Thesis Ref. No. _____

ADDIS ABABA UNIVERSITY

COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE

FOOD QUALITY AND SAFETY RISKS ALONG THE COMMERCIAL BROILER CHICKEN VALUE CHAIN IN BISHOFTU AND ADDIS ABABA, ETHIOPIA

MSc THESIS

BY

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MSc Program in Animal Production Studies

June, 2019

Bishoftu, Ethiopia

FOOD QUALITY AND SAFETY RISKS ALONG THE COMMERCIAL BROILER CHICKEN VALUE CHAIN IN BISHOFTU AND ADDIS ABABA, ETHIOPIA

A Thesis Submitted to the College of Veterinary Medicine and Agriculture of Addis Ababa University in Partial Fulfillment of the Requirements for the Degree of Master of Science in Animal Production Studies

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June, 2019

Bishoftu, Ethiopia

APPROVAL SHEET

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STATEMENT OF THE AUTHOR

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ACKNOWLEDGMENT

First and for most I would like to thank GOD that HE helped me to complete this study successfully. I am very much grateful to express my heartfelt gratitude to my divisors Dr. Gebeyehu Goshu, Dr. Gezahegn Mamo and Prof. Tadelle Dessie for their invaluable insight, guidance and constructive comments in the whole process of this study.

I am indebted to extend my deepest thank to my wife Almaz Negash, she always encouraged me and been my biggest emotional support. My son Ezra Alemayehu, you are the source of my joy, thank you so much.

I would like to thank the Ethiopian Institute of Agricultural Research (EIAR) and International Livestock Research Institute (ILRI) for their financial support. This study has cost a lot of money which was not possible without the financial support of ILRI - African Chicken Genetic Gains (ACGG) Project. I am very much grateful to extend my thanks to Wubalem Dejene and Lidia Abebe for their unreserved support during the study. My thank should also goes to the then EIAR Livestock Director - Dr. Getnet Assefa, Human Resource Director - Alemu Asres, and Training Coordinator - Girma Tezera.

My thank should also goes to the National Veterinary Institute, Research and Development Directorate head- Dr. Esayas Gelagaye, and the researchers- Dr. Takele Abayneh and Dr. Liyouwork Tesfaw who allow me to use the laboratory facility for bacteriology analysis. My heartfelt thank also goes to Dawit Dufera and Eyob Assefa who carried out all the laboratory works.

I am also indebted to broiler chicken rearing households, backyard broiler slaughterers and retail markets who allow me to access their farms and/or shops, and for giving me their precious time for the interview. My thank also goes to Hiruh H/Michael and Biruk H/Michael who help me to link with broiler chicken rearers and backyard slaughterers. I am also indebted to extend my thanks to Gelila Wondmagegn (candidate DVM) and our driver Dereje Lema for their patience to stay with me up to the mid-night during the data collection period.

I have been supported by many people during conducting this research. Hence, I would like to thank my friends and colleagues, Solomon Chanyalew, Dr. Etalem Tesfaye, Misba Alewi, Shambel Taye, Solomon Abiy, Tewodros Fekadu, Dr. Tadios Habte, Shewaye Getaneh, Girma Asres, Dr. Amanuel Tsegaw, Joni Tesfamariyam, Tesfanesh Demie, Amsale Kebede, Dr Solomon Abegaz, Dr. Mekonen Girma and Assefa Funga for all supports throughout the completion of this study.

LIST OF ABBREVIATIONS

ATP	Adenosine Triphosphate
CAC	Codex Alimentarius Commission
CAS	Controlled Atmosphere Stunning
CFU	Colony Forming Unit
DFD	Dark, Dray and Firm
DOCs	Day-Old Chicks
EAVFP	Ethiopian Association of Veterinary and Feed Producers
EPPPA	Ethiopian Poultry Producers and Processors Association
ESA	Ethiopian Standard Agency
ETB	Ethiopian Birr
FAO	Food Agriculture Organization
FSANZ	Food Standards Australia New Zealand
HACCP	Hazard Analysis and Critical Control Points
IBD	Infectious Bursal Disease
ISO	International Standardization Organization
MUFA	Mono-unsaturated Fatty Acids
NABC	Netherlands Africa Business Council
NVI	National Veterinary Institute
OIE	Office International des Epizooties
PPPSPM	Primary Production and Processing Standard for Poultry Meat
PSE	Pale, Soft and Exudative
SFA	Saturated Fatty Acids
UK	United Kingdom
USA	United States of America
WHC	Water Holding Capacity
WHO	World Health Organization

