the Country

- The bacteriological properties of meat will help provide a clue in establishing possible causes of food-borne diseases incident in Abia state when controlling any possible

food-borne disease outbreak (as it will expose areas of gross compromised meat qualities).

- It will serve as a reference material for other researchers

CHAPTER TWO

LITERATURE REVIEW

2.1: CONCEPTUAL FRAMEWORK

2.1.1: Concept of Meat

Meat is animal flesh that is eaten as food. Animals have been hunted and killed by humans for many years and it has been a steady source of meat (FAO, 2020). Recently, animals such as cattle, sheep, goat and cow have been domesticated to provide meat for the growing global population resulting in the opening of slaughter houses for meat processing/production and marketing in open markets and meat shops.

Red meat is meat red and dark in colour when cooked (Olumide, 2016); while white meat is pale in color before and after cooking (Joseph, 2017; Pellet & Young, 2010). Red meat could be said to be meat that have more myoglobin than white meat (Larsson & Orsini, 2014; Ranjitka *et al*., 2016). Most poultry meat are white, but duck and goose meat are red. Pork have both red and white. It is believed that red meat contains more quantities of fats, vitamins and minerals including iron, zinc, phosphorus, B-vitamins, lipoic acid, small amounts of vitamin D, etc (Wolk, 2016; Lawrie & Ledward, 2006). White meat is made up of fast-twitch muscle fibers, while red, or dark, meat is made up of muscles with fibers that are slow-twitch. (Joseph, 2017; Pellet & Young, 2010). Beef is generally referred as of red meat and it is widely believed to contain fatty acids which is not good for the health. Excessive consumption of beef is believed to be a risk factor for cardiovascular diseases etc (Shimelis *et al.,* 2017; Zhu, 2013; Loir *et al.,* 2013; Micha *et al.,* 2010). Chicken is one of the most commonly consumed 'white meat' globally due to its delicious and sweet taste (Saenz *et al.,* 2007; Tegegne, 2017). It is rich in vitamins and minerals such as vitamin B, potassium, selenium, phosphorus and could be consumed fried, roasted, boiled or steamed with different variety of meals.

2.1.2: Meat Spoilage

Lulietto *et al.,* (2015); Doulgeraki *et al.,* (2012) and Dave and Ghaly, (2011) reported that meat is one of the most perishable foods and is a good medium for microbial growth due its high nutrient and water contents, moderate pH and inherent chemical and enzymatic activities. According to Cerveny *et al*., (2009) the growth of bacteria and spoilage of meat depends on the type of bacteria, nutrients availability, pH, temperature, moisture and gaseous atmosphere. Meat spoilage is caused by the following three primary mechanisms Microbial growth, oxidation (lipid oxidation) and enzymatic autolysis (enzyme reactions). Researchers believed that off-odours, off-flavors, and slime production come from the breakdown of fat, protein, and carbohydrates in meat, thus making the meat unfit for human consumption (Lulietto *et al.,* (2015); Casaburi *et al.,* (2015); Nychas *et al.,* (2008) and Ercolini *et al.,* (2006)).

2.1.3: Microbial Contamination of Meat

Microbial contamination of meat as earlier stated comes from external source during meat handling and processing (Jhalka *et al.,* 2014). When meat is left unpreserved it spoils in a matter of hours or days and thus will no longer be appealing and appetizing to the consumer. It will become poisonous and a source of illness from meat-borne diseases resulting from spoilage caused by the contamination of the meat by microorganisms such as bacteria and fungi present in the animal itself or from unhygienic conditions of the meat handlers/contact surfaces (Larsson & Orsini, 2014). Chicken like other poultry meat is more likely to harbor foodborne bacteria (such as salmonella and E. coli strains) than red meat (Ashwathi, 2017; Lawrie & Ledward, 2006) when not properly preserved.

When meat is not properly preserved with the application of preservatives, the fat in it will decompose after it is cooked, and it will have an unpleasant taste. According to Ifedike *et al.,* (2012), contaminated meat is believed to contribution significantly to food borne diseases

occurrence in Nigeria, due to its high nutritive nature and the easy with which meat support the growth of biological contaminants especially bacteria which constitute the major causes of food borne diseases in Nigeria and other developing countries. Grace (2015) also reported that food mostly implicated in food borne diseases outbreaks in developing countries are mainly from animal sources (livestock and fish products and produce), fresh, perishable foods sold in informal markets and street vended foods. Lawrie and Ledward (2006) report identified contaminated meat as a major vehicle for the transmission of *E.coli* from animals to humans.

Friis, (2007) suggested that food borne diseases are caused by biological, chemical, physical or nutritional hazards in food. The biological hazards consist of microscopic organisms such as bacteria, viruses and parasites. The chemical hazards are harmful substances which can cause illness if ingested with food such as those from **natural source** [eg. food allergens; toxins associated with molds and plants (mushrooms); certain species of fish (puffer fish); shell fish etc.] and **human origin** [eg. pesticide, cleaning agents, metals and Polychlorinated biphenyles (PBCs)]. Physical hazards are foreign objects such as stones, bone fragments from animals, pieces of glass, jewels introduced into the food from poor handling practices during the food processing, transport and marketing. Nutritional hazards include the presence of nutrients and other food constituents in excessive or deficient amounts that can lead to disease.

Adesokan and Raji (2014) reported that food contamination from raw meat is an important cause of food borne diseases outbreaks or food poisoning. They attributed this to improper handling of food that could result in cross contamination when raw meat is stored above ready-to-eat meals; or when food that are eaten raw such as salad is cut or prepared using a chopping board that has been previously used to cut raw meat without adequate washing.

2.1.4: Shelf-life and microbial meat spoilage

According to Ray and Bhunia (2013), the shelf-life of meat and meat products refers to the amount of time that food may be stored while maintaining its qualities until spoiling occurs. The shelf-life of items is closely connected to their degradation, resulting in a line between an acceptable and unacceptable bacterial concentration, which determines sensory changes such as off-odors, off-flavors, and an undesirable appearance which are all linked to the amount and kinds of microorganisms present at the start, as well as their continuing development. They gave the total starting microbiota for meat products to be around 10^2-10^3 cfu gr-1, with a wide range of species (Lulietto *et al.,* 2015; Ray and Bhunia, 2013). You can increase the shelf life of fresh neat by finding ways of keeping spoilage organisms away from the meat or reducing their growth rates; or to select meat with low spoilage potentials. Depending upon conditions, the shelf life of fresh meat is in the range of days before signs of spoilage (off-odour and slime) are evident. An extension of shelf life is achieved by hindering the growth of Gram-negative organisms relative to Gram-positive ones (micrococcaceae and lactic acid bacteria).

It is believed that the environmental conditions of meat at various stages of production and handling produce a unique ecological niche that favors some microbial strains that were already present in the meat or were introduced through cross-contamination, while others are disadvantaged. The predominance of a particular microbial strain is determined during handling/processing, transportation, and storage (Lulietto *et al.,* 2015; Castellano *et al.,* 2008; Nychas *et al.,* 2008).

2.1.4.1: Factors influencing shelf-life and spoilage of meat and meat products

Researchers believed that the various factors affecting the ability of microorganisms to grow and cause spoilage of meat and meat products could be intrinsic (inherent in the substrate) or extrinsic, and that both factors have impact in altering the natural environment and producing new ecological environment. Packaging (aerobically, vacuum, or modified atmosphere), storage temperature, product composition (presence of fat, NaCl content, nitrites, aw, pH), and other factors, such as antibacterial substances or bio-preservatives, are the main factors that affect the shelf-life of meat products and favor some bacterial strains over others (Lulietto *et al.,*2015; Remenant *et al.,* 2015; Nychas *et al.,* 2008).

2.1.4.1.1: Extrinsic factors

- **Packaging**

Studies have shown that the composition of meat spoilage organisms is determined by the meat packaging conditions and the gaseous composition of the surrounding atmosphere of the meat (Lulietto *et al.,* 2015; Rossaint *et al.,* 2015). Storage of meat/meat products under aerobic conditions at the temperature ranges from -1 to 25°C encourages the growth of Pseudomonads (*Pseudomonas* spp.), *Acinetobacter* spp., *Moraxella* spp. Predominant among the *Pseudomonas* spp. isolated from aerobically packed spoiled meat are *P. fluorescens* group, psychrotrophic *P. fragi, P. ludensis* and *P. putida*. Pseudomonads are responsible for the production of slime and off-odors in compromised meat/meat products (Lulietto *et al.,* 2015; Rossaint *et al.,*2015; Ercolini *et al.,* 2010; Ercolini *et al.,* 2006).

Lulietto *et al.,* (2015) and Doulgeraki *et al.,* (2012) reported *S. putrefaciens* as one of the most common spoiling microorganisms in chilled, vacuum-packed (VP) meat and VP meat with a

high pH. However, Lulietto *et al.*, (2015) reported that packing of beef under vacuum or in a CO_2 and N_2-modified environment resulted in a longer shelf life, and prolongs aerobic bacteria' lag phase thus promoting the development of facultative and strict anaerobic species.

- **Storage temperature**

Doulgeraki *et al.*, (2012) also reported that the meat storage temperature affects the duration of the lag phase, the maximum specific growth rate and the final microbial loads.

They opined that lower refrigeration temperatures reduced the bacterial growth and change the composition of the microbiota present on meat thus, psychrotrophic bacteria could grow, either Gram-positive, such as lactic acid bacteria (LAB), or Gram-negative, such as *Pseudomonas* spp. at chill temperature.

Ray and Bhunia, (2013) reported that in Modified Atmosphere Packaging (MAP) and vacuum-packed meat/meat products, lactic acid bacteria LAB are the predominant microbs under refrigerated conditions even though the growth rate is affected. *Carnobacterium* spp. is present in a vacuum at -1.5°C, and homofermentative *Lactobacillus* spp. are found at 4°C and 7°C.

2.1.4.1.2: Intrinsic factors

Meat is rich in protein, lipids, minerals and vitamins and poor in carbohydrates; thus, making it a good composition/medium for the growth of some particular microorganisms that need these nutrient requirements. Microorganisms require energy for metabolism, critical compounds that they cannot make, and components for cell formation; all of these materials are gathered from the food environment, and their presence allows food-borne strains to survive throughout the lag phase (Lulietto *et al.*, 2015).

- **Buffer capacity and pH**

Meat pH also controls the selection of the range of bacteria that can grow on the meat as each microbial species has an optimum and a range of pH for its growth (Lulietto *et al.,* 2015).

- **Redox potential**

Redox potential of meat also affects its predisposal to microbial growth and spoilage. The oxidation-reduction potential (Redox potential) is a function of the pH, gaseous atmosphere and presence of reductants and is measured in electrical units of millvolts (mV). For meat/food, redox potential is related to its chemical composition, processing treatments and storage. Raw meat has an redox potential (E*h*) of -200 mV, ground raw meat +225 mV and cooked meat a range of +90mV to -50mV (Lulietto *et al.,* 2015).

- **Water activity**

Water activity (a_w) is the measure of the amount of water in a food which is available for the growth of micro-organisms, including pathogens. It is the water available for carrying out enzymatic reactions, synthesizes cellular materials and takes part in other biochemical reactions. Raw meat has Water activity (a_w) values of 0.98-0.99 and cooked meat approximately 0.94; and these values could allow for the growth of most microorganisms. A water activity of 0.85 or below will prevent the growth and toxin production of pathogens, including *Staphylococcus aureus* and *Clostridium botulinum*. However, *S. aureus* grows at a lower water activity than other pathogens, and there should be regarded as the target pathogen for drying (Lulietto *et al.,* 2015).

2.1.5: Preservation of Meat

As national and international trades and commerce grow, the idea of meat preservation was introduced to ensure the transportation of meat for long distances without spoiling of texture, colour and nutritional value (Dave & Ghaly, 2011; Nychas *et al*., 2008). The preservation methods were aimed at inhibiting the microbial spoilage and minimizing the oxidation and enzymatic spoilage. Traditionally, meat was preserved by drying, smoking, brining, fermentation, refrigeration and canning. However, over the years, new preservation techniques such as chemical, bio-preservative and non-thermal techniques have been introduced. These meat preservation techniques all worked by three major principles- controlling temperature, controlling water activity and use of chemical or bio-preservatives (Dave & Ghaly, 2011; Zhou *et al*., 2010).

2.1.5.1: Low temperature methods

The principle behind the low temperature/cooling techniques is to slow or limit the spoilage rate at a temperature below the optimal range that can inhibit/stop the microbial growth and they are employed in three levels of chilling, freezing and super chilling(Dave & Ghaly, 2011; Zhou *et al*., 2010).

2.1.5.1.1: Chilling

Chilling is used at the slaughterhouses after the animals have been slaughtered, as well as during transportation and storage. The storage temperature of the meat carcases should be reduced to 4°C within 4 hours of slaughtering. Meat chilling is necessary for meat hygiene, safety, shelf life, appearance and nutritional quality (Zhou *et al*., 2010). Chilling could be done in two ways either by immersion (water) chilling (which involves immersing the product in cooled (0- 4°C) water) or by air chilling (which involves misting the carcasses with water in a

chamber with circulating refrigerated air) (Carroll and Alvarado, 2008). The air chilled is better than the water chilling.

2.1.5.1.2: Freezing

Researchers reported that fresh meat contains about 50-75% percent water by weight, depending on the species, and the freezing process transforms the majority of the water into ice while retaining the original characteristics of fresh meat. Red meat has a shelf life of 6 to 24 months when kept at 15°C to 30°C while the shelf life of frozen chicken is also affected by the storage temperature (Dave & Ghaly, 2011; Belitz *et al.,* 2009).

2.1.5.1.3: Super chilling

Super chilling is another method of preservation where part of the internal water of the meat/foods is frozen and works as a refrigeration reservoir and no external ice is added thus ensuring its refrigeration during distribution and transportation. Super-chilling refers to the temperature zone below its initial freezing point (1-2°C) but where ice crystals are not generated. Super chilling has the main advantage of increasing the shelf life of meat up to 4 times (Dave & Ghaly, 2011; Magnussen *et al*., 2008) and it is mainly used for the preservation of fish and chicken/poultry. It has been reported that during super chilling, most of the microbial activities are stopped/inhibited while chemical and physical changes may continue and, in some cases, may even accelerate (Dave & Ghaly, 2011; Frperc, 2004; Magnussen *et al*., 2008).

2.1.5.2: Controlled water activity methods

Ghaly *et al.,* (2010) defined water activity (aw) as the water which is not bound to food molecules and can support the growth of microorganisms. Water activity represents the ratio of

the water vapour pressure of the food/meat to the water vapour pressure of pure water under the same conditions.

Microbiological safety of meat and food is directly influenced by the water activity (aw). Dave & Ghaly, (2011) and Comaposada *et al.,* (2000) reported that water activity in meat products is equivalent to the relative humidity of air in equilibrium with the products. According to Dave & Ghaly, (2011) most of the fresh meats, fruits and vegetables fall within food with high moisture contents and have a water activity of more than 0.85 and therefore needs refrigeration or another barrier to control the growth of microorganisms.

There are minimal, optimal, and maximum water activities for each microbe. Microorganisms thrive best between a_w values of 0.980 - 0.995, and stop growing at a_w< 0.900. At aW of 0.6, yeasts and molds can develop. Pathogen growth is inhibited at aW of 0.85, though (Dave & Ghaly, 2011; and Ghaly *et al.,* 2010).

2.1.5.2.1: Use of Sodium Chloride to reduce water activity

Chawla *et al.,* (2006) reported a reduction in water activity of fresh lamb intestine from 0.95 to 0.80 with the addition of 10% (w/w) of sodium chloride. Bennani *et al.,* (2000) reported that *Enterobactereaceae species* were eliminated in dry-salted meat product (kaddid) because of reduced water activity (a_w) below 0.9 after three days of salting, spicing and drying. Domowe (2010) reported that adding 3% salt reduced initial water activity level to 0.97 in sausages and to 0.95 after six day drying process thus controlling the growth of pathogenic bacteria such as *Salmonella* and *Bacillus*.

Wijnker *et al*., (2006) also reported that the activities of most of the spoilage and pathogenic bacteria such as *Escherichia coli, Salmonella typhimurium, Listeria monocytogenes,*

Staphylococcus aureus and *E. coli O157:H7* were stopped due to the antimicrobial properties of salt (NaCl) for the preservation of meat at controlled water activity (aw) level of 0.89. The use of sodium salt in meat preservation is a Good Manufacturing Practice (GMP) in Canada according to the Canadian Food and Drug Act, (DJC, 2009). Also, in the United States, curing salts are GRAS-listed (Generally Recognized as Safe) according to the American Food and Drug Administration (USFDA, 2009).

2.1.5.2.2: Use of Sugar to reduce water activity

Sugars have the ability to bind moisture and lower the amount of water in meals. Dextrose, sucrose, brown sugar, corn syrup, lactose, honey, molasses, maltodextrins, and starches are commonly used as sugars or carbohydrates in dry meat processing to improve flavor, minimize salt harshness, and lower water activity (USDA, 2005).

2.1.5.3: Chemical methods for controlling microbial spoilage

Several chemicals have been used over the years as food additives for preservation of meat; however, each country has rules and regulations on the established limits for their use so as to prevent adverse effects on humans as well as restrictions. For instance, such chemical must be GRAS-listed (Generally Recognized As Safe) according to the American Food and Drug Administration (USFDA, 2009) in the United States and also fall under GMP (Good Manufacturing Practice) in accordance with the Canadian Food and Drug Act (HC, 2006) in Canada. These compounds when used in combination with refrigeration give excellent results and should not be utilized to make up for poor processing conditions or to cover up an already spoiled product. Some of the antimicrobial chemicals are chlorides (Sodium chloride), nitrites (sodium nitrite or potassium nitrite), sulfides (sodium sulfite) and organic acids (Ascorbic acid (vitamin C), Benzoic acid), (Dave & Ghaly, 2011; Chipley, 2005;Ray and Bhunia, 2013; Archer, 2002).

2.1.6: Concept of Meat Hazard Assessment

Frumkin, (2010) grouped the food/meat borne disease hazards into biological, physical and chemical hazards. He classified food borne diseases caused by this food/meat borne disease hazards as follows:

- **food borne infections**: these are caused by consuming biological hazards together with food leading to the multiplication of the pathogenic organism in the victim's stomach and intestine and producing symptoms of infection such as nausea, abdominal pain, fever and diarrhea.
- **food intoxication**: This is poisoning caused by eating food that contains toxic chemicals. Food intoxication could also come from toxic waste produced by ingesting bacteria (even when the bacteria is death); from the consumption of poisonous plants (mushrooms) or fish; from the consumption of food containing chemicals such as cleaning agents or pesticides.

2.1.6.1: Quantitative Microbial Risk Assessment (QMRA) of Beef Meat

Kirk *et al*., (2015) reported that a variety of biological hazards had continued to contaminate foods, meat and meat products resulting in microbial foodborne diseases outbreak - a serious public health problem. They reported that in 2010, contaminated food by enteric pathogen caused more than 580 million illnesses and 351,000 deaths globally. Notably among these contaminated foods, meat and meat-based products were identified as one of the main vehicles for the transmission of the pathogens responsible for more than 16% of all foodborne outbreaks in Europe (EFSA & ECDPC, 2015). It is also reported that there have been an increase in foodborne diseases with some implicated predominant microorganisms including-

Campylobacter, *Salmonella*, *Yersinia, Shiga Toxin-producing E. Coli* (*STEC*) and *Listeria monocytogenes* (EFSA & ECDPC, 2022).

According to Tesson *et al.*, (2020), a study conducted in France shows that contaminated meat consumption accounts for 177,610 illnesses per year among 67 million people with very mild and severe effects. Campylobacter spp. was found to be the most frequently isolated and identified pathogen and was responsible for 66,140 cases while Brucella spp was the pathogens responsible for the severe cases. Schroeder *et al.,* (2005) reported that there have been increase in *E. coli* O157 outbreaks from plants and animal produce attributable partly to produce already contaminated with *E. coli* O157 before purchase and to kitchen-level cross-contamination (hence the need for awareness creation for food/meat handlers and preparers on preventive strategies).

The presence of *E. coli (a* normal flora of the human and animal intestine*)* and its various strains such as *E. coli* 0157: H7, enterotoxigenic *E. coli* (ETEC) in meat or food material is of great public health concern as most of the recorded food borne diseases outbreaks were traceable to the eating of beef contaminated with the *E. coli* 0157:H7 strain which is potentially associated with high mortality. In fact, *E. coli* has been identified globally as a leading cause of foodborne diseases (Gutema *et al.,* 2021; Hussein, 2007). Gutema *et al.,* (2021) and Qadri *et al., (*2005) reported that enterotoxigenic *E. coli* (ETEC) commonly spread by contaminated water and food is responsible for most of the diarrheal outbreaks among young children and travellers in developing countries.

According to Gutema *et al.,* (2021); CDC, (2008) and Ibekwe *et al.,* (2008), *Salmonella* species such as *Salmonella enteritidis* and *Salmonella typhi* are of severe public health concern in developing countries including Nigeria due to poor sanitary conditions and lack of access to adequate potable water supply. While *Salmonella enteritidis* has been mostly isolated from

foodborne diseases outbreaks linked to the consumption of contaminated chickens, eggs/foods containing eggs; *Salmonella typhi* causes typhoid fever (enteric fever) which is an acute, life-threatening febrile illness. These diseases are transmitted through food, drink and water contaminated by the urine or feaces of infected person.

Reported cases of food poisoning /food borne diseases in Nigeria

Onyeneho and Hedberg (2013) and Ajayeoba *et al.*, (2015) reported that Nigeria has no official food borne disease surveillance system. However, they documented some reported cases of food poisoning resulting in deaths and hospitalizations including the following:

- An outbreak of food poisoning in Ibadan, Nigeria that claimed 20 lives and the causative organism- a new phage type U282 of Salmonella Typhimurium was isolated from a sandwich filling.
- Food poisoning in Kano involving three families due to consumption of yam flour contaminated by lethal preservatives used in the processing.

Tesson *et al.,* (2020) documented that in the last 20 years, international organizations such as the Codex Alimentarius Commission (CAC) have proposed and adopted a risk-based food safety management strategy that includes Risk Assessment, Risk Management, and Risk Communication. Microbial Risk Assessment is a scientific evaluation that seeks to offer an estimate of a risk based on the likelihood and severity of health impacts induced by a hazard to aid decision-making; and it involves the four (4) steps of Hazard Identification, Exposure Assessment, Hazard Characterization, and Risk Characterization. The Quantitative Microbial Risk Assessment (QMRA) method was developed for water and subsequently expanded to include a variety of foods.

QMRA begins with the formulation of a risk question in order to assess the situation by identifying the danger, polluted matrix, affected population, and exposure. The model for the evaluation must then be built and loaded with data and information about the consequences of the processes that the food matrix goes through, as well as the pathogen's reaction to them in terms of growth or inactivation. Experts may assess the danger to which the public may be exposed using QMRA models, evaluate viable risk mitigation techniques, and provide information for better risk management in event of contamination occurrences.

Despite the fact that QMRA is now well-established and refined, there is significant variation among all QMRAs done, even when using the same matrix-pathogen combination. It is common knowledge that the resources and information created by one QMRA are difficult to reuse and utilize in another (Tesson *et al.,* 2020). Since pathogen contamination can occur at any point along the farm-to-fork chain, evaluating the impact of pathogen contamination on cattle meat may necessitate knowledge of the whole farm-to-fork chain. Given the current data and knowledge gaps, it is critical to be able to transfer results from one setting to another, such as identical processes of pathogen growth or inactivation on a similar matrix of interest. This conversion is not always easy, and harmonization of QMRA models is clearly needed (Tesson *et al.*, 2020).

2.1.6.1.1: Identification of Main Hazards in Beef Products

Tesson *et al.*, (2020) also reported that the identification and selection of hazards to be assessed is the initial stage in QMRA. While assessing for the bacterial hazards, the main bacteria to consider are *Escherichia coli* (especially the *Enterohemorrhagic E. coli (EHEC) and the wild antibiotic resistance strains*), *Salmonella spp., Listeria monocytogenes, Campylobacter spp., Cryptosporidium spp., and Bovine Spongiform Encephalopathy* (BSE), among others.

2.1.6.1.2: Exposure Assessment- sources of meat contamination

According to Tesson *et al.,* (2020), meat could be exposed to contamination during the transportation of animals from farm to slaughter house; transportation of the product from slaughter house to retail shop/ market and to the consumer's house. While the transportation of live animals/potentially infected live animals may result in an increase in the prevalence of infected animals in the transportation truck, it does not pose any risk of an increase in fecal prevalence among the animals, despite its duration.

2.1.6.1.3: Risk Mitigation techniques:

Researchers in Canada believed that if cows are vaccinated against EHEC before the processing phase; it could be a very effective risk mitigation technique for reducing pathogen prevalence in Canadian ground beef and cuts (Smith *et al.,* 2013).

2.1.7: Meat Safety Management systems

2.1.7.1: Hazard Analysis Critical Control Point (HACCP) and Meat Safety

The Codex Alimentarius Commission is the principal organ of joint FAO/ WHO food standards programme and formulates food standards for International market (Parks, 2007).The Codex Alimentarius Commission (CAC, 2005) provides code of hygienic practices for raw meat, meat preparations and manufactured meat from the time of life animal production up to the point of retail sales. It also develops the recommended international Code of Practice such as General principle of food hygiene in respect of meat products; and the Hazard Analysis and Critical Control Point system and Guideline for its application. Nigeria meat hygienic practices are also based on this code. The CAC/RCP 58-2005 gave the following requirements for hygienic practices for meat and meat products. In food/meat manufacturing, the main microbiological concern is that of safety. In meat plants and value chain, HACCP plan focus

on control measures that can reduce the likelihood of contamination of meat from microbiological hazards such as salmonella, E.coli 0157 and campylobacter during production (HACCP in meat plan). Though cooking may kill most of the meat borne pathogens, cross contamination may occur during washing and handling.

2.1.8: Concept and use of Hazard Analysis and Critical Control Point (HACCP)

In order to ensure meat safety, there should be a combination of formulation and processing conditions to ensure that pathogenic microorganisms are controlled in the handling design and that is where the Hazard Analysis Critical Control Point (HACCP) protocol/system comes in. HACCP system is used to ensure that the safe handling design is implemented and the operational safety index maintained. HACCP is a preventive Food Safety Management System that uses the approach of identifying, evaluating and controlling hazards that are significant for food safety; and it will reveal if microbiological hazards are under control. The Hazard Analysis Critical Control Point (HACCP) Principles involved the use of specific measures based on science and risk assessment aimed at prevention and control of contamination during all aspects of meat production and processing /handling (CAC, 2005).

Ehiri *et al.,* (2001) used the HACCP approach to investigate processes and procedures that contributed to microbial contamination, growth and survival; and to identify points where control could be applied to prevent, eliminate or reduce those microbial hazards in foods in Imo State. They observed that though the hygienic quality of food could be assured if basic food safety principles are followed; and in a situation where many factors are implicated in food contamination, identification of CCP is extremely important and very essential in deciding on the appropriate preventive efforts and thus maximizing available resources.

Hazards analysis of critical control points (HACCP) is a system for reducing the risk of food borne illness. It is used to monitor food from the time of harvest to the time of consumption.

2.1.8.1: Principles of the HACCP System

According to Friis (2007), HACCP as a preventative approach to food safety is based on the following seven principles which focused attention on the identification and control of microbiological, chemical and physical food safety hazards during production:

HACCP in meat value chain or plant involves the following 7 steps:

1. Identify what could go wrong - the hazard
2. Identify the most important points where things can go wrong - the Critical Control Points (CCPs)
3. Set Critical Limits at each CCP (eg. cooking temperature/time)
4. Carry out checks at CCPs to prevent problem from occurring – monitoring
5. Decide what to do if something goes wrong – corrective action
6. Prove that your HACCP Plan is working – verification
7. Keep records of all the above – documentation

(HACCP (b))

2.1.8.1.1: Identify/Analyze any hazards that must be prevented, eliminated or reduced

Potential hazards associated with food and measures to control those hazards are identified. The hazards could be biological (ie microbes- E.Coli 0157, Campylobacter); chemical (e.g veterinary medicine or cleaning product residues, toxin) or physical (e.g wool, ground glass or metal fragments)

2.1.8.1.2: Identify critical control points (CCPs)

These are points in food's protection from its raw state through processing, transportation to consumption by the consumer which the potential hazard could be controlled or eliminated. Examples are cooking, cooling, packaging, metal detection, transportation.

2.1.8.1.3: Establish preventive measures with critical limits for each control point

(i.e. establish critical limit which must be met to ensure the CCP is under control). Example for a cooked food, this might include setting the minimum cooking temperature and time required to ensure the elimination of a harmful microbes.

2.1.8.1.4: Establish procedures to monitor the CCPs

Such procedures might include determining how and by whom cooking time and temperature should be monitored.

2.1.8.1.5: Establish corrective actions to be taken

When monitoring shows that a critical limit has not been met/or that a particular CCP is not under control. Example reprocessing of food if the minimum cooking temperature is not met.

2.1.8.1.6: Establish Procedures to verify that the HACCP system (as indicated in the above procedures) is working properly (effectively).

2.1.8.1.7: Establish effective documents/record keeping to document the HACCP system

This would include records of hazarads and their control methods, the monitoring of safety requirement and action taken to correct potential problems.

Each of these principles must be backed by sound scientific knowledge: example published microbiological studies on time and temperature factors for controlling food borne pathogen.

2.1.9: Meat Safety, Hygiene and Sanitation practices

Meat (Food) hygiene refers to all the measures or steps taken to ensure that meat (food) remains safe, wholesome and sound at all stages from its growth, production or manufacture until it is consumed. (Zacchaeus and Amadi, 2012). While meat (food) sanitation refers to environmental measures which facilitates meat (food) hygiene and it includes those sanitary measures (such as cleanliness of premises and equipment used in the processing, handling and storage of food) taken to make meat/food safe for human consumption and disease prevention. Poor handling methods and dirty habits (especially personal hygiene) of meat/food handlers exposes meat/food to flies, rats thereby transferring disease agents such as bacteria, viruses, parasites, viable worm's egg/cysts and chemical to the food leading to food poisoning and other ailments.

Many food-borne diseases among humans have been attributed to the consumption of meat. Thus, it is right to apply the major hygiene measures at the points in the food chain where the greatest value is achieved in mitigating food-borne diseases on the part of the consumers. Researchers have documented that poor food/meat handling practices and hygiene may result in contamination of ready-to-eat foods with adverse health conditions to consumers due to the presence of indicator organisms (Okonko *et al.*, 2009).

The application of the Hazard Analysis Critical Control Points (HACCP) principles is an essential element in controlling these hazards at those critical points where the meat is most vulnerable to contamination. (Wilson *et al.*, 2008; Dussault, *et al.*, 2010; Bryant, *et al.*, 2014). Tesson *et al.*, (2020) documented that meat contamination by EHEC, Salmonella spp., and *Campylobacter spp*. is believed to come from contamination events at the farm as well as intestinal contents (fecal and hide cross-contamination) and could result to gastroenteritis (from EHEC, Campylobacter spp. and Salmonella spp.); human uremic syndrome and the production

of bacterial toxins of severe lethal consequences (from EHEC). However, they noted that there have been reported cases of bacterial exposure and growth during transportation and storage, even at very low temperatures attributable to L. monocytogenes responsible for listeriosis which affect mainly infants, pregnant women, elderly, and immunocompromised people.

A study conducted in Ethiopia revealed that there were both good and unhygienic meat handling practices at the slaughter houses and meat markets in Bishoftu town, Ethiopia. On the observed bad /unhygienic meat handling practices, there were lack of hot water baths for hand washing and dipping of knives; infrequent hand washing; lack of training on meat safety, sanitation and hygiene; lack of regular medical check-up and lack of cooling facilities (Gutema *et al.,* (2021)). Hot water is essential and needed for effective washing and sanitization of hands and equipment (knives) to remove potential surface contaminants and thus prevent further cross contamination of meat from contact surfaces. These studies also revealed that there are lack of adherence to CAC meat safety guidelines such as the stipulation for the steady provision of adequate and easily accessible hot and potable cold water supply at the slaughter houses/ meat markets for cleaning and sanitizing of equipment and hands by the meat handlers in Ethiopia a CAC member countries (Gutema *et al.,* 2021; CAC, 2005).

2.1.9.1: Slaughter House/ Abattoir and Market hygiene and Sanitation practices

Abattoir Sanitation: Abattoirs need to meet certain basic sanitary standards for prevention of meat contamination and zoonotic diseases most of which affect people. There should be potable water supply, good drainage, proper wastes disposal, transport facilities including cleaning and hygiene of equipment etc. are necessary for adequate Abattoirs sanitation. Transportation of meat in passenger vehicle, wheel barrow, motorbikes etc should be discouraged in order to protect the meat products from dust, flies and other contaminants in the environment (Amadi, 2009)

2.1.9.1.1: Slaughtering, dehiding, cutting and other handlings at the slaughter house

Based on extensive studies, slaughtering is one of the most well documented phases in the meat supply chain because the monitoring of numerous parameters of the processing steps carried out by meat manufacturers, as well as the fact that most of these steps are relatively similar between processing plants in the same country as a result of national and international guidelines for meat handling and processing (Tesson *et al.,* 2020). In a study carried out in Ethiopia, Gutema *et al.* (2021) observed that in the slaughter houses, bleeding of cows was carried out on the ground, and the de-hiding of the carcass was done manually. These practices could lead to carcass contamination/cross contamination from the contact surfaces - ground, workers' hands and from carcass to carcass contact (FAO, 2019).

Gutema *et al.,* (2021) in their study conducted in Ethiopia identified the major possible sources of carcass contamination at the slaughter house to include feces during evisceration, the hides, handlers' hands and knifes. Previous studies also reported the occurrence of foodborne pathogens such as *E. coli* O157 and *Salmonella* in cattle feces and on hides and the possibility of their transfer to carcass during slaughter operations (El-Gamal & EL-Bahi, 2016; Gutema *et al.,* 2020). Dehiding and evisceration are among the major sources of contamination during meat handling/processing steps as there could be cross-contamination from hide and gastro-intestinal tract content leakages during dehiding and evisceration leading to secondary contamination between carcasses or through contact with the cutting equipment. It should be noted here that secondary contamination is an occurrence that some writers may overlook because they claim it has no influence on final prevalence or concentration or is difficult to predict (Tesson *et al.,* 2020; Duffy *et al.,* 2006). Contamination during dehiding has been associated to hide-to-carcass transfers during the removal of dirty surface spots, dirt-spreading during hide removal, and surface lymph node rupture (Tesson *et al.,* 2020; Li *et al.,* 2015).

Gonzales-Barrón *et al.,* (2016) used meta-analysis to estimate the mean prevalence of carcasses infected with EHEC after dehiding to be 4.8 percent (SD: 0.014), compared to 12.5 percent after bleeding (SD: 0.011).

According to Tesson *et al.,* (2020), when it comes to dehiding, Brookes *et al.,* (2015) found that contamination of carcasses by GIT has a significant impact on the frequency of pre-chilled carcasses based on fecal bacteria prevalence and loads. On the other hand, Kosmider, (2010) assumed that carcass bacterial prevalence remains the same and unchanged after dehiding or evisceration, whereas Gonzales-Barrón *et al.,*(2016) reported that the follow up dehiding, washing/rinsing and chilling of meat carcass may not fully offset the possible bacterial concentration increase which occurs in event of guts rupturing during evisceration. Evisceration is one of the most critical meat handling/processing steps because if not properly done could result in the bursting and discharging of the contents of the guts/gastrointestinal tract (GIT) with its high bacterial load on the meat carcass. Researchers have predicted that zero to two percent of carcasses would be contaminated by gut rupture while contamination from evisceration should be the same level/degree as contamination from dehiding (Tesson *et al.,* 2020; Brown *et al.,* 2013).

2.1.9.1.2: Temperature Control and storage of leftover meat:

Appropriate temperature control should be put in place to ensure that there is no temperature abuse and that cold storage chain is maintained at the slaughterhouse, retail outlet, or during transportation to retail outlets. However, most studies reported the occurrence of microbial growth and contamination due to non-maintenance of cold chain during transportation as negligible (Tesson *et al.,* 2020; Kiermeier *et al.,* 2015; Kosmider, 2010). The temperature of meat determines its safety. According to CAC (2005) in the absence of suitable temperature,

humidity and other environmental controls, meat is particularly vulnerable to survival and growth of variety of pathogens and spoilage micro-organisms. Thus, Facilities and equipment should therefore be adequate for:

- Cooling, chilling and/or freezing of meat accordingly;
- Storage of meat at temperatures that achieve the safety and suitability requirements;
- Monitoring of temperature, humidity, air flow and other environmental factors so as to assure that process control regimes are achieved.

Proper management of time and temperature in meat value chain is very important and help in the control of growth of microorganisms and production of toxins as well as the spoilage of the meat by the microorganisms. Thus, the meat is prevented from getting compromised when the appropriate temperatures are maintained (Lulietto *et al.,* 2015; Cenci-Goga *et al.,* 2014; Leonard, 2011). In some reported works, 83.8% of the meat sellers stored their leftover meats in a refrigerator; 10% preserved theirs by drying; 2.5% smoked their leftover meats while 3.7% use other available methods (Adzitey *et al.,*2018b). Gutema *et al.,* (2021), in their own study in Ethiopia observed that meat are stored at room temperature estimated at 20.2 °C (range: 10.9–29.5 °C) at the slaughter house/ meat markets and transported from the slaughter house to meat markets with vehicles that have no provisions for cooling or maintaining cold chain. At the meat markets, meats for sale are displayed openly with no cover thus being exposed to flies, dust particles and other contaminants and with no cooling facility in place for hours before being sold. This prevailing temperature range provides suitable temperature for the growth of a variety of spoilage and pathogenic organisms on the meat to potentially unsafe levels.

2.1.9.1.3: Transportation:

Proper temperature control and cold chain management in meat storage, transportation and supply is a requirement that helps in ensuring the quality and safety of meat and meat products (Nastasijević *et al.,* 2017; Sani & Siow, 2014). According to CAC (2005), the vehicles or containers for the transportation of meat should:

- Be designed and equipped so that meat does not contact the floor;
- Have joint and door seals that prevent entry of all sources of contamination; and
- Where necessary, be equipped so that temperature control and humidity can be maintained and monitored.

2.1.9.2: Meat sellers' meat safety, hygiene and sanitation practices in the market:

2.1.9.2.1: Display of meat in the market

According to Adzitey *et al.*,(2020) and Sulleyman *et al.*, (2018), most of the meat sellers (48%) display and sold meat on open tables, which exposed the meat to flies, dust, car smoke, and other contaminants; and without any kind of temperature control in place for the meat being sold.

2.1.9.2.2: Cleaning and sterilizing of equipment and meat contact surfaces/ Hand washing

According to Alhaji and Biawa (2015) frequent cleaning and sterilizing of meat contact surfaces and equipment is one of the most common preventative meat safety and hygiene practices (due to the protective capacity of the frequent cleaning and sanitation of meat handling facilities). Majority of the meat sellers (94%) indicated that they wash their equipment (knives, tables, cutting slabs etc) with soap and cold water while 91% claimed they wash or scrape their cutting tables three or more times each day Adzitey *et al.,* (2020). However, none of the meat sellers disinfect their shops nor sterilize their knives and equipment. Bas *et al.,* (2006) reported that the majority of the meat sellers (96%) washed their

hands before touching raw meat. Meat handlers' hands could act as vehicle for the transmission of pathogenic bacteria such as *Escherichia coli* and *Staphylococcus aureus* (via cross-contamination) (Bas *et al.,* 2006 & Adzitey *et al.,* 2020).

2.1.9.2.3: Potable water supply

The source of water supply at abattoirs and slaughter houses has a major role to play in determining the cleanliness and safety of the meat. Secondary contamination can occur when contaminated water is used in washing the meat carcasses. Many slaughter houses and markets especially those in the rural communities lack potable water source and thus make use of stream water as their source of water supply. People take their bath, wash clothes, urinate and play in the same stream. The immediate surroundings of the stream littered with human feces and animal droppings. Thus, the water is likely to be heavily loaded with bacteria. It is from this same stream that the meat handlers will fetch the water they will use in washing the meat, tables, the utensils and equipment. There may be the possibility of skin infections from the usage of this water and this can be another source of meat contamination. Therefore, there is need for meat handlers to be cautious of their water sources. Source of potable water supply must for provided in the abattoir /slaughter house and at the markets. According to CAC (2005) there should be provision for adequate potable water supply and facilities provided for:

- An adequate and easily accessible supply of hot and cold potable water at all times for hand-washing, washing of knives, etc;
- Hot potable water for effective sanitizing of equipment, or an equivalent sanitation system;
- Sanitizing solution used according to manufacturers' specification supplied as and where necessary.

2.1.9.3: Personal Hygiene of Meat Handlers/ sellers

One of the most important and common sources of contamination of meat is by the meat handlers (Wilson *et al.,* 2008). This is because most of them do not have a good sense of hygiene. The personal hygiene of the meat handlers must meet the specified standards for meat safety (Olubunmi *et al.,* 2017; Azuamah *et al.,* 2018; Grace, 2015; Frumkin, 2010). Thus, Personal hygiene practices should help to prevent undue general contamination of meat, and prevent cross-contamination with human pathogens that may cause food-borne disease (Wambui, *et al*., 2017). When a meat handler or any other person is moving from rooms or areas containing raw meat to rooms for meat preparations, they are to wash their hands thoroughly and also change their clothes and sanitize them.

2.1.9.3.1: Injuries and Health of the Meat Handler

The health of the meat handler is also important. Any injury or bruise they may have on their fingers is a potential source of contamination. Proper initial and routine periodic medical examination is very essential for an individual handling/selling meat to the public so as to ensure that their health remains in good condition as long as they continue to handle meat sold to the public (Tegegne, 2017). Any injuries or cuts sustained by the meat handlers must be properly dressed and they must wear their gloves at all times during work. Cross-contamination of microorganisms can occur during the cutting /dressing of animals and also during handling and inspection of meat (Balaban & Rasooly, 2010; Bryant *et al.,* 2014; Friis, 2007).

2.1.9.3.2: Medical check ups

Gutema *et al.,* (2021), reported that 98% of meat sellers involved in their study in Ethiopia confirmed undergoing medical check-up even though not periodic and as regular as stipulated by the Ethiopian regulatory body. Conducting periodic medical check-up on meat sellers would

go a long way in breaking the chain of transmission of disease pathogens from those who are sick or potentially carrier to the public.

2.1.9.3.3: Wearing of Protective clothing

Adzitey *et al.*, (2020) reported that 58% of meat sellers do not wear apron; 94% do not wear hand gloves; 61% appeared dirty while 25% smoke during work. Appearing dirty here means that the meat sellers' clothes were covered with fresh and/or old meat particles and blood splashes. Gutema *et al.* (2021), in their own study in Ethiopia observed that none of the meat sellers in the slaughter houses and meat markets wore gloves while handling meat. However, in the slaughter houses, the meat handlers were wearing aprons, white coats, boots and hair covering. The wearing of protective clothes is an important practice that helps to protect the meat handlers as well as the meat from exposure to disease pathogens. When meat handlers are not appropriately dressed with hair nets, face masks and aprons, contamination can occur. According to Okonko *et al*. (2009),

- Meat handlers must wear protective clothing that is light colored and clean. Their clothing must also be in good condition without any tear. They must include safety hats; hair nets, white gumboots and safety boots amongst others. They must all be compliant with hygiene requirements and waterproof aprons as required by the work situation.
- Each meat handler must be provided with protective clothing at the start of each working day.
- Clean protective clothing need not be put together with other clothings.
- There should be lockers available for private clothing and only for that purpose.
- At any point in time whereby the protective clothing is stained or contaminated, it must be changed immediately to a new one.

- The workers in the clean and dirty areas must wear distinctive protective clothing, respectively.
- All the personal clothing worn by the personnel must be completely covered by a protective clothing.
- Personnel may change into protective clothing only in rooms designated for change of clothes and at the same time, clothes that are used in the abattoirs may be kept in rooms designated for them.
- Wearing of the protective clothing outside the premises is not allowed. Also, the meat handlers cannot sit or lie on the ground in their protective clothing.
- All protective clothing must be washed in a laundry which is provided for by the abattoirs. No personnel can take their protective clothing home to wash.

2.1.9.3.4: Showering and Regular washing of hands

Personnel who handle meat must Shower before assuming duties; and Wash their hands and forearms with a liquid germicidal soap and potable water after they use the toilet or after they have been soiled or stained in the course of their work (Wambui, *et al.*, 2017) Gutema *et al.*, (2021) in their study observed that though there were presence of sinks and water supply for washing of hands, 53.6% of the meat sellers in Ethiopia do not wash their hands frequently. This is contrary to CAC guidelines and requirements that stipulate regular hand washing along the meat/food processing chain in order to break disease transmission chain and protect consumers from foodborne illnesses.

2.1.9.3.5: Prohibitions

According to Wambui, *et al.,* (2017) and Okonko *et al*., (2009), the following prohibitions should be observed in meat handling areas:

- No wearing of jewellery or any traditional objects that are worn on the wrist or neck at workplace where meat is located.
- Fingernails must be short, clean and free of nail varnish.
- Meat handlers should not be allowed to eat, drink or smoke tobacco in the area were meat is handled.
- Any person who is drugged or intoxicated cannot be allowed in the area were meat is kept. At the same time, there should not be any drugs, alcohol or tobaccos around the area were meat is kept.
- Personnel must refrain from any actions that could contaminate the product.

2.1.9.4: Training; Level of Education, knowledge, attitude and safe meat handling practices:

All personnel handling meat must be adequately trained in meat hygiene and personal hygiene procedures by the government and owner of meat stores, and training records must be kept in line with the Codex Alimentarius Commission CAC - Good Hygiene Practices (GHPs) and Hazard Analysis Critical Control Point (HACCP) - based standard operating procedures (SOPs) (Okonko *et al*., 2009 and Iro *et al.,* 2020).

2.1.9.4.1: Training on hygienic handling of meat

Gutema *et al.,* (2021) reported that about 40% and 85.8% of meat handlers in slaughter houses and meat markets in Ethiopia respectively were not given any fundamental training on hygienic handling of meat. This is also contrary to the CAC requirements and Food, Medicine and

Health Care Administration and Control Proclamation (No. 661/2009) of Ethiopia, which stipulated the possession of a certificate of competence from the appropriate organ for any person working in meat/food handling outfits. Routine Food safety training for meat/food handlers is also recommended by the Food and Agriculture Organization (FAO) as an important intervention to improving their knowledge and skill. (EFNG ,2010; Wassie *et al.*, 2017 & FAO, 2019).

2.1.9.4.2: Level of Education, knowledge, attitude and safe meat handling practices:

Studies conducted in Tamale Metropolis and Bawku Municipality of Ghana indicated that majority of the meat sellers/butchers (60-64 percent) had no formal education; only a small proportion (29 percent) had any form of education (Adzitey *et al.*, 2020). They reported that the lack of formal education could be responsible for poor knowledge and adherence to adequate sanitation and safe meat handling practices (required for the prevention of meat contamination) among the meat sellers. Tegegne (2017) reported that there is no significant association between educational status and safe meat practices knowledge level among meat handlers in retail shops in Jigjiga town of Ethiopia. However, Adesokan and Raji (2014), in their own work found a significant relationship between educational status and the knowledge, attitude, and safe meat handling practice levels amongst meat sellers in southwestern Nigeria.

2.1.9.4.3: Work experience:

Majority of the meat sellers (95%) were found to have been selling meat for more than five years and so appeared to have acquired some safe meat handling practices from experience (Adesokan and Raji, 2014).

2.1.9.4.4: Meat safety Knowledge levels among meat sellers

In their study on meat safety knowledge among meat sellers in Tamale market metropolis Ghana, Adzitey *et al.* (2020) reported that 62% of the meat sellers had heard about meat safety; 96% were aware that meat could be contaminated by poor handling; although 96% of the meat sellers had no form of training in meat safety yet almost all the meat sellers (99%) were aware that contaminated meat could cause meat/food borne disease/illness, and 67% indicated they were aware of the health risks/meat safety risks associated with eating/drinking while selling meat; also almost all the meat sellers (99%) were aware that washing hands before work reduces the risk of meat contamination, that it is necessary to take leave from work when infected with a skin disease and that it is necessary to refrigerate leftover meat; 95% of the meat sellers were aware that using gloves during work reduces the risk of meat contamination. The meat sellers in this study reported that though they had no form of formal education in meat safety and hygiene, they had benefited from routine talks on meat safety from their leaders, veterinary technicians, Environmental health inspectors and from Television/ radio (mass media). Sulleyman *et al.*, (2018), also reported that 90% of the meat sellers in Accra, Ghana had no formal education in safe meat handling.

The above findings ran contrary to the FAO (2008) report which stipulates that meat and food handlers should trained and equipped with adequate and necessary knowledge and skills in meat/food safety and hygiene before venturing into business in this field so as to enable them to handle meat/food hygienically. Thus, it is pertinent therefore that training and retraining in meat safety, sanitation and hygiene practices should be regularly organized for the meat sellers to impart knowledge, modify their behavior and attitudes and provide emerging information in

this field (Egan *et al.*, 2007). This will go a long way in controlling the high levels of poor hygiene practices observed among meat sellers which researchers over the years have attributed to lack of training. In line with World Health Organization standards, Meat/Food workers should maintain a high level of personal hygiene; wear appropriate protective clothes, headgear, and footwear; and abstain from smoking, spitting, chewing, sneezing, or coughing over exposed meat/food, have the meat for sale displayed on a table covered with net among others(Adzitey *et al.*, 2020 & WHO, 2001).

Recommendations:

1.) Meat handlers and sellers should be routinely enlightened on the adverse effects of poor and inadequate personal and environmental hygiene and sanitation;

2.) Meat handlers also should be trained on the Good hygiene and handling practices and on the need to strictly adhered to them such as proper disposing of the wastes, washing of hands and meat contact surfaces

3.) Various actors in the environmental and public health sectors should ensure that animals to be slaughter are duly inspected and cleared fit for human consumption before being slaughtered and meat sold to the public

4.) Fresh meat to be separated from other fresh vegetables and fruits that are eaten raw to avoid cross-contamination.

5.) Fresh meat should be properly cooked before consumption.

2.1.9.5: Pest and vector Control: Pest and Vectors such as mosquitoes and rats transmit parasitic and viral disease including malaria, Lassa fever, yellow fever, schistosomiasis etc.

Effective pest and vector control will involve proper waste management, good drainage, control of weed and vegetation which provide food and hiding places for their survival (Amadi, 2009)

2.1.10: Meat Microorganisms, Meat Microbiological Criteria and Testing

2.1.10.1: Food Safety and Regulations in Nigeria

National Policy of Food Hygiene and Safety:

The National Policy of Food Hygiene and Safety was launched in 2000 as an integral part of the Nigeria National Health Policy with the overall goal of the attainment of a high level of food hygiene and safety practices that will promote health, control food borne diseases, minimize and finally eliminate the risk of diseases related to poor food hygiene and safety (Omotayo and Denloye, 2002).According to Ifenkwe (2012) and Omotayo and Denloy (2002), the enforcement of food hygiene and safety; and other public Health laws are done by the Health Officers who are under the Local Government Authorities who also are bestowed with the powers to develop by-laws for the regulation and control of food premises. They listed specific laws enacted to ensure food safety in Nigeria as follows:

- The Public Health Law/ ordinances Cap 164 (1917 and 1958)
- Standards Organization of Nigeria (SON) Decree (1971)
- The Food and Drugs Decree number 10 (1988)
- The Marketing of Breast Milk Substitute Decree number 41, (1990)
- Consumer Protection Council Decree number 66 (1992)
- National Agency for Food and Drugs Administration and Control (NAFDAC) Decree, number 15 (1999)
- The counterfeit/ fake drugs/ unwholesome processed food Decree, number 15 (1999).

Majority of meat are sold fresh and warm, exposed on the table in the market without any refrigeration and other means of maintaining cold chain; wheel barrows are used to carry meat etc (Olubunmi *et al.,* 2017; Azuamah *et al.,* 2018; Grace, 2015; Frumkin, 2010). It is believed that there is a general poor food/meat handling practices across the country due to poor enforcement of food hygiene regulations; lack of proper monitoring and supervision by food safety officers (Onyeneho & Hedberg, 2013); non-adherence to stipulated guidelines and regulations during processing, preservation and storage; and these could have resulted in an increased in food/meat contamination and thus contributed significantly in the increase in disease burden globally and in Nigeria. It is also believed that lack of basic knowledge of hygiene practices to be observed and poor level of hygiene by meat handlers and poor sanitation at the abattoirs and butchers' shops; could be responsible for meat contamination from the working surfaces especially the slaughter slabs, knives and hands of meat handlers by microorganisms and hence high bacterial loads in meat samples.

2.1.10.2: Meat Microorganisms

The predominate groups of microorganisms on meat depends on the characteristics of the meat, the environment in which the meat is slaughtered, stored and the processing that the meat might have undergone. Thus, the meat contact surfaces and the water sources play vital role meat contamination (Board & Davies, 1998). Bacteria are generally recognized as the most significant food-borne hazards from fresh meat as they (the pathogenic bacteria such as *Salmonella, Campylobacter* and human pathogenic *E. coli* such as *E. coli O157* can easily cause diseases in humans. Only a few *E. coli O157* is required to cause food poisoning in humans. WHO, (2015 A) listed some of the Bacteria implicated in food borne diseases of meat origin as follows:

- *Salmonella, Campylobacter and Enterohaemorrhagic Escherichia Coli:* these bacteria manifest with symptoms such as fever, headache, nausea, vomiting, abdominal pain and diarrhea. These bacteria have been implicated in food borne diseases outbreaks from under cooked meat and other animal products.

- *Listeria:* infections from Listeria lead to unplanned abortions in pregnant women or death of new born babies. Listeria has been implicated in food borne disease outbreaks from ready-to-eat foods and unpasteurized dairy products; and can grow at refrigeration temperature.

- *Vibrio Cholerae*: it manifests with symptoms such as abdominal pain, vomiting, profuse watering diarrhea and dehydration. Rice, vegetables and sea foods are implicated in cholera outbreaks.

Gram- negative bacteria constitute the greatest spoilage potential for meat and meat products. When fresh meat is chill-stored aerobically, members of the genera *Pseudomonas*; *Acinetobacter; Psychrobacter and Moraxella* species display the fastest growth rates and hence the greatest spoilage potentials. *Enterobacteriaceae* and *Shewenella* species need conditions more favorable to develop and produce spoilage metabolites.The major category of microorganisms in meat is summarized in Table 2.1 below (Meat Industry Guide, 2017).

Table 2.1: Meat category micro-organisms

Micro-organisms	Description Test	Indication
Enterobacteriacae (ENT)	The name given to a group of bacteria that live predominantly in the intestines of animals. The group includes most of the major food-borne pathogens of animal origin such as Salmonella, Yersinia and E.coli O157.	The presence of these organisms on the surface of carcases is an indicator of faecal and environmental contamination.
Generic E.coli (EC)	A group of bacteria that live in the intestines and are shed in the faeces of man and food producing animals. Presence of E.coli is an indicator of faecal contamination.	The test procedure does not specifically recover E.coli O157 but does indicate the risk of contamination with this and other dangerous faecally-derived bacteria.
Salmonella species (Sal)	A group of bacteria that includes several pathogens of significance in human food poisoning disease. They mainly arise from faecal contamination but can also arise from the processing environment.	Further analysis of the type of Salmonella can be useful in investigating and preventing the reoccurrence of positive results as well as providing information that can be used in a risk analysis.
Salmonella Typhimurium Salmonella Enteritidis	Types of Salmonella that have been associated with frequently causing disease in humans. Known as salmonella with public health significance (SPHS). Also includes monophasic salmonella typhimurium with the antigenic formula 4 5 12 i	
Listeria Monocytogenes	A pathogenic bacterium that occurs in the environment. Able to survive and grow at chill temperatures.	The presence of the bacteria in ready to eat food that can support the growth can be a problem.

(Source: Meat Industry Guide, 2017)

The presence of bacteria that can cause meat spoilage could result changes in the color, texture or odor of the meat (Ashwathi, 2017). There could also be a change in the taste of the meat which can become unpleasant. There are multiple spoilage mechanisms, and they can result from the production of various metabolites such as volatiles or exo-polysaccharides. Storage temperature is one factor to be considered in the spoilage of meat. Bacteria thrive at specific temperatures and therefore meat must be stored at temperatures that will not help bacterial growth but ensure their death. Storage at low temperature favors the growth of psychrotrophic and psychrophilic bacteria while carbondioxide (CO_2) has an inhibitory effect on *Pseudomonas* spp. (Waite & Taylor, 2014). It is very possible for microbial load in the meat carcasses to increase during the storage period; and bacteria that dominate spoiled food/meat have been considered as those responsible for spoilage. (Waite & Taylor, 2014; Mohd *et al*., 2015; Ranjitkar, *et al*., 2016). Measures must be put in place to ensure that storage of meat does not lead to increased bacterial load. Meat must be safe from microorganisms at the time it is sold to the consumer.

The Meat Industry Guide (2017) reported that microbiological contamination of meat which may result to a serious food safety hazard could come from poor slaughtering and dressing operations without proper inspection procedures; or could be introduced from equipment, handling, working environment and poor temperature control. Meat handlers need to be aware and informed on spoilage bacteria and the environmental conditions in which they thrive. It is not enough to be informed of these bacteria, but adequate precautionary steps must be taken to prevent the spoilage of meat. This is where government agencies responsible for meat safety have to come in to monitor and supervise the meat industries responsible for meat processing. At the abattoirs, meat handlers must comply with government rules and standards otherwise the meat will be compromised and spoilage will occur (Giuggioli *et al.*,2017).

2.1.10.2.1: `Meat Microbiological Criteria

Harmonized safety criteria on the acceptability of food/meat, in particular as regards the presence of certain pathogenic micro-organisms are established by legislations to protect public health and prevent differing interpretations (Meat Industry Guide, 2017). According to the Meat Industry Guide (2017), the Microbiological Criteria Regulation 2073/2005 provided Legal basis for microbiological criteria. It establishes microbiological criteria for certain micro-organisms and provides rules to be complied with by food/meat business operators when implementing the general and specific hygiene measures. The Microbiological Criteria Regulation 2073/2005 made provision that meat handling procedures should be based on HACCP principles together with Good Hygienic Practices (GHP) to ensure that:

- The Process Hygiene Criteria are met while they are handling/selling meat
- The Food Safety Criteria applicable throughout the shelf life of the meat can be met in the storage, distribution and use of the meat etc.

Microbiological criteria should be used in validation and verification of procedures based on HACCP principles and failure of meeting the limit of a criterion indicates that the HACCP based procedures have failed. The Regulation 2073/2005 established two different types of criteria namely: the food safety criteria and the process hygiene criteria (the main difference between them being in the additional action required). Failure to meet either class of criteria should always result in an investigation to find the cause of contamination and action taken to prevent contamination of future production.

2.1.10.2.2: Meat Microbiological Criteria- Food Safety Criteria

The Meat Industry Guide (2017) reported that Food safety criteria are used to assess the safety of a product or batch of food stuff. They have been set for fresh poultry meat, minced meat,

meat preparations, meat products, mechanically separated meat and ready to eat food and, if exceeded, indicate that the batch tested is unsatisfactory and should be removed from the market. Demonstration of compliance with food safety criteria for meat and processed meat is required as follows:

1. Absence of Salmonella in: minced meat and meat preparations intended to be eaten raw; minced meat and meat preparations intended to be eaten cooked; mechanically separated meat (MSM); meat products intended to be eaten raw; meat products made from poultry meat intended to be eaten cooked; fresh poultry meat etc.

2. Listeria Monocytogenes less than 100cfu/g in ready to eat meats that either do not support the growth of Listeria or have evidence that Listeria will not reach levels greater that 100cfu/g during shelf life.

3. Absence of Listeria Monocytogenes before the food is placed on the market for foods that support growth and do not have shelf life assessment data.

When a food safety criterion is not met, the batch of food/meat in question should be withdrawn from the market (Meat Industry Guide, 2017).

2.1.10.2.3: Meat Microbiological Criteria- Process Hygiene Criteria:

The Meat Industry Guide (2017) also reported that The Process Hygiene Criteria should be used to ensure the production processes are operating properly. The Process Hygiene Criteria results provide an indication of performance and control of the slaughter, dressing and production process at the time of sampling, and must be used accordingly. It is not to assess the fitness of individual carcases or processed meat for human consumption. If the process hygiene criteria are exceeded, corrective action to improve future production must be initiated but there is no requirement to remove product from the market.

The Meat Industry Guide (2017) gave some of the process hygiene criteria for meat and processed meat as follows:

- Aerobic Colony Count and Enterobacteriaceae – on cattle, sheep, goats, horses and pig carcases (below specified limits).
- Salmonella spp – on cattle, sheep, goats, horses, pig, broiler and turkey carcases (absence from a specified number of samples per 50 samples examined).
- Aerobic colony count and E.coli – in minced meat and mechanically separated meat (below specified limits).
- E.coli – in meat preparations (below specified limits)

2.1.10.2.4: Meat Microbiological Testing

According to the Meat Industry Guide (2017), Microbiological Testing of meat is to ensure that safe and wholesome meat and meat products are being sold to the public. During sample collection and processing, samples are collected in areas free of air currents on work surfaces and in aseptic manner ensuring that no foreign sources of microbial contamination are introduced. Sterilized tools are used and collected samples are placed on sterilized containers and then placed on ice-packed containers.

2.1.10.2.5: Microbiological Testing Results:

Meat samples are tested and the following indicator microorganisms were isolated and presented in cfu/g (colony forming unit/gram)

1. Standard plate count (mesophilic aerobic)- with critical limits of 100,000 cfu/gram
2. Total coliform count- with critical limits of 1,000 cfu/gram
3. Generic E. coli count - with critical limits of 500 cfu/gram

Any meat sample found to exceed any of these control limits is rejected for purchase by the public

4. Indicators of process control

5. Foodborne pathogens such as: *Salmonella spp, Listeria monocytogenes. E. coli*.

It's been reported that collection of data on pathogens presence and/or their concentration in beef during the farm stage is indeed a very difficult task because, the transmission dynamics are influenced by the breeding techniques/practices, location, the seasonal frequency of asymptomatic shedders, and variability of prevalence and concentration within the herd, thus making it difficult to estimate the true prevalence of contaminated animals/beef (Tesson *et al.,* 2020). From available records, the use of indicator organisms in the assessment of meat/food safety could be traced as far back as in 1892 when Shardinger proposed the use of *Escherichia coli* (*E. coli)* as an indicator of fecal contamination due to the abundant presence and wide distribution of *E. coli* in the intestine of humans and warm blooded animals (human and animal feces) and not usually found in other niches (Feng *et al.,* 2020).

E. coli (originally known as *Bacterium coli* commune) was identified by Theodor Escherich (German pediatrician) in 1885. *E. coli* is a member of the *Enterobacteriaceae* family with other genera and pathogens such as *Salmonella, Shigella* and *Yersinia.* Some strains of *E. coli* pathogenic and can cause gastrointestinal disorder in healthy human when ingested; while some are not regarded as pathogens but can only cause infections in immunocompromised hosts as be opportunistic pathogens (Feng *et al.,* 2020).

2.1.10.3: Indicator Organisms

Indicator organisms could be defined as those organisms whose presence signal the risk of poor bacteriological quality as there are indications of the presence of pathogens. Their presence in numbers exceeding certain thresholds indicates poor processing (Smith and Schaffner, 2004). Buchanan (2000) defined indicator organisms in connection to process control in food industry as ‘‘microorganism or group of microorganisms that are indicative that a food has been exposed to conditions that pose an increased risk and that the food may be contaminated with a pathogen or held under conditions conducive for pathogen growth.’’ Therefore, classifying an indicator organism for use in a meat/food safety and meat/food industry processing control requires:

(i) acceptance of the assumption that, in response to monitoring levels of indicator organisms, their presence above certain threshold is an indication of poor processing;

(ii) acceptance of the assumption that, in response to monitoring levels of indicator organisms, actions to improve the process or introduce new process controls to help provide consistent processing could eliminate or reduce the number of indicator organisms;

(iii) that such activities may have an impact on pathogen levels or presence. Assume that a processing deficiency has the effect of creating conditions favorable to bacterial growth, resulting in higher-than-expected levels of the indicator organism; then, a corrective action that eliminates these favorable conditions, resulting in lower levels of indicator organisms, could also result in lower levels of pathogens.

The microbiological testing of meat is to ensure that safe and wholesome meat is being sold to the public. It is documented in the Meat Industry Guide (2017) that the presence and / or number of bacteria present on the surface of meat or in processed meat can be assessed objectively by Microbiological testing. The testing against microbiological criteria provides a way of measuring how well the meat handler has controlled the slaughter, dressing and production processes to avoid and control contamination; and the results of testing can be used to ascertain whether the meat handler's HACCP-based procedures are controlling meat safety/quality and verify they are being correctly applied. Microbiological testing may be appropriate at certain stages to validate/verify that the procedures based on HACCP principles are adequate, operational and effectively in control. Final product microbiological testing against the criteria can be used to verify that the overall process is in control.

According to the Meat Industry Guide (2017) the bacteriological quality of meat can be objectively assessed by the following microbiological testing:

- **Aerobic Colony Count (ACC)**

The Aerobic Colony Count (ACC) also known as Aerobic Plate Count (APC) and Total Viable Count (TVC) is a measure of bacteria in the sample that can survive in the conditions on the surface of carcases or in processed meat, and can be harvested by the sampling procedure used and grow in the presence of air on an agar plate. They include bacteria arising both from animals and from the slaughterhouse or meat processing environment. ACC also give an indication of the keeping quality of meat as it includes the organisms responsible for spoilage of meat. ACC is a general measure of the background microbiological status of meat, but ACC results and the number of pathogens present may not always be related hence the need to measure for indicator organisms.

- **Indicator organisms**

Indicator organisms are larger groups of bacteria, including certain pathogenic bacteria, which are relatively easy to measure as a group and whose presence is likely to indicate an increased risk of the presence of pathogenic bacteria. E.g:

- ✓ *Enterobacteriaceae:* Testing for *Enterobacteriaceae,* a group of indicator organisms that live in the intestines of animals and the environment will give a better indication of the risk of pathogenic organisms being present. Control measures that reduce the number of *Enterobacteriaceae, E.coli* and the ACC will reduce the risk of the presence of pathogenic bacteria being present on meat carcases and processed meat.
- ✓ *Salmonella spp*.: If animals enter the slaughter process carrying *Salmonella* on their feathers, hide or fleece, there is a risk that their carcases will be contaminated after dressing. Although the *Salmonella* group of organisms does contain bacteria of significance in terms of human disease, there are also many *Salmonellae* that may occur in animal production that are rarely associated with human disease.

  It should be noted that ACC, *Enterobacteriaceae and Salmonella spp.* criteria set for carcases are process criteria. Failure to meet these does not in itself indicate the meat from the carcase tested or batch of carcases tested will be unfit for human consumption but it does mean that investigations to find the cause of contamination to prevent a reoccurrence should take place, hence the need for adequate public health intervention and the need for this project work.

- ✓ Food safety criteria for *Salmonella Typhimurium and Salmonella Enteritidis* in fresh chicken and turkey meat are also in place. Failure to meet the criteria means the meat from the tested batch must be removed from the market.

- ✓ Generic *E. coli*: Process control is best achieved by setting a criterion for Generic *E. coli* in beef than for *E. coli O157.* This is because a large surface area or a high proportion of carcases needs to be tested to obtain a statistically valid result for many pathogenic bacteria such as *E. coli O157.* This is neither practical nor economically feasible and is why *E. coli O157* on beef and sheep carcases or in processed meat is not currently included in Regulation 2073/2005. This does not mean that this organism is unimportant but that process control is best achieved by setting a criterion for an indicator group of micro-organisms such as *Enterobacteriaceae or generic E. coli*.
- ✓ *Campylobacter: Campylobacter* is present in a high percentage of chicken and turkey flocks and on carcases from birds slaughtered from those flocks.

2.2: THEORETICAL FRAMEWORK

2.2.1: Germ Theory of Disease

Farley documented that the Germ Theory of Disease, initially introduced by Louis Pasteur and later advanced by Robert Koch, greatly transformed the understanding of infectious diseases by indicating that numerous illnesses are attributed to microorganisms such as bacteria, viruses, and fungi; and the Theory has greatly influenced studies/researches in the fields of public health, sanitation, and disease prevention (Farley, 1992). According to Farley (1992), the Germ Theory postulates that the occurrence of specific diseases can be attributed to pathogens, and emphasizes the importance of effective control and elimination of these pathogens for the betterment of the health of the general public. The application of the Germ Theory of Disease to the assessment of the bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigeria, holds significant academic relevance. The primary objective of this study is to examine samples of meat being sold to the public and identify and isolate the bacteria found in meat and on surfaces that come into contact with the meat. This research is in line with the fundamental principles of the Germ Theory because through the process of

identification and isolation of various bacterial isolates in meat being sold to the public, researchers would be able to evaluate/predict the potential/possible bacterial hazards that could be implicated/be associated with possible foodborne diseases outbreaks in the studied areas. Thus, the Germ Theory assumes a fundamental role in emphasing the importance of adhering to appropriate protocols for meat/food handling and maintaining standard hygiene practices. This statement underscores the necessity of implementing rigorous measures to mitigate the proliferation and dissemination of bacteria within marketplaces. The theory emphasizes the importance of maintaining suitable storage conditions, handling procedures, and sanitation practices etc throughout the meat supply chain in order to prevent possible microbial contamination of the meat.

Also, the Germ Theory also emphasizes the importance of personal hygiene in both food/meat handlers and consumers as the spread of bacteria could be significantly influenced by the actions of both the sellers and buyers within the market environments. Thus, there is need for adherence to standard hygiene protocols and enlightening the sellers and buyers on the significance of practicing proper meat/food safety handling measures as ways of prevention of pathogen transmission and mitigation of foodborne illnesses. Therefore, the Germ Theory of Disease is a fundamental concept in this research as it provides the theoretical foundation for acknowledging the involvement of microorganisms, particularly bacteria, in the etiology of diseases, while emphasizing the imperative nature of implementing effective food safety protocols to ensure the wholesomeness of meat being sold to the public; and possibly identify potential sources of bacterial contamination and recommend effective strategies to improve meat/food safety and mitigate the occurrence of foodborne illnesses.

2.2.2: Knowledge, Attitudes and Practices (KAP) theory

The Theory of Knowledge, Attitudes and Practices (KAP) is a useful theoretical framework to understand and explain food/meat safety behaviors and often used in public health and food/meat safety researches to assess and address the factors that influence individuals' behaviors related to food/meat safety. KAP is one of the most frequently used theories to examine, explain and study food safety practices measures (Zanin et al., 2017); and the theory have been used by researchers in recent studies and articles in Food Safety and Control (Al-Kandari *et al.*, 2019; Letuka *et al.*, 2021; Ncube *et al.*, 2020; Nyokabi *et al.*, 2021; Siddiky *et al.*, 2022). The theory of KAP was propounded in the 1950s to look into the cognitive facets of food management. The KAP theory in summary believed that people who handle food will adopt good food safety practices/measures if they have the necessary knowledge and positive attitudes (Baş *et al.*, 2006). In the KAP theory in food safety:

Knowledge (K):

Knowledge refers to people's information and understanding of food/meat safety handling procedures/practices such as knowing the proper methods of handling, storing, and preparing food/meat etc so as to prevent contamination and foodborne illnesses. To determine knowledge, **t**he researcher will have to determine how much the people know about the meat safety principles and practices using surveys, questionnaires, or interviews. Any identified gaps in the people's knowledge, ignorance or prejudices of food safety are corrected and filled through educational campaigns, training sessions, and distribution of instructive materials.

Attitude (A):

Attitude here deals with individuals' feelings, beliefs, and ideas regarding meat safety. For individuals to adopt safe meat handling habits/practices, they must have positive attitudes toward food/meat safety. Thus, it is important to find out the individuals' attitudes toward meat

safety practices; how important they think meat/food safety is and what they think about how safe or dangerous practices could affect their businesses and customers. Corrective education could be employed to address any negative attitudes unfavorable beliefs.

Practice (P):

Practice refers to the actual meat/food safety-related behaviors and actions people take such as putting knowledge of meat/food safety into practice and incorporating positive attitudes into daily activities in their businesses. It explains and evaluates the people's actual meat/food handling practices/techniques by watching/observing them and could be done through on-site observations or self-reporting. Any observed lapses could be addressed through trainings and provision of assistance/resources to increase adherence to meat safety regulations/guidelines.

KAP theory in meat/food safety can help expose factors that influence individuals' behaviors in safe meat/food handling practices and help in designing targeted interventions to promote safer meat/food handling practices. The KAP approach involves addressing knowledge gaps, fostering positive attitudes, and supporting individuals in translating their knowledge and attitudes into safe meat/food handling practices; and thus contribute to reducing the risk of foodborne illnesses and creating a culture of meat/food safety within communities and meat/food-related businesses

2.2.3: Hazard Analysis and Critical Control Points (HACCP) Approach

The Hazard Analysis and Critical Control Points (HACCP) system is a methodical and proactive strategy for ensuring food safety. It involves the identification, assessment, and management of potential hazards at various stages of food production and handling (Dewettinck *et al.,* 2001). The Hazard Analysis Critical Control Point (HACCP) approach is use to investigate the processes and procedures/management practices that contribute to bacterial contamination, growth and survival; and to identity points where control measures

could be applied to prevent or eliminate the bacteriological hazards or reduce them to acceptable levels. .According to Friis (2007), HACCP system was adopted in the 1950s to assure the safety of food used in the US space programme; in 1990s, the FDA established HACCP for the processing of sea foods; in the late 1990s, the US Department of agriculture initiated HACCP for plants that process meat and poultry products; and in 2002 HACCP was applied to the juice industry.The HACCP system has been developed with the primary objective of guaranteeing the safety of food products for human consumption. This is achieved through a meticulous examination of every stage involved in the food supply chain, coupled with the implementation of appropriate control measures aimed at mitigating, eliminating, or minimizing potential hazards to a level that is deemed acceptable. The utilization of this tool has been widely acknowledged and implemented as a highly effective method for augmenting the safety of food and mitigating the potential hazards associated with foodborne illnesses (National Advisory Committee on Microbiological Criteria for Foods, 1998).

The application of the Hazard Analysis and Critical Control Points (HACCP) system to the investigation of the bacteriological characteristics of meat and contact surfaces in markets in Abia State, Nigeria, yields significant advantages. The implementation of the Hazard Analysis and Critical Control Points (HACCP) approach facilitates the identification of key stages within the meat supply chain and market settings, wherein the probability of bacterial contamination is most likely. Through the implementation of a comprehensive hazard analysis, scholars are able to identify plausible origins of contamination, including but not limited to improper handling techniques, unhygienic practices, and insufficient sanitation measures. The initial phase of HACCP implementation entails performing a hazard analysis, wherein one must identify plausible biological, chemical, and physical hazards that may be linked to the

meat and market settings. Within the confines of this study, the primary objective would be to ascertain the precise bacterial pathogens that present a potential hazard to consumers.

Subsequently, the identification of critical control points (CCPs) takes place. Critical Control Points (CCPs) refer to specific stages within a process where control measures could be implemented to mitigate, eliminate, or decrease the identified hazards to levels that are deemed safe. The study examines the potential inclusion of critical control points (CCPs) within the meat handling process, encompassing various stages such as slaughtering, transportation, storage, and display. Additionally, it explores the identification of market areas characterized by significant contact with the seller, buyer and the contact surfaces. The Hazard Analysis and Critical Control Points (HACCP) system is an invaluable instrument for investigating the bacteriological characteristics of meat and contact surfaces in markets in Abia State, Nigeria. The study aims to utilize HACCP principles in order to identify and address critical points of contamination. This approach will contribute to the safe handling and distribution of meat in markets, thereby reducing the potential risk of meat contamination and its attendant effects.

2.2.4: Food Safety Risk Assessment theory

Food Safety Risk Assessment is a methodical and structured approach employed to identify and assess potential hazards that may be linked to food products, processes, and environments (Jaykus, 1996). This process involves analyzing the probability of events taking place and the magnitude of potential health impacts associated with these hazards; and it holds significant importance within the field of food safety management because it facilitates the process of making well-informed decisions and implementing appropriate control measures aimed at mitigating risks and safeguarding public health (Powell, *et al.,* 2004). The utilization of the

Food Safety Risk Assessment framework is imperative in comprehending and effectively addressing potential risks associated with the bacteriological characteristics of meat and contact surfaces in markets in Abia State, Nigeria. The objective of this study is to evaluate the extent of bacterial contamination in meat and on surfaces that come into contact with the meat. The bacterial contaminatants if present constitute potential biological food hazards to the consumers. Through the utilization of a risk assessment methodology, researchers are able to methodically identify the weakest point within the meat supply chain and the specific markets where the likelihood of contamination is more likely.

Within this particular framework, the initial stage would entail the process of hazard identification. This involves the recognition and acknowledgment of potential biological hazards, specifically bacteria that may be associated with meat and contact surfaces. This would involve the identification and isolation of the predominant bacteria in the meat samples under study and ascertain if Indicator bacteria were among those isolated. Risk management strategies can be developed by utilizing the results obtained from the risk assessment. This may encompass the adoption of effective handling and sanitation protocols, the application of suitable food processing methodologies, and the enforcement of food safety regulations within market settings. The theory of Food Safety Risk Assessment is a valuable tool for examining the bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigeria as it facilitates a methodical assessment of the identification and isolation of bacterial isolates/ risks linked to meat being sold to the public in markets in Abia State and provides recommendations on how to improve food safety practices and protect the health of the public.

2.2.5: Model of Human Interaction with the Environment

There are numerous theories and concepts that relate the safety of meat/food and the environment. These relationships existed because the environment has a significant role and impact in food production, processing, and distribution, thus affecting the safety and quality of the meat/food we consume. One of these theories is the "farm-to-table" theory:

Farm-to-Table Approach:

The "farm-to-table" approach became popular in the 2000s and it explains the importance of maintaining standard and wholesome practices in the food production chain from farm to table. The farm-to-table movement has continued to grow and develop as consumers' concerns about food safety and quality of their food increased. This approach recognizes that the environment in which meat/food is produced directly affects its safety and quality. For instance, if agricultural methods heavily rely on the use of pesticides or other chemicals, this could result in residues in food products that could have adverse effect on human health.

2.3: EMPIRICAL STUDIES

Studies on the Bacteriological Qualities of Meat

The occurrence of different types of Bacteria in meat has been investigated by various scholars. Bacteria found more in the feces of the animals are different from those found on their skin and other part of the body; hence, the need for a thorough understanding of these disease causing organisms. (Oakley, *et al.*, 2012). Knowledge obtained must be shared with the public in order to enlighten and inform both those involved in the meat profession and the consumers who are the eventual victims of consuming contaminated meat. Different types of meat, be it chicken, beef, pork, lamb, mutton, etc. have groups of bacteria that breed on them. That is why it is imperative for the public to know what bacteria can be found in what meat. This is the first step

before knowing other vital information such as the part of the meat where each bacteria harbors, or the disease or illness its consumption could cause.

Azuamah *et al* (2018a) carried out a study to investigate the bacteriological qualities of red meat and the meat hygiene practices of meat handlers in Aba Metropolis, Nigeria. Seventy-two meat samples were purchased from 72 meat handlers at 4 different markets in Aba metropolis. A harmonized HACCP checklist was used to interview the 72 meat handlers. Results of laboratory analysis showed that the bacteria mean colony forming units (CFU/g) ranged from 3.23×10^5 to 2.13×10^8. *Staphylococcus* species has the greatest number of isolates with 96 (16.11%) occurrence followed closely by *Escherichia coli* with 93 (15.60%) occurrence. *Klebsiella* species had 78 (13.09%) isolates; *Campylobacter* species had 68 (11.41%) isolates; *Pseudomonas* species and *Enterococcus* species had 64 (10.74%) and 63 (10.57%) respectively. Other bacteria isolated include *Bacillus* species, 34 (5.70%); *Enterobacter* species, 30 (5.03%); *Salmonella* species, 28 (4.70%); *Shigella* species, 40 (6.71%); and *Micrococcus* species, 2 (0.34%). Out of the 72 meat handlers interviewed using the harmonized checklist, the mean percentage score for meat storage and meat transportation was 28.57% and 35.71% respectively. None of the meat handlers scored above 40% in the checklist for both meat storage and meat transportation. Results from the interview also show that only 9 (11.69%) wear hand gloves; 15 (19.48%) have adequate wash-hand basins with soap and running water; 7 (9.09%) wash their hands routinely with soap and running water; and 25 (32.47%) of the meat handlers are free from skin injuries or enteric illnesses. It was recommended that meat handlers especially in developing countries need proper education and training on the meat hygiene. Regulating agencies were also advised to ensure strict compliance by meat handlers to safety standards by embarking on routine inspection at slaughter houses and market places.