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ABSTRACT

Food quality and safety are unaddressed issues in the production, processing, and marketing of broiler chicken in Ethiopia. The aim of this study was to investigate factors affecting the quality and safety of broiler meat production along the value chain. Production, processing and marketing chains were considered and both qualitative and quantitative data were collected and supported by laboratory analysis. Survey and observation data were collected from 81 respondents; 27 respondents from every value chain component. Besides, 120 faecal samples from broiler farms, 60 carcass swabs from slaughtering sites and 24 carcass swabs from retail markets were collected. Furthermore, a total of 72 carcasses; 48 and 24 carcasses from slaughtering sites and retail markets were collected, respectively and physicochemical meat quality was conducted. The majority (77.8%) of the farms were located in residential areas either in the same or separate compound by sharing with the resident people which makes difficult to implement strict biosecurity. Broiler chicken rearing households who did not follow the day-old chicks' suppliers' vaccination program and provide antibiotic treatment without veterinary experts' prescription were 88.2% and 45.5%, respectively. All broiler processors did not off-feed birds for the required duration before slaughtering. Besides, all broiler chicken slaughtering processes were carried out in the same compound near the house wherein birds were grown-out. Furthermore, all slaughtering processes which causes carcass cross-contamination such as bleeding, scalding, defeathering, and evisceration were carried out at the same place. Almost all retail markets did not check the meat from backyard slaughtering sites against temperature and cold chain transportation. Out of 120 faecal samples, 14.2% and 27.5% were positive for Salmonella spp. and Escherichia coli, respectively. Besides, out of the 60 carcass swab samples from backyard slaughtering sites 15% and 46.7% were positive for Salmonella spp. and Escherichia coli, respectively. Furthermore, out of the 24 carcass swab samples from the retail markets, 70.8% and 79.2% were positive for Salmonella spp. and Escherichia coli, respectively. The contamination of both Salmonella spp. and E. coli were significantly ($P<0.001$) higher at retail markets. Of the breast meat fillets subjected to CIE L, a* and b* color test, 72.9% were normal. A significantly ($P<0.001$) higher drip loss and shear force were observed in the pale breast meat group. Besides, a significantly ($P<0.001$) higher pH_{24h} was observed in the dark breast meat fillets whereas a significantly ($P<0.05$) low moisture was observed in the pale breast meat group. The biosecurity of broiler chicken rearing farms was poor and broiler processing at backyard slaughtering sites was unhygienic. But, the proximate chemical composition of the breast, thigh and drumstick meat cuts were in the range of the*

expected nutritional value. The physical qualities of broiler breast meat fillets were comparable with the findings of other studies. To ensure the quality and safety of the broiler meat, multifaceted intervention approaches are required at broiler chicken rearing farms, backyard slaughtering sites, and retail markets.

Key words: *Value chain, Broiler meat quality, and Broiler meat safety.*

1. INTRODUCTION

Poultry production is an important activity in terms of income generation, job creation, food security, and animal source protein particularly for low-income countries where most of the population do not afford to buy other sources of livestock meat. As chicken has fast proliferation and growth rate, it is a potential agri-food source to respond to the fast-growing population of developing countries like Ethiopia. Besides, chicken meat is high in protein content, rich in vitamins and minerals, and has considerable health benefits such as causing weight loss, helping the control of blood pressure, reduced cancer risk and cholesterol (Mitchell, 2016). Despite the fact that, commercial poultry production is not well developed because of the prevailing constraints particularly disease, shortage and high cost of production inputs and lack of a sustainable market (Gezahegn and Karl, 2010; NABC, 2012). The per capita consumption of chicken meat of Ethiopia (0.5 kg) was very low compared with the average per capita consumption of Sub-Saharan Africa (2.3 kg) in 2015 (Michael, 2017).

The market for chicken and chicken products are continuously fluctuating. Although there is a shortage in supply, the price of chicken products particularly chicken meat may be sold at a skyrocketing price and then automatically decrease up to two-fold within a month period of time. On the other hand, the country has been importing chicken meat for long years ago (Gezahegn and Karl, 2010). International hotels and Ethiopian Airline have been importing chicken meat to feed their clients. These institutions are abided by international food quality and safety regulations, which is no commercial broiler meat supplier HACCP/ISO certified in the country (NABC, 2012). For instance, the Ethiopian Airline has been importing 2000 Kg of broiler meat every day. Besides, for the first time in the year 2017, importation of the product mostly from Brazil (Qualiko brand) and Ukraine (Sadia brand) is available in the major retail grocery outlets. This results in the country spent a substantial amount of hard currency which is already a limited reserve in the country (Michael, 2017).

The government has designed an intervention strategy that helps to develop the poultry sector, to satisfy the local demand and export the surplus. It is planned to increase the total chicken meat production from 48,900 tonnes in the year 2015 to 163,900 tonnes in the year 2020, a 235% increase (Shapiro *et al.*, 2015).

Quality and safety of broiler meat is a major problem to exploit local market available which is explained for instances by 135.3 metric tonnes of broiler meat imported and the associated 162,577 US$ expenditure in the year 2016 (Michael, 2017). Furthermore, quality and safety

could be a future market challenge to the product increased and surpluses meant for export, achieved if at all as envisaged by the government. These constraints are laid in the chain of broiler production where different actors with various functions are involved, and directly or indirectly affect the quality and safety of the meat (NABC, 2012).

Value chain approach has paramount importance as it helps to map the activities of actors involved in the production, processing and marketing of broiler chicken and the associated food quality and safety of effects of broiler meat. Therefore, this study was conducted with the following specific objectives;

Objectives

1. To assess the status of broiler chicken farm biosecurity.
2. To assess the status of hygiene practices at the backyard slaughtering sites and retail markets;
3. To determine the microbial quality (level of contamination of *Salmonella* spp. and *Escherichia coli*) at production, processing, and marketing of broiler meat; and
4. To examine the physical and nutritional qualities of chilled and frozen broiler chicken meat.