Another study (Azuamah, *et al.* 2018b), was conducted to investigate the HACCP checklist scores by meat handlers at critical control points using a harmonized checklist. A total of 156 meat handlers from 10 different markets in Imo State, Nigeria were used for this study. Scores were awarded based on observations and information obtained from the meat handlers on meat transportation, meat storage, personal hygiene of the meat handlers, sanitation, pest control, waste disposal and staff training of the meat handlers. The mean percentage scores obtained for meat transportation was 24.55±5.97; for meat storage, 22.36±6.24; for personal hygiene, 27.93±4.81; for sanitation, 21.42±6.70; for pest control, 23.80±5.46; for waste disposal, 27.11±4.95; and for staff training, 26.78±5.62. The meat handlers at all the markets in the state had very low HACCP scores at all the control points. Data analysis with SPSS version 21 using the one-way at 0.05 level of significance and 95% confidence interval showed no significant difference ($P>0.05$) in the mean HACCP scores at the critical control points. The meat handlers were advised to undergo proper training on meat safety and comply with HACCP standard operating procedures.

Azuamah, *et al.* (2019) further carried out a study in Southeastern Nigeria to determine the bacterial isolates found in the contact surfaces of meat handlers at their workplace. Samples were collected using sterile swab sticks from 108 contact surfaces which included 36 tables, 36 hands and 36 knives of the meat handlers. The samples were taken to the laboratory for bacterial analysis. A well-structured questionnaire was also used to interview the meat handlers. Results of the bacterial isolates of the samples showed that Staphylococcus aureus was isolated in 22 (61.11%) of the 36 samples from tables, 18 (50.00%) from the hands of meat handlers and 15 (41.67%) from their knives; Escherichia coli, 18 (50.00%) from tables, 9 (25.00%) from hands and 6 (16.67%) from knives; Shigella dysenteriae, 17 (47.22%) from tables, 9 (25.00%) from hands and9 (25.00%) from knives; Klebsiella pneumonia, 17(47.22%)

from tables, 13 (36.11%) from hands and 11 (30.56%) from knives; Enterococcus faecalis, 15 (41.67%) from tables, 16 (44.44%) from hands and 12 (33.33%) from knives; Pseudomonas aeruginosa, 10 (27.78%) from tables, 9 (25.00%) from hands and 11 (30.56%) from knives. The sanitary and personal hygiene practices of the meat handlers were found to be very poor and this resulted to the high bacterial isolates found on their tables, hands and knives. It was recommended that regulatory agencies embark on routine inspection of abattoirs to ensure compliance of meat handlers to meat safety standards.

Studies also carried out in some parts of Nigeria revealed that meat sold to the public contain high microbial loads which could constitute serious food-borne and public health hazards (Azuamah *et al.*, 2018; Joseph, 2017; Iro *et al.*, 2020). Ukut, *et al.* (2010) reported that samples of fresh meat (beef) randomly selected from two major markets in Calabar, Nigeria were grossly contaminated with pathogenic bacteria such as Klebsiella Pneumonia, Salmonella and Escherichia coli among others. A study in Abia state, Nigeria (Eze and Nwosu, 2012) found that *Salmonella* species, *Proteus* species, *Staphylococcus aureus, Pseudomonas* species, and *Escherichia coli* were prevalent microorganisms found in meat sold to the public. Amadi *et al.* (2020) investigated the water supply and bacteriological qualities of drinking water in primary schools located at North central Nigeria. One thousand five hundred and fourteen water samples were collected from 48 schools located at North central Nigeria. A well-structured questionnaire was used to interview 1,514 primary school children with the consent of their parents. Results that 1066 (70.4%) children had access to drinking water while 448 (29.6%) did not. The sources of drinking water was 383 (25.3%) from piped water; 463 (30.6%), tube well; 131 (8.7%) covered well; 27 (1.8%), rain water; 11 (0.7%) open well; 18 (1.2%) tanker truck; 24 (1.6%) stream; 246 (16.2%) bottled water and 104 (6.9%) sachet water. On the utilization of water supply, 1004 (66.3%), responded that drinking from the main source

is currently available for the school while 510 (33.7%) said it is not available. The response to treatment of water showed that 623 (41.1%) always treat their water before using it; 361 (23.8%) sometimes; 530 (35.1%), never; 697 (46%) responded to boiling; 354 (23.4%), chlorine; 285 (18.8%), water filter; 99 (6.5%) solar disinfection; 79 (5.2%) let it stand and settle. The distribution of the bacterial isolates from water samples showed that *Staphylococcus aureus* has the greatest number of isolates with 319 (21.1%); *Escherichia coli* with 76 (12.3%) occurrence. *Klebsiella pneumonia* had 200 (13.2%) isolates; *Enterobacter* species had 76 (5.0%) isolates; *Pseudomonas aeruginosa*, 162 (10.7%); *Salmonella* species, 56 (3.7%) and *Shigella* species, 94 (6.2%). It was recommended that Governmental agencies ensure that every school complies with the provision of potable drinking water for their pupils.

The bacteriological and parasitological assessment of some fresh meat marketed in Owerri, Nigeria was carried out using standard bacteriological and parasitological methods (Mgbemena, *et al.*, 2015). They concluded that there is need for proper hygienic practices to be observed by the butchers. The hygiene practices implicated here was the lack of regular hand washing with soap and water, poor pest control practices. Also sanitation and cleanliness was lacking. The markets did not have adequate waste disposal facilities. There were no clean floors but muddy walk ways in the open environment which made it easy for dirt to spread around. Flies were seen buzzing everywhere and this is dangerous as they carry bacteria with them as they move from place to place. There were no visible boreholes present or any source of potable water supply. All these measures were needed to be improved on to be able to ensure that meat sold to the public was not contaminated.

Ten duplicate samples of fresh meat (beef) were randomly sampled from 2 major markets in Calabar, Nigeria and analyzed microbiologically for the rates of Gram negative bacteria. A

total of 36 isolates belonging to eight genera include *Klebsiella pneumoniae* which was the most predominant, followed by *Enterobacter spp, C. freundii, Escherichia coli, Salmonella spp, Ps. aeruginosa, S. marcescens*, and *Pseudomonas spp* (8.3%). *Proteus vulgaris* was less predominant. *Staphyloccus aureus* was not among the isolates. Statistical analysis of the mean microbial load and total coliform count showed no significant difference between the two markets (P>0.05). This study reveals that fresh meats were often contaminated with bacteria possibly constituting significant public health hazards (as food borne disease burden continues to increase) and hence the need for adequate attention (Ukut, *et al*., 2010). They observed that most of the organisms found were normally found in soil and water. The isolation of *E. coli* and *Enterobacter spp* in the fresh meat samples was an indication of faecal contamination of the meats. They concluded that fresh meat sold at the studied markets in Calabar, Nigeria were grossly contaminated with coliform bacteria and pathogenic gram-negative bacteria due to poor and unhygienic handling of meat from the slaughter houses to markets; and could serve as sources foodborne diseases. Therefore, there is the need for the regular training of meat handlers on proper hygienic meat handling procedures and the adverse effects of meat contamination.

Bacteria continue to contaminate food consumed by the public due to lack of sanitation, cleanliness and personal hygiene. If meat handlers can improve on their hygiene practices, the result will reflect on the decrease in number of meat-borne diseases. Ndalama, *et al*., (2013) carried out the assessment of the hygiene practices and faecal contamination of beef at Vingunguti slaughterhouses in Dar es Salam, Tanzania and reported that there was poor hygiene and sanitation practices and lack adequate knowledge of meat contamination among the meat handlers. Their work also reported as observed in other studies in developing countries that there were no adequate sources of potable running water, no provision for proper

waste collection and disposal; no facilities for temperature control in the meat value chain in the sampled slaughterhouses, the meat handlers we not wearing protective clothings etc. *E. coli* was the predominant bacterial isolates from the meat samples. They recommended amongst other enlightenment and proper training of the handlers operating in the various slaughter houses in Tanzaina on the need to adhere to HACCP – Good hygiene practices in all the meat handling processes- slaughtering, dressing/dehiding, transportation, etc.

In another work carried out by Ayesha, *et al*., (2016) to evaluate the microbiological quality of different meat samples including chicken, mutton and beef, almost all meat samples were unfit for human consumption due to the presence of high aerobic count, coliforms, fecal coliforms and *Salmonella* spp. The poor microbiological quality of meat was attributed to the poor handling and processing of the meat in unsanitary conditions. The researchers called on Government agencies responsible for the regulation of the meat industry and meat safety to take adequate control measures towards improving meat hygiene and prevent the contamination of meat so as to control the alarming rate of meat (food) borne diseases which has been on the increase. If poultry feed get in contact with vegetative matter, it could be contaminated with fungi, hence the need for a veterinary doctor to regularly check these livestock feeds for the levels of bacteria and fungi which they habor so as to guide the poultry farmer on which livestock are safe for human consumption and which are not. We must consider the fact that the poultry farmer is only interested in making profit and as a result may not take the necessary steps to separate the healthy from the unhealthy livestock and so government agencies responsible for meat safety have to come in and do this job. Gutema *et al.*, (2021) and Kabir (2009) also supported that food animals are the main reservoir of zoonotic *Salmonella* with fresh meat products from broiler chickens and layer hens among others as sources of infections.

Pork meat is quite popular as a favorite to a lot of people across the world and in Nigeria. However, the safety of pork meat needs to be evaluated. Pigs are commonly known to be filthy animals that like to reside in dirty environments thus they attract a lot of bacteria. Thus, the safety of pork meat needs to be thoroughly investigated before being sold to the public for consumption. Thus, there is need for research on the bacterial load of pork meat to ascertain its safety levels. Also, consumers must cook pork thoroughly to ensure that all bacteria have been properly killed before consumption. Igbinosa *et al.*, (2016) carried out a study to characterize methicillin-resistant staphylococci from raw meat. A total of 126 meat samples were obtained from open markets and antimicrobial susceptibility testing was carried out using the disc diffusion method. The study showed that raw meats in the Benin metropolis were possibly contaminated with pathogenic and multi-drug resistant *staphylococci* strains and therefore could constitute a risk to general public.

Staphylococcus contamination of meat appears to be very common and the organism is becoming resistant to various antibacterial agents thus imposing a big problem on the treatment of people with *staphylococcal* infections. As *Staphylococcus species* tends to adapt and adjust to the conditions it is faced with; it develops resistant to some of the major antibacterial agents thus making the control of infections resulting from it difficult. Therefore, meat handlers must be cautious of their environment and take their personal hygiene seriously because *Staphylococcus species* and other bacteria thrive in dirty environment. They have to practices regular washing of their hands and keep their surroundings clean at all times. Ndahi, *et al*., (2014), also carried out another study to simultaneously isolate and characterize *L. monocytogenes* and *Staphylococcus* species from 300 samples of raw meat and meat products so as to determine the susceptibility of the organisms to commonly used antimicrobial

agents. They subjected the *Staphylococcus aureus* isolates to sensitivity test to sixteen (16) antimicrobial agents, and observed that eleven (11) were resistant to methicillin (even though none of the bacteria carried the methicillin resistance gene). Bacterial resistance to anti-bacteria agents continued to be a major challenge to the medical field as new anti-bacterial agents have to be developed to tackle the problem posed by non-effective conventional anti-bacterial agents due to the resistance of the bacteria.

Ghaderpoori *et al.,* (2009) in their work on the microbial quality of drinking water in Saqqez, Iran reported that the predominant isolated microorganisms from the water samples were *Klebsiella sp., Streptococcus faecalis and P. aeruginosa.* In 88% of the studied rural water samples, no average indicator organism such as *E. coli* was isolated. Brucellosis is a neglected zoonosis of public health importance. Ayoola, *et al.* (2017) conducted a study to determine the prevalence and risk factors of brucellosis among slaughtered cattle as well as challenges to the protection of abattoir workers in Nigeria and observed moderate prevalence of bovine brucellosis. Most of the meat handlers wore no protective gloves and other protective equipment as they claimed their use was uncomfortable for them. The very high temperature in tropical Africa makes people feel more comfortable wearing lesser outfit at work. Thus, protective dresses such as aprons, gum boots, gloves and hair nets make the meat handler hot and uncomfortable. However, they advocated that meat handlers should be educate on the need for good personal hygiene and wearing of personal protective equipment (even if they find it uncomfortable under the hot sun) as a control measures against brucellosis.

In another study carried out by Iro *et al.,* (2019) to determine the bacteriological qualities of Beef sold in Abia and Imo States and the implications for the sustenance of enteric diseases indicated that the bacteriological quality of beef sold in the two states was very poor and may

be exposing meat consumers to high risk of enteric diseases. Predominant bacteria isolated from meats in the two states are; *Staphylococcus spp., Bacillus spp., Escherichia coli, Proteus spp., Salmonella spp., Klebsiella spp., Enterococcus spp., micrococcus* etc. They observed that poor hygiene and sanitary practices among meat handlers during transportation and storage could lead to the contamination of meat; and recommended that Nigerian government at all levels should enact and enforce laws on meat safety management based on good hygiene principles of Codex Alimentarius Commission. In a study to assess the bacterial quality of raw beef being sold to the public in Finland and Nigeria using mesophilic aerobic bacteria (MAB) and thermotolerant coliform bacteria (TCB) counts, Osemwowa *et al.,* (2021) observed that the bacterial load of the raw beef surfaces from meat markets in Benin City, Nigeria were significantly higher than that of the raw beef being sold in Helsinki, Finland. They concluded that most of the sampled beef were of poor quality due their high bacterial loads which they attributed to poor meat handling practices such as poor hygiene and sanitation during slaughtering, transportation, at the marketing outlet, poor temperature control which encouraged bacterial growth. It should be noted also that very high thermotolerant coliform bacteria (TCB) counts as observed in fresh beef samples in Nigeria is an indication of high contamination during the meat production chain and improper storage temperatures (Osemwowa *et al.*, 2021).

According to Osemwowa *et al.* (2021), the PCR screening results of raw meat samples from Nigeria showed a very high prevalence of *Salmonella* (42%) and STEC (100%); and also isolation rates of *Salmonella* (30%) and STEC (36%). This result was in agreement with an earlier reported (30%) isolation rate of STEC in beef products in Benin City, Nigeria by Omoruyi *et al.,* (2018). Osemwowa *et al.* (2021) also explained that no *Salmonella* was detected in Finland, and that the STEC prevalence was also lower than in Nigeria due to successful and efficient Finnish *Salmonella* Control Program. Tesson *et al.,* (2020) in their beef

meat quantitative risk assessment review noted that carrier animals at the farm, dehiding, and chilling at the slaughterhouse and poor storage temperatures at the retail level were the most important risk factors for *Salmonella* and STEC contamination in beef meat. Osemwowa *et al.*, (2021) reported that Cephalosporin-Resistant *E. coli (CREC)* was isolated from 96% of the Nigerian meat samples as against one Finnish sample. They attributed this to the very high TCB counts on the meat surfaces an indicator of feacal contamination of meat samples in Nigeria. They also opined that this could also be due to overuse and misuse of antimicrobial drugs by animal farmers in Africa (Alonso *et al.,* (2017)) as well as the purchase and use of veterinary drugs without veterinary prescriptions or supervision as practiced in Nigeria (Adesokan *et al., (*2015); Alhaji and Isola, (2018). They also were of the opinion that the reported low (2%) prevalence of CREC on the beef surface samples in Finland could be due to the strict control and monitored use of antimicrobials drugs by animals farmers in Finland and the restricted use of cephalosporins for treating diseases in food animals in Finland as observed by Nyk¨asenoja *et al.*, (2019).

In conclusion to their study in Ethiopia, Gutema *et al.*, (2021) observed unhygienic practices at the slaughterhouses and retail shops which was linked to lack or inadequate knowledge of basic hygienic practices, lack of modern basic infrastructure or facilities and non-compliance to CAC standards of good handling practices of food, lack of supervision and poor implementation of the government policies and corrective actions on meat/food safety management. These have continued to sustained unhygienic meat handling practices with possible increasing risk to human infections and increase in food borne diseases outbreaks in developing countries, and hence need for urgent interventions.

2.4: SUMMARY OF GAPS FROM EXISTING LITERATURE

The existing literature on the bacteriological qualities of meat and contact surfaces in Abia State, Nigeria, reveals several research endeavors, such as those conducted by Eze and Nwosu (2012), Azuamah et al. (2018, 2019), and Iro et al. (2019), each focusing on specific aspects of red meat quality in various locations within the State, including Umuahia and Aba Metropolis. However, a comprehensive understanding of the bacteriological qualities of beef and chicken sold in markets across all three Senatorial Zones of Abia State is notably absent. These studies also fall short in providing insights into the environmental conditions surrounding the markets and slaughterhouses, neglecting the importance of a walk-through sanitary inspection to identify potential sources of contamination and ascertain the existence of environmental nuisances that might contribute to increased bacterial loads in meat. Furthermore, the existing works do not address whether there were any failures in meat processing criteria at the time of sampling, leaving a critical gap in knowledge. Therefore, the present study aims to fill these gaps by offering a more holistic investigation into the bacterial qualities of beef and chicken sold in markets across all three Senatorial Zones of Abia State, conducting a thorough walk-through sanitary inspection of market environments, and assessing potential failures in meat processing criteria during sampling.

CHAPTER THREE

MATERIALS AND METHODS

3.1 Study Area

Abia State:

Abia State was created from part of Imo State in 27th August 1991. The geographical coordinates of Abia State is 5.4527°N 7.5248°E. As at the 2006 census, the population of Abia State was put at 2,845,380, (Federal Republic of Nigeria Official Gazette, 2009). Its capital city is Umuahia and the major commercial city is Aba. English is widely spoken and serves as the official language in governance and business. Christianity is the predominant religion of Abia people. Abia State has 3 senatorial zones with 17 Local Government Areas (LGAs). The senatorial zones are Abia Central, Abia North and Abia South. The LGAs include: Aba North, Aba South, Arochukwu, Bende, Ikwuano, Isiala Ngwa North, Isiala Ngwa South, Isuikwuato, Obi Ngwa, Ohafia, Osisioma Ngwa, Ugwunagbo, Ukwa East, Ukwa West, Umuahia North, Umuahia South and Umu Nneochi. Figure 3.1 shows the 3 senatorial zones and the LGAs in each zone of Abia State.

Figure 3.1: Geographyical Map of the Study Area- Abia State showing the three (3)Senatorial Zones and LGAs

(Source: Nigerian Muse, 2010)

3.1.1: Justification of the Study Area:

There are not much visible published works on the bacteriological assessment of red and white meat together with the contact surfaces in markets in the three Senatorial Zones of Abia State, hence this present study in this area.

3.2 Study Design

This research design is a descriptive, cross-sectional study with field and Laboratory components involving the use of questionnaires, laboratory tests/analysis and observational sanitary inspection to assess the bacteriological qualities of meat and meat contact surfaces in selected markets in Abia State. Questionnaires would be used in the interviewing of meat sellers; laboratory analysis/tests would be used to examine the meat and meat contact samples while observational sanitary inspection would help to detect any environmental nuisances in the slaughter markets/markets.

3.3 : Study Population

Meat handlers include those who slaughtered the animals (cows), dressed/cut the slaughtered animals up at the abattoirs/slaughter houses; those who move the animal carcases from the abattoirs to the markets/ meat shops and the meat sellers in the markers and meat shops. The study population are meat (red (beef) and white (chicken)) sellers in markets in Abia State, Nigeria. According to the information from the **Meat Sellers Associations in Abia State**, there are about **three thousand one hundred (3100)** meat sellers across the various markets in Abia State. Ten (10) Local Government Areas (LGAs) out of the Seventeen (17) LGAs from the three Senatorial Zones in Abia State were randomly through balloting selected for this study.

3.3.1 Scope of Study

The scope of this study includes:

- Geographical scope: which covers meat handlers/sellers in markets in Abia State where meat are sold.
- Content scope: involves laboratory analysis of meat samples (beef and chicken), water sources and meat contact surface samples from markets in Abia State to identify the predominant bacterial isolates; and to determine the level of compliance to sanitation and hygiene practices criteria among the meat sellers using questionnaires.
- Population: the population for this study is all meat handlers/ sellers in the seventeen (17) Local Government Areas (LGAs) of Abia State.
- Variables: the independent variable is the "Assessment" and the dependent variables are "the Bacteriological qualities of meat and contact surfaces.
- A descriptive cross sectional survey was used for this study

3.4: Sample Size and Sampling Technique

3.4.1: Sample Size

The sample size calculation of the population of meat sellers in the markets for this study was determined using Taro Yamane formula (Yamane, 1967):

$n = N/1+N(e)^2$

Where;

n=sample size (?);

N=Population size (3100 meat sellers [Meat sellers Association of Abia State record Data, 2021])

e=Level of precision (5%) i.e 0.05

Thus,

$n= 3100/1+3100 \times (0.05)^2$

$= 3100/1+3100 \times .0025$

$=4250/1 + 7.75$

$=3100/8.75$

$= 354.28$ approximately 354

Adding 20% to account for attrition, then the 20% of 354 = 0.20 x 354 = 70.85 approximately 71

Therefore, the total sample size for this study is 354 + 71 = **425 meat sellers**

3.4.2: Sampling Techniques

A Multi stage simple random sampling technique (through balloting) together with systematic and purposive sampling were adopted for this study.

3.4.2.1: Selection of LGAs

A simple random sampling using balloting was used for the selection of ten (10) out of the seventeen (17) Local Government Areas (LGAs) in Abia State for the study thereby giving every LGA in Abia State an equal chance of selection by the researcher. Based on the geographical size and population, Four (4) LGAs were randomly selected out of the six (6)

LGAs in the Aba senatorial zone through balloting; while three (3) LGAs each were also randomly selected out of the six (6) and five (5) LGAs in Umuahia and Ohafia zones respectively through the same balloting.

3.4.2.2: Selection of Markets

Purposive sampling techniques was employed in the selection of markets for sampling from the enumerated major markets in the selected LGAs and communities.

3.4.2.3: Selection of Respondents

The selection of respondents together with the meat samples for the study were done through systematic and random selection by balloting whereby all respondents present at the time of study who picked even numbers were selected until the minimum sample size of the study was obtained.Thus, a total of 425 samples of meat and meat sellers who were systematically and randomly selected from markets in ten (10) LGAs in Abia State, Nigeria were used for this study. The sampled markets in Aba, Umuahia and Ohafia Senatorial Zones have a total number of 340, 250 and 100 meat sellers respectively out of which 200, 160 and 65 randomly selected meat sellers were drawn; and participated in this study from the three senatorial zones respectively. Tables 3.1 to 3.4 below is a proportional table showing the total number of meat sellers in the selected LGAs per zone and the number/percentage of respondents selected from each zone for the allocation of questionnaires

Table 3.1: Table of proportion showing the total number of meat sellers in the selected LGAs per zone and the number/percentage of respondents selected from each zone for the allocation of questionnaires

Study Area **(Senatorial zones with selected the Local Government Areas- LGAs)**	**Total number of meat sellers in the selected LGAs**	**Number selected respondents for interview**	**Percentage of the Respondents/ meat sellers selected for interview**
Aba Senatorial Zone (LGAs: Aba North, Aba South, Ugwunagbo, Obingwa)	**340** (R = 210; W=130)	**200** (R = 120; W=80)	58.82
Umuahia Senatorial Zone (LGAs: Umuahia North, umuahia South, Ikwuano)	**250** (R = 100; W=150)	**160** (R = 62; W=98)	64.0
Ohafia Senatorial Zone (LGAs: Ohafia, Bende, Isuikwuato)	**100** (R = 65; W=35)	**65** (R = 42; W=23)	65.0
Total		**425** (R = 224; W=201)	

R= Red Meat (Beef), W = White Meat (Chicken)

Inclusion and Exclusion Criteria

All meat sellers in the markets (both male and females from the ages of 18 years and above) who practice their trade in Abia State; and gave their consent for the study were part of this research work. Meat sellers/handlers who did not give an informed consent to be part of the study were excluded.

3.5 Instrument for Data Collection

The instrument for data collection were questionnaire and Laboratory equipment for the assessment of the bacteriological qualities of meat samples. An observational sanitary inspection of the selected markets was also done for deduction of environmental nuisances around the markets.

3.5.1 Questionnaire

The Questionnaire as an instrument of data collection was used to obtain information on the sanitation and hygiene practices of meat sellers in markets at Abia State; and other relevant information on the socio demographic characteristics of the meat sellers. Physical observations were also made from the observational sanitary survey. The questionnaire has 17 research questions with an introductory cover note. Four hundred and twenty five (425) copies of the questionnaires were administered to participants face to face. English Language was the main language used, however, local dialects – Igbo Language was used to verbally explain the contents of the questionnaire to some respondents. The questionnaire comprised of sections on the demographic profile of the meat sellers; information on the personal hygiene practices of the meat sellers; information on the cleaning and sanitation practices of the meat sellers and finally on the field report. The questions were prepared in line with the research objectives.

The hygiene and sanitation of the meat handlers were also assessed by direct observation using the questionnaire/checklist.

Validity and Reliability of the questionnaire:

The face and content validity of the questionnaire was established by the project supervisors and two other experts (in the environmental/public health discipline) after critical and constructive modification in line the research objectives.

Also, a pilot study with 45 participants was carried out to pre-test the questionnaire and ascertain its reliability for use in a study of larger sample size. The questionnaire was test and retested on a small group of meat sellers and the scores of the pilot studies at both times were found to be highly correlated, >0.60, thus indicating the reliability of the questionnaire. (SS, 2023)

The questionnaires were administered according to the following Proportional/ distribution table 3.02 to 3.04

Table 3.2: **Table of proportion for Red and white meat samples collection and the distribution questionnaires to red and white meat sellers in the sampled markets according to the Senatorial Zones in Abia State**

Study Area **(Senatorial zones with selected the Local Government Areas- LGAs)**	**Frequency**	**Percentage**	**Cumulative Percent**
Aba Senatorial Zone (LGAs: Aba North, Aba South, Ugwunagbo, Obingwa)	**200** (R = 120; W=80)	47.06	47.06
Umuahia Senatorial Zone (LGAs: Umuahia North, umuahia South, Ikwuano)	**160** (R = 62; W=98)	37.64	84.7
Ohafia Senatorial Zone (LGAs: Ohafia, Bende, Isuikwuato)	**65** (R = 42; W=23)	15.30	100
Total	**425** (R = 224; W=201)	100	

R= Red Meat (Beef), W = White Meat (Chicken)

Table 3.3: Table of proportion for Red meat samples collection and the distribution questionnaires to red meat sellers in the sampled markets according to the Senatorial Zones in Abia State

Study Area **(Senatorial zones with selected the Local Government Areas- LGAs)**	**Frequency**	**Percentage**	**Cumulative Percent**
Aba Senatorial Zone (LGAs: Aba North, Aba South, Ugwunagbo, Obingwa)	**120**	53.57	53.57
Umuahia Senatorial Zone (LGAs: Umuahia North, umuahia South, Ikwuano)	**62**	27.68	81.25
Ohafia Senatorial Zone (LGAs: Ohafia, Bende, Isuikwuato)	**42**	18.75	100
Total	**224**	100	

Table 3.4: Table of proportion for white meat samples collection and the distribution questionnaires to white meat sellers in the sampled markets according to the Senatorial Zones in Abia State

Study Area **(Senatorial zones with selected the Local Government Areas- LGAs)**	**Frequency**	**Percentage**	**Cumulative Percent**
Aba Senatorial Zone (LGAs: Aba North, Aba South, Ugwunagbo, Obingwa)	**80**	39.80	39.80
Umuahia Senatorial Zone (LGAs: Umuahia North, umuahia South, Ikwuano)	**98**	48.76	88.56
Ohafia Senatorial Zone (LGAs: Ohafia, Bende, Isuikwuato)	**23**	11.44	100
Total	**201**	100	

R= Red Meat (Beef), W = White Meat (Chicken)

3.6 Procedure for Samples (Data) Collection/preparation and analysis.

3.6.1 Collection of Samples

Four hundred and twenty-five (425) meat samples weighing 30gm each were collected from meat sellers in markets in Abia State. Collections of the meat samples were in sterile containers and collected samples were transported in an ice packed cooler to the laboratory. Twenty (20) Samples of 1 litre of water each were taken from the water sources in the market. Samples were also taken from the meat contact surfaces which included 22 table top surface swab samples; 22 meat cutting knives surface swab samples and 14 transport vehicles boots meat contact surface samples.

Samples from contact surfaces were collected using sterile specimen sponges wetted with 10ml of buffered peptone water (Oxoid) from sterile Whirl-Pak bags (Sponge-Bag, PBI-International) using a template of 100cm^2 surface area. Sponging within the selected area consisted of 5 passes vertically (up and down was considered as one pass) and then 5 passes horizontally (side to side was considered one pass). The sponge was placed into a Stomacher bag, labelled and delivered in a cold box to the laboratory within 4 hours. All samples collection were done in the morning time between 7am and 11am. Collected samples were properly labelled and taken to the Environmental Health Laboratory, College of Health Sciences, Abia State University Aba and analysed/processed within 12 hours of collection. Copies of the questionnaires were administered to the meat sellers with the help of Field Assistants who have already been trained for that purpose.

3.6.2 Preparation of Media and Diluents

All bacteriological media were prepared according to manufacturer's specification. Nutrient agar was used in the isolation of heterotrophic bacteria, MacConkey Agar for faecal coliform bacteria, Eosin Methylene Blue Agar for *Escherichia coli*, Campylobacter Agar for *Campylobacter* species, Mannitol Salt Agar strictly for *Staphylococcus aureus* and Salmonella Shigella Agar for the isolation of *Salmonella* and *Shigella* species. Physiological saline used as diluents was prepared by dissolving 9.8 g of sodium chloride in 1000ml of distilled and dispensed in 90 ml and 9ml portions. Both diluents and media were sterilized in an autoclave at 121^0C for 15 minutes.

3.6.3 Sample analysis and Tests: Preparation of Samples and Inoculation

Ten (10) grams of meat sample was macerated in a sterile laboratory blender containing 90 ml of sterile peptone water. Ten-fold dilution method was used by transferring 1 ml from each tube until the required dilution was obtained. Aliquot portion (0.1ml) of appropriate dilution was inoculated into the pre-sterilized and surface dried medium. Inocula were spread evenly to ensure uniform and countable colonies and plated on different types of media for microbial growth and enumeration. Plates were incubated at 28^oC for 48 hours for heterotrophic bacteria. Test tubes containing swabs were shaken on a vortex mixer for 30 seconds for uniform distribution of bacteria. Tenfold serial dilution of all samples (10mls of water samples and contact surface swabs diluents samples) were prepared using sterile normal saline solution (NSS) 0.1ml of each sample was pipetted into agar plate and incubated at 37^oC for 42-48 hours for total viable bacteria count.

For Total Aerobic Mesophilic Count (TAMC), on an agar media plate, 0.1ml of each sample was pipetted and spread. Inoculated plate was incubated at 32^oC for 48-72 hours.

For Total coliforms and fecal Coliform Count, 0.1ml of each sample was pipetted and spread on Violet red Bile agar. Inoculated plate was incubated at 32^{o}C for 18-24 hours to determine the total coliforms; and at 44.5^{o}C for 18-24 hours to determine the fecal coliform.

For Enterobacteriaceae Count, 0.1ml of each sample was pipetted and spread on MacConkey agar supplemented with glucose. Inoculated plate was incubated at 35^{o}C for 24 hours. All reddish purple/pink colonies were counted as members of the Enterobacteriaceae.

For Aerobic spore former bacterial count, meat sample suspension was first heated at 80^{o}C in the water bath for ten minutes to kill the vegetative cells. Then, 0.1ml of each sample was pipetted and spread on plate count agar (PCA) plate. Inoculated plate was incubated at 35^{o}C for 36-72 hours.

- **Determination of Microbial Population**

After incubation, plates with colonies between 30 and 300 were counted using Colony counter and the result of the bacterial loads of the meat samples were expressed as colony forming units per gram (CFU/g) to obtain total population; and the results of the bacterial loads from the swabs of the meat contact surface were expressed as colony forming units per squared centimetres (cfu/cm^{2}).

- **Characterization and Identification of Microbial Isolates**

After incubation of the various inoculated plates, the predominant bacterial colonies were picked randomly from countable plates and inoculated into test tubes containing about 5ml nutrient broth. The bacterial culture were purified by repeated streak plating and characterization. The predominant bacterial isolates were characterized based on cultural (colonial), microscopic and biochemical methods with reference to standard manuals. The

identities of the isolates were cross-matched with reference to standard manuals for the identification of bacteria (Cheesbrough, 2000).

- **Microscopic Characterization**

i. Gram Staining Test:

The Gram staining technique was used for the bacterial isolates as described by Cheesbrough (2000). A smear of the isolate was made on grease free glass slide with a drop of water and allowed to dry. The smear was fixed by mild heating, flooded with crystal violet and allowed to stand for 30 seconds. The crystal violet was rinsed off with water. Lugol's iodine was added and allowed to stand for 30 seconds. This was washed off with water and acid alcohol, till discoloration. It was counter stained with Safranin for 10 seconds and rinsed with water. The wet slide was allowed to air dry. A drop of oil immersion was added on the slide and viewed using X100 objective lens of the microscope.

ii. Spore Staining Test:

The spore stain was used to confirm the presence of spores when indicated in the Gram stain. Isolates were heat fixed on a slide and flooded with 5% malachite green. It was steamed for 3 minutes (without allowing it to boil), dried and cooled. It was then rinsed off and stained with Safranin for 30 seconds. This was rinsed, dried with filter paper and viewed under the microscope using oil immersion tens. The positive spores showed green while the negative cells were stained pink.

iii. Motility Test:

This test was used to determine the motility of bacteria isolated. The test was carried out on a semi-solid agar medium in which motile bacteria swarm and gave a diffuse spreading growth.

The medium was dispensed into test tubes, sterilized and allow to set in an upright position. It was then inoculated using an inoculation needle by stabbing it into the medium in the test tube. This was incubated at 37°C for 24 hours. Diffuse growth from the straight line of inoculation was recorded as positive result (Cheesbrough, 2000).

- **Biochemical Characterization of Bacteria Isolates**

Microorganisms that were not identified by the colonial and microscopic characteristics were further subjected to few biochemical tests described by Cheesbrough (2000).

i. Catalase Test:

The enzyme catalase is present in most cytochrome containing aerobic and facultative anaerobic bacteria. Catalase has one of the highest turnover numbers of all enzymes such that one molecule of catalase can convert millions of molecules of hydrogen peroxide to water and oxygen in a second. Catalase activity can be detected by adding the substrate H_2O_2 to an appropriately incubated (18-24 hours) tryptic soy agar slant culture. Organisms which produce the enzyme breakdown the hydrogen and the resulting O_2 production produces bubbles in the reagent drop indicating a positive test. Organisms lacking the cytochrome system also lack the catalase enzyme and are unable to breakdown peroxide into O_2 and water and are catalase negative.

ii. Coagulase Test:

Coagulase is an enzyme that clots blood plasma by a mechanism that is similar to normal clotting. The coagulase test identifies whether an organism produces this exoenzyme. This enzyme clots the plasma component of blood. The only significant disease-causing bacteria of humans that produce coagulase are *Staphylococcus aureus.* Thus, this enzyme is a good indicator of *S. aureus.* In the test, the sample is added to rabbit plasma and held at 37ºC for a

specified period of time. Formation of clot within four hours is indicated as positive result and indicative of a virulent *Staphylococcus aureus* strain. The absence of coagulation after 24 hours of incubation is a negative result indicative of a virulent strain.

iii. Oxidase Test:

Oxidase test is an important differential procedure that should be performed on all gram-negative bacteria for their rapid identification. The test depends on the ability of certain bacteria to produce indophenol blue from the oxidation of dimethyl-p-phenylenediamine and α-naphthol. This method uses N, N-dimethyl-p-phenylenediamine oxalate in which all *Staphlococci* are oxidase negative. In the presence of the enzyme cytochrome oxidase (gram negative bacteria) the N, N-dimethhyl-p-phenylenediamine oxalate and α-naphthol react to indophenol blue. *Pseudomonas aeruginosa* is an oxidase positive organism.

iv. Sugar Fermentation/Oxidation:

This test is used to differentiate between bacteria groups that oxidize carbohydrate such as members of Enterobacteriaceae. One milliliter (1ml) of 10% glucose, maltose, lactose, fructose, mannitol, and sucrose were separately under aseptic conditions transferred into duplicate tubes containing 9ml of sterile Hugh and Leifson's medium to obtain a final concentration of 1% of each of sugar. The tubes were stab-inoculated in duplicates while two un-inoculated tubes serve as control. Vaseline was used to cover one set of the duplicate tubes, one control to discourage oxidative utilization of sugar. All tubes were incubated at 37^{o}C for 48 hours. After the incubation, they were observed for acid production in the culture. Yellow coloration indicates acid production in the open tubes only suggesting oxidative utilization of the sugar while acid production in the sealed tubes suggests a fermentative reaction.

v. Hydrogen Sulphide Production (H_2S) Test:

The test isolates were aseptically inoculated into a tube containing triple sugar iron agar started by stabbing the agar to the bottom and streaking the surface of the slant. The inoculated tube was incubated at 37^oC for 72 hours and was examined daily. Black precipitation and yellow coloration was checked for. Black precipitate indicates H_2S production and yellow coloration for sucrose, lactose and glucose fermentation.

vi. Urease Test:

Urease Agar slant in McCartney bottle was inoculated with the bacteria isolate at 30^oC for 4 hours and then overnight. A pink color in the medium indicated a positive result.

vii. IMViC Test:

This test consists of four different test; they are Indole production, Methyl-Red test, Voges Proskaeur test and Citrate utilization test. This test is specifically designed to determine the physiological properties of microorganism. They are especially useful in the differentiation of Gram-negative intestinal bacilli, particularly *Escherichia coli* and the *Enterobacter-Klebsiella* group.

viii. Indole Test:

This test demonstrates the ability of certain bacteria to decompose the amino acid-Tryptophan to Indole. The bacteria isolates were inoculated into the medium and incubated at 37°C for 48 hours. At the end of incubation period, 3 drops of kovac's reagents was added and then shaken. A red color ring at the interface of the medium denotes a positive result. Methyl red and

Voges-Proskaeur test must be considered together since they are physiologically related. Opposite test is usually obtained from the MR and VP test, that is, MR+, VP-, or MR-, VP+.

Methyl red test was performed to demonstrate the capacity of different organisms to produce acid from the fermentation of sugar (dextrose). Methyl-red positive organisms produce a red coloration when five drops of methyl-red indicator is added into 48 hour old MR-VP broth culture.

The Voges-Proskaeur test demonstrates the ability of organisms to produce acetone from glucose metabolism. Some organisms metabolize glucose to produce pyruvic acid which is further broken down to yield Butane-diol and acetyl-methyl carbinol as an intermediate product. Into one milliliter of the culture, one milliliter of six percent alcoholic solution of alpha-naphtol was added to one milliliter of 16% KOH and allowed to stand for 15-20 minutes. Development of a red to pink color was a positive test.

ix. Citrate Utilization Test:

This is one of the several techniques used to assist in the identification of Enterobacteria. Principle of the test is based on the ability of an organism to use citrate as its only source of carbon. The test was carried out using Simmon's citrate agar. The slopes of the media were prepared in bijou bottles as recommended by the manufacturers. A sterile straight wire was used to the slope with a saline suspension of the test organisms before stabbing the butt. The bottles were incubated at 37^{o}C for 48 hours. Bright blue colors in the medium means positive test while no change in color of medium indicates negative citrate test (Cheesbrough, 2000)

3.7 Data Management and Statistical Analysis

The data from this research work was collated manually by the Researcher; and then entered into the computer by a statistician. The Statistical Package for the Social Sciences (SPSS) software (version 20) was used in the analysis of the data. Results were expressed in percentages, frequencies, tables. One-way ANOVA and the independent sample T-test was used to test the hypotheses at 95% confidence interval and 0.05 Level of significance.

3.8: Ethical clearance/ Informed Consent

An informed consent was gotten from all meat handlers who participated in the study. The purpose of the research was explained to each respondent and verbal informed consent obtained from them before inclusion into the study. Also, anonymity of the respondents was assured and ensured.

CHAPTER FOUR

RESULTS

The results of Data collected and analyzed are presented in the tables below.

4.1 Socio-Demographic Characteristics of meat sellers

4.1.1 Age of meat sellers in Abia State according to Senatorial zones

For the Tables, "n" represents the number while "%" represents percentage value.

From the table below, a total of **160** (37.65%), **200** (47.06%) and **65** (15.30%) meat sellers were part of this study in Umuahia, Aba and Ohafia Senatorial Zones of Abia State respectively.

The table 4.1 below showed that meat sellers of the 18 – 20 years age group were **8** (1.88%), **11** (2.58%) and **5** (1.18%) respectively in Umuahia, Aba and Ohafia Senatorial Zones. 21–30 years age group were **18** (4.23%), **23** (5.41%) and **7**(1.64%); 31-40 years age group- **40** (9.41%), **49** (11.52%) and **16** (3.76%); 41-50 years age group - **28** (6.58%); **34** (8.00%) and **11** (2.59%); 51-60 years age group – **46** (10.82%), **57** (13.41%) and **18** (4.23%); and 60+years age group were – **20** (4.70%), **26** (6.12%) and **8** (1.88%) respectively in Umuahia, Aba and Ohafia Senatorial Zones of Abia State.

Table 4.1: Age of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Age of Respondents	18–20 years	**24**	(5.64%)	**8**	(1.88%)	**11**	(2.58%)	**5**	(1.18%)
	21–30years	**48**	(11.30%)	**18**	(4.23%)	**23**	(5.41%)	**7**	(1.64%)
	31-40years	**105**	(24.70%)	**40**	(9.41%)	**49**	(11.52%)	**16**	(3.76%)
	41-50years	**73**	(17.17%)	**28**	(6.58%)	**34**	(8.00%)	**11**	(2.59%)
	51-60years	**121**	(28.47%)	**46**	(10.82%)	**57**	(13.41%)	**18**	(4.23%)
	60+years	**54**	(12.70%)	**20**	(4.70%)	**26**	(6.12%)	**8**	(1.88%)
	Total	**425**	(100%)	**160**		**200**		**65**	

4.1.2 Gender of meat sellers in Abia State according to Senatorial zones

The Table 4.2 below showed that **131** (30.82%) and **29** (6.82%) males and females meat sellers respectively participated in this study from Umuahia Senatorial zone; **164** (38.59%) and **36** (8.47%) males and females meat sellers were drawn from Aba Zone, while **53** (12.47%) and **12** (2.82%) males and females meat sellers participated from Ohafia Zone

Table 4.2: Gender of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Gender of Respondents	Male	**348**	(81.88%)	**131**	(30.82%)	**164**	(38.59%)	**53**	(12.47%)
	Female	**77**	(18.11%)	**29**	(6.82%)	**36**	(8.47%)	**12**	(2.82%)
	Total	**425**		**160**		**200**		**65**	

4.1.3 Educational Level of meat sellers in Abia State according to Senatorial zones

The Table 4.3 below showed that **a**mong the participating meat sellers; there was no record for non-formal education. **82** (19.29%), **102 (24.00%)**and **34** (8.00%) meat sellers had primary school education in Umuahia, Aba and Ohafia Senatorial zones respectively. **65** (15.29%), **81** (19.06%) and **26** (6.12%) had secondary education while **13** (3.06%), **17** (4.00%) and **5** (1.18%) had tertiary school education as their highest level of education respectively in the three senatorial zones of Umuahia, Aba and Ohafia.

Table 4.3: Educational Level of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Educational level	No Formal Education	**0**		**0**		**0**		**0**	
	Primary Education	**218**	(51.29%)	**82**	(19.29%)	**102**	(24.00%)	**34**	(8.00%)
	Secondary Education	**172**	(40.47%)	**65**	(15.29%)	**81**	(19.06%)	**26**	(6.12%)
	Tertiary Education.	**35**	(8.24%)	**13**	(3.06%)	**17**	(4.00%)	**5**	(1.18%)

4.1.4 Marital status of meat sellers in Abia State according to Senatorial zones

The Table 4.4 below showed that the marital status of the participating meat sellers in the Umuahia, Aba and Ohafia senatorial zones respectively were as follows:

Single - **53** (12.47%); Married - **70** (16.47%); divorced - **11** (2.59%); separated - **9** (2.12%); widow/widower - **17** (4.0%).

Single - **66** (15.53%); Married – **88** (20.71%); divorced – **13** (3.06%); separated - **11** (2.59%); widow/widower - **22** (5.18%).

Single – **21** (4.94%); Married – **29** (6.82%); divorced – **4** (0.94%); separated – **4** (0.94%); widow/widower - **7** (1.65%).

Table 4.4: Marital Status of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Marital	Single	**140**	(32.94%)	**53**	(12.47%)	**66**	(15.53%)	**21**	(4.94%)
Status	Married	**187**	(44.00%)	**70**	(16.47%)	**88**	(20.71%)	**29**	(6.82%)
	Divorced	**28**	(6.59%)	**11**	(2.59%)	**13**	(3.06%)	**4**	(0.94%)
	Separated	**24**	(5.65%)	**9**	(2.12%)	**11**	(2.59%)	**4**	(0.94%)
	Widow/Widower	**46**	(10.82%)	**17**	(4.0%)	**22**	(5.18%)	**7**	(1.65%)

4.1.5 Religion of meat sellers in Abia State according to Senatorial zones

The Table 4.5 below showed that the religion of most of meat sellers who participated in this study was Christianity followed by Traditional worship and Islam.

The distribution of the participating meat sellers' religion in the Umuahia, Aba and Ohafia senatorial zones respectively were as follows:

Christainity - **114** (26.82%); Islam - **17** (4.00%) and Traditional worship – **29** (6.82%).

Christainity – **143** (33.65%); Islam - **21** (4.94%) and Traditional worship – **36** (8.47%).

Christainity – **47** (11.06%); Islam – **7** (1.65%) and Traditional worship – **11** (2.59%).

Table 4.5: Religion of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Religion of respondents	Christianity	**304**	(71.53%)	**114**	(26.82%)	**143**	(33.65%)	**47**	(11.06%)
	Islam	**45**	(10.59%)	**17**	(4.00%)	**21**	(4.94%)	**7**	(1.65%)
	Traditional Worship	**76**	(17.88%)	**29**	(6.82%)	**36**	(8.47%)	**11**	(2.59%)

4.1.6 Years of Experience of Meat sellers in Abia State according to Senatorial zones

The table 4.6 below showed that the years of experience among the participating meat sellers were recorded respectively in Umuahia, Aba and Ohafia Senatorial Zones as follows:

1 – 5 years of experience had **15** (3.53%); 6 – 10 years of experience had **18** (4.24%); 11 – 15 years of experience had **29** (6.82%); 16 – 20 years of experience had **43** (10.12%); Above 20 years of experience had **55** (12.94%) for Umuahia zone.

1 – 5 years of experience had **19** (4.47%); 6 – 10 years of experience had **22** (5.18%); 11 – 15 years of experience had **37** (8.70%); 16 – 20 years of experience had **53** (12.47%); Above 20 years of experience had **69** (16.24%) for Aba zone.

1 – 5 years of experience had **6** (1.41%); 6 – 10 years of experience had **7** (1.65%); 11 – 15 years of experience had **12** (2.82%); 16 – 20 years of experience had **17** (4.00%); Above 20 years of experience had **23** (5.41%) for Ohafia zone.

Table 4.6: Years of Experience of meat sellers in Abia State according to Senatorial zones

Variables		Abia State		Distribution according to Senatorial Zones n(%)					
				Umuahia		Aba		Ohafia	
		n	(%)	n	(%)	n	(%)	n	(%)
Years of Experience	1 – 5 years	**40**	(9.41%)	**15**	(3.53%)	**19**	(4.47%)	**6**	(1.41%)
	6 – 10 years	**47**	(11.06%)	**18**	(4.24%)	**22**	(5.18%)	**7**	(1.65%)
	11 – 15 years	**78**	(18.35%)	**29**	(6.82%)	**37**	(8.70%)	**12**	(2.82%)
	16 – 20 years	**113**	(26.59%)	**43**	(10.12%)	**53**	(12.47%)	**17**	(4.00%)
	Above 20 years	**147**	(34.59%)	**55**	(12.94%)	**69**	(16.24%)	**23**	(5.41%)

4.2 Response on personal Hygiene by meat sellers in Abia State

The result of data collected on the response on personal hygiene by meat sellers are presented in the table 4.7 below.

Table 4.7 below showed that 71(16.70%) meat sellers responded “yes” to wearing proper clothing; 152 (35.76%) to Jewellery limited to wrist watches and plain rings; 53(12.47%) to wearing hand gloves; 77 (18.12%) to wash-hand basins and running water being available; 59 (13.88%) to routine washing of hands with soap and water; 135 (31.76%) to being free from skin infection/open cuts.

Whereas, 354 (83.29%) meat sellers responded “No” to wearing proper clothing; 273 (64.23%) to Jewellery limited to wrist watch and plain rings; 372 (87.52%) to wearing hand gloves; 348 (81.88%) to wash-hand basins and running water being available; 366 (86.11%) to routine washing of hands with soap and water; 290 (68.23%) to being free from skin infection/open cuts.

Table 4.7: Response on personal hygiene by meat sellers in Abia State

Criteria for Personal Hygiene	YES		NO	
	N	%	n	%
Meat handlers wear proper clothing – apron, hair restraints	71	16.70	354	83.29
Jewellery is limited to wristwatches and plain rings.	152	35.76	273	64.23
Wearing hand gloves	53	12.47	372	87.52
Wash-hand basins with soap and running water available	77	18.12	348	81.88
Hands are washed routinely with soap and water	59	13.88	366	86.11
Meat handlers are free from skin infection/open cuts	135	31.76	290	68.23

4.2.1. Comparison of response on personal Hygiene by meat sellers in the three Senatorial Zones in Abia State

The result of the comparison of response on personal hygiene by meat sellers in the three Senatorial Zones in Abia State is presented in the table 4.8 below.

Table 4.8 showed that 25 (15.58%) meat sellers responded "yes" to wearing proper clothing in Umuahia, 30(14.81%) in Aba, and 8 (12.96%) in Ohafia; 55 (34.42%) to Jewellery limited to wrist watch and plain ring in Umuahia, 70 (35.19%) in Aba and 19 (29.63%) in Ohafia; 18 (11.04%) to wearing of hand gloves in Umuahia, 26 (12.96%) in Aba and 7 (11.11%) in Ohafia; 27 (16.88%) to wash-hand basins and running water being available in Umuahia, 33 (16.67%) in Aba and 12 (18.52%) in Ohafia; 20 (12.34%) to routine washing of hands with soap and water in Umuahia, 37(18.52%) in Aba and 11(16.67%) in Ohafia; 49 (30.52%) to being free from skin infection/open cuts in Umuahia, 63 (31.48%) in Aba and 18 (27.78%) in Ohafia.

Whereas, 135(84.42%) meat sellers responded "No" to wearing proper clothing in Umuahia, 170(85.19%) in Aba and 57(87.04%) in Ohafia; 105(65.58%) to Jewellery limited to a wristwatch and plain ring in Umuahia, 130(64.81%) in Aba and 46(70.37%) in Ohafia; 142(88.96%) to wearing of hand gloves in Umuahia, 174(87.04%) in Aba and 58(88.89%) in Ohafia; 133(83.12%) to wash-hand basins and running water being available in Umuahia, 167(83.33%) in Aba and 53(81.48%) in Ohafia; 140(87.66%) to routine washing of hands with soap and water in Umuahia, 163(81.48%) in Aba and 54(83.33%) in Ohafia; 111(69.48%) to be free from skin infection/open cuts in Umuahia, 137(68.52%) in Aba and 47(72.22%) in Ohafia.

The chi-square test was conducted to assess the association between personal hygiene criteria and their corresponding "Yes" and "No" responses across the locations (Umuahia, Aba, Ohafia). The results revealed that there is no statistically significant association for any of the variables. The p-values for each criterion were as follows: for "Meat seller wear proper clothing," the p= 0.733; for "Jewellery is limited to wristwatch and plain ring," the p= 0.175; for "Wearing of hand gloves," the p= 0.442; for "Wash-hand basins with soap and running water available," the p= 0.495; for "Hands are washed routinely with soap and water," the p= 0.220; and for "Meat sellers are free from skin infection/open cuts," the p= 0.331.

These p-values, all greater than the common significance level of 0.05, suggest that the observed differences in the percentages of "Yes" and "No" responses for each criterion in the different locations are likely due to random chance rather than meaningful differences. A one-way ANOVA gave a P value of **0.781** showing that there was no significant difference (P>0.05) in the response of meat sellers on personal hygiene in the three Senatorial Zones of Abia state.

Table 4.8: Comparison of response on personal hygiene by meat sellers in the 3 Senatorial Zones in Abia State

Criteria for Personal Hygiene	Umuahia		Aba		Ohafia		X^2	P-value	Decision
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)			
Meat handler wear proper clothing	25(15.58)	135(84.42)	30(14.81)	170(85.19)	8(12.96)	57(87.04)	0.62	0.733	NS
Jewellery is limited to wristwatch and plain ring.	55(34.42)	105(65.58)	70(35.19)	130(64.81)	19(29.63)	46(70.37)	6.30	0.175	NS
Wearing of hand gloves	18(11.04)	142(88.96)	26(12.96)	174(87.04)	7(11.11)	58(88.89)	1.63	0.442	NS
Wash-hand basins with soap and running water available	27(16.88)	133(83.12)	33(16.67)	167(83.33)	12(18.52)	53(81.48)	1.41	0.495	NS
Hands are washed routinely with soap and water	20(12.34)	140(87.66)	37(18.52)	163(81.48)	11(16.67)	54(83.33)	3.03	0.220	NS
Meat handlers are free from skin illnesses/open cuts	49(30.52)	111(69.48)	63(31.48)	137(68.52)	18(27.78)	47(72.22)	2.21	0.331	NS

One-way ANOVA P value = 0.781

NS*- Not Significant; S*- Significant

4.3 Response on Sanitation by meat sellers in Abia State

The result of data collected on the response on sanitation by meat sellers are presented in the table 4.9 below.

Table 4.9 showed that 23 (5.50%) meat sellers responded “yes” to worktables being clean (washed and sanitized between operations); 59 (13.88%) to cleaning and sanitizing of equipment and utensils; 82 (19.38%) to storing cleaning chemicals away in the store; 29 (6.94%) to washing of mops after use; and 25 (5.98%) to cleaning of buckets after use.

Whereas, that 402 (94.50%) meat sellers responded “No” to worktables being clean(washed and sanitized between operations); 366 (86.12%) to cleaning and sanitizing equipment and utensils; 343 (80.62%) to storing cleaning chemicals away in the store; 396 (93.06%) to washing of mops after use; and 400 (94.02%) to cleaning of buckets after use.

Table 4.9: Response on sanitation by meat sellers in Abia State

Criteria for Sanitation	YES		NO	
	n	%	n	%
Worktables and work surfaces are clean (washed and sanitized between operation)	23	5.50	402	94.50
Small equipment and utensils including cutting boards, knives, etc. are thoroughly cleaned and sanitized between use	59	13.88	366	86.12
Cleaning chemicals and equipment are stored properly away in the store	82	19.38	343	80.62
Mops are washed after use and stored head up	29	6.94	396	93.06
Buckets are cleaned after use and inverted to drain	25	5.98	400	94.02

4.3.1 Comparison of response on sanitation by meat sellers in the three Senatorial Zones in Abia State

The result of the comparison of response on sanitation by meat sellers in the three Senatorial Zones in Abia State is presented in the table 4.10 below.

Table 4.10 showed that 15 (9.62%) meat handlers responded “yes” to worktables being clean(washed and sanitized between operations) in Umuahia, 15(7.41%) in Aba and 7(10.00%) in Ohafia; 28 (17.31%) to cleaning of equipment and utensils in Umuahia, 30 (14.82%) in Aba and 9 (14.00%) in Ohafia; 37 (23.08%) to storing cleaning chemicals away in the store in Unuahia, 37(18.52%) in Aba and 13 (20.00%) in Ohafia; 31 (19.23%) to washing of mops after use Umuahia, 33 (16.67%) in Aba and 12 (18.00%) in Ohafia; 34 (21.15%) to cleaning of buckets after use in Umuahia, 37 (18.52%) in Aba and 10 (16.00%) in Ohafia.

Whereas, 145(90.38%) meat handlers responded “No” to worktables being clean(washed and sanitized between operations) in Umuahia, 185(92.59%) in Aba, and 58(90.00%) in Ohafia; 132(82.69%) to cleaning of equipment and utensils in Umuahia, 170(85.18%) in Aba and 56(86.00%) in Ohafia; 123(76.92%) to storing cleaning chemicals away in the store in Umuahia, 163(81.48%) in Aba and 52 (80.00%) in Ohafia; 129(80.77%) to washing of mops after use Umuahia, 167(83.33%) in Aba and 53(82.00%) in Ohafia; 126(78.85%) to cleaning of buckets after use in Umuahia, 163(81.48%) in Aba and 55(84.00%) in Ohafia.

SPSS analysis using the Chi-square showed no significant difference in the criteria for sanitation among the three cities mentioned. ‘Worktables and work surfaces are clean (washed and sanitized between operations)’; ($p= 0.395$), ‘small equipment and utensils including cutting boards, knives, etc. are thoroughly cleaned’; ($p= 0.168$), ‘cleaning chemicals and equipment are stored properly away in the store’; ($p= 0.541$), ‘mops are washed after use and stored head up’; ($p= 0.541$) and ‘buckets are cleaned after use and inverted to drain’; ($p = 0.779$). A one-

way ANOVA gave a P value of **0.722** showing that there was no significant difference (P>0.05) in the response of meat handlers on sanitation in the three Senatorial Zones of Abia state.

Table 4.10: Comparison of response on sanitation by meat sellers in the 3 Senatorial Zones in Abia State

Criteria for Sanitation	Umuahia		Aba		Ohafia		X^2	P-value	Decision
	Yes (%)	No (%)	Yes (%)	No (%)	Yes (%)	No (%)			
Worktables and work surfaces are clean(washed and sanitized between operations)	15(9.62)	145(90.38)	15(7.41)	185(92.59)	7(10.00)	58(90.00)	1.86	0.395	**NS**
Small equipment and utensils including cutting boards, knives, etc. are thoroughly cleaned and santized	28(17.31)	132(82.69)	30(14.82)	170(85.18)	9(14.00)	56(86.00)	3.58	0.168	**NS**
Cleaning chemicals and equipment are stored properly away in the store	37(23.08)	123(76.92)	37(18.52)	163(81.48)	13(20.00)	52(80.00)	1.23	0.541	**NS**
Mops are washed after use and stored head up	31(19.23)	129(80.77)	33(16.67)	167(83.33)	12(18.00)	53(82.00)	1.23	0.541	**NS**
Buckets are cleaned after use and inverted to drain	34(21.15)	126(78.85)	37(18.52)	163(81.48)	10(16.00)	55(84.00)	0.50	0.779	**NS**

One way Anova P value = 0.722

NS*- Not Significant; S*- Significant

4.4 HACCP CHECKLIST SCORES BY MEAT SELLERS IN ABIA STATE

4.4.1 Total HACCP adherence/compliance scores of the meat sellers

The result of the HACCP adherence/compliance observation Checklist Scores by meat sellers in in Abia State is presented in the table 4.11 below.

Table 4.11 showed that 183 (43.05%) of the meat sellers scored between 0 – 20; while 242 (56.94%) scored within 21 – 40; none of the meat handlers scored above 40%.

Table 4.11: Total percentage HACCP adherence/compliance scores by meat sellers in Abia State

Percentage Scores (%)	n	%
0 – 20	183	43.05
21 – 40	242	56.94
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.2 Descriptive statistics of total HACCP adherence/compliance scores by the meat sellers

The result of the descriptive HACCP adherence/compliance scores by meat sellers in Abia State is presented in the table 4.12 below.

Table 4.12 showed that the minimum HACCP adherence/compliance score for the meat handlers was 17; the maximum score was 39; the mean was 24.66 and the standard deviation was 6.08.

Table 4.12: Descriptive statistics of total HACCP adherence/compliance scores by meat sellers in Abia State

n	Min.	Max.	Mean	S.D
425	17	39	24.66	6.08

n- Number; Min- Minimum value; Max- Maximum value; S.D- Standard Deviation

4.4.3 HACCP observation checklist scores on meat transportation by meat sellers

The result of the HACCP observation Checklist Scores on meat transportation by meat sellers in in Abia State is presented in the table 4.13 below.

From the table 4.13, 208 (48.94%) of the meat handlers scored between 0 – 20 on meat transportation; 217 (51.05%) scored within 21 – 40 transportation. None of the meat handlers scored above 40%.

Table 4.13: Percentage HACCP scores on meat transportation by meat sellers in Abia States

Percentage Scores (%)	**n**	**%**
0 – 20	208	48.94
21 – 40	217	51.05
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.4 HACCP observation checklist scores on meat storage by meat sellers

The result of the HACCP observation Checklist Scores on meat storage by meat sellers in in Abia State is presented in the table 4.14 below.

From the table 4.14: 194 (45.65%) of the meat handlers scored between 0 – 20 on proper meat storage; 231 (54.35%) scored within 21 – 40. None of the meat handlers scored above 40%.

Table 4.14: Percentage HACCP scores on meat storage by meat sellers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	194	45.65
21 – 40	231	54.35
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.5 HACCP observation checklist scores on personal hygiene by meat sellers

The result of the HACCP observation Checklist Scores on personal hygiene by meat sellers in in Abia State is presented in the table 4.15 below.

From the table 4.15, 191 (44.94%) of the meat handlers scored between 0 – 20 on personal hygiene; 234 (55.06%) scored within 21 – 40. None of the meat handlers scored above 40%.

Table 4.15: Percentage HACCP scores on personal hygiene by meat handlers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	191	44.94
21 – 40	234	55.06
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.6 HACCP observation checklist scores on cleaning and sanitation by meat sellers

The result of the HACCP observation Checklist Scores on cleaning and sanitation by meat sellers in in Abia State is presented in the table 4.16 below.

From the table 4.16, 204 (48.00%) of the meat handlers scored between 0 – 20 on cleaning and sanitation; while 221 (52.00%) scored within 21 – 40. None of the meat handlers scored above 40%.

Table 4.16: Percentage HACCP scores on cleaning and sanitation by meat sellers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	204	48.00
21 – 40	221	52.00
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.7 HACCP observation checklist scores on pest control by meat handlers

The result of the HACCP observation Checklist Scores on pest control by meat sellers in in Abia State is presented in the table 4.17 below.

From the table 4.17: 207 (48.70%) of the meat handlers scored between 0 – 20 on pest control; 218 (51.30%) scored within 21 – 40. None of the meat handlers scored above 40%.

Table 4.17: Percentage HACCP scores on pest control by meat sellers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	207	48.70
21 – 40	218	51.30
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	**425**	**100.00**

4.4.8 HACCP observation checklist scores on waste disposal by meat handlers

The result of the HACCP observation Checklist Scores on waste disposal by meat sellers in in Abia State is presented in the table 4.18 below.

From the table 4.18, 204 (48.00%) of the meat handlers scored between 0 – 20 on waste disposal; 221 (52.00%) scored within 21 – 40. None of the meat handlers scored above 40%.

Table 4.18: Percentage HACCP scores on waste disposal by meat sellers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	204	48.00
21 – 40	221	52.00
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	425	100.00

4.4.9 HACCP observation checklist scores on staff competence and Training by meat handlers

The result of the HACCP observation Checklist Scores on staff competence and training by meat sellers in in Abia State is presented in the table 4.19 below.

From the table 4.19: 214 (50.35%) of the meat handlers scored between 0 – 20 on staff Competency and traning; 211 (49.65%) scored 21 - 40. None of the meat handlers scored above 40%.

Table 4.19: Percentage HACCP scores on competence and staff training by meat sellers in Abia State

Percentage Scores (%)	**n**	**%**
0 – 20	214	50.35
21 – 40	211	49.65
41 – 60	0	0.00
61 – 80	0	0.00
81 – 100	0	0.00
Total	425	100.00

4.4.10 Descriptive statistics of Percentage HACCP observational checklist scores at critical control points by meat handlers in Abia State

The Descriptive statistics of Percentage HACCP scores at critical control points by meat handlers in Abia State is presented in the table 4.20 below.

From the table 4.20, the minimum percentage HACCP score, maximum score, mean and standard deviation for the meat handlers on transportation was 17, 34, 22.51 and 4.70 respectively; storage was 11, 30, 20.99 and 5.87 respectively; personal hygiene was 23, 39, 27.97 and 5.30 respectively; cleaning and sanitation was 13, 31, 26.30 and 5.65 respectively; pest control was 12, 25, 20.44 and 4.81 respectively; waste disposal was 18, 35, 26.13 and 5.09 respectively; staff competency and training was 10, 29, 21.58 and 4.89 respectively.

Table 4.20: Descriptive statistics of Percentage HACCP scores at critical control points by meat sellers in Abia State

Critical Point	**n**	**Min. (%)**	**Max. (%)**	**Mean (%)**	**S.D**
Transportation	425	17	34	22.51	4.70
Storage	425	11	30	20.99	5.87
Personal Hygiene	425	23	39	27.97	5.30
Cleaning and Sanitation	425	13	31	26.30	5.65
Pest Control	425	12	25	20.44	4.81
Waste Disposal	425	18	35	26.13	5.09
Staff Competency and Training	425	10	29	21.58	4.89

n- Number; Min- Minimum value; Max- Maximum value; S.D- Standard Deviation

4.5: BACTERIOLOGICAL QUALITIES OF MEAT SAMPLES AND CONTACT SURFACES – MICROBIAL POPULATION

The results of the bacterial loads of the meat samples (cfu/g) and from the swabs of the meat contact surface (cfu/cm^2) from markets in Abia State on the various culturing media were as presented in the tables below:

4.5.1 Total Bacterial load counts (cfu/g) of red meat (beef) samples from markets in the three zones of Abia State

The results of the bacterial loads counts (cfu/g) of the red meat (beef) samples from markets in different zones of Abia State on the various culturing media are presented in the tables 4.21.

The table shows that the higher bacteria counts were detected in the meat samples in Umuahia and Ohafia zones than in Aba zone. The mean bacterial loads counts in Umuahia zone were in EMBA (2.57 x 10^3), MSA (3.9 x 10^3), NA (2.33 x 10^6), SSA (2.41 x 10^3), MCA (2.44 x 10^5) and CAMPY Agar (3.02 x 10^3). The mean bacterial loads counts in Aba zone were in EMBA (1.63 x 10^3), MSA (1.74 x 10^3), NA (1.99 x 10^5), SSA (1.67 x 10^3), MCA (1.70 x 10^5) and CAMPY Agar (1.95 x 10^3). The mean bacterial loads counts in Ohafia zone were in EMBA (2.16 x 10^3), MSA (2.68 x 10^3), NA (2.73 x 10^5), SSA (2.80 x 10^3), MCA (2.05 x 10^5) and CAMPY Agar (2.75 x 10^3).

The mean bacterial loads of the red meat samples on the Nutrient Agar plates of 2.33 x 10^6, 1.99 x 10^5 and 2.73 x 10^5 cfu/g for Umuahia, Aba and Ohafia zones respectively.

Table 4.21: Total Bacteria load counts (CFU/g) of red meat (beef) samples from markets in the three zones of Abia State

	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
Umuahia zone						
Mean	2.57×10^3	3.9×10^3	2.33×10^6	2.41×10^3	2.44×10^5	3.02×10^3
St. Dev	1.66×10^3	2.44×10^3	1.87×10^5	1.63×10^3	1.14×10^5	2.14×10^3
Aba Zone						
Mean	1.63×10^3	1.74×10^3	1.99×10^5	1.67×10^3	1.70×10^5	1.95×10^3
St. Dev	0.61×10^3	0.88×10^3	1.27×10^5	1.07×10^3	1.11×10^5	1.31×10^3
Ohafia zone						
Mean	2.16×10^3	2.68×10^3	2.73×10^5	2.80×10^3	2.05×10^5	2.75×10^3
St. Dev	1.38×10^3	2.60×10^3	1.85×10^5	1.79×10^3	1.12×10^5	1.94×10^3

EMBA- Eosin Methylene Blue Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; SSA- Salmonella-Shigella Agar; MCA- MacConkey Agar; CAMPY Agar- Campylobacter Blood Free Agar.

4.5.2 Total Bacterial load counts (cfu/g) of white meat (chicken) samples from markets in the three zones of Abia State

The results of the bacterial loads counts (cfu/g) of the red meat (beef) samples from markets in different zones of Abia State on the various culturing media are presented in the tables 4.22.

The table shows that the higher bacteria counts were detected in the white meat samples in Aba and Ohafia zones were higher than in Aba zone. The mean bacterial loads counts in Umuahia zone were in EMBA (1.78×10^3), MSA (1.75×10^3), NA (1.81×10^5), SSA (2.22×10^3), MCA (1.89×10^5) and CAMPY Agar (1.89×10^3). The mean bacterial loads counts in Aba zone were in EMBA (2.18×10^5), MSA (2.01×10^5), NA (1.73×10^5), SSA (2.02×10^4), MCA (1.64×10^6) and CAMPY Agar (2.04×10^5). The mean bacterial loads counts in Ohafia zone were in EMBA (2.61×10^5), MSA (2.18×10^5), NA (2.20×10^6), SSA (2.16×10^5), MCA (1.99×10^5) and CAMPY Agar (2.25×10^5).

The mean bacterial loads of the white meat samples on the Nutrient Agar plates were 1.81×10^5, 1.73×10^5 and 2.20×10^6 cfu/g for Umuahia, Aba and Ohafia zones respectively.

Table 4.22: Total Bacteria load counts (cfu/g) of white meat (chicken) samples from markets in the three zones of Abia State

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
Umuahia zone						
Mean	1.78×10^3	1.75×10^3	1.81×10^5	2.22×10^3	1.89×10^5	1.89×10^3
St. dev	1.10×10^3	1.09×10^3	1.13×10^5	1.57×10^3	0.98×10^5	1.29×10^3
Aba zone						
Mean	2.18×10^5	2.01×10^5	1.73×10^5	2.02×10^4	1.64×10^6	2.04×10^5
St. dev	1.22×10^5	1.08×10^5	1.09×10^5	1.09×10^3	0.83×10^5	0.84×10^5
Ohafia Zone						
Mean	2.61×10^5	2.18×10^5	2.20×10^6	2.16×10^5	1.99×10^5	2.25×10^5
St. dev	1.28×10^5	1.45×10^5	1.57×10^6	0.99×10^5	0.93×10^5	0.97×10^5

EMBA- Eosin Methylene Blue Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; SSA- Salmonella-Shigella Agar; MCA- MacConkey Agar; CAMPY Agar- Campylobacter Blood Free Agar.

4.5.3 Total Bacterial load counts (cfu/cm^2) from swabs of contact surfaces and water samples from markets in the three zones of Abia State

The results of the bacterial loads counts (cfu/cm^2) of the various meat contact surfaces samples and water samples from markets in Abia State on the various culturing media are presented in the tables 4.23.

The table shows that the mean bacterial loads counts in table surfaces were in EMBA (1.16 x 10^3), MSA (1.65 x 10^3), NA (2.15 x 10^5), SSA (1.53 x 10^3), MCA (2.18 x 10^5) and CAMPY Agar (nil).

The mean bacterial loads counts in water samples were in EMBA (1.31 x 10^5), MSA (1.30 x 10^3), NA (2.35 x 10^6), SSA (1.48 x 10^3), MCA (1.60 x 10^5) and CAMPY Agar (1.66 x 10^3).

The mean bacterial loads counts in knife surface samples were in EMBA (1.24 x 10^3), MSA (1.07 x 10^3), NA (1.54 x 10^5), SSA (nil), MCA (1.27 x 10^5) and CAMPY Agar (1.00 x 10^3).

The mean bacterial loads counts in transportation vehicle boot contact surface samples were in EMBA (1.54 x 10^3), MSA (1.88 x 10^5), NA (2.82 x 10^5), SSA (nil), MCA (2.00 x 10^5) and CAMPY Agar (1.56 x 10^3).

The mean bacterial loads of the white meat samples on the Nutrient Agar plates of 1.81 x 10^5 and 1.73 x 10^5 cfu/cm^2 for Umuahia and Aba zones respectively were all slightly within the Meat Industry allowable limit/standard of 1.00 x 10^5 cfu/cm^2. However, the average bacterial loads of 2.20 x 10^6 cfu/cm^2 for white meat in Ohafia zone was far above the Meat Industry allowable limit/standard of 1.00 x 10^5 cfu/cm^2.

Table 4.23: Total Bacteria load counts (cfu/cm^2) of meat contact surfaces and water samples in markets in the three zones of Abia State

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
Table surfaces						
Mean	1.16×10^3	1.65×10^3	2.15×10^5	1.53×10^3	2.02×10^5	-
St. Dev	0.53×10^3	0.89×10^3	1.38×10^5	0.69×10^3	1.10×10^5	-
Water samples						
Mean	1.31×10^5	1.30×10^3	2.35×10^6	1.48×10^3	1.60×10^5	1.66×10^3
St. Dev	0.63×10^5	0.50×10^3	1.81×10^6	0.74×10^3	0.98×10^5	1.19×10^3
Knife surfaces						
Mean	1.24×10^3	1.07×10^3	1.54×10^5	-	1.27×10^5	1.00×10^3
St. Dev	0.45×10^3	0.09×10^3	0.82×10^5	-	0.48×10^5	0.00
Transportation vehicles boot contact surface						
Mean	1.54×10^3	1.88×10^5	2.82×10^5	-	2.00×10^5	1.56×10^3
St. Dev	0.62×10^3	0.87×10^5	1.63×10^5	-	0.79×10^5	0.61×10^3

EMBA- Eosin Methylene Blue Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; SSA- Salmonella-Shigella Agar; MCA- MacConkey Agar; CAMPY Agar- Campylobacter Blood Free Agar.

4.6: BACTERIOLOGICAL QUALITIES OF MEAT, CONTACT SURFACES AND WATER SAMPLES FROM MARKETS IN ABIA STATE- PREDOMINANT BACTERIAL ISOLATES

The results of the predominant bacterial isolates of the meat, meat contact surfaces and water samples from markets in Abia State are as presented in the tables below:

4.6.1 Predominant bacteria isolated from the meat samples (red and white meat) from markets in Abia State

The result of the Bacteria isolated from the 425 meat samples (red and white meat) from markets in Abia State is presented in the table 4.24 below.

Table 4.24 showed that out of the total of 425 meat samples collected and analyzed, *Staphylococcus sp*. was isolated in 335 (78.80%) of the meat samples; *Escherichia coli*, 264 (62.11%); *Micrococcus* sp., 191 (44.94%); *Salmonella* sp., 264 (62.11%); *Bacillus* sp., 311 (73.17%); *Campylobacter* sp., 185 (43.52%); *Klebsiella* sp., 218 (51.29%); *Enterococcus* sp., 272 (64.00%); *Shigella* sp., 106 (24.94%); *Pseudomonas* sp., 64 (15.05%); *Enterobacter* sp., 161 (37.88%)

Table 4.24: Predominant Bacteria isolated from the meat samples (red and white meat) from markets in Abia State

Bacterial Isolates	**n**	**%**
Staphylococcus sp	335	78.80
Escherichia coli	264	62.11
Micrococcus sp	191	44.94
Salmonella sp	264	62.11
Bacillus sp	311	73.17
Campylobacter sp	185	43.52
Klebsiella sp	218	51.29
Enterococcus sp	272	64.00
Shigella sp	106	24.94
Pseudomonas sp	64	15.05
Enterobacter sp	161	37.88
N= 425		

4.6.2 Predominant Bacteria isolated from red meat samples from markets in Abia State

The result of the predominant bacteria isolated from red meat samples from markets in Abia State is presented in the table 4.25 below.

Table 4.25 showed that out of the 224 red meat sampled, *Staphylococcus* sp was isolated in 175 (78.12%) of the red meat samples; *Escherichia coli*, 139 (62.05%); *Micrococcus* sp., 100 (44.64%); *Salmonella* sp., 138 (61.60%); *Bacillus* sp., 167 (74.55%); *Campylobacter* sp., 99 (44.19%); *Klebsiella* sp., 116 (51.78%); *Enterococcus* sp., 142 (63.39%); *Shigella* sp., 55 (24.55%); *Pseudomonas* sp., 34 (15.17%); *Enterobacter* sp., 84 (37.50%)

Table 4.25: Predominant bacteria isolated from red meat samples in markets in Abia State

Bacterial Isolates	n	%
Staphylococcus sp	175	78.12
Escherichia coli	139	62.05
Micrococcus sp	100	44.64
Salmonella sp	138	61.60
Bacillus sp	167	74.55
Campylobacter sp	99	44.19
Klebsiella sp	116	51.78
Enterococcus sp	142	63.39
Shigella sp	55	24.55
Pseudomonas sp	34	15.17
Enterobacter sp	84	37.50

N= 224

4.6.3: Comparison of bacteria isolated from red meat samples from markets in the Three Senatorial zones in Abia State

The result of the comparison of the Bacteria isolated from 224 red meat-beef samples from markets in the three Senatorial Zones in Abia State is presented in the table 4.26 below.

Table 4.26 showed that *Staphylococcus* sp was isolated in 81.09% of the red meat in Umuahia, 77.18% in Aba and 77.11% in Ohafia; *Escherichia coli*, 64.12% in Umuahia, 60.00% in Aba and 65.06% in Ohafia; *Micrococcus* sp, 48.10% in Umuahia, 43.55% in Aba and 43.55% in Ohafia; *Salmonella* sp, 65.28% in Umuahia, 59.19% in Aba and 65.14% in Ohafia; *Bacillus* sp, 73.43% in Umuahia, 76.23% in Aba and 71.28% in Ohafia; *Campylobacter* sp, 40.58% in Umuahia, 43.84% in Aba and 49.84% in Ohafia; *Klebsiella* sp., 51.40% in Umuahia, 50.10% in Aba and 58.25% in Ohafia; *Enterococcus* sp., 68.81% in Umuahia, 60.05% in Aba and 64.33% in Ohafia; *Shigella* sp., 25.66% in Umuahia, 24.68% in Aba and 22.61% in Ohafia; *Pseudomonas* sp., 14.92% in Umuahia, 13.91% in Aba and 18.16% in Ohafia; *Enterobacter* sp., 39.70% in Umuahia, 37.60% in Aba and 33.89% in Ohafia.

SPSS analysis using the one-way ANOVA showed that there was no statistically significant difference between bacteria isolated from red meat samples from markets in the Senatorial Zones in Abia State [$p = 0.7678) > 0.05$].

Table 4.26: Comparison of bacteria isolated from red meat samples from markets in the Senatorial Zones in Abia State

Bacterial Isolates	Umuahia		Aba		Ohafia	
	n	%	N	%	n	%
Staphylococcus sp	50	81.09	93	77.18	32	77.11
Escherichia coli	40	64.12	72	60.00	27	65.06
Micrococcus sp	30	48.10	52	43.55	18	43.55
Salmonella sp	40	65.28	71	59.19	27	65.14
Bacillus sp	46	73.43	91	76.23	30	71.28
Campylobacter sp	25	40.58	53	43.84	21	49.84
Klebsiella sp	32	51.40	60	50.10	24	58.25
Enterococcus sp	43	68.81	72	60.05	27	64.33
Shigella sp	16	25.66	30	24.68	9	22.61
Pseudomonas sp	9	14.92	17	13.91	8	18.16
Enterobacter sp	25	39.70	45	37.60	14	33.89
ANOVA P value = 0.7678						
Decision = NS						

NS*- Not Significant; S*- Significant

4.6.4: Predominant bacteria isolated from white meat samples from markets in Abia State

The result of the predominant bacteria isolated from white meat-chicken samples from markets in Abia State is presented in the table 4.27 below.

Table 4.27. showed that out of the total 201 white meat sampled, *Staphylococcus* sp was isolated in 160 (79.60%) of the white meat samples; *Escherichia coli*, 125 (62.18%); *Micrococcus* sp., 91 (45.27%); *Salmonella* sp., 126 (62.68%); *Bacillus* sp., 144 (71.64%); *Campylobacter* sp., 86 (42.78%); *Klebsiella* sp., 102 (50.74%); *Enterococcus* sp., 130 (64.67%); *Shigella* sp., 51 (25.37%); *Pseudomonas* sp., 30 (14.92%); *Enterobacter* sp., 77 (38.30%);

Table 4.27: Predominant bacteria isolated from white meat samples in markets in Abia State

Bacterial Isolates	n	%
Staphylococcus sp	160	79.60
Escherichia coli	125	62.18
Micrococcus sp	91	45.27
Salmonella sp	126	62.68
Bacillus sp	144	71.64
Campylobacter sp	86	42.78
Klebsiella sp	102	50.74
Enterococcus sp	130	64.67
Shigella sp	51	25.37
Pseudomonas sp	30	14.92
Enterobacter sp	77	38.30
N= 201		

4.6.5: Comparison of bacteria isolated from white meat samples from markets in the Three Senatorial zones in Abia State

The result of the comparison of the Bacteria isolated from 201white meat-chicken samples from markets in the three Senatorial Zones in Abia State is presented in the table 4.28 below.