2. LITERATURE REVIEW

2.1 The Concept of Value Chain

The concept of the value chain was derived from Porter (1990) in the analysis of competitive advantage for industrial firms. Kaplinsky and Morris (2001), also describe that value chain is the full range of activities which are required to bring a product or service from conception, through the different phases of production, (involving a combination of physical transformation and the input of various producer services) delivery to final consumers, and final disposal after use.

Value chain approach has become a commonly used tool in the development literature since the late 1990s to highlight the linkages and institutional arrangements embedded in various commodity sectors (Kaplinsky and Morris 2001). However, more recently, the concept has been applied in the context of food quality and safety to identify actors involved in the process of production of food products and impacts associated with quality and safety (Gereffi and Lee, 2009). Since food safety and quality risks take place in the context of a system, with attributing factors laid on measures taken throughout the chain, it is important to place these impacts in their appropriate value chain setting.

2.2 The Commercial Broiler Value Chain of Ethiopian

Various researchers have mapped the poultry sector of Ethiopian and identified value chain actors and inputs involved in the commercial broiler chicken. Value chain actors in commercial broiler are breeder farms, hatcheries, commercial broiler farms, processors/slaughters, traders and consumers (Gezahegn and Karl, 2010; NABC, 2012) as illustrated in (Fig. 1). Functions performed by the said value chain actors in the whole process of broiler production are summarised in the section below;

Breeding and hatching: The production process includes broiler parent stock sourced abroad either in the form of DOCs or fertile eggs. Large scale poultry farms having breeder stock and hatchery facilities play a major role in this regard. They collect fertile eggs from their breeder stock and hatch chicks using their facilities, and sell to broiler growers who produce from large to small scales of production and at the same time keep themselves to fatten for the market (Gezahegn and Karl, 2010; NABC, 2012).

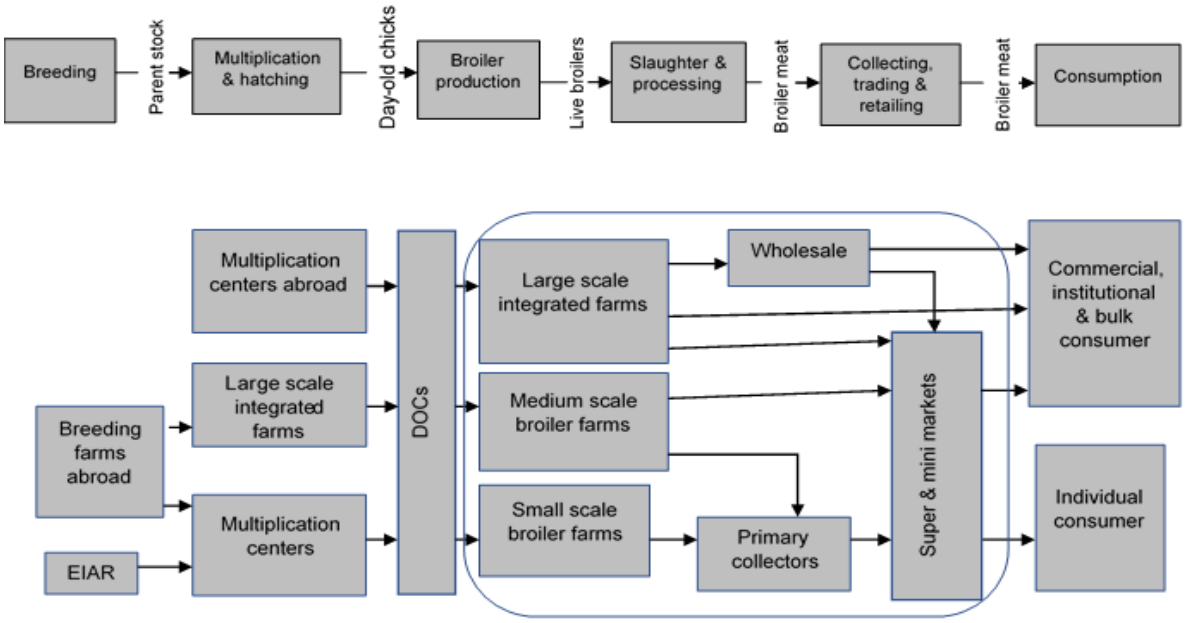


Figure 1. The Schematic representation of Ethiopian broiler value chain (Adopted from NABC, 2012)

Production of broiler and processing: In Ethiopia, the commercial broiler poultry is categorized into three based on the scale of production. These are, 1) Small-scale commercial farms (50 to 1000 birds); 2) Medium-scale commercial farms (1000 to 10,000 birds) and 3) Large-scale commercial farms (over 10,000 birds) (NABC, 2012).

Large scale commercial poultry farmers are vertically integrated with the necessary facilities such as feed processing plant, breeder stocks, hatchery, and slaughtering facility. Whereas, most the medium and small-scale broiler farms are highly dependent on big farms for their production inputs day-old chicks (DOCs) and feed, and are located at human residence areas where chicks are kept both in same and separate compound with people (Gezahegn and Karl, 2010; NABC, 2012).

All healthy broiler chicken grow-out for about 45-60 days by these farms are ready for slaughter or to be sold live. Large scale farms usually slaughter and process the birds themselves using a facility they have. Whereas the medium and small-scale broiler producers have not to access or lack this facility slaughter and process at their backyard traditionally (NABC, 2012).

Collecting, transporting and trading: The broiler meat produced at the backyard slaughtering sites are entered into the market directly by producers themselves and primary collectors. Big poultry farms (e.g. ELFORA and Alema) transport and sell their own meat in

bulk to super-and minimarkets and to bulk consumers such as hoteliers, bakeries, restaurants, etc. or directly sold in their own retail shops (Gezahegn and Karl, 2010).

On the other side, primary collectors are the main market getaway for products of medium and small-scale broilers producers (Gezahegn and Karl, 2010). But they do not use appropriate means of transportation (cold chain) designed for the purpose. They rather use vehicles designed for loading goods and sometimes use minibuses' and load the meat with people (Gezahegn and Karl, 2010; NABC, 2012).

Retailers in chicken meat and egg marketing chain are those actors who perform the last marketing function by linking consumers with other traders and/or producers. The retailing of broiler meat is segmented into high-end markets such as min/super/hypermarkets, hotels and restaurants (Michael, 2017). In Ethiopian, there is no any HACCP/ISO certified broiler meat supplier (NABC, 2012) which results to international hotels and Ethiopian airline still being dependent on importation to fed their clients (NABC, 2012; Michael, 2017).

2.3 Attributes of Chicken Meat Quality

The concept quality is 'in the eyes beholder.' There are many definitions of quality, but the most preferred one is; ''Quality is the composite of those characteristics that differentiate individual units of a product and which have significance in determining the degree of acceptability of that unit to the user''. However, for the meat industry, meat quality is a term used to describe the overall meat characteristics including its physical, chemical, morphological, biochemical, microbial, sensory, technological, hygienic, nutritional and culinary properties (Nasir *et al*., 2017).

Color, texture, juiciness, wateriness, firmness, tenderness, odor and flavour are the most important and perceptible meat features that influence the initial and final quality judgment by consumers before and after purchasing a meat product (Cross *et al*., 1986). These factors affect the consumer either to purchase the product or not. For processors, manufacturing value-added meat products with quantifiable properties of meat such as water holding capacity, cook loss, pH, shelf life, collagen content, protein solubility, cohesiveness, and fat binding capacity are indispensable to acquire excellent functional properties that will ensure a final product of exceptional quality and profitability (Allen *et al*., 1998; Nasir *et al*., 2017).

Besides, the poultry meat quality grading system used worldwide still continues to be based on aesthetic attributes such as color, texture, flavor, presence or absence of carcass defects,

bruises, and missing parts. Furthermore, consumers with increasing health consciousness, are becoming more aware of the nutritional value of the foods they eat (Kralik *et al*., 2018).

2.3.1 *Color*

It could be argued that color is the most important quality attribute of raw or cooked poultry meat because consumers associate it with the product's freshness, and they decide whether or not to buy the product based on their opinion of its attractiveness. Consumers will often reject products in which the color varies from the expected normal appearance pointed out that color is everywhere and those psychological responses to color, as they relate to appetite, are considered important to processors and consumers. Consequently, color is often used to determine the economic value of food (Qiao *et al*., 2002).

The color of meat can be determined visually or using instruments (colorimeters). For the visual evaluation of the meat color, it is necessary to have trained panellists, who evaluate the appearance of meat by using the hedonic scale. The instrumental determination of meat color is more efficient and the methods of reflection or extraction are used to quantify the amount of pigment. The color of foods can be defined as the interaction of light, an object, an observer and the surroundings of the food. Instruments used for evaluation of meat color by reflection method are colorimeters, for example, CR Minolta 300/400 and Hunter Lab Mini Scan EZ that work on the principle of meat color comparison in regard to standard color values. The International Commission on Illumination lists three values: CIE L*, a* and b*. CIE L* indicates lightness, where values range from 0 (black) to 100 (white). The value of CIE a* shows redness while CIE b* indicates yellowness (Kralik *et al*., 2018).

However, different muscles of the chicken have dramatic extremes in color (white and dark meat) (Northcutt, 2009). Raw breast meat exhibits a pale pink color, while the raw thigh and leg meat appear dark red. The color of chicken meat particularly breast fillet is related to pH and pre-slaughter handling, and processing practices. As the result of the effect of these factors, pale, soft and exudative (PSE), and dark, firm and dry (DFD) colored meats are shown in the chicken meat industry. These are the two most common color defects potentially affect consumer preference and functional values of chicken meat for further processing (Solomon *et al*., 1998).

Droval *et al*. (2012) were examined the consumers' opinions using sensory panellists toward pale, soft and exudative chicken meat on the basis of meat color. The examinees made differences between PSE and meat of normal quality in stores, while panellists assessed the

sensory quality of cooked meat and showed preference toward control samples (meat of "normal" quality). Accordingly, Qiao *et al.* (2001) and Droval *et al*. (2012) determined the border values for the color of chicken breast muscle: lighter than normal (L* > 53), normal (48 < L* < 53) and darker than normal (L* < 48). The other scholar, Woelfel *et al*. (2002) determined the border values for "normal" chicken breasts L* 52.15, drip loss 3.32% and cooking loss 21.02%, while for PSE meat these values were: L* 59.81, drip loss 4.38% and cooking loss 26.39%. The border values reported by Karunanayaka *et al*. (2016) are slightly higher than those determined by the authors mentioned above. According to these scholars, the value for normal and PSE meats are L* 56.82 and L* 61.83, respectively.