Table 4.28: showed that *Staphylococcus* sp was isolated in 81.18% of the white meat in Umuahia, 77.17% in Aba and 76.12% in Ohafia; *Escherichia coli*, 64.12% in Umuahia, 60.05% in Aba and 62.53% in Ohafia; *Micrococcus* sp, 48.10% in Umuahia, 43.52% in Aba and 42.50% in Ohafia; *Salmonella* sp, 65.22% in Umuahia, 59.11% in Aba and 64.17% in Ohafia; *Bacillus* sp, 73.44% in Umuahia, 70.28% in Aba and 71.45% in Ohafia; *Campylobacter* sp, 40.53% in Umuahia, 43.88% in Aba and 47.60% in Ohafia; *Klebsiella* sp., 51.47% in Umuahia, 50.10% in Aba and 51.13% in Ohafia; *Enterococcus* sp., 68.86% in Umuahia, 60.04% in Aba and 64.34% in Ohafia; *Shigella* sp., 25.69% in Umuahia, 24.66% in Aba and 27.70% in Ohafia; *Pseudomonas* sp., 14.90% in Umuahia, 13.98% in Aba and 15.41% in Ohafia; *Enterobacter* sp., 39.73% in Umuahia, 37.67% in Aba and 36.51% in Ohafia.

SPSS analysis using the one-way ANOVA showed no significant difference [P(0.19)>0.05] between bacteria isolated from white meat samples from markets in the Senatorial Zones in Abia state.

Table 4.28: Comparison of bacteria isolated from white meat samples from markets in the Senatorial Zones in Abia State

Bacterial Isolates	Umuahia		Aba		Ohafia	
	n	%	n	%	n	%
*Staphylococcu s*sp	80	81.18	62	77.17	18	76.12
Escherichia coli	63	64.12	48	60.05	14	62.53
Micrococcus sp	47	48.10	35	43.52	9	42.50
Salmonella sp	64	65.22	47	59.11	15	64.17
Bacillus sp	72	73.44	56	70.28	16	71.45
Campylobacter sp	40	40.53	35	43.88	11	47.60
Klebsiella sp	50	51.47	40	50.10	12	51.13
Enterococcus sp	67	68.86	48	60.04	15	64.34
Shigella sp	25	25.69	20	24.66	6	27.70
Pseudomonas sp	15	14.90	11	13.98	4	15.41
Enterobacter sp	39	39.73	30	37.67	8	36.51
ANOVA P value = 0.19						
Decision = NS						

NS*- Not Significant; S*- Significant

4.6.6: Comparison of predominant bacteria isolated from red and white meat samples from markets in Abia State

The result of the comparison of the predominant bacteria isolated from the 224 red meat and 201white meat samples from markets in Abia State is presented in the table 4.29 below.

Table 4.29: showed that out of the total 224 red and 201 white meat sampled, *Staphylococcus* sp was isolated in 175 (78.12%) of the red meat samples and 160 (79.60%) of the white meat samples; *Escherichia coli*, 139 (62.05%) red meat and 125 (62.18%) white; *Micrococcus* sp., 100 (44.64%) red meat and 91 (45.27%) white; *Salmonella* sp., 138 (61.60%) red meat and 126 (62.68%) white; *Bacillus* sp., 167 (74.55%) red meat and 144 (71.64%); *Campylobacter* sp., 99 (44.19%) red meat and 86 (42.78%) white; *Klebsiella* sp., 116 (51.78%) red meat and 102 (50.74%) white; *Enterococcus* sp., 142 (63.39%) red meat and 130 (64.67%) white; *Shigella* sp., 55 (24.55%) red meat and 51 (25.37%) white; *Pseudomonas* sp., 34 (15.17%) red meat and 30 (14.92%) white; *Enterobacter* sp., 84 (37.50%) red meat and 77 (38.30%) white.

SPSS analysis using the one-way ANOVA showed no significant difference [P(0.527)>0.05] in bacteria isolated from red and white meat samples from markets in Abia State.

Table 4.29: Comparison of Bacteria isolated from red and white meat samples from Markets in Abia state

Bacterial Isolates	Red meat (N = 224)		White meat (N = 201)	
	n	%	n	%
Staphylococcus sp	175	78.12	160	79.60
Escherichia coli	139	62.05	125	62.18
Micrococcus sp	100	44.64	91	45.27
Salmonella sp	138	61.60	126	62.68
Bacillus sp	167	74.55	144	71.64
Campylobacter sp	99	44.19	86	42.78
Klebsiella sp	116	51.78	102	50.74
Enterococcus sp	142	63.39	130	64.67
Shigella sp	55	24.55	51	25.37
Pseudomonas sp	34	15.17	30	14.92
Enterobacter sp	84	37.50	77	38.30
ANOVA P value = 0.527				
Decision = NS				

NS*- Not Significant; S*- Significant

4.6.7: Comparison of bacteria isolated found on meat contact surface samples - tables, knives, transporting car boots and water samples in markets in Abia State

The result of the comparison of the Bacteria isolated from 78 meat contact surface samples (comprised of 22 table surfaces, 22 knives surfaces, 14 transporting car boots; and 20 water samples) from markets in Abia State is presented in the table 4.30 below.

Table 4.30 below showed that *Staphylococcus* sp was isolated in 13 (61.11%) of the 22 samples from tables, 7 (50.00%) of the 14 samples from car boots floors, 9 (41.67%) of the 22 samples from knives, and 9 (46.32%) of the 20 water samples; *Salmonella* sp, in 10 (47.22%) of the tables, 5 (36.11%) of car boots floors, 7 (30.56%) of knives and 9 (43.85%) of water samples; *Bacillus* sp., in 9 (41.67%) of the tables, 6 (44.44%) of car boots floors, 7 (33.33%) of knives and 5 (23.70%) of water samples; *Campylobacter* sp., in 6 (27.78%) of the tables, 4 (25.00%) of car boots floors, 7 (30.56%) of knives and none in water. No other bacteria were isolated from the samples.

SPSS analysis using the one-way ANOVA showed that there was no statistically significant difference between the bacterial isolates found on tables, knives, water, and car boots floors in use in markets in Abia State ($p = 0.8100$).

Table 4.30: Comparison of bacterial isolates found on tables, knives, transporting car Boots floors and water samples in markets in Abia State

Bacteria	Table		Car Boots floors		Knife		Water	
	n	%	n	%	n	%	n	%
Staphylococcus sp	13	61.11	7	50.00	9	41.67	9	46.32
Escherichia coli	0	0.00	0	0.00	0	0.00	0	0.00
Micrococcus sp	0	0.00	0	0.00	0	0.00	0	0.00
Salmonella sp	10	47.22	5	36.11	7	30.56	9	43.85
Bacillus sp	9	41.67	6	44.44	7	33.33	5	23.70
Campylobacter sp	6	27.78	4	25.00	7	30.56	0	0.00
Klebsiella sp	0	0.00	0	0.00	0	0.00	0	0.00
Enterococcus sp	0	0.00	0	0.00	0	0.00	0	0.00
Shigella sp	0	0.00	0	0.00	0	0.00	0	0.00
Pseudomonas sp	0	0.00	0	0.00	0	0.00	0	0.00
Enterobacter sp	0	0.00	0	0.00	0	0.00	0	0.00
P value = 0.8100								
Decision = NS								

NS*- Not Significant; S*- Significant

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATIONS

5.1 Discussion

The assessment of the bacteriological qualities of meat and contact surfaces in markets is a crucial aspect of ensuring food safety and safeguarding public health. In Nigeria, particularly in Abia State, the consumption of meat is a significant part of the daily diet for many individuals. However, the handling and storage of meat in marketplaces can pose potential risks of bacterial contamination, leading to foodborne illnesses. This study aims to investigate and analyze the bacteriological quality of meat and contact surfaces in markets in Abia State, Nigeria. Through examining samples of meat being sold in the markets in Abia State together with samples collected from the meat contact surfaces; and evaluating the hygiene and sanitation practices of the meat sellers, this research seeks to identify the bacteriological qualities of the meat being sold to the public, potential sources of contamination and recommend measures for improved meat safety standards. The findings of this study will provide valuable insights into the existing practices and enable policymakers, regulatory bodies, and meat vendors to implement effective interventions that ensure the safety and quality of meat/meat products, and thus, ultimately protecting the health of the public.

The demographic characteristics of the meat sellers in this study indicated that males dominated in the meat selling business. The highest level of formal education of the meat sellers was primary level with 51.29% of the total studied population; followed by secondary level with 40.47%. Only 8.24% of the meat sellers have tertiary education (Table 4.3). This can explain why the most of the meat sellers lack the proper knowledge and awareness of HACCP Standard Operating Procedures (SOPs) for meat safety and also do not comply with them in

line with the study by Adesokan and Raji (2014). The meat sellers also fail to understand the importance of HACCP protocol adherence as a way of protecting meat consumers from meat/food-borne diseases.

This study exposed the lack of awareness and knowledge of the meat handlers in Abia State to HACCP Standard Operating Procedures for the handling of meat. From Table 4.11, on the total HACCP adherence/compliance observation scores by meat sellers showed that 183 (43.05%) of the meat sellers scored between 0 – 20%; while 242 (56.94%) scored within 21 – 40%. The minimum HACCP adherence/compliance score for the meat handlers was 17%; the maximum score was 39% and the mean was 24.66 ± 6.08%. None of the meat handlers scored up to 40% (Table 4.20) in the HACCP checklist used for this study. This is an indicator of non-compliance of the meat sellers to HACCP Standard Operating Procedures for meat safety. These findings are in agreement with previous findings of Azuamah *et al.,* (2018a) and Azuamah *et al.,* (2019) who reported low HACCP scores of less than 50% in their studies.

The mean Percentage HACCP scores at some critical control points by meat sellers in Abia State were 22.51 ± 4.70% for transportation; 20.99 ± 5.87% for storage; 27.97 ± 5.30% for personal hygiene; 26.30 ±5.65% for cleaning and sanitation; 20.44 ± 4.81% for pest control; 26.13 ± 5.09% for waste disposal; and 21.58 ± 4.89% for staff competency and training (table 4.20). Basic facilities for meat transportation were not provided thus predisposing the meat carcasses to contamination. The Meat Industry Guide (2017) of transporting meat at the temperatures of 4^{O}C or below was not adhered to. Meat carcasses were transported from the slaughter house to the various markets on taxi cabs or pick-up trucks boots that were not cleaned or sanitized; and without any cool-chain or means of refrigeration. There were no

provision of storage facilities with cool-chain and thermometers for routine checking of the meat temperature in the markets. From the three Senatorial zones of Abia State, it was observed that carcasses of slaughtered cattles from the slaughter houses were transported to the market in make-shift vehicles; and sold to the public without any regard to standard operating procedures thus possibly compromising the bacteriological quality of the meat being sold. This lack of adequate transport and storage facilities for the meat carcasses could have contributed in the high microbial load of the meat samples as observed in this study. The low mean Percentage HACCP scores in transportation, storage, personal hygiene, cleaning and sanitation, pest control, waste disposal and staff competency and training as recorded in markets in Abia State (table 4.20) could have accounted for the reported high bacterial loads in the meat samples as previous studies by researchers have also reported significant increase in bacterial loads of meat samples among meat handlers with low HACCP scores (Gutema *et al.,* (2021); Adzity *et al.,* (2020); Azuamah *et al.,* (2018a)) .

The personal hygiene practices of the meat handlers was one of the major source of concern as the meat sellers failed to meet the basic standards of personal hygiene during the handling of meat. Most of the meat sellers do not wear proper clothing such as hand gloves, aprons and hair restraints when handling meat. Their fingers were dirty, some had open cuts and wounds on their hands and they did not practice regular hand washing with soap and potable water. By touching their hands on dirty contact surfaces, coughing and sneezing with their bare hands, they could transfer microorganisms to the meat. This is in line with the findings of Gutema *et al.,* (2021); Adzity *et al.,* (2020); Azuamah *et al.,* (2018a), Azuamah *et al.,* (2019) and Tegegne, (2017). The cleanliness and sanitary conditions of the workplace of the meat handlers was also found to be below standard. With low HACCP scores for cleaning and sanitation among the meat sellers. Work tables and work surfaces were not kept clean. There were no

routine cleaning procedures in place for the cleaning of the premises, equipment and utensils after and before use. All these factors could have served as possible sources of contamination of the meat carcasses in line with the findings of Wambui, *et al*. (2017) in their study.

There were no adequate Pest control measures in place to control pests. This is an important procedure for the protection of meat from vectors that could serve as agents in the transmission of bacterial organisms to the meat carcasses. Thus, pest infestation as was seen in the markets and slaughter houses could easily transfer bacteria such as *E. coli* from fecal matter to the meat carcasses. This is in line with the findings of Shimelis, *et al*. (2017). Waste that were not properly disposed in the markets attract flies and other insects that could act as vectors for bacterial contamination of the meat. Improper waste disposal has been reported as one of the major causes of pest infestation in markets and slaughter houses. As mentioned above, lack of basic knowledge and training in meat safety as observed in this study could have accounted for the recorded very low/poor scores in the HACCP checklist adherence among the meat sellers. None of the meat handlers interviewed in this study had ever heard the word "HACCP" and many of them were not aware that there were some basic rules of which meat sellers must adhere to, to ensure meat safety. Most of the meat sellers have Primary Education as their highest level of formal education, thus making most of the meat sellers to lack the proper knowledge of meat safety practices.

Findings on the personal hygiene practices of meat handlers in the study indicated that a significant proportion of meat handlers did not adhere to basic standards of personal hygiene while handling meat. Only a small percentage (16.70%) reported wearing proper clothing, such as aprons and hair restraints, which are essential for preventing contamination of meat.

Similarly, a low percentage (12.47%) of meat handlers reported wearing hand gloves, which can act as a barrier to prevent direct contact between hands and meat, thus, reducing the risk of bacterial transfer. Additionally, a relatively low number (18.12%) of meat sellers reported having access to wash-hand basins with running water, which is crucial for maintaining hand hygiene during meat handling. Routine hand washing with soap and water is a fundamental practice to minimize the risk of bacterial being transferred to meat, yet only 13.88% of meat sellers reported this practice. Moreover, a relatively low percentage (31.76%) of meat sellers reported being free from skin infections or open cuts, which can be potential sources of bacterial contamination. Conversely, a considerable majority of meat handlers responded negatively to most of the personal hygiene practices assessed in the study. The majority (83.29%) reported not wearing proper clothing. Similarly, a large proportion (87.52%) of meat sellers reported not wearing hand gloves, and (81.88%) reported not having access to wash-handing basins with running water, both of which are critical measures for maintaining hand hygiene during meat handling. Routine hand washing with soap and water, another important practice, was reported to be neglected by a significant majority (86.11%) of meat sellers. Moreover, a considerable percentage (68.23%) of the meat sellers reported having skin infections or open cuts, which can serve as reservoirs for bacteria and pose serious risks to meat safety. These findings are in line with previous studies which reported poor sellers' personal hygiene practices in various regions by Gutema *et al.,* (2021); Adzity *et al.,* (2020); Azuamah *et al.,* (2018a), Azuamah *et al.,* (2019) and Tegegne, (2017).

Information on the personal hygiene practices of meat sellers in the markets in the three sanatorial zones of Abia State, Nigeria, namely Umuahia, Aba, and Ohafia showed that the majority of meat handlers across all locations responded negatively to several personal hygiene criteria, indicating potential lapses in hygiene practices during meat handling. Firstly, regarding

the use of proper clothing, only a small percentage of meat handlers responded affirmatively, with Umuahia having the highest response (15.58%), followed by Aba (14.81%) and Ohafia (12.96%). Similarly, the use of hand gloves was reported by a limited number of meat handlers, and the availability of wash-hand basins with running water was also reported by only a fraction of respondents in all three zones. Furthermore, the study did not find any significant association/relationship between personal hygiene criteria and their corresponding responses across the three senatorial zones. The p-values for all the criteria were above the common significance level of 0.05, indicating that any observed differences in responses are likely due to random chance rather than meaningful disparities. These findings raised concerns about the overall personal hygiene practices among meat sellers in the studied locations. Such poor personal hygiene practices in meat handling among meat sellers/handlers can lead to the transfer of harmful microorganisms to the meat and have been identified as contributing factors to bacterial contamination of meat and the occurrences of foodborne diseases when consumed by the public in line with the reports of Gutema *et al.,* (2021). These findings (The low compliance with essential hygiene practices, such as wearing proper clothing, using hand gloves, and washing hands with soap and water etc) underscore the need for regular training and awareness programs for meat sellers/handlers in the markets to improve their knowledge of personal hygiene practices. Also, regulatory authorities and market managers should collaborate to ensure that regular monitoring and supervision of the meat sellers by the relevant authorities are sustained; as well as the provision of necessary facilities, such as wash-hand basins with running water and incentives like aprons, gloves etc. to ensure the safety and wholesomeness of meat/meat products sold to the public.

Insights into the sanitation practices of the meat handlers in Abia State revealed concerning trends, as the majority of meat sellers/handlers in all sampled markets demonstrated poor compliance with essential sanitation criteria during meat handling. Table 4.9 above highlighted

the limited adherence to sanitation practices, with only a small percentage of meat sellers responding positively to criteria such as worktables being clean (5.50%), cleaning and sanitizing of equipment and utensils (13.88%), storing cleaning chemicals away in the store (19.38%), washing of mops after use (6.94%), and cleaning of buckets after use (5.98%). On the other hands, the majority of meat sellers responded negatively to these criteria, indicating potential lapses in sanitation practices across all markets. There were variations in responses across the three senatorial zones of the State, with Umuahia, Aba, and Ohafia showing different levels of compliance with sanitation criteria. However, the Chi-square test indicated no statistically significant difference in sanitation practices among the three cities, as evidenced by the p-values for each criterion ($p > 0.05$).

These findings of inadequate hygiene and sanitation practices, potentially leading to the contamination of meat products with harmful microorganisms and the subsequent attendant risk of foodborne illnesses are in line with previous findings by Adzitey *et al.* (2020) who reported non provision of facilities for thorough cleaning and sanitization of equipment and utensils in meat handling to prevent the transmission of pathogens; and Gutema *et al.* (2021), who reported poor hygiene and sanitation practices among meat handlers in slaughter houses and markets in Bishoft town, Ethiopia. Hot water is essential and needed for effective washing and sanitization of hands and equipment (knives) to remove potential surface contaminants and thus prevent further cross contamination of meat from contact surfaces.

The lack of significant differences among the meat sellers/handlers in the markets in the three senatorial zones suggests that sanitation practices among meat sellers in Abia State require immediate attention and improvement. The low compliance with proper sanitation measures also, highlights the need for targeted interventions, including comprehensive training,

enlightenment and educational programs for meat sellers/handlers. Thus, it is crucial to emphasize the importance of keeping work surfaces clean, regularly sanitizing equipment and utensils (with hot water), and appropriately storing cleaning chemicals. Additionally, proper hygiene practices, such as washing mops after use and cleaning buckets, are essential to prevent cross-contamination and ensure food safety in line with the previous works of Azuamah *et al.,* (2019a); Tesson *et al.,* (2020) and others.

Also, the meat handlers in the study areas did not comply with HACCP standards of operations checklists. Plates 4.01 to 4.07 showed that the immediate environment of the slaughterhouses/meat markets and the standard practices therein fall below international standards for meat handling and processing. Animals were slaughtered on dirty slaughter slabs and those slaughtering the animals stepped into the slaughtering slabs bare-footed on dirty legs, dehidding and esciveration were done in such a way that exposes the meat carcass to possible cross-contamination from the microbial contents of the animal skins and the guts/wastes in agreement with previous studies of Gutema *et al.* (2021) who identified the major possible sources of carcass contamination at the slaughter house to include feces during evisceration, the hides, slaughter slabs, handlers' hands and knifes amongst others. Dirty contact surfaces characterized with constant buzzing of flies around the tables of the meat sellers could encourage microorganisms to thrive and cross-contamination the meat carcasses. The results of the bacterial loads from the tables, knives and boots of the vehicles used in transporting the meat showed significant high bacteria loads on the contact surfaces. This is also in line with the findings of Ayesha, *et al*. (2016) and Eze and Nwosu, (2012) that contact surfaces such as tables and equipment could be possible sources of meat contamination.

Additionally, there was a lack of sufficient potable water supply, posing challenges for proper cleaning and handwashing. Contamination of the water sources for the cleaning of the meat carcasses is another possible source of contamination. At some of the slaughter houses, most of the meat sellers fetched their water from nearby streams which were very unhygienic. People were seen bathing and washing their clothes in the streams. *Salmonella* and *Escherichia coli* can be found in dirty water and have been implicated in fresh contamination by Mgbemena *et al.* (2015) in their studies.

Another alarming observation was the open display of meat on tables, leading to the attraction of flies, which could potentially contaminate the meat with harmful microorganisms. Moreover, prospective buyers freely examine the displayed meat without proper hygiene measures further adds to the risk of bacterial contamination. Furthermore, the transportation of meat from the slaughter areas to the market using inadequate vehicles such as wheelbarrows, motorcycles, and car boots instead of covered containers with appropriate temperature control devices violates standard protocols, potentially compromising the quality and safety of the meat. These unhygienic practices are as observed in the markets and slaughter houses are in line with previous studies of Amadi *et al.* (2020), which associated such conditions with the presence of bacterial pathogens like *Staphylococcus aureus* and *Escherichia coli.*

To address these issues, urgent interventions are required. Market authorities should implement proper waste management practices in the markets and in the animal slaughter areas; ensure the provision and access to potable water, and enforce regulations on the proper handling and display of meat. It is essential to educate meat sellers/handlers and prospective buyers on proper hygiene practices, including the use of aprons and gloves, and discouraging the handling of displayed meat without appropriate precautions. Additionally, strict monitoring and

enforcement of regulations on the transportation of meat using covered containers with temperature control mechanisms are crucial to ensure temperature control and meat safety and protect public health. By improving hygiene and sanitation practices in the meat markets, the risk of foodborne illnesses and bacterial contamination could be significantly reduced, safeguarding the health and well-being of consumers.

All the meat samples taken to the laboratory for analysis showed growth of bacterial isolates. The mean bacterial loads of the red and white meat samples on nutrient agar plates were 2.33 x 10^6, 1.99 x 10^5 and 2.73 x 10^5 cfu/g; and 1.81 x 10^5, 1.73 x 10^5 and 2.20 x 10^6 cfu/g for Umuahia, Aba and Ohafia zones respectively. The results of this study revealed the presence of various bacterial isolates in the meat samples (both red and white meat), with *Staphylococcus* sp, *Bacillus* sp, *Escherichia coli*, *Enterococcus* sp, *Salmonella* sp, *Klebsiella* sp, *Micrococcus sp*, and *Campylobacter* sp being the prevalent isolates. These findings are of great concern as they indicate the potential for bacterial contamination in the meat sold in the markets. *Staphylococcus* sp was the most prevalent isolate, present in a high percentage (78.80%) of the meat samples. This bacterium is known to be commonly associated with human skin and can be transferred to meat during handling and processing, highlighting the significance of proper hygiene practices among meat handlers. Similarly, *Escherichia coli*, a common indicator of fecal contamination, was found in a substantial proportion (62.11%) of the meat samples, suggesting possible contamination from improper slaughter and processing practices. Other bacterial isolates, such as *Micrococcus* sp, *Salmonella* sp, *Bacillus* sp, and *Campylobacte*r sp, were also detected at varying rates. The presence of these organisms on the surface of meat samples and the contact surfaces, such as tables, vehicles, and knives, indicates potential fecal and environmental contamination. The poor personal hygiene and sanitation practices among meat sellers/handlers as observed in this study could have contributed to the contamination of

the meat. Most of the predominant bacteria in the meat contact surfaces such as *Staphylococcus* sp., *Salmonella* sp., *Bacillus* sp., and *Campylobacter* sp. were also predominant in the meat samples suggesting a possible cross-contamination of the meat carcasses from the contact surfaces. This contamination can occur during various stages, from slaughter to transportation and display of meat in the markets. The findings of this study are in agreement with previous studies by other researchers including Gutema *et al.,* (2021) who reported and linked the isolation of *Salmonella* sp from contaminated chicken meat to poor sanitary and sanitation conditions; Shimelis, *et al.* (2017) who in their studies isolated *E. coli* and *Salmonella* species as the common bacterial isolates from beef at selected slaughter houses and attributed their sources of contamination to include equipment, transport vehicle, cutting board and worker's hand.

Also, the statistical analysis showed no significant difference in the bacteria isolated from the various markets ($P>0.05$), suggesting that the prevalence of these bacterial isolates is consistent across the studied markets. This finding raises concerns about the overall hygiene and sanitation practices in the meat markets, as the presence of these bacteria on meat surfaces can pose significant health risks to consumers. The high prevalence of these bacterial isolates underscores the importance of implementing stringent hygiene and sanitation measures in meat handling and processing as already suggested by previous researchers including Azuamah *et al.,* (2019) and Tesson *et al.,* (2020).

Meat sellers/handlers should be trained on proper hygiene practices, including handwashing, wearing gloves and aprons, and ensuring the cleanliness of equipment and contact surfaces. Additionally, market authorities should enforce regulations and conduct regular inspections to ensure compliance with hygiene and sanitation standards. The findings of this study are

consistent with previous research on meat contamination and highlight the need for continuous monitoring and improvement of meat handling practices to ensure the safety and quality of meat products. By addressing the issues of bacterial contamination in meat markets, public health risks can be minimized, and consumers can have greater confidence in the safety of the meat they purchase and consume.

5.2 CONCLUSION

In conclusion:

Most of the meat sellers in Abia State lack the basic knowledge and awareness of HACCP Standard Operating Procedures for meat safety and also do not comply with them due to their low level of education. 51.29% of the meat sellers have primary education; 40.47% have secondary education and only 8.24% of the meat sellers have tertiary education.

There was a general observation of non-compliance to HACCP Standard Operating Procedures (SOPs) for meat safety by the meat sellers. None of the meat sellers scored up to 40% in the HACCP SOPs Checklist compliance. The mean HACCP adherence/compliance score by the meat sellers was 24.66 ± 6.08%.

Thus, there was no adequate control in the meat handling safety practices among meat sellers in Abia State. All the mean percentage HACCP scores of the meat sellers at the observed HACCP critical control points in this study were all below 40%. Transportation of meat score was 22.51 ± 4.70% ; Meat storage - 20.99 ± 5.87% ; personal hygiene - 27.97 ± 5.30% ; cleaning and sanitation - 26.30 ±5.65% ; pest control - 20.44 ± 4.81% ; waste disposal - 26.13

± 5.09% ; and staff competency and training - 21.58 ± 4.89%. These lapses could have counted for reported high bacterial loads recorded from the meat samples in this study.

All the meat samples analysed showed growth of bacterial isolates. The mean bacterial loads of the red and white meat samples on nutrient agar plates were 2.33 x 10^6, 1.99 x10^5 and 2.73 x10^5 cfu/g; and 1.81 x 10^5, 1.73 x 10^5 and 2.20 x 10^6 cfu/g for Umuahia, Aba and Ohafia zones respectively. The prevalent bacterial isolates include *Staphylococcus* sp (78.80%), *Bacillus* sp (73.17%), *Enterococcus* sp (64.00%), *Escherichia coli* (62.11%), *Salmonella* sp (62.11%), *Klebsiella* sp (51.29%), *Micrococcus sp* (44.94%) and *Campylobacter* sp (43.52%). SPSS analysis using the one way ANOVA showed no significant difference (P>0.05) in bacteria isolated from markets in the three Senatorial Zones of the State. *Staphylococcus* sp was isolated in 61.11% of the tables, 50.00% of vehicles, 41.67% of knives and 46.32% of water; *Salmonella* sp was isolated in 47.22% of the tables, 36.11% of vehicles, 30.56% of knives and 43.85% of water; *Bacillus* sp was isolated in 41.67% of the tables, 44.44% of vehicles, 33.33% of knives and 23.70% of water; *Campylobacter* sp was isolated in 27.78% of the tables, 25.00% of vehicles, 30.56% of knives and none in water. There was no significant difference (P>0.05) in bacteria isolated from the contact surfaces and water from the markets in the three zones of the State. The poor HACCP checklist compliance in meat handling (during transportation, storage, personal hygiene and sanitation practices etc) as observed in this study and indicated by low mean percentage HACCP score of 24.66 ± 6.08% could have contributed in the contamination of the meat carcasses resulting in high mean bacterial loads from the meat samples. Thus, the bacteriological quality of meat in markets in Abia State could be said to be poor due to the recorded high mean bacterial load counts and the isolation of Indicator bacteria such as *E, coli, Salmonella and Campylobacter* from the studied meat samples.

The meat sellers/handlers failed the meat Process Hygiene Criteria in the slaughter, dressing and other production processes as at the time of sampling. Thus, Meat displayed for sale could have been contaminated/cross contaminated from external sources such as dirty contact surfaces, soil, body discharges and excreta from animals.

The presence of the isolated bacteria on the surface of meat samples and the contact surfaces, such as tables, vehicles, and knives, indicates potential fecal and environmental contamination which could have resulted from poor personal hygiene and sanitation practices among meat sellers/handlers as observed in this study.

There is need for the enlightenment of meat sellers/handlers in Abia State on proper meat handling procedures.

5.3 Contribution to Knowledge

This study has added to existing knowledge that meat sellers/handlers in Abia States, Nigeria failed to meet the basic standards of personal hygiene and sanitation practices during the handling of meat in the sampled markets; and this could have led to the compromised the bacterial qualities of the meat being sold.

There was non-compliance to HACCP Standard Operating Procedures (SOPs) for meat safety by the meat sellers; and none of the meat sellers scored up to 40% in the HACCP SOPs Checklist compliance.

Also, there was no adequate control in the meat handling safety practices among meat sellers in Abia State at some HACCP critical control points (such as in the transportation of meat; Meat storage; personal hygiene; cleaning and sanitation; pest control; waste disposal and staff competency and training) and these could have contributed in the reported high bacterial loads recorded from the meat samples in this study.

This study successfully isolated, identified and documented the predominant bacterial isolates on meat sold in markets in Abia State as *Staphylococcus sp., Escherichia sp., Salmonella sp., Bacillus sp., Entercoccus sp*. and *Campylobacter sp.*; while *Staphylococcus sp., Salmonella sp., Bacillus sp., and Campylobacter sp.* were predominant bacteria on the meat contact surfaces.

This study has also showed that the contamination of meat could have come from external sources through cross contamination of the meat carcasses from the various contact surfaces during handling.

The bacteriological quality of the meat sold across markets in Abia State indicated that there is a Process hygiene criteria failure in meat handling which does not called for the withdrawal of meat being sold to the public but for corrective measures to be put in place to correct reoccurrence. Meat sellers/handlers in Abia State should be enlightened/trained on proper meat handling standards of operation.

5.4 RECOMMENDATIONS

(i) Meat handlers are advised to undergo proper training and regular update on their knowledge of meat safety especially on proper sanitation and good personal hygiene practices.

(ii) Meat handlers should be educated on the need to comply with standard operation procedures for the handling of meat such as the wearing of aprons and gloves, proper temperature control, and improved means of transportation.

(iii) The public should be enlightened on the dangers of meat safety to make informed decisions on where to purchase their meat for consumption.

(iv) Laboratories in Universities and other research organizations should be properly funded and equipped with state-of-the-art facilities to encourage research on meat safety.

(v) Government and other professional Agencies should ensure proper supervision and enforcement of existing regulations on meat safety and hygiene in the country.

(vi) Government and Non-governmental agencies should fabricate a prototype of a customized cold chain chest for storage and transportation of meat; as well as for display of meat in the markets.

(vii) Fresh meat to be separated from other fresh vegetables and fruits that are eaten raw to avoid cross-contamination.

(viii) Fresh meat should be properly cooked before consumption.

REFERENCES

Adesokan, H. K., Akanbi, I. O., Akanbi, I. M. and Obaweda, R. A. (2015) Pattern of antimicrobial usage in livestock animals in south-western Nigeria: the need for alternative plans. *Onderstepoort J. Vet. Res*.82:1-12

Adesokan, H. K., and Raji, A. O. Q. (2014). Safe-meat-handling knowledge, attitude and practices of private and government meat processing plants workers: implications for future policy. *J. Preventive Medicine and Hygiene, 55:10-16*

Adzitey, F., Abu, A., Teye, G. A., Weyire, A., Issahaku, A. and Boateng, E. F. (2018b) Handling and storage of leftover meat by butchers in the Tamale Metropolis and Bolgatanga Municipality of Ghana. *J. Meat Sci. Tech.* 6, 30–35.

Adzitey, F., Slleyman, K. W. and Kum, P. K. (2020). Knowledge and Practice of Meat Safety by Meat Sellers in the Tamale Metropolis of Ghana. *Food Protect Trends, 40:40-47.*

Adzitey, F., Sulleyman, K. W. and Mensah, S. S. (2018a). Knowledge and practices of meat safety by meat sellers in the Kumasi Metropolis of Ghana. *Res. Rev: J. Food Sci. Tech*. *7:31–41*.

Ajayeoba, T. O., Atanda, O. O., Obadina, A. O., Bankola, M. O. and Adelowo, O. O. (2015). The incidence and distribution of Listeria monocytogenes in ready-to-eat vegetable in South-Western Nigeria. *Food Sci. Nutr*. *4: 59–66*

Alhaji, N. B. and Isola, T. O. (2018) Antimicrobial usage by pastoralists in food animals in North-central Nigeria: the associated socio-cultural drivers for antimicrobials misuse and public health implications. *One Health, 6:41–47.*

Alhaji, N. B., and Baiwa, M. (2015) Factors affecting workers' delivery of good hygienic and sanitary operations in slaughterhouses in north-central Nigeria. *Sokoto J. Vet. Sci. 13:29–37.*

Al-Kandari, D., Al-abdeen, J. and Sidhu, J. (2019). Food safety knowledge, attitudes and practices of food handlers in restaurants in Kuwait. *Food Contr.103:103–110.*

Alonso, C. A., Zarazaga, M., Ben Sallem, R., Jouini, A., Ben Slama, K. and Torres, C. (2017) Antibiotic resistance in *Escherichia coli* in husbandry animals: The African perspective. *Lett. Appl. Microbiol*. 64:318–334.

Amadi, A. N. (2009). *Modern Environmental Sanitation.* Owerri, *Nationwyde Printers and Publishing* Co. Ltd.

Amadi, C. O. A., Yakubu, M. B., Iro, O. K., Azuamah, Y. C., Amadi, A. N., and Ukah, A. (2020). Water Supply and Bacteriological Qualities of Drinking Water in Primary Schools of North Central Nigeria. *Inter. J. of Res.7:407-412*.

Archer, D. L. (2002) Evidence that ingested nitrate and nitrite are beneficial to health. *J. Food Protection*, 65:872-875.

Ashwathi, P. (2017). Microbial contamination of meat. *Microbiology*. http//www.biologydiscussions.com.

Ayesha, Z., Erum, A. and Hafiza, W. (2016).Microbiolgical evaluation of raw meat products available in local markets of Karachi, Pakistian . *B. life Envtal.Sci.53:103–109*

Ayoola, M. C., Akinseye, V. O., Cadmus, E., Awosanya, E., Papoola, O. A., Akinyemi, O. O., Perrett, L., Taylor, A., Stack, J., Moriyon, I. and Cadmus, S. I. (2017) Prevalence of

bovine brucellosis in slaughtered cattle and barrriers to better protection of abattoir workers in Ibadan South-Western Nigeria. *Pan African Medical Journal, 28:68.*

Azuamah, Y. C., Amadi, A. N., Iro, O. K., Amadi, C. O. A. and Braide, W. (2018a). Bacteriological qualities of red meat (Beef) and meat hygiene practices among meat handlers in Aba Metropolis, Nigeria. *Inter. J. Res. 8:41-49.*

Azuamah, Y. C., Amadi, A. N., Iro, O. K., Azuamah, E. C. and Amadi, C. O. A. (2018b). HACCP Checklist Scores at Critical Control Points by Meat Handlers in Abia State, Nigeria. *Inter. J. Res* 9:*30162-30165.*

Azuamah, Y. C., Amadi, A. N., Iro, O. K., and Amadi, C. O. A. (2019). Distribution of Bacterial Isolates from Contact Surfaces of Meat Handlers in Abattoirs of Southeastern Nigeria. *International Journal of Research, 6:109-119.*

Balaban, N., and Rasooly, A. (2010). Staphylococcal enterotoxins. *Inter. J. Food Microbiol. 61:1-10.*

Bas, M., Ersun, A. S. and Kıvanç, G. (2006). The evaluation of food hygiene knowledge, attitudes, and practices of food handlers in food businesses in Turkey. *Food Control, 17:317–322.*

Baş, M., Ersun, A. Ş., and Kıvanç, G. (2006). Implementation of HACCP and prerequisite programs in food businesses in Turkey. *Food Contr. 17: 118-126*

Belitz, H. D., Grosch, W. and Schieberle, P. (2009) Food Chemistry (4th Edition). *Springer-Verlag Berlin Heidelberg,* Germany, pp: 596.

Bennani, L., Faid, M. and Bouseta, A. (2000) Experimental manufacturing of kaddid, a salted dried meat product: control of the microorganisms. *European Food Res. Techn.,* 211: 153-157.

Board, R. J and Davies, A. R (1998). T*he Microbiology of Meat and Poultry*. Boundary Row, London, UK: Blackie Academic and Professionals.

Brookes, V.J., Jordan, D., Davis, S., Ward, M.P. and Heller, J. (2015). Satellite global sensitivity analysis and simulation modeling to identify intervention strategies to reduce the prevalence of Escherichia coli O157 contaminated beef carcasses. *Inter. J. Res 23:1-10*

Brown, V.R., Ebel, E.D. and Williams, M.S. (2013). Risk assessment of intervention strategies for fallen carcasses in beef slaughter establishments. *Food Control.*, 33:254–261

Bryant, J., Gill, C. O., Jones, T. and Brereton, D.A. (2014) The microbiological conditions of the carcasses of six species after dressing at a small abattoir. *Food Microbiol.*, 17:233–239.

Buchanan, R.L. (2000) Acquisition of Microbiological data to enhance food safety. *J. of Food Protection., 63:832 - 838*.

Carroll, C. D. and Alvarado, C. Z. (2008) Comparison of air and immersion chilling on meat quality and shelf life of marinated broiler breast fillets. *Poultry Sci.,* 87:368-372.

Casaburi, A.,Piombino, P., Nychas, G. J., Villani, F. and Ercolini, D. (2015). Bacterial populations and the volatilome associated to meat spoilage.*Food Microbiol. 45:83– 102*

Castellano, P., Belfiore, C., Fadda, S. and Vignolo, G. (2008) A review of bacteriocinogenic lactic acid bacteria used as bioprotective cultures in fresh meat produced in Argentina. *Meat Sci., 79:483-499*

Cenci-Goga, B.T., Karama, M., Sechi, P., Iulietto, M. F., Novelli, S. and Mattei, S. (2014) Evolution under different storage conditions of anomalous blue coloration of

Mozzarella cheese intentionally contaminated with a pigment-producing strain of Pseudomonas fluorescens. *J. Dairy Sci.,* 97:6708-6718

Centers for Disease Control and Prevention (CDC) (2008) Health Information for International Travel. http://www.cdc.gov/travel/index.htm.

Cerveny, J., Meyer, J. D. and Hall, P. A. (2009) Microbiological Spoilage of Meat and Poultry

Chawla, S.P., Chander, R. and Sharma, A. (2006) Safe and shelf-stable natural casing using hurdle technology. Food Control, 17:127-131.

Cheesbrough, M. (2000). *Microbiological test: District Laboratory Practice in Tropical Countries.* London: *Cambridge University Press,* pp. 1-226.

Chipley, J.R. (2005) Sodium benzoate and benzoic acid In: Antimicrobials in Food, 3rd Ed., Davidson, P. M., Sofos, J. N. & Branen, A. L. (Eds.). *CRC Press,* FL, pp: 11-48.

Codex Alimentarius Commission (CAC) (2005) Code of Hygienic Practice for Meat: https://www.fao.org/fao-who-codexalimentarius/

Comaposada, J., Gou, P. and Arnau, J. (2000) The effect of sodium chloride content and temperature on pork meat isotherms. *Meat Sci., 55:291-295.*

Dave, D. and Ghaly, A. E. (2011) Meat Spoilage Mechanisms and Preservation Techniques: A Critical Review. *A. J. of Agric. and Biol. Sci., 6:486-510.*

Deecke, T. (1874). On the germ-theory of disease. *American J. of Psychiatry, 30:443-463.*

Department of Justice Canada (DJC) (2009) Food and Drug Act. http://laws.justice.gc.ca/en/showtdm/cr/C.R.C.-c.870.

Dewettinck, T., Van Houtte, E., Geenens, D., Van Hege, K., and Verstraete, W. (2001). HACCP (Hazard Analysis and Critical Control Points) to guarantee safe water reuse and drinking water production-a case study. *Water Sci. and Technol., 43*:*31-38.*

Domowe, W., (2010) Safety Hurdles. http://www.wedlinydomowe.com/fermentedsausages/fermented-sausages-safety-hurdles.htm.

Doulgeraki, A. I., Ercolini, D., Villani, F. and Nychas, G. J. (2012) Spoilage microbiota associated to the storage of raw meat in different conditions. *Int. J. Food Microbiol., 157:130-141.*

Duffy, G., Cummins, E., Nally, P., O'Brien, S. and Butler, F. (2006). A review of quantitative microbial risk assessment in the management of Escherichia coli O157: H7 on beef. *Meat Science, 74:*76–88.

Dussault, F., Gill, C. O. and Holley, R. A. (2010) Evaluation of the hygienic performances of the processes for dressing and cooling pig carcasses at eight packing plants. *International J. of Food Microbiol., 58:65–72.*

Egan, M. B., Raat, M. M., Grubb, S. M., Eves, A. M., Lumbers, L. and Dean, M. S. (2007) A review of food safety and food hygiene studies in the commercial sector. *Food Control, 18:1180–1190*

Ehiri, J. C., Azubuike, M. C., Ubbaonu, C. N., Anyanwu, E. C., Ibe, K. M. amd Ogbonna, M. O. (2001). Critical Control points of complementary food preparation in eastern Nigeria. *World Health organization, 79:423-33.*

El-Gamal, A.M. and EL-Bahi, E.F. (2016) Molecular Characterization of Rectal Carriage of *E Coli O157: H7* and Salmonella Spp. in Feedlot Animals and Its Effects on Carcasses Contamination. *Alex. J. Vet. Sci., 48:42–49.*

Ercolini, D., Ferrocino, I., La Storia, A., Mauriello, G., Gigli, S., Masi, P. and Villani, F. (2010) Development of spoilage microbiota in beef stored in nisin activated packaging. *Food Microbiol., 27:137-143.*

Ercolini, D., Russo, F., Torrieri, E., Masi, P. and Villani, F. (2006) Changes in the spoilage-related microbiota of beef during refrigerated storage under different packaging conditions. *Appl. Environ. Microbiol., 72:4663-4671.*

Ethiopian Federal Negarit Gazeta (EFNG) (2010). Federal Negarit Gazeta No. 9, 16th Year, 13 January 2010, pp. 5157–5191. Food, Medicine and Health Care Administration and Control Proclamation No. 661/2009. www.Ethiopar.Net.

European Food Safety Authority and European Centre for Disease Prevention and Control (EFSA and ECDC, 2015). The European Union summary report on trends and sources of zoonoses, zoonotic agents and food-borne outbreaks in 2013. *EFSA J.* 13:3991. https://doi.org/10.2903/j.efsa.2015.3991

European Food Safety Authority and European Centre for Disease Prevention and Control (EFSA and ECDC) (2022). The European Union One Health 2021 Zoonoses Report. *EFSA J.20: 7666*. https://doi.org/10.2903/j.efsa.2022.7666

Eze, V.C. and Nwosu, I. (2012). Evaluation of microbial quality of fresh goat meat sold in Umuahia Market, Abia state, Nigeria. *Pak. J, Nutrition, 11: 880-884.*

Farley, J. (1992). Parasites and the germ theory of disease. *Hospital Practice, 27*:*175-196.*

Federal Republic of Nigeria Offical Gazette (2009). Legal notice on publication of 2006 Census final results. *Federal Government of Nigeria, Lagos*. http//www.ng-government-gazette-dated-2009-02-02-no-2.pdf

Felsenstein, J. (1985). Confidence limits on phylogenies: An approach using the bootstrap. *Evolution 39:783-791*.

Feng, P., Weagant, S. D. and Grant, M. A. (2020) Bacteriological Analytical Manual (BAM) Chapter 4: Enumeration of Escherichia coli and the Coliform Bacteria. https://www.fda.gov>food>bam-c.....

Food and Agricultural Organization (FAO) (2019) Technical Guidance Principles of Risk-Based Meat Inspection and their Application. FAO; Rome, Italy.

Food and Agricultural Organization, (FAO) (2020) Food and Nutrition in Review, Role of meat as a source of protein and essential amino acids in human nutrition.

Food and Agriculture Organization, (FAO) (2008) Microbiological hazards in fresh leafy vegetables and herbs: *Meeting Report. Microbi. Risk Assessment Series, 14:151-159*

Food borne bacterial pathogens in marketed raw meat of Dhara. https://www.ncbi.nlm.nih.gov>pmc

Friis, R. H. (2007). Essentials of environmental health. Jones and Bartlett Publishers. Boston, USA: pp 27-35

Frperc, S.J., (2004) Poultry refrigeration. In: Poultry meat processing and quality, G. Mead (Ed.), *Woodhead Publishing Limited*, Cambridge, England, pp: 164-181.

Frumkin, H. (2010). Environmental Health from Global to Local. Second edition. California, USA: John Wiley & sons, Inc. Food borne illness. https://www.niddk.nih.gov/health-information/digestive-diseases/foodborne-illness

Ghaderpoori, M., Dehghani, M.H., Fazlzadeh, M. and Zarei, A. (2009) Survey of Microbial Quality of Drinking Water in Rural Areas of Saqqez, Iran. *American-Eurasian J. Agric. and Environ. Sci., 5:627-632*

Ghaly, A. E., Dave, D., Budge, S. and Brooks, M. S. (2010) Fish spoilage mechanisms and preservation techniques: Review. *Am. J. Applied Sci., 7: 846-864*.

Giuggioli, G., Olivastri, A., Pennisi, L., Paludi, D., Ianieri, A., and Vergara, A. (2017). The hygiene-sanitary control in the wild game meats. *Italian J. of Food Safety*, 6:68-75.

Gonzales-Barrón, U., Piza, L., Xavier, C., Costa, E. and Cadavez, V. (2016). An exposure assessment model of the prevalence of *Salmonella spp*. along the processing stages of Brazilian beef. *Food Sci. Technol. Int. 22:10–20.*

Grace, D. (2015). Food Safety in Low and Middle Income Countries. *International Journal of Environmental Research and Public Health*, 12:10490 – 10507 www.mdpi.com/journal/ijerph

Gurmu, E. B. and Gebretinsae, H. (2013). Assessment of bacteriological quality of meat cutting surfaces in selected butcher shops of Mekelle city, Ethopia. *J. of Environ. and occupational sci., 2:61-66.*

Gutema, F. D., Agga, G. E., Abdi, R. D., Jufare, A., Duchateau, L., De Zutter, L. and Gabriel, S. (2021). Assessment of Hygienic Practices in Beef Cattle Slaughterhouses and Retail Shops in Bishoftu, Ethopia: Implications for Public Health. *Inter. J. of Environ. Research and Pub. Health, 18*:27-29. https://doi.org/10.3390/ijerph18052729

Gutema, F.D., Rasschaert, G., Agga, G.E., Jufare, A., Duguma, A.B., Abdi, R.D., Duchateau, L., Crombe, F., Gabriël, S. and De Zutter, L. (2020) Occurrence, Molecular Characteristics, and Antimicrobial Resistance of *Escherichia Coli* O157 in Cattle, Beef, and Humans in Bishoftu Town, Central Ethiopia. https://doi:10.1089/fpd.2020.2830.

HACCP (A) (2015). HACCP – Based SOPs Food safety checklist. www.sop.nfsmi.org/records/foodsafetychecklist.

HACCP(B) (2015). HACCP) in meat plants. https://www.food.gov.uk/business-industry/meat/haccp/meat/plants

Hald, T. (2013). Advances in microbial food safety: Pathogen Salmonella. London: Elsevier. pp22.

Havelaar, A. H., Kirk, M. D., Torgerson, P. R., Gibb, H. J., Hald, T., Lake, R. J., et al. (2015). World Health Organization global estimates and regional comparisons of the burden of foodborne disease in 2010. *PLoS Med.* 12, e1001923. doi: 10.1371/journal.pmed.1001923

Health Canada, Ottawa, Canada (HC) (2006) Good manufacturing practices guidance document. http://www.hcsc.gc.ca/dhpmps/alt_formats/hpfbdgpsa/ pdf/prodnatur/gmp-bpf-eng.

Hussein, H. S. (2007). Prevalence and Pathogenicity of Shiga toxin producing *Escherichia coli* in beef cattle and their products. *J. Anim. Sci.* 85:63-72. https://Doi:10.2527/jas.2006-421

Ibekwe, A. C., Okonko, I. O., Onunkwo, A. U., Donbraye, E., Babalola, E. T. and Onoja, B. A. (2008) Baseline *Salmonella* agglutinin titres in apparently healthy freshmen in Awka, South Eastern, Nigeria. *Scientific Research and Essay*, 3:225-230

Ifeadike, C. O., Ironkwe, O. C., Adogu, P., Nnebue, C. C., Emelumadu, O. F., Nwabueze, S. A. and Ubajaka, C. F. (2012) Prevalence and pattern of bacteria and intestinal parasites among food handlers in the Federal Capital of Nigeria. Niger. Med. J.,53:166 - 171. http://www.nigeriamedj.com.article.asp?issn-1652;year=2012...

Ifenkwe, G. E. (2012) Food safety regulation: reducing the risk of food borne diseases in rural communities in Abia State, Nigeria. *Agric. Sci. Res. J., 2:384-380.* http://resjournals.com/AR/pdf/2012/July/Ifenkwe.

Igbinosa, E. O., Bashiru, A., Akporehe, L. U., Oviasogie, F. E. and Igbinosa, O. O. (2016) Prevalence of Methicillin-Resistent *Staphylococcus aureus* and other *Staphylococcus species* in raw meat samples intended for human consumption in Benin city, Nigeria : Implication for Public Health . *Int. J. Environ. Res. Public Health, 13:949. https://doi.org/10.3390/ijerph13100949*

Irichokchatchawan, W., Taneepanichskul, N. and Prapasarakul, N. (2021). Predictors of knowledge, attitudes, and practices towards food safety among food handlers in Bangkok Thailand. *Food Contr.126:124-131*

Iro, O. K., Amadi, A. N., Enebeli, U. U. and Amadi, C. O. A. (2019). Bacteriological qualities of Beef sold in Abia and Imo States Nigeria: Implications for sustenance of Enteric Diseases. *Intern. J. of Res. Sci., 8:539-546.*

Iro, O. K., Enebeli, U. U., Iloh, G. U. P., Azuamah, Y. C., Amadi, A. N., Amadi, C. O. A., Ezejindu, C., Ingwu, J.and Ogamba, S. E. (2020). Food Hygiene and Safety Management in Nigeria. *Intern. J. of Res. Sci., 7:101-109.*

Jaykus, L. A. (1996). The application of quantitative risk assessment to microbial food safety risks. *Critical reviews in microbial., 22:279-293.*

Jhalka, K., Tara, C. and Dipendra, T. (2014). Staphylococcus aureus and Staphylococcal Food-Borne Disease: An Ongoing Challenge in Public Health. *Biomedical Res. Inte. 8:65-70.*

Joseph, M. (2017). Eight types of meat and their benefits. *Nutrition Advance, 9:121-127.*

Jukes, T. H. and Cantor, C.R. (1969). Evolution of protein molecules: In Munro HN, editor, Mammalian Protein Metabolism. *Academic Press,* New York. pp. 21-132

Kabir, S. M. L. (2009) Effect of probiotics on broiler meat quality. *A. J. of Bioethanol.,* 8: 3623-3627

Kiermeier, A., Jenson, I. and Sumner, J. (2015**).** Risk Assessment of Escherichia coli O157 Illness from Consumption of Hamburgers in the United States Made from Australian Manufacturing Beef. *Risk Anal., 35:77–89.*

Kirk, M.D., Pires, S.M., Black, R.E., Caipo, M., Crump, J.A., Devleesschauwer, B., et al. (2015). World Health Organization Estimates of the Global and Regional Disease Burden of 22 Foodborne Bacterial, Protozoal, and Viral Diseases, 2010: A Data Synthesis. *PLoS Med 12: 10.-113*

Kosmider, R. (2010). EU0701: A UK VTEC O157 Risk Assessment Model for Meat Products; Veterinary Laboratories Agency: Webbridge, UK.

Larsson, S. C. and Orsini, N. (2014). Red meat and processed meat consumption and all-cause mortality: a meta-analysis. *A. J. of Epidemio., 179:282–289.*

Lawrie, R. A. and Ledward, D. A. (2006). *Lawrie's meat science.* 7th ed. Cambridge: *Woodhead Publishing Limited,* 182-190.

Lee, E. (2014). The Truth About Red Meat. *Web MD, 15: 34-40.*

Leonard, B. (2011) Fish and fishery products: hazards and controls guidance, 4th ed. *Diane Publ. Co.*, Darby, PA, USA, pp 12-24

Letuka, P., Nkhebenyane, J., and Thekisoe, O. (2021). Street food handlers' food safety knowledge, attitudes and self-reported practices and consumers' perceptions about street food vending in Maseru, Lesotho. *British Food Journal, 123:302– 316.*

Li, M., Malladi, S., Hurd, H.S.; Goldsmith, T.J., Brichta-Harhay, D.M. and Loneragan, G.H. (2015) *Salmonella spp*. in lymph nodes of fed and cull cattle: Relative assessment of risk to ground beef. *Food Control, 50:423–434.*

Loir, Y., Baron, F. and Gautier, M. (2013). Staphylococcus aureus and food poisoning. *Genetic Molecular Res., 2:63-76.*

Lowy, F. D. (2008). Medical progress: Staphylococcus Aureus infections. *New England J, of Med., 339:520-532.*

Lues, J. F. R. and Tonder, I. V. (2007) The occurrence of indicator bacteria on hands and aprons of food handlers in the delicatessen sections of a retail group. *Food Control, 18:326–332.*

Lulietto, M. F., Sechi, P., Borgogni, E. and Cenci-Goga, B. T. (2015) A Critical Review of a Neglected Alteration due to Ropy Slime Producing Bacteria. *Italian J. of Animal Sci., 14:4011-4016.* https://doi.org/10.4081/ijas.2015.4011

Magnussen, O. M., Haugland, A., Torstveit, A. K.; Hemmingsen, S. and Johansen, T.S. *et al*., (2008) Advances in super chilling of food-process characteristics and product quality. *Trends Food Sci. Technol., 19: 418-424*

Meat Industry Guide (2017). Food Standards: Microbiological Criteria. https://www.foodstandards.gov.scot/downloads/Mead_Industry_Guide_Chapter_13.pdf

Mgbemena, I. C., Ebe, T., Nnadozie, A. I. and Iloanya, U. C. (2015) Bacterialogical and Parasitological Assessment of fresh meat marketed in Owerri, Imo State, Nigeria.. *J. of Pharm. and Biol. Sci. 10: 71–76*. www.iosrjournals.org

Micha, R., Wallace, S. K.and Mozaffarian, D. (2010). Red and Processed Meat Consumption and Risk of Incident Coronary Heart Disease, Stroke, and Diabetes Mellitus: A Systematic Review and Meta-Analysis. *Circulation, 121:2271–2283.*

Mohd, M. A., Sieo, C. C., Chong, C. W., Gan, H. M. and Ho, Y. W. (2015). Deciphering chicken gut microbial dynamics based on high-throughput 16S rRNAmetagenomics analyses. *Gutlier Pathogenesis, 7:41-48.*

Nastasijević, I., Lakićević, B. and Petrović, Z. (2017) Cold Chain Management in Meat Storage, Distribution and Retail: A Review in IOP Conference Series. *Earth Environ. Sci., 85:120–122.*

National Advisory Committee on Microbiological Criteria for Foods. (1998). Hazard analysis and critical control point principles and application guidelines. *J. of Food Protection, 61*:1246-1259.

Ncube, F., Kanda, A., Chijokwe, M., Mabaya, G., and Nyamugure, T. (2020). Food safety knowledge, attitudes and practices of restaurant food handlers in a lower-middle-income country. *Food Sci. and Nutrition, 8:1677– 1687.*

Ndahi, M. D., Kwaga, J. K., Bello, M., Kabir, J., Umoh, V. J., Yakubu, S. E. and Nok, A. J. (2014) Prevalence and antimicrobial susceptibility of Listeria monocytogene and

methicillin-resistent Staphylococcus aureus strains from raw meat and meat products in Zaria, Nigeria.. *Lett. Apppl. Microbiol. 58:262-9.* Doi:10.1111/lam.12183.

Ndalama, E., Mdgela, R. H. and Nonga, H. E. (2013). Assessment of hygienic practices and faecal contamination of beef at Vingunguti slaughterhouse in Dar es salam, Tanzania. *Tanzania Veterinary Journal*, *28.*

Nigeria Muse (2010). Map showing the LGAs of Abia State. http//www.nigerianmuse.com.

NPFSIS (2014): National Policy on Food Safety and its Implementation Strategy. Federal Ministry of Health, Abuja. www.health.gov.ng/doc/foodsafetypolicy.

Nychas, G. J. E., Skandamis, P. N., Tassou, C. C. and Koutsoumanis, K. P. (2008) Meat spoilage during distribution. Meat Sci., 78: 77-89

Nyk¨asenoja, S., Olkkola, S., Pohjanvirta, T., Bistr¨om, M., Kaartinen, L., Helin- Soilevaara, H., Aarnio, M., Raunio-Saarnisto, M., Kivilahti-M¨antyl¨a, K. and Nevalainen, M. (2019) FINRES-vet 2018: Finnish Veterinary Antimicrobial Resistance Monitoring and Consumption of Antimicrobial Agents. https://helda.helsinki.fi/handle/10138/307519.

Nyokabi, S. N., de Boer, I. J. M., Luning, P. A., Korir, L., Lindahl, J., Bett, B., and Oosting, S. J. (2021). Milk quality along dairy farming systems and associated value chains in Kenya: An analysis of composition, contamination and adulteration. *Food Contr. 119:112-119*

Oakley, B. B., Morales, C. A., Line, J. E., & Seal, B. S. (2012). Application of high-throughput sequencing to measure the performance of commonly used selective cultivation methods for the foodborne pathogen Campylobacter. *FEMS Microbiol Ecology*, 79, 327–336.

Okereke, E. E., Amadi, C. O. A., Iro, O. K., Obasi, K. O., Azuamah, Y. C., Braide, W., Ede, A. O., Igwe, C. N. and Amadi, A. N. (2019). Bacteriological qualities of drinking water among residents of Umuahia, Southeastern Nigeria. *Inter. J. of Food Microbiol., 6:324-330.*

Okeudo, N. J. (2017). "Human food and healthy lives: Confronting insufficient production and preservation of good quality meat and egg", being a 32nd Inaugural Lecture of the Federal University of Technology, Owerri delivered on 26th April, 2017 at FUTO.

Okojie, P. W. and Isah, E. C. (2014). Sanitary conditions of food vending sites and food handling practices of street food vendors in Benin City, Nigeria; Implications for food hygiene and safety. *J. of Environ. and Pub. Health, 6:324-330.*

Okonko, I. O., Adejoye, O. D., Ogun, A. A., Ogunjobi, A. A., Nkang, A. O. and Adebayo-Tayo, B. C. (2009). Hazards analysis critical control points (HACCP) and microbiology qualities of sea-foods as affected by handler's hygiene in Ibadan and Lagos, Nigeria. *A. J. Food Sci., 3:35-50.*

Oloruntoba, E. O., Adebayo, A. M.and Omokhodion, F. O. (2014). Sanitary conditions of abattoirs in Ibadan, Southwest Nigeria. *A. J. of Med. Sci.*, 43:231-237.

Olubunmi, L., Balogun, T. A., Ayo-Bello, O. J., Afodu Oladele, T.and Akinwole, L. C. (2017). Determinants of Waste Management Techniques among the Poultry Farmers in Ikenne Local Government Area of Ogun state, Nigeria. *Inter. J. of Livestock Research, 7:41-51.*

Olumide, A. O. (2016). Public health implication of microbial food safety and food borne diseases in developing countries. *Food and Nutri. Res., 60:10-13*

Omojokun, J. (2013). Regulation and Enforcement of Legislation on Food safety in Nigeria, p 251-268. Chapter in Mycotoxin and Food Safety in Developing Countries. *INTECH Open Publisher* dx.doi.org/10.5772/54423.

Omoruyi, I. M., Uwadiae, E., Mulade, G. and Omoruku, E. (2018). Shiga toxin producing strains of *Escherichia coli* (STEC) associated with beef products and its potential pathogenic effect. *Microbiol. Res. J. Inter., 14:1–7.*

Omotayo, R. K.and Denloye, S. A. (2002). The Nigerian Experience on Food Safety Regulation, FAO/ WHO Global Forum on Food Safety Regulation, Marrakesh, Morocco.

Onyeike, E. N.and Osuji, J. O., (2003). Research techniques in biological and chemical sciences. Owerri, Abia State: *Springfield Publishers Ltd*. Pp 44-49.

Onyeneho, S. N. and Hedberg, C. W. **(**2013). An Assessment of Food Safety Needs of Restaurants in Owerri, Imo State, Nigeria. *Intern. J.l of Environ. Res. and Pub. Health,* 10:3296 – 3309. https://doi.org/10.3390/ijerph10083296

Osemwowa, E., Omoruyi, I. M., Kurittu, P., Heikinheimo, A. and Fredriksson-Ahomaa, M. (2021). Bacterial quality and safety of raw beef: A comparison between Finland and Nigeria.*Food Microbiol., 100:2-7*. https://doi.org/10.1016/j.fm.2021.103860

Pardo, J. E., Penaranda, J. A., Alvarez-Ortí, M., Zied, D. C. and Pardo, A. (2011) Application of the hazard analysis and critical control point (HACCP) system on the mushroom processing line for fresh consumption. *Italian J. of Food Sci., 23:126–135.*

Park, K. (2007). Park's textbook of preventive and social medicine. 19th Edition. India: M/S Banarsidas

Parry-Hanson, K. A., Ofosu, D. B., Aboagye, E. and Tao-Debrah, K. (2016) Food safety knowledge, attitudes and self-reported practices of food handlers in institutional foodservice in Accra, Ghana. *Food Contro.l, 69:2234-2239.*

Pellet, P. L., and Young, V. R. (2010). Role of meat as a source of protein and essential amino acids in human nutrition. *Architecture of Inter. Med., 157:329-370.*

PETA (2010). People for the Ethical Treatment of Animals. *Meat contamination*. www.peta.org/living/food/meat-contamination

Powell, M., Schlosser, W., and Ebel, E. (2004). Considering the complexity of microbial community dynamics in food safety risk assessment. *Inter. J. of food microbiol., 90:171-179.*

Qadri, F, Khan, A. I., Faruque, A. S. G., Begum, Y. A., Chowdhury, F., Nair, G. B., *et al.*, (2005) Enterotoxigenic *Escherichia coli* and *Vibrio cholerae* diarrhea, Bangladesh, 2004. *Emerging Infectious Diseases, 11:1264-1266*

Ranjitkar, S., Lawley, B., Tannock, G., & Engberg, R. M. (2016). Bacterial succession in the broiler gastrointestinal tract. *Applied Environ. Microbiol.*, 82:2399–2410.

Ray, B. (2004) Fundamental food microbiology. 3rd ed. CRC Press, FL., pp. 439 – 534.

Ray, B. and Bhunia, A. (2013) Fundamental food microbiology, 5th ed. *CRC Press*, Boca Raton, FL, USA. Pp 154-162

Remenant, B., Jaffres, E., Dousset, X., Pilet, M. F. and Zagorec, M. (2015) Bacterial spoilers of food: behavior, fitness and functional properties. *Food Microbiol., 45:45-53.*

Rossaint, S., Klausmann, S. and Kreyenschmidt, J. (2015) Effect of high-oxygen and oxygen-free modified atmosphere packaging on the spoilage process of poultry breast fillets. *Poultry Sci., 94:93-103.*

Russell, J. B., and Jarvis, G. N. (2011). Practical mechanisms for interrupting the oral-fecal lifecycle of Escherichia coli. *Journal of Molecular Microbiol. and Biotechnol., 3:265–272.*

Saenz, Y., Zarazaga, M., Lantero, M., Gastanares, M. J., Baquero, F., and Torres, C. (2007). Antibiotic resistance in Campylobacter strains isolated from animals, foods, and humans in Spain in 1997–1998. *Antimicrobial Agents Chemotherapy, 44:267–71.*

Saitou, N. and Nei, M. (1987). The neighbor-joining method: A new method for reconstructing phylogenetic trees. *Molecular Biol. and Evol.4:406-425.*

Sani, N.A. and Siow, O.N. (2014) Knowledge, Attitudes and Practices of Food Handlers on Food Safety in Food Service Operations at the Universiti Kebangsaan Malaysia. *Food Control*, 37:210–217.

Saulat, J. (2012). Epidemiology of Foodborne Illness, Scientific, Health and Social Aspects of the Food Industry, Dr. Benjamin Valdez (Ed.), ISBN: 978-953-307-916-5, In Tech, http://www.intechopen.com/books/scientific-health-and-social-aspects-of-the-food-industry/epidemiology-of-foodborne-illness

Schroeder, C. M., Naugle, A. L., Schlosser, W. D., Hogue, A. T., Angulo, F. J., Rose, J. S., et al. (2005) Estimate of illnesses from Salmonella enteritidis in eggs, United States, 2000. *Emerging Infectious Diseases, 11:394-401*

Shimelis, M., Edget, A., and Daniel, S. (2017). E. coli O157:H7 and Salmonella Species: Public Health Importance and Microbial Safety in Beef at Selected Slaughter Houses and Retail Shops in Eastern Ethiopia. *J. of Veterinary Sci. and Technol., 8:46-54.*

Siddiky, N.A., Sarker, S., Khan, S.R., Rahman, T., Kafi, A. and Samad, M.A. (2022**).** Virulence and antimicrobial resistance profile of non-typhoidal Salmonella enterica serovars recovered from poultry processing environments at wet markets in Dhaka, Bangladesh. *PLoS 17:14-21*

Smith, B.A., Fazil, A. and Lammerding, A.M. (2013) A risk assessment model for Escherichia coli O157:H7 in ground beef and beef cuts in Canada: Evaluating the effects of interventions. *Food Control, 29:364–381.*

Smith, S. and Schaffner, D. W. (2004). Indicator Organisms in Meat. Encyclopaedia of Meat Science. London: Elsevier Science. pp. 773-779.

Sofo, J. N. and Georgnaras, I. (2010) Overview of current meat hygiene and safety risks and summary of recent studies on biofilms, and control of Escherichia coli O157:H7 in non intact, and Listeria monocytogenes in ready- to-eat meat products. *Meat Science, 86:2–14.*

Sousa, C. P. (2008) The impact of food manufacturing practices on food borne diseases. Braz. *Arch. Boil. Technol. 51: 4-11.*

Statistics Solutions (2022) Reliability and Validity. https://www.statisticssolutions.com....

Sulleyman, K. W., Adzitey, F. and Boateng, E. F. (2018) Knowledge and practices of meat safety by meat sellers in the Accra Metropolis of Ghana. *Inter. J. Vet. Sci.,7:167–171.*

Tegegne, H. A. (2017). Food Safety knowledge, Attitude and Practices of Meat Handler in Abattoir and Retail Meat Shops of Jigjiga Town, Ethiopia. *J. of Preventive Med. and Hygiene, 58: 78-83.*

Tesson, V., Federighi, M.; Cummins, E., De Oliveira Mota, J. D., Guillou, S. and Boue, G. (2020). A Systematic Review of Beef Meat Quantitative Microbial Risk Assessment Models. *Intern. Journal of Environmental Research and Public Health, 17* :688-696.

U.S. Food and Drug Administration, USA. (USFDA) (2009). Food Generally Recognized as Safe(GRAS).http://www.USFDA.gov/Food/FoodIngredientsPackaging/GenerallyRecognizedasSafeGRAS/default.htm**.**

Ukut, I. O., Okonko, I. O., Ikpoh, I. S., Nkang, A. O., Udeze, A. O., and Babalola, T. A. (2010). Assessment of bacteriological quality of fresh meats sold in Calabar metropolis, Nigeria. *Electronic J. of Environ., Agric. and Food chem., 9:89-100.*

United State Department of Agriculture (USDA) (2005) FSRE (Food Safety Regulatory Essentials) Shelf-Stable, Principles of preservation of shelf-stable dried meat products. USDA- Food Safety and Inspection Service. http://www.fsis.usda.gov/Dippold PDF/FSRE_SS_7Principles.

Vogt, R. L., and, L. (2005). Escherichia coli O157:H7 outbreak associated with consumption of ground beef, June-July 2002. *Pub. Health Reports, 120:174-178.*

Waite, D. W., and Taylor, M. W. (2014). Characterizing the avian Gut microbiota: membership, driving influences, and potential function. *Food Microbiol., 5:223-229.*

Wambui, J., Karuri, E., Lamuka, P., and Matofan, J. (2017). Good hygiene practices among meat handlers in small and medium enterprise slaughterhouses in Kenya. *Food Control, 81:34-39.*

Wassie. B., Sisay, W., Gashaw, B., Fentahun, M., Lamesgin, B. and Muluken, T. (2017) Assessment of Microbiological Quality and Meat Handling Practices in Butcher Shops and Abattoir Found in Gondar Town, Ethiopia. *Int. J. Microbiol. Res.,8:59–68.*

WHO, (2015) B. WHO Food borne Diseases Burden Epidemiology Reference Group (FERG) 2007- 2015. http://www.who.int/foodsafety/areas_work/foodborne-disease/ferg/en/

WHO, (2015) C. WHO Report on the estimates of the global burden of foodborne diseases. http://www.who.int/mediacentre/news/releases/foodborne-disease-estimates/en/

Wijnker, J.J., Koop, G. and Lipman, L. J. A. (2006) Antimicrobial properties of salt (NaCl) used for the preservation of natural casings. *Food Microbiol., 23: 657-662.*

Wilson, D. J., Gabriel, E., Leatherbarrow, A. J. H., Cheesbrough, J., Gee, S., Bolton, E., and Fox, A. (2008). Tracing the source of campylobacteriosis. *PLoS Genetics*. *4:100-106.*

Wolk, A. (2016). Potential health hazards of eating red meat. *J. of Inter. Med., 12:79-85.*

World Health Organisation – WHO (2015) A. Food safety Fact Sheet N°399 December 2015. http://www.who.int/mediacentre/factsheets/fs399

World Health Organization (WHO) (2001) Foodborne diseases: A focus for health education, Geneva, Switzerland, World Health Organization.

Yamane,T. (1967). Statistics: An Introductory Analysis. 2nd Edition, Harper and Row, New York.

Zacchaeus, U. and Amadi, A. N. (2012). Environmental Health and Sanitation Terminologies. Aba, Nigeria: Eagle Publishers. Pp 1-64

Zanin, L. M., Da Cunha, D. T., De Rosso, V. V., Capriles, V. D., and Stedefeldt, E. (2017). Knowledge, attitudes and practices of food handlers in food safety: An integrative review. *Food Res. Inter., 100:53– 62.*

Zhou, G. H., Xu, X. L. and Liu, Y. (2010) Preservation technologies for fresh meat: A review. *Meat Sci.,* 86:119-128.

Zhu, H. (2013). Red and processed meat intake is associated with higher gastric cancer risk: a meta-analysis of epidemiological observational studies. *PLOS ONE, 8:278-285.*

APPENDIX 1: Questionnaire

Informed Consent

Questionnaire for the Research on the Assessment of the Bacteriological Qualities of Meat and Contact Surfaces in Markets in Abia State, Nigeria

Dear Respondent,

I am a Doctor of Philosophy Degree (Ph.D) Research Student of the Department of Public Health, School of Health Technology, Federal University of Technology, Owerri.

I am conducting a research on the topic: ***Assessment of the Bacteriological Qualities of Meat and Contact Surfaces in Markets in Abia State, Nigeria***.

It is believed that Poor meat handling practices including non-adherence to internationally recommended standards such as the Codex Alimentarius Commission CAC - Good Hygiene Practices (GHPs) and Hazard Analysis Critical Control Point (HACCP) -based Standard Operating Procedures (SOPs) as seen in : lack of basic knowledge of hygiene practices to be observed by meat handlers; poor sanitation at the abattoirs and butchers' shops; non maintenance of cool chain, poor storage infrastructures, lack of safety awareness, poor waste disposal etc could be responsible for meat contamination by microorganisms and high bacterial loads in meat samples. Contaminated meat have been implicated in food poisoning and food borne illnesses with symptoms including nausea, vomiting, diarrhea, abdominal cramps/pains, headaches, fever and dehydration etc.

Contaminated food is important cause of illness, disability and death globally; and food borne diseases impede socioeconomic development by straining health care systems, harming national economies, tourism and trade.

Food borne illness poses a significant public health challenges as it is a serious threat to the health and well being of millions globally, contributing to decrease in workers' productivity; loss in school days; reduce family income as huge sum of money are spend on medical bills and legal fees; causing pains, suffering and early death.

The information generated from this study will be use to determine the meat management practices in your locality with the view to ascertaining the level of compliance of meat handlers to international standards and the bacteriological quality of meat. This will help in recommending and articulating appropriate public health interventions.

This research is not a tool for assessing taxation.

All information provided will be kept confidential and used only for academic purposes.

Kindly provide honest and accurate answers to the questions below.

Thanks for your co-operation.

Yours Faithfully

Iwuagwu, Uchechukwu O. (Reg. No. 20144920088)
Department of Public Health
School of Health Technology, FUTO

Please tick in the box provided which category of options best fits you.

SECTION 1: GENERAL INFORMATION

A. DEMOGRAPHIC CHARACTERISTICS

Location: LGA ☐ ZONE ☐

1. Sex: Male ☐ Female ☐
2. Age ……years/ (18-20; 21-30; 31-40; 41-50; 51-60; 60 above)
3. Marital Status: Single/Never Married ☐

   Widowed ☐ Married ☐

   Separated ☐ Divorced ☐
4. For how many years have you been selling meat? /Years of Experience as meat seller?

   1 – 5 /below 5 years ☐ 6 – 10 ☐

   11 – 15 ☐ 16 – 20 ☐

   Above 20 ☐
5. Religion of Respondents: Christianity ☐ Islam ☐ Traditional worship ☐ None ☐
6. What is your highest level of education?