The degree of protein denaturation and physical appearance of meat, dependent on post-mortem temperature and pH as they influence the amount of light that is reflected from the interior and exterior of the meat surface. Because light scattering is directly proportional to the extent of protein denaturation. Light scattering affects meat lightness (L*) in a fashion inverse to that caused by haeme pigment concentration, having a minimal effect on meat redness (a*) and yellowness (b*) (Nasire *et al*., 2017). The major pigments responsible for color in meat are myoglobin, haemoglobin and cytochrome. In well bleed carcass, myoglobin constitutes 80 to 90 percent of the total pigment followed by haemoglobin (Mead, 2004b).

When freshly cut meat is exposed to air, the reduced pigments will react with oxygen and form relatively stable pigment called oxymyoglobin. Formation of oxymyoglobin in fresh meat is responsible for its bright red color which is otherwise termed as 'bloom'. The oxidized form of myoglobin is known as metmyoglobin and imparts a brown color to the meat. Metmyoglobin is formed when small quantities of oxygen are present as in case of partial vacuum or a sealed semi-permeable package.

Research reports have shown that color variations occurring in the production of boneless and skinless raw broiler breast meat. In Canada, the occurrence of PSE meat in broiler chickens ranged from 0 to 28% in seven different flocks (Bartu, 1997). A grocery store survey of 1,000 boneless, skinless, broiler breast fillet packages in the USA showed that approximately 7% of the multiple-fillet packages had one or more fillets that were significantly different in color, either lighter or darker, than the other fillets in the same package (Qiao *et al*., 2001). Kralik *et al*., (2014) in their experiment in investigating the quality indicators of broiler breast meat in relation to color; the PSE and DFD meat observed in Cobb 500 were 20% and 4.71% respectively.

PSE meat has lower ultimate pH (pH_{24h} < 5.6), water-holding capacity and technological yield after curing and cooking (Mead, 2004b). The processing value of such meat is limited and moreover cannot be considered as fully valuable culinary meat and directed to retail distribution. Similarly, DFD meat with high ultimate pH>6.3 has restricted application because it is prone to microbial contamination even when initially being relatively low microbially-contaminated (Nasir, 2017).

2.3.2 *pH*

pH has a direct bearing effect on the meat quality attributes such as tenderness, water-holding capacity, color, juiciness and shelf life. The pH of broiler meat is the function of the amount of glycogen in the muscle prior to slaughter and the rate of glycogen conversion into lactic acid after slaughter. The broiler breast meat with high pH has a higher water binding capacity than meat with lower pH. Identification of color is an easy way to determine the pH of meat. If the meat is very dark, it will have a high pH and if it is very light, it will have a low pH (Anadon, 2002).

Chicken meat may have different pH value ranges from 5.5 to 6.8 which refers to different meat quality characteristics. Chicken meat with ultimate pH (pH_{24h}) from 5.4 - 6.2 considered good quality while meat less than 5.2 to 5.3 and greater 6.5 to 6.8 are considered pale, soft and exudative (PSE) and dark, firm and dry (DFD) meat, respectively, and generally considered as poor quality. Scholars affirmed that pH is a determining factor of other physio-chemical qualities of meat. Bihan-Duval *et al*. (2008) established the final pH value of 5.64 for chickens of commercial lines affirming that it was a relevant selection criterion on determining the meat's quality due to being strongly associated with color, water-holding capacity, and texture.

2.3.3 *Texture*

The texture is probably the most important quality factor associated with consumer satisfaction in the eating quality of poultry. The texture and degree of firmness of the meat is a function of the amount of water held intramuscularly. Water tightly bound to the muscular proteins has a swelling effect on muscle proteins, occupying the spaces between myofibrils and giving the meat a more firm structure (FSANZ, 2005). While conversion into the meat, the rate, and extent of the chemical and physical changes occurring in the muscle also determine its tenderness. Slaughtering of a bird stops blood circulation which in turn blocks the supply of oxygen or nutrients to the muscles. Thus, muscles run out of energy, contract

and become stiff. This stiffening, called rigor mortis, is followed by softening again making meat tender when cooked Any breach in this normal conversion of muscle to meat will affect its tenderness (Northcutt, 2009).

The major factors affecting meat tenderness are the maturity of the connective tissues and contractile state of the myofibrillar proteins along with environmental stress, scalding temperature, age of birds and rate of rigor development. The maturity of connective tissue is a function of chemical cross bonding of the collagen in the muscle which increases with age, hence the tough meat is found in older birds. Whereas, the contractile state of the myofibrillar proteins depends on the rate and severity of rigor mortis development. However, there are no age-related differences in the tenderness of breast and thigh meat (5 - 8 weeks of age) of broilers with more juiciness in the breast meat of older birds (Northcutt, 2009)

The meat tenderness can be analysed using trained panellists' sensory responses to tenderness and mechanically using meat shear force analyser machine. Lyon and Lyon (1990) cited in Mead (2004b) established relationships between objective shear procedures (mechanically by machine) and sensory responses to tenderness for broiler Pectoralis major muscles. Their findings indicated that Warner-Bratzler values in the range of 6.5±3.5 kg and Allo-Kramer values in the range of 8.8±6.0 kg would correspond to the `slightly tender' to `moderately tender' part of the sensory scale (Soares *et al*., 2009 and Nasir, 2017)

2.3.4 *Nutritional quality*

The major components of raw poultry meat are proteins, lipids and minerals at proportions between 18.4 and 23.4%, 1.3 and 6.0%, 0.8 and 1.2%, respectively. Breast meat contains less than 3 g fat/100 g and the corresponding average value for dark meat (skin off) is 5-7 g/100 g. (Culioli *et al*., 2003). According to Kralik *et al*. (2001) the nutritive content of broiler meat per 100g should be Energy/kcal 165, Water/moisture/g 65.26, Protein/g 31.02, Total fat/g 3.57, Saturated fatty acids 1.01, Monounsaturated fatty acids 1.24, Polyunsaturated fatty acids 0.77 and Cholesterol (mg) 85.0. In general, the proximate composition of the carcass will depend on their genetic makeup, age, diet, and management, as well as environmental conditions (da Silva *et al*., 2017).

2.3.5 *Water holding capacity*

The water holding capacity is the ability of fresh meat to retain moisture. The majority (88-95%) of the water in the muscle is held intracellularly within the space between actin and

myosin filaments and rest is located between the myofibrils (Cross *et al*., 1986). Water holding capacity (WHC) is an important property of poultry meat to determine the quality and consumer acceptability. It has also a direct effect on the color and tenderness of the meat. Increase in the water content of muscles, enhancing tenderness, juiciness, firmness, and appearance, improve the quality and economic value of meat. Poor water holding capacity of the meat could be performed by high drip and cooking losses (Suwattitanun and Wattanachant, 2014).

Many factors could affect the WHC of broiler meat, process conditions such as carcass temperature, delay time, storage temperature and time. Hence, all those factors must be controlled during chicken meat production. However, a variation of temperature and time during the process was normally observed depending on production capacity and production management (Suwattitanun and Wattanachant, 2014). Besides, pH and development of rigor mortis which act by altering the cellular and extracellular components are also among the major factors affecting WHC of broiler meat (Culioli *et al*., 2003; Nasir *et al*., 2017).

After death, due to lack of oxygen supply, lactic acid production occurs resulting into the decline of pH which causes protein denaturation, loss of protein solubility and in an overall reduction of reactive groups available for water binding on muscle proteins. The reduction of reactive groups occurs because the pH of the muscle reaches the isoelectric point at which positive and negative charges on the reactive groups of the proteins are equal which attract each other leaving almost nothing to react with the charged groups of water and thus impairing the ability of the proteins to bind water (Nasir *et al*., 2017).

2.4 Attributes of Food Safety Risks of Chicken Meat

Food safety is an assurance that food will not cause any harm to the consumer when it is prepared or eaten according to its intended use (Codex Alimentarius) (FAO, 2001). Food safety is a scientific discipline describing handling, preparation, and storage of food in ways that prevent foodborne illness. It refers to all those hazards either chronic or acute that may be injurious to consumer health which is not negotiable (FAO and WHO, 2002). The contamination can be considered as any horrible or harmful element or material in the food for consumption. They are of microbiological, physical and chemical types that can potentially affect consumer's health (Rosemary, 2009).

Chemical Risks: Chemical hazards may be introduced into the food chain during broiler production. The concern may range from chemicals used on the farm to mycotoxins in feed

and veterinary drug residues to cleaning solutions used in processing. Chemicals may be added deliberately during the primary production and/or processing (e.g. antimicrobial agents) or unintentionally via environmental exposure e.g. heavy metals, (polychlorinated biphenyls) (Margaret, 2013).

Anticoccidial drugs are antimicrobial agents that are widely used for therapeutic and prophylactic purposes in intensive poultry rearing. Furazolidone is an example of an anticoccidial drug that has been used for years for the treatment of bacterial and protozoal infections. While the administration of furazolidone is prohibited in food-producing animals in the United States and European countries, the drug is commonly used by farmers in the Middle East, Far East, and Africa as a coccidiostat (Rosemary, 2009). The same author also shows that coccidiostats are widely used in feeds to prevent coccidiosis (a protozoal disease of poultry), potential chemical risk otherwise assured the required withdrawal period at least, five days.

The use of chemicals during the processing of poultry is largely limited to the use of chlorine-treated water during washing and chilling of the carcass. During and after the slaughter processes the most probable risk of contamination is of biological nature. At primary production, the risk posed is both biological and chemical in nature. Sanitizing and disinfecting chemicals for chicken house, equipment and utensils are major sources for chemical contamination (Mead, 2004a).

Physical Risk: Is any extraneous object or foreign matter in a food item which may cause illness or injury to a person consuming the product. These foreign objects include, but are not limited to bone or bone chips, metal flakes or fragments, injection needles, BB's or shotgun pellets, pieces of product packaging, stones, glass or wood fragments, insects or other filth, personal items, or any other foreign material not normally found in food products. Sources for such contaminants include raw materials, badly maintained facilities and equipment, improper production procedures and poor employee practices (Margaret, 2013).