   None/No formal education ☐ Primary School ☐

   Secondary School ☐ Tertiary Institution ☐

   Post graduate ☐

SECTION 2: HACCP CHECKLIST

S/No	Criteria for Control	YES	NO
1	**Personal Hygiene practices**		
1.1	Meat handler wear proper clothing – clean uniforms/aprons and hair restraints.		
1.2	Jewellery is limited to wristwatch and plain ring.		
1.3	Wearing of hand gloves where appropriate and changed at necessary intervals.		
1.4	Wash-handing basins with soap, running water are available		
1.5	Hands are washed routinely with soap and clean water		
1.6	Meat handlers are free from skin infections/open sores, cuts, or wounds		
2	**Sanitation practices**		
2.1	Worktables and work surfaces are clean to sight and touch and washed and sanitized between operations.		
2.2	Small equipment and utensils including cutting boards, knives, etc. are thoroughly cleaned between uses and sanitized.		
2.3	Cleaning chemicals and equipment are stored properly away in the store.		
2.4	Mops are washed after use and stored head up.		
2.5	Buckets are cleaned after use and inverted to drain.		
	Total Score		

SECTION 3: FIELD REPORT:

1. **Location code:**
2. **Meat Type:** Red ☐ White ☐
3. **Date :**

SECTION 2: HACCP CHECKLIST

S/No	Criteria for Control	Max	Min	NA
1	**Transportation**			
1.1	Proper temperatures are maintained during transport at 4 ºC or below	2		
1.2	Meat is not kept at temperature above 4 ºC for more than 2 hours.	2		
1.3	Transport vehicles, carts, and containers for meat are covered, cleaned regularly and sanitized	2		
1.4	Incoming meat are inspected on receipt	1		
1.5	Receiving area is clean and free of waste materials	1		
1.6	Refrigerated and frozen meats arrive at the appropriate temperatures.	2		
1.7	General condition of meat is satisfactory (odorless, non-stinky, no dents etc.)	1		
1.8	Proper handling procedures of meat upon receiving.	1		
1.9	Supplier/Contractor informed of observations made on meat received.	1		
2.0	Unwholesome meat is rejected.	1		
2	**Storage**			
2.1	Adequate, clean and functional cold storage facilities.	2		
2.2	Temperature checked twice daily.	1		
2.3	Thermometer is a conspicuous, functional and accurate temperature-recording sheet available	1		
2.4	Normal temperatures are maintained at 4 ºC or lower in refrigerators and –18ºC or lower in freezers.	2		
2.5	Meat types are stored separately and are not expired	1		
3	**Personal Hygiene**			
3.1	Meat handler wear proper clothing – clean uniforms/aprons and hair restraints.	1		
3.2	Uniform/apron is not worn outside meat preparation area.	1		
3.3	Fingers are short, unpolished, and clean.	1		
3.4	Jewellery is limited to wristwatch and plain ring.	1		
3.5	Wearing of hand gloves where appropriate and changed at necessary intervals.	1		
3.6	Adequate wash-hand basins with soap, running water, and drying facilities available	2		
3.7	Hands are washed routinely and thoroughly with soap and clean water	2		

3.8	Meat handlers move away from meat and cover nose with disposal tissue when coughing or sneezing.	1		
3.9	Eating, drinking, or chewing gum is carried out only in designated places away from work areas.	1		
3.10	Meat handlers are free from skin/enteric illnesses.	1		
3.11	Meat handlers with infections (open sores, cuts, or bandages on hands inclusive) are restricted.	1		
4	**Cleaning and Sanitation**			
4.1	Cleaning procedures are in place for structures, equipment & utensils, premises and waste bins.	1		
4.2	Floors, walls, ceilings are intact and well maintained.	1		
4.3	Worktables and work surfaces are clean to sight and touch and washed and sanitized between operations.	1		
4.4	Small equipment and utensils including cutting boards, knives, etc. are thoroughly cleaned between uses and sanitized.	1		
4.5	Equipment and utensils are adequate and in good working condition.	0.5		
4.6	Refrigerators, freezers, are thawed and cleaned with other storage areas at least once weekly.	0.5		
4.7	Thermometers are washed and sanitized between each use.	0.5		
4.8	Doorknobs, drawers, racks, switches are cleaned daily.	0.5		
4.9	Cleaning chemicals and equipment are stored properly away in their own store.	0.5		
4.10	Mops are washed after use and stored head up.	0.5		
4.11	Buckets are cleaned after use and inverted to drain.	0.5		
5	**Pest Control**			
5.1	Screens on windows and doors and in good condition	1		
5.2	No evidence of pest infestation.	1		
6	**Waste Disposal**			
6.1	Waste bins provided adequately and properly labelled.	1		
6.2	Waste bins are emptied regularly and cleaned and sanitized daily and inverted to drain overnight.	1		
6.3	Proper storage is available for brooms, mops, and other cleaning equipment outside the meat storage area	1		

7	**Potable Water Supply**			
7.1	Water supply available in sufficient quantity	2		
8	**Staff Competency and Training**			
8.1	Evidence of staff training in meat handling procedures.	1		
8.2	Available records of training attendance completed by meat handler.	0.5		
	Total Score	**50**		

APPENDIX 2

Table 4.31: Raw table of Bacteria load counts (CFU/g) of red meat (beef) samples from markets in Umuahia zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
UMHIA 01	-	-	3.8×10^5	-	1.3×10^5	-
UMHIA 2	1.4×10^3	1.2×10^3	1.2×10^5	-	2.9×10^5	-
UMHIA 3	5.8×10^3	2.9×10^3	1.0×10^5	-	1.1×10^3	2.3×10^3
UMHIA 4	-	-	2.2×10^5	-	3.1×10^5	2.3×10^3
UMHIA 5	-	-	1.9×10^5	2.4×10^3	1.5×10^3	1.6×10^3
UMHIA 6	-	7.2×10^3	2.16×10^6	4.1×10^3	3.1×10^5	-
UMHIA 7	-	3.6×10^3	2.04×10^6	5.4×10^3	3.0×10^5	-
UMHIA 8	3.8×10^3	6.5×10^3	1.02×10^6	3.1×10^3	2.6×10^5	-
UMHIA 9	2.1×10^3	3.0×10^3	1.22×10^6	1.1×10^3	2.4×10^5	3.2×10^3
UMHIA 10	1.2×10^3	4.1×10^5	2.7×10^5	2.1×10^3	3.9×10^5	-
ORIE 01	6.5×10^3	2.1×10^3	4.6×10^5	2.9×10^3	1.1×10^5	1.1×10^3
ORIE 02	-	-	1.1×10^5	2.8×10^3	4.2×10^5	1.1×10^3
ORIE 03	2.1×10^3	9.7×10^3	1.1×10^5	4.1×10^3	2.6×10^5	1.9×10^3
ORIE 04	1.2×10^3	2.4×10^3	2.7×10^5	2.1×10^3	3.1×10^5	7.2×10^3
ORIE 05	1.5×10^3	1.7×10^3	1.8×10^5	2.1×10^3	3.4×10^5	1.1×10^3
ORIE 06	1.3×10^3	9.7×10^3	1.2×10^5	6.1×10^3	4.0×10^5	1.9×10^3
ORIE 07	-	-	6.1×10^7	7.2×10^3	2.1×10^5	1.6×10^3
ORIE 08	-	-	1.3×10^5	3.1×10^3	4.9×10^5	1.1×10^3
ORIE 09	6.3×10^5	-	3.6×10^5	3.8×10^3	4.6×10^5	6.4×10^3
ORIE 10	6.4×10^3	1.5×10^3	1.91×10^6	7.3×10^3	2.8×10^5	-
ORIE 11	2.1×10^3	-	1.04×10^6	3.6×10^3	1.6×10^5	-
ORIE 12	1.9×10^3	-	1.06×10^6	1.7×10^3	1.2×10^5	-
OGW 01	-	-	3.0×10^5	1.0×10^3	1.00×10^6	-
OGW 01	-	-	1.2×10^5	1.0×10^3	1.21×10^6	-
OGW 03	-	7.0×10^3	1.03×10^6	1.0×10^3	1.11×10^6	2.9×10^3
OGW 04	-	-	1.71×10^6	2.1×10^3	2.9×10^3	7.0×10^3
OGW 05	-	-	6.1×10^5	1.1×10^3	1.8×10^5	1.5×10^3
OGW 06	-	-	1.36×10^6	-	-	1.3×10^3
OGW 07	1.0×10^3	-	2.10×10^6	1.9×10^3	-	2.1×10^3
OGW 08	1.0×10^3	-	1.20×10^6	-	-	1.8×10^3
OGW 09	-	-	3.3×10^5	-	1.0×10^5	2.9×10^3
OGW 10	1.2×10^3	-	1.0×10^5	-	$2\ 7 \times 10^5$	6.0×10^3
OGW 11	3.8×10^6	-	4.9×10^5	1.9×10^3	-	2.5×10^3
UBA 01	1.7×10^3	-	3.9×10^5	2.0×10^3	2.1×10^5	4.1×10^3
UBA 02	1.0×10^3	1.0×10^3	3.6×10^5	-	1.7×10^5	1.0×10^3
UBA 03	2.0×10^3	1.5×10^3	3.2×10^5	2.0×10^3	1.0×10^5	2.0×10^3
UBA 04	2.1×10^3	-	2.0×10^5	1.2×10^3	1.1×10^5	6.0×10^3
UBA 05	1.1×10^3	1.1×10^3	1.37×10^6	-	-	1.6×10^3
UBA 06	3.1×10^3	1.5×10^3	8.6×10^5	-	-	1.4×10^3
UBA 07	1.0×10^3	-	2.5×10^5	-	-	-
UBA 08	3.5×10^3	-	3.6×10^5	-	1.4×10^5	-
UBA 09	1.0×10^3	1.6×10^3	1.8×10^5	1.0×10^3	2.1×10^5	-
AHIA 01	4.9×10^3	6.0×10^3	3.4×10^5	-	3.1×10^5	-
AHIA 02	-	4.0×10^3	1.1×10^5	1.0×10^3	2.1×10^5	1.7×10^3
AHIA 03	-	6.0×10^3	1.0×10^5	2.5×10^3	-	5.7×10^3
AHIA 04	-	-	4.0×10^5	1.0×10^3	-	1.2×10^3
AHIA 05	1.9×10^3	7.0×10^3	1.1×10^5	1.0 x 105	-	1.0×10^3
AHIA 06	1.1×10^3	4.0×10^3	1.08×10^6	1.9×10^3	1.3×10^5	6.0×10^3
AHIA 07	2.3×10^3	1.3×10^3	2.17×10^6	1.3×10^3	-	7.1×10^3
AHIA 08	1.6×10^3	3.6×10^3	6.6×10^5	-	-	2.2×10^3
AHIA 09	3.0×10^3	4.0×10^3	1.01×10^6	-	1.1×10^5	-
AHIA 10	4.4×10^3	1.6×10^3	2.11×10^6	2.0×10^3	4.4×10^5	-
MMM 01	4.9×10^3	6.0×10^3	3.4×10^5	-	3.1×10^5	-
MMM 02	-	4.0×10^3	1.1×10^5	1.0×10^3	2.1×10^5	1.7×10^3

MMM 03	-	6.0×10^3	1.0×10^5	2.5×10^3	-	5.7×10^3
MMM 04	-	-	4.0×10^5	1.0×10^3	-	1.2×10^3
MMM 05	1.9×10^3	7.0×10^3	1.1×10^5	1.0 x 105	-	1.0×10^3
MMM 06	1.1×10^3	4.0×10^3	1.08×10^6	1.9×10^3	1.3×10^5	6.0×10^3
MMM 07	2.3×10^3	1.3×10^3	2.17×10^6	1.3×10^3	-	7.1×10^3
MMM 08	1.6×10^3	3.6×10^3	6.6×10^5	-	-	2.2×10^3
MMM 09	3.0×10^3	4.0×10^3	1.01×10^6	-	1.1×10^5	-
MMM 10	4.4×10^3	1.6×10^3	2.11×10^6	2.0×10^3	4.4×10^5	-

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.32: Raw table of Bacteria load counts (CFU/g) of red meat (beef) samples from markets in Aba zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
A 01	1.6×10^3	1.0×10^3	1.0×10^5	1.0×10^3	1.11×10^6	-
A 02	3.1×10^3	1.3×10^3	1.19×10^6	1.3×10^3	2.14×10^6	1.0×10^3
A 03	4.4×10^3	1.6×10^3	1.15×10^6	1.6×10^3	2.0×10^5	1.0×10^3
A 04	1.0×10^3	2.5×10^3	4.5×10^5	2.5×10^3	1.17×10^6	1.2×10^3
A 05	1.3×10^3	2.0×10^3	4.1×10^5	1.0×10^3	7.0×10^5	1.0×10^3
A 06	1.6×10^3	4.0×10^3	1.09×10^6	1.3×10^3	1.0×10^3	6.3×10^3
A 07	2.5×10^3	1.1×10^3	2.17×10^6	1.6×10^3	1.3×10^3	2.5×10^3
A 08	1.0×10^3	3.6×10^3	6.6×10^5	1.0×10^3	1.6×10^3	1.4×10^3
A 09	1.3×10^3	2.0×10^3	1.6×10^5	1.0×10^3	1.2×10^3	1.0×10^3
A 10	2.0×10^3	1.0×10^3	2.7×10^5	1.3×10^3	1.0×10^3	1.7×10^3
B 01	1.3×10^3	5.1×10^3	3.6×10^5	3.3×10^3	2.5×10^3	1.0×10^3
B 02	2.4×10^3	1.0×10^3	4.1×10^5	3.7×10^3	1.0×10^3	1.3×10^3
B 03	3.3×10^3	1.3×10^3	2.1×10^5	1.8×10^3	6.0×10^5	1.6×10^3
B 04	1.0×10^3	1.6×10^3	2.0×10^5	1.0×10^3	1.00×10^6	2.5×10^3
B 05	1.3×10^3	2.5×10^3	$3.8 \text{ X } 10^5$	1.3×10^3	2.50×10^6	6.2×10^3
B 06	1.6×10^3	1.0×10^3	1.27×10^6	1.6×10^3	3.0×10^5	3.3×10^3
B 07	2.5×10^3	5.3×10^3	2.36×10^6	2.5×10^3	1.0×10^5	1.3×10^3
B 08	1.0×10^3	2.0×10^3	$2.01 \text{ x}10^6$	1.0×10^3	3.0×10^5	3.0×10^3
B 09	2.2×10^3	1.8×10^3	3.9×10^5	1.3×10^3	2.7×10^5	-
B 10	1.8×10^3	2.8×10^3	1.0×10^5	1.6×10^3	1.4×10^5	2.4×10^3
C 01	-	1.4×10^3	7.1×10^5	2.5×10^3	1.8×10^5	1.7×10^3
C 02	1.9×10^3	1.0×10^3	1.5×10^5	1.0×10^3	1.3×10^5	1.7×10^3
C 03	1.0×10^3	1.3×10^3	5.1×10^5	1.3×10^3	4.1×10^5	5.8×10^3
C 04	1.3×10^3	1.6×10^3	3.8×10^5	1.6×10^3	6.8×10^5	2.3×10^3
C 05	1.6×10^3	2.5×10^3	$2.8\text{x } 10^5$	2.5×10^3	1.1×10^5	3.1×10^3
C 06	2.5×10^3	1.0×10^3	1.0×10^5	1.3×10^3	1.6×10^5	2.5×10^3
C 07	1.0×10^3	1.3×10^3	4.8×10^5	-	2.08×10^6	2.1×10^3
C 08	1.3×10^3	1.6×10^3	2.6×10^5	2.1×10^3	-	3.1×10^3
C 09	1.6×10^3	2.5×10^3	1.6×10^5	2.2×10^3	1.7×10^5	1.5×10^3
C 10	2.5×10^3	1.0×10^3	3.8×10^5	7.6×10^3	4.2×10^5	6.1×10^3
D 01	1.0×10^3	1.3×10^3	3.0×10^5	1.0×10^3	1.8×10^5	3.1×10^3
D 02	1.3×10^3	1.6×10^3	2.9×10^5	2.0×10^3	1.0×10^3	3.0×10^3
D 03	1.6×10^3	2.5×10^3	6.9×10^5	1.1×10^3	1.3×10^3	-
D 04	2.5×10^3	1.0×10^3	1.9×10^5	4.6×10^3	1.6×10^3	-
D 05	1.0×10^3	-	1.4×10^5	1.2×10^3	2.5×10^3	1.7×10^3
D 06	1.3×10^3	2.0×10^3	2.5×10^5	-	1.0×10^3	4.7×10^3
D 07	1.6×10^3	3.4×10^3	1.7×10^5	-	1.3×10^3	4.0×10^3
D 08	2.1×10^3	-	1.0×10^5	1.2×10^3	1.0×10^3	1.0×10^3
D 09	1.5×10^3	2.3×10^3	1.5×10^5	2.2×10^3	1.8×10^3	2.7×10^3
D 10	1.0×10^3	1.4×10^3	1.2×10^5	1.0×10^3	1.0×10^3	2.0×10^3
E 01	2.5×10^3	5.0×10^3	2.7×10^5	-	1.6×10^3	3.1×10^3
E 02	1.1×10^3	1.6×10^3	1.6×10^5	1.5×10^3	2.5×10^3	3.3×10^3
E 03	1.2×10^3	4.4×10^3	2.1×10^5	7.7×10^3	1.0×10^3	8.1×10^3
E 04	2.4×10^3	$1.7 \text{ x}10^3$	2.8×10^5	1.4×10^3	-	1.6×10^3
E 05	1.2×10^3	3.0×10^3	6.2×10^5	3.2×10^3	6.0×10^5	2.0×10^3
E 06	1.0×10^3	1.0×10^3	1.0×10^3	1.0×10^3	1.0×10^3	1.0×10^3

E 07	1.3×10^3	1.3×10^3	1.3×10^3	1.3×10^3	1.3×10^3	1.3×10^3
E 08	1.6×10^3	1.6×10^3	1.6×10^3	1.6×10^3	1.6×10^3	1.6×10^3
E 09	1.0×10^3	1.2×10^3	2.0×10^5	-	1.1×10^3	2.7×10^3
E10	1.2×10^3	1.1×10^3	1.0×10^5	-	1.0×10^3	2.0×10^3
F01	1.7×10^3	2.0×10^3	1.7×10^5	-	1.6×10^3	2.1×10^3
F02	1.0×10^3	1.3×10^3	1.3×10^5	2.5×10^3	2.5×10^3	1.2×10^3
F 03	2.1×10^3	1.6×10^3	1.1×10^5	3.2×10^3	1.0×10^3	1.1×10^3
F 04	1.0×10^3	1.0×10^3	1.8×10^5	-	-	1.4×10^3
F 05	1.5×10^3	2.0×10^3	2.2×10^5	1.2×10^3	1.4×10^5	1.0×10^3
F 06	1.2×10^3	1.8×10^3	2.1×10^3	1.4×10^3	1.2×10^3	1.0×10^3
F 07	1.0×10^3	2.1×10^3	2.0×10^3	1.0×10^3	1.0×10^3	1.8×10^3
F 08	2.0×10^3	1.1×10^3	1.0×10^3	-	-	1.2×10^3
F 09	-	1.0×10^3	2.1×10^5	1.5×10^3	1.0×10^5	1.0×10^3
F 10	1.3×10^3	1.8×10^3	1.0×10^5	1.6×10^3	1.0×10^5	1.1×10^3
G 01	1.0×10^3	2.0×10^3	1.1×10^5	1.0×10^3	1.1×10^5	1.8×10^3
G 02	1.0×10^3	1.2×10^3	3.0×10^5	1.0×10^3	1.8×10^5	2.0×10^3
G 03	2.1×10^3	2.0×10^3	$1.2x\ 10^5$	1.5×10^3	1.0×10^5	1.1×10^3
G 04	1.5×10^3	1.0×10^3	1.2×10^5	1.0×10^3	1.0×10^5	1.2×10^3
G 05	1.0×10^3	1.0×10^3	2.4×10^5	-	2.1×10^6	1.1×10^3
G 06	2.0×10^3	1.0×10^3	1.6×10^5	1.1×10^3	-	1.1×10^3
G 07	1.0×10^3	1.5×10^3	1.0×10^5	2.0×10^3	1.3×10^5	1.0×10^3
G 08	-	1.0×10^3	1.1×10^5	1.1×10^3	1.2×10^5	1.0×10^3
G 09	1.1×10^3	1.1×10^3	1.0×10^5	2.0×10^3	1.0×10^5	1.1×10^3
G 10	2.0×10^3	1.3×10^3	2.1×10^5	1.0×10^3	1.1×10^5	2.2×10^3
AB 01	1.8×10^3	1.0×10^3	2.0×10^5	1.0×10^3	2.1×10^5	2.0×10^3
AB 02	1.2×10^3	1.2×10^3	1.0×10^5	1.0×10^3	1.2×10^6	-
AB 03	2.1×10^3	1.5×10^3	1.1×10^6	1.0×10^3	2.4×10^6	-
AB 04	1.4×10^3	1.4×10^3	1.5×10^6	1.0×10^3	2.0×10^5	1.0×10^3
AB 05	1.8×10^3	2.0×10^3	2.5×10^5	2.0×10^3	1.7×10^6	1.2×10^3
AB 06	1.6×10^3	1.0×10^3	1.1×10^5	1.0×10^3	2.1×10^5	-
AB 07	2.6×10^3	2.0×10^3	1.9×10^6	1.1×10^3	2.0×10^3	2.3×10^3
AB 08	2.2×10^3	2.1×10^3	2.2×10^6	1.0×10^3	2.3×10^3	2.0×10^3
AB 09	1.6×10^3	1.6×10^3	2.3×10^5	1.0×10^3	1.6×10^3	1.0×10^3
AB 10	2.3×10^3	1.0×10^3	$1.60x\ 10^5$	1.0×10^3	2.2×10^3	1.0×10^3
AC 01	2.0×10^3	-	1.0×10^5	2.0×10^3	1.0×10^5	1.1×10^3
AC 02	2.3×10^3	1.1×10^3	1.9×10^5	2.2×10^3	1.0×10^3	3.0×10^3
AC 03	1.0×10^3	1.5×10^3	2.6×10^5	1.1×10^3	1.3×10^3	-
AC 04	1.5×10^3	1.0×10^3	1.0×10^5	2.6×10^3	1.6×10^3	-
AC 05	1.0×10^3	1.3×10^3	1.1×10^5	1.2×10^3	2.0×10^3	1.7×10^3
AC 06	1.8×10^3	1.0×10^3	1.5×10^5	-	1.0×10^3	4.7×10^3
AC 07	1.0×10^3	3.4×10^3	0.7×10^5	1.2×10^3	1.3×10^3	4.0×10^3
AC 08	1.1×10^3	2.3×10^3	1.0×10^5	-	1.0×10^3	1.0×10^3
AC 09	2.5×10^3	-	2.5×10^5	2.0×10^3	1.8×10^3	2.4×10^3
AC 10	1.1×10^3	1.0×10^3	2.2×10^5	1.0×10^3	1.0×10^3	2.0×10^3
DD 01	2.0×10^3	2.0×10^3	2.0×10^5	-	1.6×10^3	3.1×10^3
DD 02	1.0×10^3	1.6×10^3	1.9×10^5	2.0×10^3	1.0×10^3	-
DD 03	1.0×10^3	1.8×10^3	2.9×10^5	1.1×10^3	1.3×10^3	3.0×10^3
DD 04	2.1×10^3	-	1.0×10^5	3.2×10^3	1.5×10^3	-
DD 05	1.0×10^3	1.0×10^3	1.0×10^5	1.2×10^3	2.5×10^3	1.3×10^3
DD 06	1.2×10^3	2.1×10^3	1.1×10^5	1.0×10^3	1.1×10^5	1.8×10^3
DD 07	1.9×10^3	1.1×10^3	1.0×10^5	1.0×10^3	1.8×10^5	2.0×10^3
DD 08	2.8×10^3	1.0×10^3	$1.2x\ 10^5$	1.5×10^3	1.0×10^5	1.1×10^3
DD 09	1.3×10^3	1.3×10^3	1.2×10^5	1.0×10^3	1.0×10^5	1.2×10^3
DD 10	1.0×10^3	1.4×10^3	2.0×10^5	-	2.1×10^6	1.1×10^3
OG 01	2.3×10^3	1.8×10^3	1.3×10^5	1.1×10^3	1.8×10^5	1.1×10^3

OG 02	1.1×10^3	1.0×10^3	1.0×10^5	2.5×10^3	1.3×10^5	1.0×10^3
OG 03	1.6×10^3	2.0×10^3	1.1×10^5	1.1×10^3	1.2×10^5	1.0×10^3
OG 04	2.1×10^3	2.1×10^3	1.0×10^5	2.0×10^3	1.0×10^5	1.1×10^3
OG 05	1.0×10^3	1.3×10^3	2.1×10^5	1.0×10^3	1.4×10^5	2.2×10^3
OG 06	2.3×10^3	2.5×10^3	1.1×10^5	3.0×10^3	1.7×10^5	1.8×10^3
OG 07	2.0×10^3	2.2×10^3	1.0×10^5	1.0×10^3	-	2.0×10^3
OG 08	1.1×10^3	2.2×10^3	$1.2x\ 10^5$	1.5×10^3	1.2×10^5	1.1×10^3
OG 09	1.0×10^3	1.0×10^3	1.2×10^5	1.0×10^3	1.0×10^5	1.2×10^3
OG 10	1.5×10^3	1.4×10^3	2.0×10^5	1.5×10^3	1.1×10^6	1.1×10^3
AY 01	2.2×10^3	1.0×10^3	1.1×10^5	1.1×10^3	-	1.1×10^3
AY 02	1.6×10^3	1.2×10^3	1.0×10^5	2.2×10^3	1.0×10^5	1.0×10^3
AY 03	1.1×10^3	1.0×10^3	$1.2x\ 10^5$	1.5×10^3	1.0×10^5	1.1×10^3
AY 04	1.0×10^3	2.1×10^3	1.2×10^5	1.0×10^3	1.0×10^5	1.2×10^3
AY 05	2.0×10^3	1.3×10^3	2.4×10^5	1.4×10^3	2.1×10^6	1.1×10^3
AY 06	2.2×10^3	1.7×10^3	1.6×10^5	1.1×10^3	1.1×10^3	1.1×10^3
AY 07	1.4×10^3	1.3×10^3	1.0×10^5	2.0×10^3	1.3×10^5	1.0×10^3
AY 08	1.1×10^3	1.0×10^3	1.1×10^5	1.1×10^3	1.2×10^5	1.0×10^3
AY 09	1.0×10^3	2.1×10^3	1.0×10^5	2.0×10^3	1.0×10^5	1.1×10^3
AY 10	2.3×10^3	2.3×10^3	1.1×10^5	1.0×10^3	1.1×10^5	1.2×10^3

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.33: Raw table of Bacteria load counts (CFU/g) of red meat (beef) samples from markets in Ohafia zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
IHIA 01	3.8×10^5	-	3.8×10^5	-	1.3×10^5	-
IHIA 2	1.2×10^5	2.3×10^3	1.2×10^5	-	2.9×10^5	-
IHIA 3	1.0×10^5	2.3×10^3	1.0×10^5	-	1.1×10^3	2.3×10^3
IHIA 4	2.2×10^5	1.6×10^3	2.2×10^5	-	3.1×10^5	2.3×10^3
IHIA 5	1.9×10^5	-	1.9×10^5	2.4×10^3	1.5×10^3	1.6×10^3
IHIA 6	2.16×10^6	-	2.16×10^6	4.1×10^3	3.1×10^5	-
IHIA 7	2.04×10^6	-	2.04×10^6	5.4×10^3	3.0×10^5	-
IHIA 8	1.02×10^6	3.2×10^3	1.02×10^6	3.1×10^3	2.6×10^5	-
IHIA 9	1.22×10^6	-	1.22×10^6	1.1×10^3	2.4×10^5	3.2×10^3
IHIA 10	2.7×10^5	1.1×10^3	2.7×10^5	2.1×10^3	3.9×10^5	-
NKO 01	4.6×10^5	1.1×10^3	4.6×10^5	2.9×10^3	1.1×10^5	1.1×10^3
NKO 02	1.1×10^5	-	1.1×10^5	2.8×10^3	1.1×10^5	1.1×10^3
NKO 03	1.1×10^5	9.7×10^3	1.1×10^5	4.1×10^3	2.7×10^5	1.9×10^3
NKO 04	2.7×10^5	2.4×10^3	2.7×10^5	2.1×10^3	1.8×10^5	7.2×10^3
NKO 05	3.8×10^5	1.7×10^3	1.8×10^5	2.1×10^3	1.2×10^5	1.1×10^3
NKO 06	1.2×10^5	9.7×10^3	1.2×10^5	6.1×10^3	6.1×10^7	1.9×10^3
NKO 07	1.0×10^5	-	6.1×10^7	7.2×10^3	1.3×10^5	1.6×10^3
NKO 08	2.2×10^5	-	1.3×10^5	3.1×10^3	3.6×10^5	1.1×10^3
NKO 09	6.3×10^5	-	3.6×10^5	3.8×10^3	1.91×10^6	6.4×10^3
NKO 10	6.4×10^3	1.5×10^3	1.91×10^6	7.3×10^3	1.04×10^6	-
NKO 11	3.8×10^5	1.9×10^3	1.04×10^6	3.6×10^3	1.06×10^6	-
NKO 12	1.2×10^5	1.6×10^3	1.06×10^6	1.7×10^3	3.0×10^5	-
BIRI 01	1.0×10^5	1.1×10^3	3.0×10^5	1.0×10^3	1.2×10^5	-
BIRI 02	2.2×10^5	6.4×10^3	1.2×10^5	1.0×10^3	3.6×10^5	-
BIRI 03	1.9×10^5	-	1.03×10^6	1.0×10^3	1.91×10^6	2.9×10^3
BIRI 04	2.16×10^6	-	1.71×10^6	2.1×10^3	1.04×10^6	7.0×10^3
BIRI 05	2.04×10^6	-	6.1×10^5	1.1×10^3	1.06×10^6	1.5×10^3
BIRI 06	1.02×10^6	-	1.36×10^6	-	3.0×10^5	1.3×10^3
BIRI 07	1.0×10^3	1.9×10^3	2.10×10^6	1.9×10^3	1.2×10^5	2.1×10^3
BIRI 08	1.0×10^3	-	1.20×10^6	-	1.03×10^6	1.8×10^3
BIRI 09	-	-	3.3×10^5	-	1.0×10^5	2.9×10^3
BIRI 10	1.2×10^3	-	1.0×10^5	-	$2\ 7 \times 10^5$	6.0×10^3
BIRI 11	3.8×10^6	-	4.9×10^5	1.9×10^3	-	2.5×10^3
EBE 01	1.7×10^3	-	3.9×10^5	2.0×10^3	2.1×10^5	4.1×10^3
EBE 02	1.0×10^3	1.0×10^3	3.6×10^5	-	1.7×10^5	1.0×10^3
EBE 03	2.0×10^3	1.5×10^3	3.2×10^5	2.0×10^3	1.0×10^5	2.0×10^3
EBE 04	2.1×10^3	-	2.0×10^5	1.2×10^3	1.1×10^5	6.0×10^3
EBE 05	1.1×10^3	1.1×10^3	1.37×10^6	-	-	1.6×10^3
EBE 06	3.1×10^3	1.5×10^3	8.6×10^5	-	-	1.4×10^3
EBE 07	1.0×10^3	-	2.5×10^5	-	-	-
EBE 08	3.5×10^3	-	3.6×10^5	-	1.4×10^5	-
EBE 09	1.0×10^3	1.6×10^3	1.8×10^5	1.0×10^3	2.1×10^5	-

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.34: Raw table of Total Bacteria load counts (CFU/g) of white meat (chicken) samples from markets in Umuahia zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
A 01	1.1×10^3	1.7×10^3	1.12×10^6	-	2.0×10^5	1.7×10^5
A 02	1.08×10^4	1.09×10^4	1.1×10^5	-	-	2.1×10^5
A 03	1.00×10^4	1.01×10^4	1.7×10^5	3.1×10^3	4.0×10^5	3.1×10^5
A 04	1.33×10^4	1.19×10^4	2.1×10^5	3.8×10^3	1.16×10^6	2.0×10^5
A 05	1.47×10^4	1.5×10^3	1.21×10^6	1.7×10^5	-	6.0×10^5
A 06	2.9×10^3	1.2×10^3	1.4×10^5	2.1×10^5	2.6×10^5	2.0×10^5
A 07	1.0×10^3	1.7×10^5	1.6×10^5	3.1×10^5	1.1×10^5	1.1×10^5
A 08	1.7×10^5	2.1×10^5	2.0×10^5	2.0×10^5	-	1.3×10^5
A 09	2.1×10^5	3.1×10^5	3.3×10^5	6.0×10^5	-	8.0×10^8
A 10	1.1×10^3	1.3×10^5	1.2×10^5	1.1×10^5	1.1×10^5	1.1×10^5
B 01	3.1×10^5	2.0×10^5	1.0×10^5	2.0×10^5	1.1×10^5	1.7×10^5
B 02	2.0×10^5	6.0×10^5	1.0×10^5	1.1×10^5	2.8×10^5	1.1×10^5
B 03	6.0×10^5	2.0×10^5	1.7×10^5	1.3×10^5	-	1.0×10^5
B 04	2.0×10^5	1.1×10^5	2.1×10^5	8.0×10^8	-	1.7×10^5
B 05	1.1×10^5	1.3×10^5	3.1×10^5	1.7×10^5	1.17×10^6	2.1×10^5
B 06	1.3×10^5	1.0×10^3	2.0×10^5	1.1×10^5	-	3.1×10^5
B 07	8.0×10^8	-	6.0×10^5	1.0×10^5	3.3×10^5	2.0×10^5
B 08	1.2×10^5	1.3×10^5	3.1×10^5	1.3×10^5	1.7×10^6	1.1×10^5
B 09	1.1×10^5	1.0×10^3	1.0×10^5	1.1×10^5	2.0×10^5	2.1×10^5
B 10	3.0×10^8	-	2.0×10^5	1.0×10^5	3.3×10^5	1.0×10^5
C 01	2.0×10^3	1.0×10^3	2.0×10^5	1.7×10^5	1.0×10^5	6.0×10^5
C 02	1.9×10^3	1.20×10^4	1.1×10^5	2.1×10^5	3.0×10^5	2.0×10^5
C 03	2.2×10^3	1.18×10^4	1.3×10^5	3.1×10^5	1.7×10^5	1.1×10^5
C 04	1.1×10^3	-	8.0×10^8	2.0×10^5	4.4×10^5	1.3×10^5
C 05	-	1.4×10^3	1.7×10^5	6.0×10^5	1.02×10^6	8.0×10^8
C 06	1.7×10^3	2.8×10^3	1.1×10^5	2.0×10^5	1.0×10^5	1.7×10^5
C 07	-	1.7×10^5	1.0×10^5	1.1×10^5	1.9×10^5	1.1×10^5
C 08	1.2×10^3	1.2×10^4	1.1×10^5	1.1×10^5	2.0×10^5	2.0×10^5
C 09	1.8×10^3	1.1×10^4	1.2×10^5	2.0×10^5	1.0×10^5	1.1×10^5
C 10	1.7×10^3	1.1×10^4	3.0×10^8	2.2×10^5	1.8×10^5	1.3×10^5
D 01	1.01×10^4	2.1×10^5	1.01×10^6	1.3×10^5	1.8×10^6	1.0×10^5
D 02	1.19×10^4	3.1×10^5	1.10×10^6	8.0×10^8	1.0×10^5	1.7×10^5
D 03	3.0×10^3	2.0×10^5	3.1×10^5	1.7×10^5	1.9×10^5	-
D 04	2.1×10^3	6.0×10^5	3.1×10^5	1.1×10^5	3.1×10^5	-
D 05	1.7×10^5	2.0×10^5	2.8×10^5	1.0×10^5	1.00×10^6	1.9×10^3
D 06	2.1×10^5	1.1×10^5	1.0×10^5	1.7×10^5	4.6×10^5	1.0×10^3
D 07	3.1×10^5	1.3×10^5	3.8×10^5	2.1×10^5	2.8×10^5	2.1×10^3
D 08	2.0×10^5	2.3×10^5	2.0×10^5	1.1×10^5	1.1×10^6	1.3×10^3
D 09	1.1×10^5	1.4×10^5	1.0×10^5	1.3×10^5	2.6×10^5	1.0×10^3
D 10	1.1×10^5	1.0×10^5	2.0×10^5	1.1×10^5	2.8×10^5	1.1×10^3
E 01	2.0×10^5	8.0×10^8	1.7×10^5	3.1×10^5	1.06×10^6	-
E 02	6.0×10^5	2.0×10^3	1.07×10^6	2.0×10^5	1.6×10^5	-

E 03	2.0×10^5	1.0×10^3	6.2×10^5	6.0×10^5	3.0×10^5	-
E 04	1.1×10^5	1.01×10^4	1.1×10^5	1.2×10^3	3.6×10^5	3.3×10^3
E 05	1.3×10^5	1.10×10^4	2.10×10^6	2.1×10^3	1.8×10^5	1.3×10^3
E 06	1.8×10^5	1.8×10^3	1.2×10^5	3.1×10^5	1.1×10^6	-
E 07	2.2×10^5	2.0×10^3	1.1×10^6	2.0×10^5	1.6×10^5	1.2×10^3
E 08	1.0×10^5	1.0×10^3	2.2×10^5	3.0×10^5	3.0×10^5	-
E 09	3.0×10^5	2.0×10^3	1.2×10^5	1.1×10^5	1.1×10^6	-
E 10	2.4×10^5	2.0×10^3	1.1×10^6	2.0×10^5	1.6×10^5	2.2×10^3
F 01	1.1×10^5	1.0×10^3	1.2×10^5	2.0×10^5	2.0×10^5	1.2×10^3
F 02	1.1×10^4	1.0×10^4	1.3×10^5	3.1×10^3	4.0×10^5	3.1×10^5
F 03	1.4×10^4	1.1×10^4	2.1×10^5	3.2×10^3	1.16×10^6	2.0×10^5
F 04	1.5×10^4	1.5×10^3	1.2×10^6	1.7×10^5	-	1.5×10^5
F 05	3.0×10^3	1.2×10^3	1.4×10^5	2.1×10^5	2.6×10^5	2.0×10^5
F 06	1.1×10^3	1.5×10^5	1.1×10^5	3.1×10^5	1.1×10^5	1.1×10^5
F 07	1.2×10^5	2.1×10^5	2.0×10^5	2.0×10^5	-	1.3×10^5
F 08	2.0×10^5	3.1×10^5	1.3×10^5	6.0×10^5	1.1×10^5	3.0×10^8
F 09	1.1×10^3	1.3×10^5	1.2×10^5	1.1×10^5	1.1×10^5	1.1×10^5
F 10	2.1×10^5	2.0×10^5	1.0×10^5	2.0×10^5	-	1.2×10^5
G 01	2.0×10^5	2.0×10^5	1.0×10^5	1.1×10^5	2.2×10^5	1.1×10^5
G 02	3.0×10^5	2.0×10^5	1.7×10^5	1.3×10^5	1.1×10^5	1.0×10^5
G 03	1.0×10^5	1.1×10^5	2.1×10^5	8.0×10^8	-	1.3×10^5
G 04	1.0×10^5	1.3×10^5	3.1×10^5	1.7×10^5	1.1×10^6	2.1×10^5
G 05	1.0×10^4	1.0×10^4	1.7×10^5	3.1×10^3	2.0×10^5	3.1×10^5
G 06	1.2×10^4	1.1×10^4	2.1×10^5	3.8×10^3	1.1×10^6	2.0×10^5
G 07	1.3×10^4	1.3×10^3	1.2×10^6	1.7×10^5	2.6×10^5	2.0×10^5
G 08	2.0×10^3	1.2×10^3	1.4×10^5	2.1×10^5	-	2.0×10^5
G 09	1.6×10^3	2.0×10^5	1.6×10^5	3.1×10^5	1.1×10^5	1.1×10^5
G 10	1.0×10^5	2.1×10^5	2.0×10^5	2.0×10^5	-	1.3×10^5
AA 01	1.3×10^5	3.5×10^5	3.3×10^5	6.0×10^5	1.1×10^5	3.0×10^5
AA 02	1.0×10^3	2.3×10^5	1.2×10^5	1.1×10^5	1.1×10^5	1.1×10^5
AA 03	3.0×10^5	2.6×10^5	1.0×10^5	2.0×10^5	1.1×10^5	1.3×10^5
AA 04	1.0×10^5	3.0×10^5	1.0×10^5	1.1×10^5	2.3×10^5	1.1×10^5
AA 05	1.0×10^5	2.0×10^5	1.4×10^5	1.3×10^5	-	1.0×10^5
AA 06	1.0×10^3	1.1×10^5	1.2×10^5	1.1×10^5	1.1×10^5	1.1×10^5
AA 07	2.1×10^5	2.2×10^5	1.0×10^5	2.0×10^5	1.1×10^5	1.7×10^5
AA 08	2.1×10^5	1.2×10^5	1.0×10^5	1.0×10^5	1.0×10^5	1.7×10^5
AA 09	1.0×10^5	1.5×10^5	1.3×10^5	2.0×10^5	1.0×10^5	2.0×10^5
AA 10	1.0×10^3	1.3×10^5	1.2×10^5	1.1×10^5	2.0×10^5	1.1×10^5
AB 01	2.0×10^5	2.0×10^5	1.0×10^5	1.0×10^5	1.1×10^5	1.1×10^5
AB 02	1.2×10^5	2.5×10^5	2.3×10^5	2.3×10^5	1.0×10^5	1.0×10^5
AB 03	2.3×10^5	2.0×10^5	1.0×10^5	1.1×10^5	2.8×10^5	1.1×10^5
AB 04	2.0×10^5	2.0×10^5	1.7×10^5	1.3×10^5	1.3×10^5	1.0×10^5
AB 05	1.0×10^5	1.1×10^5	2.1×10^5	2.0×10^5	2.3×10^5	1.7×10^5
AB 06	1.0×10^5	1.2×10^5	1.1×10^5	1.7×10^5	1.17×10^6	2.1×10^5
AB 07	1.0×10^5	1.0×10^3	2.0×10^5	1.1×10^5	-	3.1×10^5
AB 08	3.0×10^3	1.2×10^3	2.0×10^5	1.0×10^5	3.3×10^5	2.0×10^5
AB 09	1.0×10^5	1.0×10^5	3.1×10^5	1.3×10^5	1.7×10^6	1.1×10^5
AB 10	1.1×10^5	1.0×10^3	1.0×10^5	1.1×10^5	2.0×10^5	2.1×10^5
AC 01	2.0×10^3	1.0×10^3	2.0×10^5	1.0×10^5	3.3×10^5	1.0×10^5
AC 02	2.0×10^3	1.0×10^3	2.0×10^5	1.7×10^5	1.0×10^5	3.0×10^5

AC 03	1.5×10^3	1.20×10^4	1.1×10^5	2.1×10^5	3.0×10^5	2.0×10^5
AC 04	2.0×10^3	1.1×10^4	1.3×10^5	3.1×10^5	1.7×10^5	1.1×10^5
AC 05	1.0×10^3	1.2×10^3	3.0×10^3	2.0×10^5	4.4×10^5	1.3×10^5
AC 06	1.2×10^3	1.4×10^3	1.7×10^5	2.0×10^5	1.02×10^6	2.0×10^5
AC 07	1.5×10^3	2.8×10^3	1.1×10^5	2.0×10^5	1.0×10^5	1.7×10^5
AC 08	1.0×10^3	1.2×10^3	1.0×10^5	1.0×10^5	1.0×10^5	1.2×10^5