Biological Risk: It is caused by groups of germs (bacteria) results in common causes of food poisoning and human illness. Poultry is potentially contaminated by various microbial agents. Among which *Salmonella* species, *Campylobacter* species, *Listeria monocytogenes*, *Clostridium perfringens*, and *Staphylococcus aureus* and *Escherichia coli* (Molla and Mesfin, 2003; Waild *et al*., 2012). These microorganisms have been known to occur at various stages of the production process that ranges from the rearing of chicken at the farm to processing and

handling of a product (Margaret, 2013). *Salmonella, Escherichia coli* and *Campylobacter* are often referred to as part of the resident microflora of many species of poultry, notably chickens, turkeys, and ducks. This study is emphasized particularly on microbiological risks such as *Salmonella* and *Escherichia coli* as they have high public health importance (Buhr *et al*., 2002 and FSANZ, 2005).

Salmonella: *Salmonella typhimurium* and *Salmonella enteritidis* are predominant sources for human Salmonellosis. *Salmonella* is commonly isolated across the whole poultry production chain, from farm to retail market. Infection of broiler flocks is transmitted via rodents and other vermin, faeces, contaminated feed or through the hatchery (Rosemary, 2009).

***Escherichia coli* (*E. coli*)**: Most *Escherichia coli* (*E. coli*) are non-pathogenic that live in the body as normal commensals in the intestinal tract of animals including chickens. Aside to the commensal *E. coli,* there are pathogenic ones which affect chicken and humans (Kaper *et al*. 2004). *E. coli* can be categorized on pathotypes using virulence factors and type of diseases they are causing (Yohannes *et al*. 2017). One of the pathotypes E. coli O157: H7 is a known Verocytotoxigenic (VTEC) pathotype with zoonotic importance and cause hemorrhagic colitis and hemolytic uremic syndrome (HUS) in humans (Oporto *et al*. 2008). This pathogenic *E. coli* is found in the gut of chicken (Yohannes *et al*., 2017).

The most common mode of transmission to human is by consuming contaminated food and water. However, it may also spread directly from person to person and occasionally through occupational exposure (Abdalla et al. 2009). The contamination of chicken carcass and other chicken products by E. coli O157:H7 can occur during slaughtering processing and manipulation. The contamination is mainly due to faecal matter and this faecal matter contaminates the carcass through direct deposition or through indirect contact using contaminated fomites, air and personnel (Pal, 2007). Therefore, the presence of pathogenic *E. coli* O157:H7 in meat can be an indicator of faecal contamination in the chicken carcass.

2.5 Factors Affecting Broiler Meat Quality and Safety

Factors contributing broiler meat quality and safety are derived from various determinants laid in the value chain that ranges from primary production of chicken at the farm through pre-slaughter handling, primary processing of chicken and meat handling.

2.5.1 *Primary production, meat quality and safety*

Management plays an important role in meat quality, particularly in consumption features (juiciness, tenderness, flavour). Stocking density is one of the most important management/husbandry practices in poultry production. High stocking density increases the proportion of downgraded carcasses. Standard feed withdrawal period prior to slaughter reduces stress with positive effects on slaughter yield and tenderness of meat (Bilgili, 2002).

Transportation, especially in combination with high environmental temperature, will increase the incidence of PSE. The most critical stress inducing stages in the slaughtering of poultry are unloading, shackling and stunning of birds. In order to improve and make this process less stressful, automatic on farm crating systems, automatic unloading of crates in the slaughter-house combined with controlled atmosphere stunning (CAS) instead of electrical stunning have been introduced (Nasir *et al*.,2017).

The birds subjected to heat stress prior to slaughter generally have higher body temperature and result in rapid pH decline and the onset of rigor in muscles. Such pre-slaughter conditions usually lead to pale, soft, and exudative (PSE) meat, which in turn results lower possessing yields, increased cooking losses, and reduced juiciness (Nasir *et al*., 2017). The PSE condition in poultry has been associated with factors such as stress, genetic strain, pre-slaughter handling, and processing practices. Any stress shortly before or at slaughter has been reported to cause PSE due to an increased rate of post-mortem metabolism, accelerated glycolysis, and pre-mature onset of rigor mortis.

Contamination of poultry by microorganisms during primary production is multifactorial (associated with various factors carried out in husbandry and management of birds). Good hygienic practices and good agricultural practices are necessary prerequisites for the management of pathogenic microorganism on-farm.

Several studies have been undertaken both in Australia and overseas looking at factors associated with increased risk of *Salmonella* carriage in chickens. Contamination of birds by *Salmonella* can usually be traced to one of three production factors such as contaminated feed, environmental sources, and/or vertical transmission from contaminated eggs (FSANZ, 2005).

The impact of *Salmonella* contamination of birds/flocks on the subsequent prevalence of *Salmonella*-positive carcasses at the end of processing is dependent on the stage of production that the contamination occurs. For example, if contamination is limited to a particular growing

farm then it is likely that farm will be affected (assuming adequate biosecurity controls) and that the problem may be eliminated by cleaning and sanitising after depopulation and harvest. If the contamination is at the hatchery stage, then a much larger number of farms could be affected due to the possibility of mixing of eggs from different farms and the movement of contaminated chicks from the hatchery to multiple growing farms (Bailey *et al*., 2002; Russell, 2005).