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.35: Raw table of Total Bacteria load counts (CFU/g) of white meat (chicken) samples from markets in Aba zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
A 01	1.9×10^5	-	1.29×10^6	1.9×10^5	1.1×10^5	-
A 02	3.3×10^5	1.9×10^5	1.02×10^6	3.3×10^5	4.1×10^5	1.9×10^5
A 03	3.1×10^5	3.3×10^5	1.20×10^6	3.1×10^5	1.0×10^5	3.3×10^5
A 04	1.7×10^5	1.3×10^3	1.11×10^6	1.7×10^5	1.9×10^5	3.1×10^5
A 05	1.41×10^6	1.1×10^5	6.9×10^5	1.41×10^6	3.3×10^5	1.7×10^5
A 06	1.07×10^6	1.2×10^5	1.16×10^6	1.07×10^6	3.1×10^5	1.41×10^6
A 07	1.6×10^5	1.0×10^3	-	1.6×10^5	1.7×10^5	1.07×10^6
A 08	2.1×10^5	2.8×10^3	2.10×10^6	2.1×10^5	1.41×10^6	1.6×10^5
A 09	1.1×10^5	2.2×10^3	-	1.1×10^5	1.0×10^5	2.1×10^5
A 10	1.2×10^5	1.0×10^3	1.1×10^6	1.0×10^5	1.2×10^5	2.1×10^5
B 01	2.8×10^5	6.1×10^3	1.12×10^6	2.8×10^5	1.8×10^5	2.1×10^5
B 02	6.2×10^8	1.8×10^3	1.2×10^5	6.2×10^8	1.2×10^5	2.8×10^5
B 03	1.3×10^5	1.9×10^5	1.9×10^5	1.3×10^5	1.19×10^6	4.1×10^3
B 04	2.8×10^5	3.3×10^5	3.3×10^5	1.0×10^3	1.26×10^6	1.1×10^3
B 05	2.5×10^5	2.1×10^3	1.0×10^6	2.5×10^5	1.8×10^5	2.1×10^5
B 06	3.2×10^8	1.0×10^3	1.0×10^5	3.2×10^8	1.2×10^5	3.0×10^5
B 07	1.0×10^5	1.0×10^5	2.0×10^5	1.0×10^5	1.2×10^6	2.1×10^3
B 08	2.0×10^5	1.3×10^5	2.0×10^5	1.0×10^3	1.3×10^6	1.0×10^3
B 09	1.5×10^5	2.1×10^3	1.0×10^6	$2.1x\ 10^5$	1.5×10^5	2.0×10^5
B 10	2.2×10^8	1.8×10^3	1.0×10^5	2.2×10^8	1.2×10^5	2.2×10^5
C 01	1.1×10^5	1.9×10^5	2.0×10^5	1.0×10^5	2.0×10^6	3.1×10^3
C 02	1.9×10^5	3.1×10^5	3.1×10^5	2.0×10^3	-	1.7×10^3
C 03	3.3×10^5	1.7×10^5	1.7×10^5	1.0×10^5	1.9×10^5	$1.6 x10^3$
C 04	3.1×10^5	1.41×10^6	1.41×10^6	1.0×10^5	3.3×10^5	1.9×10^5
C 05	1.7×10^5	5.8×10^3	1.07×10^6	1.0×10^5	3.1×10^5	3.3×10^5
C 06	1.0×10^5	2.0×10^5	2.0×10^5	1.0×10^5	2.0×10^6	3.1×10^3
C 07	2.0×10^5	2.5×10^5	3.0×10^5	2.0×10^3	1.0×10^5	1.4×10^3
C 08	3.0×10^5	1.5×10^5	1.2×10^5	1.0×10^5	2.0×10^5	$1.6 x10^3$
C 09	3.0×10^5	1.2×10^6	1.0×10^6	1.0×10^5	3.0×10^5	1.0×10^5
C 10	1.5×10^5	2.7×10^3	1.1×10^6	-	1.1×10^5	1.3×10^5
D 01	1.0×10^5	2.0×10^5	2.0×10^5	1.0×10^5	2.0×10^6	2.1×10^3
D 02	1.41×10^6	1.9×10^3	1.6×10^5	4.5×10^3	1.7×10^5	3.1×10^5
D 03	1.07×10^6	1.0×10^3	2.1×10^5	3.9×10^3	1.41×10^6	1.7×10^5
D 04	1.6×10^5	$1.0 x10^3$	2.8×10^5	1.1×10^3	1.8×10^5	1.41×10^6
D 05	2.1×10^5	1.0×10^5	6.2×10^8	1.7×10^3	-	1.1×10^6
D 06	1.42×10^4	1.4×10^3	1.3×10^5	2.4×10^3	1.2×10^6	1.6×10^5
D 07	1.0×10^6	2.0×10^3	1.0×10^5	4.0×10^3	1.3×10^5	3.1×10^5
D 08	1.0×10^6	1.2×10^3	2.0×10^5	4.0×10^3	1.2×10^6	1.7×10^5
D 09	1.0×10^5	$1.1 x10^3$	3.0×10^5	1.0×10^3	1.3×10^5	1.4×10^6
D 10	2.0×10^5	1.2×10^5	3.2×10^8	$1.2x\ 10^3$	1.2×10^6	1.1×10^6
E 01	1.2×10^4	1.4×10^3	1.0×10^5	2.0×10^3	1.2×10^6	1.2×10^5

E 02	1.9×10^5	2.8×10^3	2.8×10^5	-	3.3×10^5	1.1×10^3
E 03	3.3×10^5	1.11×10^4	1.99×10^6	-	1.00×10^6	3.7×10^3
E 04	3.1×10^5	1.9×10^5	1.11×10^6	4.4×10^3	1.0×10^5	-
E 05	1.0×10^4	1.0×10^3	1.0×10^5	2.0×10^3	1.0×10^6	1.0×10^5
E 06	2.0×10^5	2.5×10^3	2.0×10^5	2.0×10^3	3.0×10^5	1.0×10^3
E 07	3.0×10^5	1.1×10^4	2.0×10^6	2.0×10^3	1.0×10^6	3.0×10^3
E 08	1.0×10^4	1.0×10^3	1.0×10^5	2.0×10^3	1.0×10^6	1.0×10^5
E 09	1.0×10^5	2.0×10^3	2.0×10^5	-	2.3×10^5	1.0×10^3
E 10	2.3×10^5	1.1×10^4	1.0×10^6	2.0×10^3	1.0×10^6	3.0×10^3
F 01	2.2×10^4	1.2×10^3	1.0×10^5	2.0×10^3	1.2×10^6	1.0×10^5
F 02	2.6×10^5	4.1×10^3	1.1×10^6	1.5×10^5	1.6×10^5	2.1×10^5
F 03	6.6×10^6	2.8×10^3	1.4×10^5	3.2×10^8	1.2×10^5	2.8×10^5
F 04	2.3×10^5	1.6×10^5	1.6×10^5	1.0×10^5	1.1×10^6	4.1×10^3
F 05	2.5×10^5	3.0×10^5	3.0×10^5	1.0×10^3	1.2×10^6	1.1×10^3
F 06	2.5×10^5	2.4×10^3	2.0×10^6	2.1×10^5	1.4×10^5	2.1×10^5
F 07	3.5×10^6	1.0×10^3	2.0×10^5	1.2×10^8	1.2×10^5	3.0×10^5
F 08	2.5×10^5	5.1×10^3	1.1×10^6	2.0×10^5	1.3×10^5	2.1×10^5
F 09	6.0×10^6	1.7×10^3	1.2×10^5	2.2×10^8	1.2×10^5	2.2×10^5
F 10	1.5×10^5	1.6×10^5	1.5×10^5	2.0×10^5	1.0×10^6	2.1×10^3
G 01	2.6×10^5	3.0×10^5	3.0×10^5	1.1×10^3	1.0×10^6	1.1×10^3
G 02	2.9×10^5	2.5×10^3	1.0×10^6	2.0×10^5	1.4×10^5	2.0×10^5
G 03	3.0×10^8	1.0×10^3	1.0×10^5	1.2×10^8	1.2×10^5	2.0×10^5
G 04	2.7×10^5	4.1×10^3	1.1×10^6	2.3×10^5	1.3×10^5	2.1×10^5
G 05	6.0×10^8	2.0×10^3	1.2×10^5	4.2×10^3	1.2×10^5	2.0×10^5
G 06	1.5×10^5	2.9×10^5	1.0×10^5	1.3×10^5	1.0×10^6	3.1×10^3
G 07	2.9×10^5	2.3×10^5	1.3×10^5	1.0×10^3	1.6×10^6	1.0×10^3
G 08	2.8×10^5	2.0×10^3	1.0×10^6	2.0×10^5	1.6×10^5	2.0×10^5
G 09	1.2×10^5	1.4×10^5	1.3×10^6	1.7×10^5	1.1×10^5	3.0×10^5
G 10	2.3×10^5	1.9×10^5	1.0×10^6	3.0×10^5	4.1×10^5	2.0×10^5
H 01	1.1×10^5	3.2×10^5	1.2×10^6	3.0×10^5	1.0×10^5	3.0×10^5
H 02	1.3×10^5	2.3×10^3	1.1×10^6	1.4×10^5	1.9×10^5	2.9×10^5
H 03	1.1×10^6	1.1×10^5	4.9×10^5	1.4×10^6	2.3×10^5	1.2×10^5
H 04	1.7×10^6	1.0×10^5	1.2×10^6	1.1×10^6	2.1×10^5	1.4×10^6
H 05	1.6×10^5	1.0×10^3	1.2×10^6	1.8×10^5	1.9×10^5	1.1×10^6
H 06	2.0×10^5	1.8×10^3	2.1×10^6	2.0×10^5	1.4×10^6	1.6×10^5
H 07	1.0×10^5	2.0×10^3	1.2×10^6	1.0×10^5	1.0×10^5	1.1×10^5
H 08	1.0×10^5	1.0×10^3	1.1×10^6	1.0×10^5	1.2×10^5	3.1×10^5
H 09	1.8×10^5	4.1×10^3	1.1×10^6	1.8×10^5	1.4×10^5	2.1×10^5
H 10	3.2×10^8	1.9×10^3	1.2×10^5	4.2×10^3	1.2×10^5	3.8×10^5

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.36: Raw table of Total Bacteria load counts (CFU/g) of white meat (chicken) samples from markets in Ohafia zone

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
A 01	1.9×10^5	-	1.29×10^6	1.9×10^5	1.1×10^5	-
A 02	3.3×10^5	1.9×10^5	1.02×10^6	3.3×10^5	4.1×10^5	1.9×10^5
A 03	3.1×10^5	3.3×10^5	1.20×10^6	4.1×10^5	1.0×10^5	3.3×10^5
A 04	1.7×10^5	1.3×10^3	1.11×10^6	1.0×10^5	1.9×10^5	1.7×10^3
A 05	1.41×10^6	1.1×10^5	6.9×10^5	1.9×10^5	3.3×10^5	2.4×10^3
A 06	1.07×10^6	1.2×10^5	1.16×10^6	3.3×10^5	3.1×10^5	-
A 07	1.6×10^5	1.0×10^3	-	3.1×10^5	1.7×10^5	-
A 08	2.1×10^5	2.8×10^3	2.10×10^6	1.7×10^5	1.41×10^6	4.4×10^3
B 01	2.8×10^5	6.1×10^3	1.12×10^6	1.41×10^6	1.8×10^5	-
B 02	6.2×10^8	1.8×10^3	1.2×10^5	1.8×10^5	1.2×10^5	1.7×10^3
B 03	1.7×10^3	1.9×10^5	1.9×10^5	1.2×10^5	1.19×10^6	2.4×10^3
B 04	2.4×10^3	3.3×10^5	3.3×10^5	1.19×10^6	1.26×10^6	-
C 01	-	3.1×10^5	3.1×10^5	1.26×10^6	-	-
C 02	-	1.7×10^5	1.7×10^5	-	1.9×10^5	1.6×10^3
C 04	4.4×10^3	1.41×10^6	1.41×10^6	1.9×10^5	3.3×10^5	1.9×10^5
C 05	-	5.8×10^3	1.07×10^6	4.1×10^5	3.1×10^5	3.3×10^5
D 01	1.7×10^3	1.9×10^3	1.6×10^5	3.1×10^5	1.7×10^5	3.1×10^5
D 02	2.4×10^3	1.0×10^3	2.1×10^5	1.7×10^5	1.41×10^6	1.7×10^5
D 03	-	1.0×10^3	2.8×10^5	1.1×10^3	1.8×10^5	1.41×10^6
D 04	-	1.0×10^5	6.2×10^6	1.7×10^3	-	1.07×10^6
D 05	4.4×10^3	1.4×10^3	1.3×10^5	2.4×10^3	1.20×10^6	1.6×10^5
E 01	1.9×10^5	2.8×10^3	2.8×10^5	-	3.3×10^5	1.1×10^3
E 02	3.3×10^5	1.11×10^4	1.99×10^6	-	1.00×10^6	3.7×10^3

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.37: Raw table of Total Bacteria load counts (CFU/ cm^2) of table surfaces samples in the Markets in Abia State

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
T1	1.1×10^3	1.0×10^3	3.2×10^5	-	-	-
T2	1.0×10^3	1.0×10^3	3.0×10^5	1.0×10^3	2.1×10^5	-
T3	1.0×10^3	1.0×10^3	2.0×10^5	3.1×10^5	-	-
T4	1.0×10^3	1.0×10^3	6.6×10^5	2.5×10^5	5.0×10^5	-
T5	3.0×10^3	3.1×10^5	4.7×10^5	1.0×10^3	1.0×10^5	-
T6	-	2.5×10^3	2.9×10^5	1.0×10^3	-	-
T7	-	3.5×10^3	$1.3 \text{ X } 10^5$	-	-	-
T8	1.0×10^3	-	1.2×10^5	1.0×10^3	1.6×10^5	-
T9	1.0×10^3	3.0×10^3	3.3×10^5	-	3.1×10^5	-
T10	1.0×10^3	1.0×10^3	1.4×10^5	1.0×10^3	2.5×10^5	-
T11	-	2.0×10^3	2.1×10^5	-	-	-
T12	-	1.0×10^3	1.1×10^5	1.2×10^3	-	-
T13	1.1×10^3	2.1×10^3	2.4×10^5	1.5×10^3	1.5×10^5	-
T14	1.1×10^3	3.0×10^3	1.8×10^5	2.1×10^3	1.0×10^5	-
T15	-	1.2×10^3	1.9×10^5	1.0×10^3	3.1×10^5	-
T16	1.0×10^3	1.0×10^3	1.3×10^5	2.4×10^3	1.1×10^5	-
T17	1.0×10^3	1.0×10^3	1.1×10^5	1.0×10^3	2.1×10^5	-
T18	-	-	1.0×10^5	1.6×10^3	1.0×10^5	-
T19	1.0×10^3	1.4×10^3	1.1×10^5	2.1×10^3	2.2×10^5	-
T20	-	1.0×10^3	1.4×10^5	-	2.0×10^5	-
T21	-	1.0×10^3	$1.2 \text{ X } 10^5$	-	-	-
T22	1.0×10^3	1.1×10^3	1.4×10^5	1.0×10^5	1.0×10^5	-

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.38: Raw table of Total Bacteria load counts (CFU/ml) of water samples in the markets

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
W 1	1.0×10^3	1.0×10^3	4.1×10^6	1.0×10^3	1.0×10^5	1.0×10^3
W 2	1.0×10^3	1.0×10^3	3.6×10^6	1.0×10^3	2.7×10^5	1.0×10^3
W 3	1.0×10^3	1.0×10^3	2.0×10^6	1.6×10^5	-	6.0×10^3
W4	1.0×10^5	-	1.29×10^7	1.0×10^5	3.0×10^5	1.1×10^3
W5	3.5×10^5	1.0×10^3	1.7×10^6	1.9×10^3	1.0×10^5	2.2×10^3
W6	1.6×10^5	-	1.00×10^7	2.0×10^5	-	1.5×10^3
W7	1.0×10^5	1.0×10^3	8.9×10^6	1.1×10^3	4.4×10^5	1.0×10^3
W8	1.1×10^5	1.4×10^3	1.72×10^7	1.0×10^3	1.6×10^5	1.6×10^3
W9	1.0×10^3	3.0×10^3	3.0×10^6	1.0×10^3	1.0×10^5	3.0×10^3
W10	-	1.2×10^3	1.55×10^7	4.0×10^3	1.0×10^5	1.0×10^3
W11	1.0×10^5	-	1.2×10^7	1.1×10^5	1.0×10^5	1.1×10^3
W12	1.4×10^5	-	1.00×10^7	1.0×10^5	-	1.5×10^3
W 13	1.0×10^3	1.1×10^3	4.1×10^6	2.0×10^3	1.2×10^5	1.1×10^3
W14	-	1.6×10^3	1.55×10^7	2.1×10^3	1.1×10^5	1.2×10^3
W 15	1.0×10^3	1.5×10^3	2.0×10^6	0.8×10^5	-	3.0×10^3
W 16	1.2×10^5	1.0×10^3	1.7×10^6	1.0×10^3	1.4×10^5	1.2×10^3
W 17	1.7×10^5	1.2×10^3	1.1×10^7	1.3×10^3	1.0×10^5	1.0×10^3
W 18	1.4×10^5	1.0×10^3	1.9×10^6	1.0×10^3	2.0×10^5	1.5×10^3
W 19	-	1.2×10^3	2.0×10^6	2.1×10^3	1.0×10^5	1.0×10^3
W 20	-	1.6×10^3	1.5×10^6	1.5×10^3	1.2×10^5	1.1×10^3

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.39: Raw table of Total Bacteria load counts (CFU/cm^2) of knife surfaces samples in the markets in Abia State

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
KS 1	-	1.0×10^3	1.0×10^5	-	1.0×10^5	-
KS 2	1.0×10^3	1.0×10^3	1.1×10^5	-	2.7×10^5	1.0×10^5
KS 3	1.0×10^3	1.0×10^3	2.0×10^5	-	-	1.0×10^5
KS 4	1.0×10^3	-	2.8×10^3	-	1.0×10^5	1.0×10^5
KS 5	2.1×10^3	1.0×10^3	1.1×10^5	-	-	-
KS 6	-	1.0×10^3	3.4×10^5	-	-	-
KS 7	1.0×10^3	1.0×10^3	1.0×10^5	-	1.7×10^5	1.0×10^3
KS 8	1.0×10^3	1.2×10^3	1.2×10^5	-	1.3×10^5	1.0×10^3
KS 9	1.0×10^3	1.1×10^3	1.0×10^5	-	-	-
KS 10	-	-	3.9×10^5	-	1.0×10^3	-
KS 11	1.0×10^3	1.0×10^3	1.1×10^5	-	-	-
KS 12	-	1.2×10^3	1.4×10^5	-	-	-
KS 13	2.0×10^3	1.2×10^3	1.1×10^5	-	1.0×10^5	1.0×10^3
KS 14	1.0×10^3	1.0×10^3	1.0×10^5	-	1.7×10^5	-
KS 15	-	1.2×10^3	1.1×10^5	-	1.0×10^5	-
KS 16	1.0×10^3	1.2×10^3	1.0×10^5	-	1.0×10^5	-
KS 17	-	1.0×10^3	1.0×10^5	-	1.0×10^5	-
KS 18	-	1.1×10^3	1.0×10^5	-	-	-
KS 19	2.0×10^3	1.2×10^3	1.5×10^5	-	1.0×10^5	1.0×10^3
KS 20	1.0×10^3	1.0×10^3	1.7×10^5	-	1.1×10^5	1.0×10^3
KS 21	-	1.0×10^3	1.4×10^5	-	-	-
KS 22	-	-	2.0×10^5	-	1.3×10^3	-

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.40: Raw table of Total Bacteria load counts (CFU/ cm^2) of meat transporting car boots contact surfaces samples in the markets in Abia State

Sample Code	Total counts on EMBA	Total counts on MSA	Total counts on NA	Total counts on SSA	Total counts on MCA	Total counts on CAMPY AGAR
TV 1	3.0×10^5	-	6.0×10^5	-	-	-
TV 2	1.5×10^5	-	3.0×10^5	-	2.2×10^5	1.0×10^3
TV 3	1.0×10^3	1.2×10^3	1.0×10^5	-	-	2.0×10^3
TV 4	1.0×10^3	3.0×10^5	6.0×10^5	-	3.0×10^5	1.1×10^3
TV 5	1.5×10^3	1.5×10^5	2.7×10^5	-	-	2.1×10^3
TV 6	-	3.0×10^5	4.4×10^5	-	3.0×10^5	-
TV 7	-	3.0×10^5	3.0×10^5	-	1.5×10^5	-
TV 8	1.7×10^3	1.5×10^5	1.5×10^5	-	1.3×10^3	1.6×10^3
TV 9	-	3.0×10^5	3.0×10^5	-	-	3.0×10^5
TV 10	-	1.2×10^3	2.0×10^5	-	-	1.5×10^5
TV 11	1.5×10^3	1.0×10^5	2.0×10^5	-	1.0×10^5	1.0×10^3
TV 12	1.0×10^3	1.2×10^5	1.5×10^5	-	-	1.1×10^3
TV 13	1.7×10^3	1.0×10^5	2.4×10^5	-	2.0×10^5	1.3×10^3
TV 14	-	2.0×10^5	1.0×10^5	-	-	1.5×10^5

EMBA- Eosin Methylene Blue Agar; SSA- Salmonella-Shigella Agar; MSA- Mannitol Salt Agar; NA- Nutrient Agar; CAMPY Agar- Campylobacter Blood Free Agar; MCA- MacConkey Agar

Table 4.41: Colonial and Microscopic Characteristics of Bacteria isolated from meat, contact surfaces and water samples in the Markets in Abia State

Colonial Characteristics	MT	SF	CF	Gram morphology/reaction	Probable Identity
Circular moist and shiny golden yellow colonies on Nutrient Agar and light yellow on Mannitol Salt Agar	-	-	-	Gram positive cocci predominantly in clusters, few in tetrads and pairs	*Staphylococcus* sp
Large slimy mucoid colonies on Eosin Methylene Blue Agar	+	-	+	Gram negative short thick rods in chains	*Klebsiella*sp
Small circular moist and shiny low convex cream colonies on Nutrient Agar	-	-	-	Gram positive cocci predominantly in chains and pairs	*Enterococcus* sp
Grayish white colonies on Campylobacter Blood Free Agar	+	-	-	Gram negative short slender rods	*Campylobacter*s p
Light pink mucoid moist and shiny colonies on Salmonella Shigella Agar	+	+	-	Gram negative single and short rods	*Shigella*sp
Serrated dull and dry flat cream colonies on Nutrient Agar				Large gram positive rods with central spores	*Bacillus* sp
Greenish metallic sheen on Eosin Methylene Blue Agar	+	-	-	Gram negative rods predominantly in single and pairs	*Escherichia coli*
Circular moist and shiny cream colonies on nutrient Agar and Mannitol Salt Agar	-	-	-	Gram positive cocci in clusters, few in pairs	*Staphylococcus* sp
Small moist and shiny red colonies on Campylobacter Blood Free Agar	+	-	-	Gram negative short slender rods	*Campylobacter* sp
Cream moist and slimy cream colonies on Nutrient Agar	+	+	-	Large gram positive rods with central spores in chains	*Bacillus* sp
Small shiny black fish eye colonies on Salmonella Shigella Agar	+	-	-	Gram negative short rods in single	*Salmonella* sp
Bluish green moist colonies on Nutrient Agar	+	-	-	Gram negative slightly curves rods	*Pseudomonas*sp
Dull and dry medusa head shape cream colonies	-	+	-	Gram positive rods in short chains	*Bacillus*sp
Small smooth moist and shiny low convex yellow colonies	-	-	-	Cocci predominantly in tetrads and few in pairs and irregular	*Micrococcus* sp
Orange moist and shiny colonies	-	-	-	Cocci predominantly in tetrads and few in pairs and irregular	*Micrococcus* sp
Mucoid pink colonies on Eosin Methylene Blue Agar	-	-	-	Gram negative rods in pairs and short chains	*Enterobacter*sp

MT – Motility Test; SP - Spore Formation; CF - Capsule Formation

Table showed that *Staphylococcus* sp are circular moist and shiny golden yellow colonies on Nutrient Agar and light yellow on Mannitol Salt Agar; *Klebsiella*sp are large slimy mucoid colonies on Eosin Methylene Blue Agar; *Enterococcus* sp are small circular moist and shiny low convex cream colonies on Nutrient Agar; *Campylobacter* sp are grayish white colonies on Campylobacter Blood Free Agar; *Shigella*sp are light pink mucoid moist and shiny colonies on Salmonella Shigella Agar; *Escherichia coli* are greenish metallic sheen on Eosin Methylene Blue Agar.

Table 4.42: Biochemical Characteristics and Carbohydrate Fermentation of Bacterial

Isolates from meat, contact surfaces and water samples in the Markets in Abia State

Cat	**Oxi**	**Coag**	**IN**	**VP**	**Cit**	**NO_3**	**Ure**	**G**	**S**	**L**	**M**	**Mn**	**Xyl**	**Ara**	**MR**	**Identity of Isolates**
+	-	+	-	+	-	+	+	+	+	+	+	+	-	-	-	*Staphylococcus aureus*
+	-	-	-	+	+	+	+	+	+	+	+	+	+	+	-	*Klebsiella*sp
-	-	-	-	-	+	+	-	+	+	+	=	+	-	+	-	*Enterococcus faecalis*
+	-	-	-	-	-	-	-	+	-	-	-	-	+	+	+	*Campylobacter jejuni*
-	-	-	-	-	+	+	-	-	-	-	+	-	-	+	+	*Shigella*sp
+	-	-	-	+	+	+	-	+	-	-	-	-	-	-	-	*Bacillus cereus*
+	-	-	+	-	-	+	-	+	+	+	+	+	+	+	-	*Escherichia coli*
+	-	-	-	+	-	+	-	+	+	-	+	+	+	+	+	*Staphylococcus saprophyticus*
+	-	-	-	-	-	+	-	+	-	+	-	-	+	+	+	*Campylobacter coli*
+	-	-	-	+	+	+	-	+	-	-	-	+	+	+	-	*Bacillus subtilis*
+	-	-	-	-	+	+	-	+	-	-	+	+	+	+	+	*Salmonella* sp
+	+	-	-	-	+	+	+	+	-	-	-	+	+	+	+	*Pseudomonas aeruginosa*
+	-	-	-	+	+	+	-	+	-	-	-	-	+	+	-	*Bacillus lichenformis*
+	-	-	-	-	+	-	+	-	-	-	-	-	-	-	+	*Micrococcus luteus*
+	-	-	-	-	+	+	-	+	+	-	-	-	-	-	+	*Micrococcus roseus*
+	-	-	-	+	-	+	-	+	-	+	-	-	+	-	+	*Enterobacter*sp

Cat, Catalase; Oxi, Oxidase; Coag, Coagulase; In, Indole; VP, VogesProskaeur; MR, Methyl Red; Cit, Citrate; NO_3, Nitrate reduction; Ure, Urease; G, Glucose; S, Sucrose; L, Lactose; M, Maltose; Mn, Mannitol ; Ara, Arabinose; Xyl, Xylose

Table showed that *Staphylococcus aureus, Klebsiella pneumoniae, Bacillus cereus, Escherichia coli, Bacillus subtilis,* and *Pseudomonas aeruginosa* gave a positive result to catalase test. *Klebsiella pneumoniae, Shigella dysenteriae, Bacillus cereus, Salmonella enteritidis, Bacillus lichenformis, Micrococcus luteus*and *Micrococcus roseus*gave a positive result to citrate test. *Staphylococcus aureus, Klebsiellapneumoniae, Enterococcus faecalis, Bacillus cereus, Escherichia coli, Staphylococcus saprophyticus* and *Salmonella enteritidis* were all positive to glucose.

APPENDIX C

Pictures of the results of observational sanitary inspection

Observations on sanitation and personal hygiene practices in the markets

Plate 4. 1 : The Researcher with her Research Team interacting with a meat seller

Plate 4. 2 : Meat being transported in wheel barrows and vehicles.

Plates 4. 3 : **Open waste dump - Typical waste disposal system at the meat markets.**

Plate 4. 4 : Bore holes - Typical sources of water at the meat markets.

Plate 4. 5A : Open display- Typical ways of displaying white meat for sell at the meat markets.

Plate 4. 5B: Open display- Typical ways of displaying red meat for sell at the meat markets/ Displayed Meat for sell on dirty cement slab in the market

Plate 4. 6: Prospective red and white meat buyers examining the meat at the markets

Plate 4. 7: Handling of the meat carcasses at the slaughter slab at the meat markets

Bacteriological Qualities of meat samples

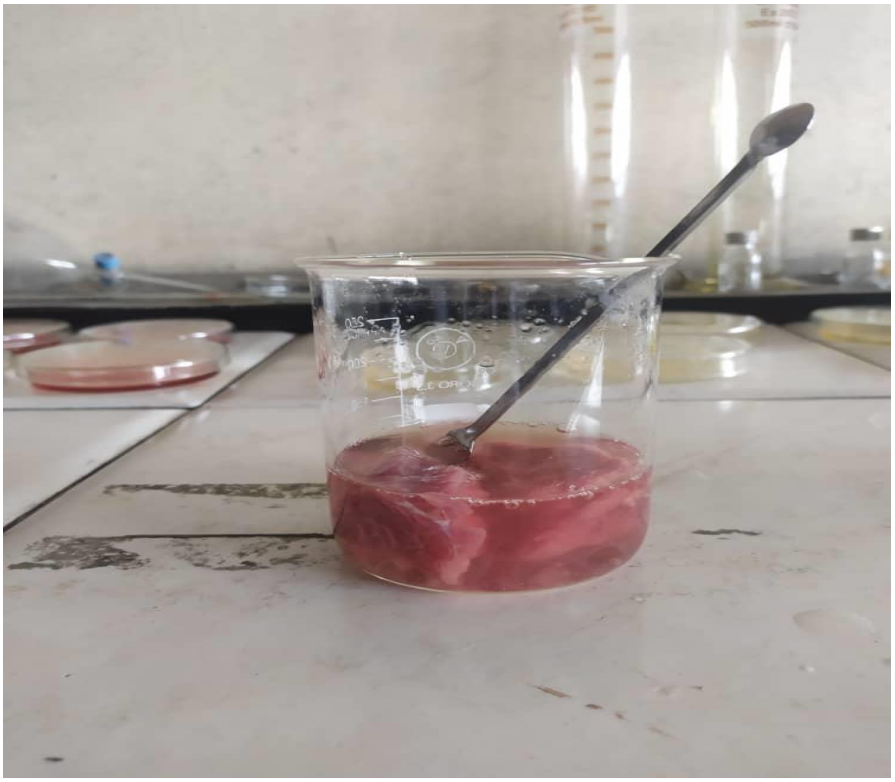

Plate 4. 8: Macerated meat sample in sterile physiological saline for inoculation/culturing

Plate 4. 9: Laboratory culturing of meat samples

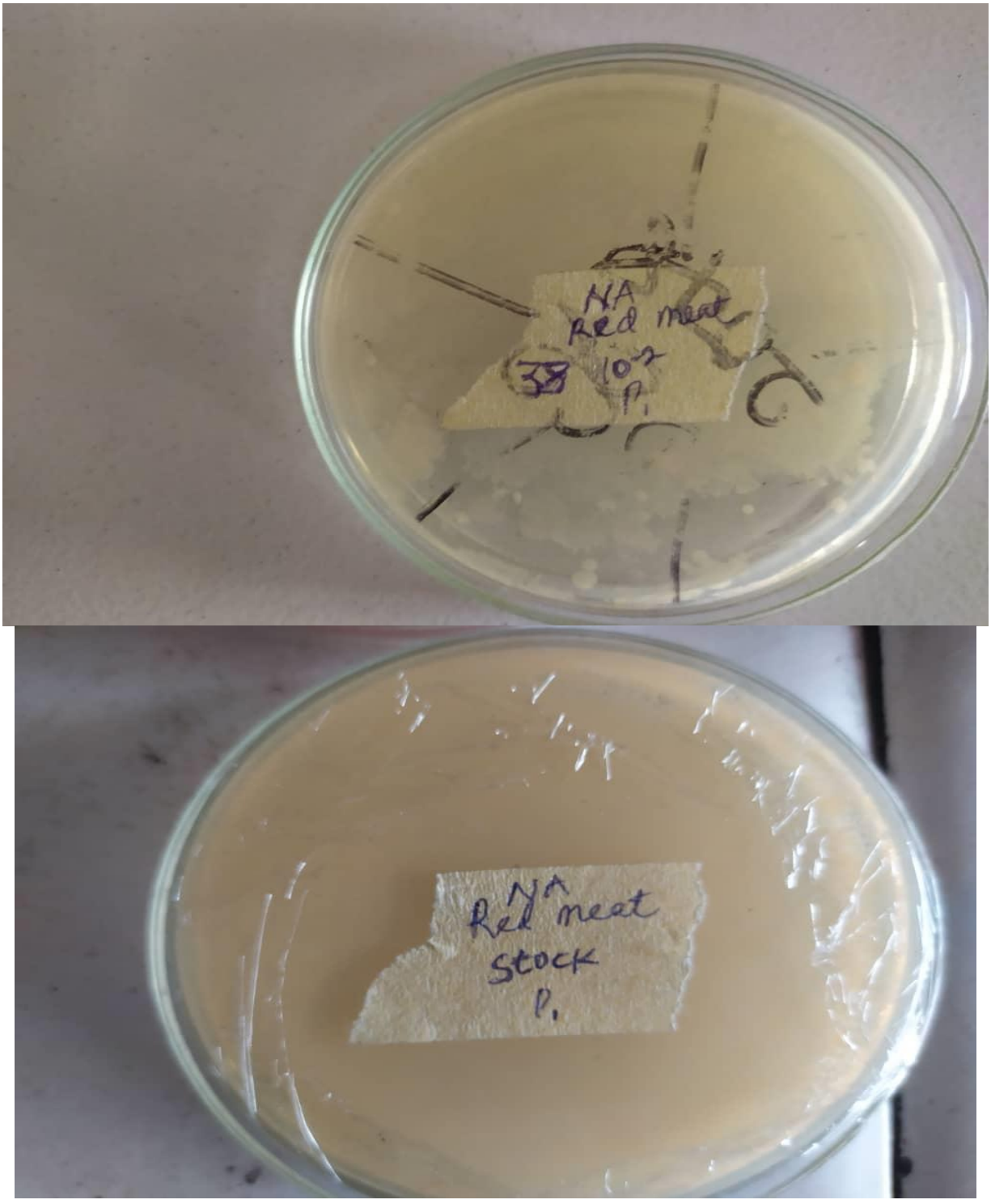

Plate 4. 10: Microbial growth on Nutrient Agar (NA) plates

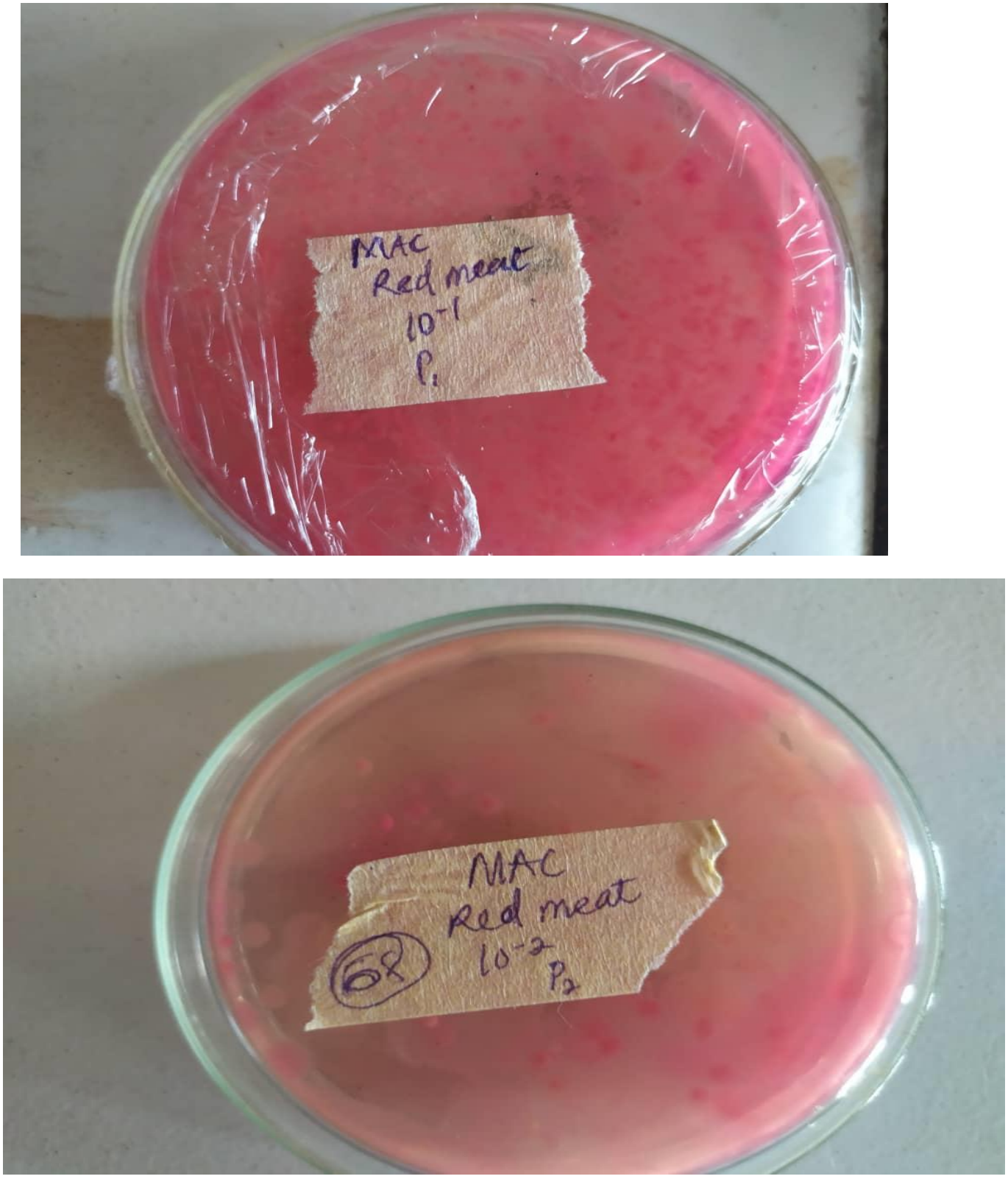

Plate 4. 11: Microbial growth on MacConkey Agar (MAC) plates

Plate 4. 12: Microbial isolates stored in Bijou bottles for further analysis

APPENDIX D:

3.2: ETHICAL APPROVAL Certificates

CITI PROGRAM

Completion Date 15-Aug-2023
Expiration Date 15-Aug-2026
Record ID 57588640

This is to certify that:

Uchechukwu Olive Iwuagwu

Not valid for renewal of certification through CME.

Has completed the following CITI Program course:

NIGERIAN NATIONAL CODE FOR HEALTH RESEARCH ETHICS
(Curriculum Group)
NIGERIAN NATIONAL CODE FOR HEALTH RESEARCH ETHICS
(Course Learner Group)
1 - Stage 1
(Stage)

Under requirements set by:

Center for Bioethics and Research (CBR), Nigeria

CITI
Collaborative Institutional Training Initiative
101 NE 3rd Avenue, Suite 320
Fort Lauderdale, FL 33301 US
www.citiprogram.org

Verify at www.citiprogram.org/verify/?wea425537-5141-40d2-bbb2-9876ee0c5973-57588640

CITI PROGRAM

Completion Date 15-Aug-2023
Expiration Date 15-Aug-2025
Record ID 57588639

This is to certify that:

Uchechukwu Olive Iwuagwu

Not valid for renewal of certification through CME.

Has completed the following CITI Program course:

Human Research
(Curriculum Group)
Group 5 - Students
(Course Learner Group)
1 - Basic Course
(Stage)

Under requirements set by:

Center for Bioethics and Research (CBR), Nigeria

CITI
Collaborative Institutional Training Initiative

101 NE 3rd Avenue, Suite 320
Fort Lauderdale, FL 33301 US
www.citiprogram.org

Verify at www.citiprogram.org/verify/?w3296dd58-91c7-4ae1-84cb-f75c63813ccf-57588639

CITI PROGRAM

Completion Date 15-Aug-2023
Expiration Date 15-Aug-2026
Record ID 57588641

This is to certify that:

Uchechukwu Olive Iwuagwu

Not valid for renewal of certification through CME.

Has completed the following CITI Program course:

Public Health Research
(Curriculum Group)
Public Health Research
(Course Learner Group)
1 - Basic
(Stage)

Under requirements set by:

Center for Bioethics and Research (CBR), Nigeria

CITI
Collaborative Institutional Training Initiative

101 NE 3rd Avenue, Suite 320
Fort Lauderdale, FL 33301 US
www.citiprogram.org

Verify at www.citiprogram.org/verify/?wcd1feefd-ee1b-4179-8ac6-df4d1f9759d2-57588641

FEDERAL UNIVERSITY OF TECHNOLOGY, OWERRI

SCHOOL OF HEALTH TECHNOLOGY

DEPARTMENT OF PUBLIC, HEALTH

E-mail: publichealth@futo.edu.ng

P. M. B. 1526
Owerri- Nigeria
Telegrams: FEDUNITECH,
OWERRI

Vice-Chancellor: Prof. (Mrs.) Nnenna N. Oti, *JP, RSS*
B. Agric. M. Sc. (Nig.), PGD (Belgium), Ph. D (FUTO)

Dean: Prof. P. U. Agbasi
B. Sc., M. Sc., Ph.D.

Head of Department: Dr. U. M. Chukwuocha
B. Sc., MPH, Ph.D.

Our Ref.: FUT/SOHT/PUH/CS.006/VOL.1

Your Ref:

November 18, 2021

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

LETTER OF INTRODUCTION

The bearer, **IWUAGWU, UCHECHUKWU OLIVE** with **Reg. No. 20144920088** is a bona-fide student of the Department of Public Health. As part of requirements for graduation, every student is required to carry out a well-articulated research.

Accordingly, **IWUAGWU, UCHECHUKWU OLIVE** is seeking to carry out her research in your establishment. The topic of her research is: ***"Assessment of the Bacteriological qualities of meat and contact surfaces in markets in Abia State, Nigerian."***

We would appreciate your kind assistance towards the realization of this compulsory requirement for her graduation.

Please give her the necessary assistance she requires for a successful programme.

Dr. U. M. Chukwuocha
Ag. HOD, Public Health