Apart from, some *salmonella* spp. which have the ability to be vertically transmitted to eggs via the reproductive tissue of infected hens, eggs may become contaminated by the pathogen via faeces, litter, nest boxes and equipment. For example, Bailey *et al*., (2002) investigated that there was no correlation between the *Salmonella* serovars isolated on breeder farms with those isolated from the hatchery. This implies that breeder stock one of the potential sources of microbial contamination. However, the same study found that there is an association between *Salmonella* serotypes isolated in the hatchery and those found on the final processed carcass. Hence, hatchery sanitation in minimising the transmission of Salmonella to growing flocks (FSANZ, 2005).

Contaminated poultry feed is considered the major avenue by which *Salmonella* spp.is introduced into poultry flocks. Animal by-products (blood, meat trimming and other animal by-products) may result in the finished mixed feed contaminated with pathogenic microorganisms. This, in turn, can result in live birds being infected, pathogens becoming endemic in the bird flock and the potential for the pathogen to be transmitted through the food chain to humans (Mead, 2004a). In the UK, *Salmonella* was isolated from feed mills at rates ranging from 1.1 to 41.7% (Davis and Way, 1997). Equipment in feed mills can become contaminated leading to a high prevalence in the final product. Contamination by rodents and birds is thought to be the main source of *Salmonella* in the feed. Contaminated feed was identified as the major source of contaminated flocks in a UK study of *Salmonella* carriage in chicken flocks presented for slaughter at two abattoirs (Davis and Way, 1997). The Codex (2002), also highlighted the persistence of *Salmonella* in sheds between flocks as an important source of contamination of subsequent flocks housed in that shed.

2.5.2 *Broiler chicken processing, meat quality and safety*

The contamination of poultry meat is very much dependent on the status of the birds prior to processing and hygienic operations during processing. If the birds are contaminated prior to slaughter, mostly not possible to process poultry without some level of microbial

contamination. The risks to public health occur especially during and after the slaughter of the broiler chicken due to unhygienic slaughter practices and poor post-slaughter handling; transportation and storage of meat (Rosemary, 2009).

Poultry processing which includes stunning, scalding, plucking/defeathering, chilling, freezing and cold storage. The diagrammatic presentation in (Figure 2) highlights stages in processing that have to be considered for understanding for the effects of bacterial contamination resulting from two main sources (i.e. the birds themselves and cross-contamination from other birds or the environment) during processing (FSANZ, 2005).

Stun and slaughter: Prior to stunning, birds can be contaminated with large numbers of *Salmonella* through cross-contamination during collection and transport. According to the study conducted by FAO/WHO (2002), the levels of *Salmonella* contamination were about 10^6 cfu/g on the outside of birds immediately after stunning.

Scalding: The primary purpose of scalding is to facilitate the removal of the feathers. Scalding temperatures differ for different poultry species depending on the difficulty in removing feathers. The recommend scalding water temperature is 53^0C. It also ranges 50 - 58^0C. High-temperature scalding processes will have a beneficial effect in reducing bacterial numbers, however, at high-temperature, there is a reduction in meat quality due to discoloration of the outside surface (skin) of the carcass (Fletcher, 2002; Mead, 2004b).

Salmonella spp. are washed from the external surfaces of the birds during scalding and they have been shown to survive in scald water at low temperature. Birds processed at low temperatures can, therefore, become contaminated. According to FAO/WHO (2002), scalding has little effect on *Salmonella* reduction. There are a number of interventions that can be applied to decrease the likelihood of contamination during scalding such as, the addition of as much fresh water as possible and having the scalding temperature as high as possible. The temperature of the scalding water and the dwell time in the scalding system and therefore its size will depend on whether carcasses are to be soft (50-51^0C for 2.5-3 min), medium or hard scalded (58-60^0C for 1.5-2 min) for sale fresh or frozen (Russell, 2002).

Generally, the scalding process cannot eliminate excessively high numbers of microorganisms entering the process, and the effect of scalding is very dependent on the method used since immersion scalding has been shown to increase the level of contamination in cases where the operating conditions are poor. This was probably caused by an accumulation of dirt and

faeces in the scalding water due to an inadequate flow of fresh water into the tank, making the scald tank a source of cross-contamination for subsequent carcasses (FAO/WHO (2002)

Defeathering: In larger processing facilities defeathering is carried out by machines that remove the loosened feathers from the carcass. Hand defeathering is rarely if ever practiced in chicken processing. Defeathering is considered to be a major source of cross-contamination. In mechanical defeathering microorganisms such as *Salmonella* spp. and *E. coli*. can become trapped in cracks and/or joins of the fingers and contaminate the carcasses of other birds (Keener *et al*., 2004).

Washing: Carcasses are washed after defeathering to help remove loose feathers and contamination, and after evisceration to remove visible signs of contamination. In general, removal of bacteria from carcasses will be difficult because bacteria may be trapped within the skin and feather follicles. Washing will remove some *Salmonella* from the carcass as demonstrated by the detection of *Salmonella* in the wash water. For immersion washing, carcasses cannot remain in the tank for more than 15 minutes, unless the temperature of the wash water is <4°C.

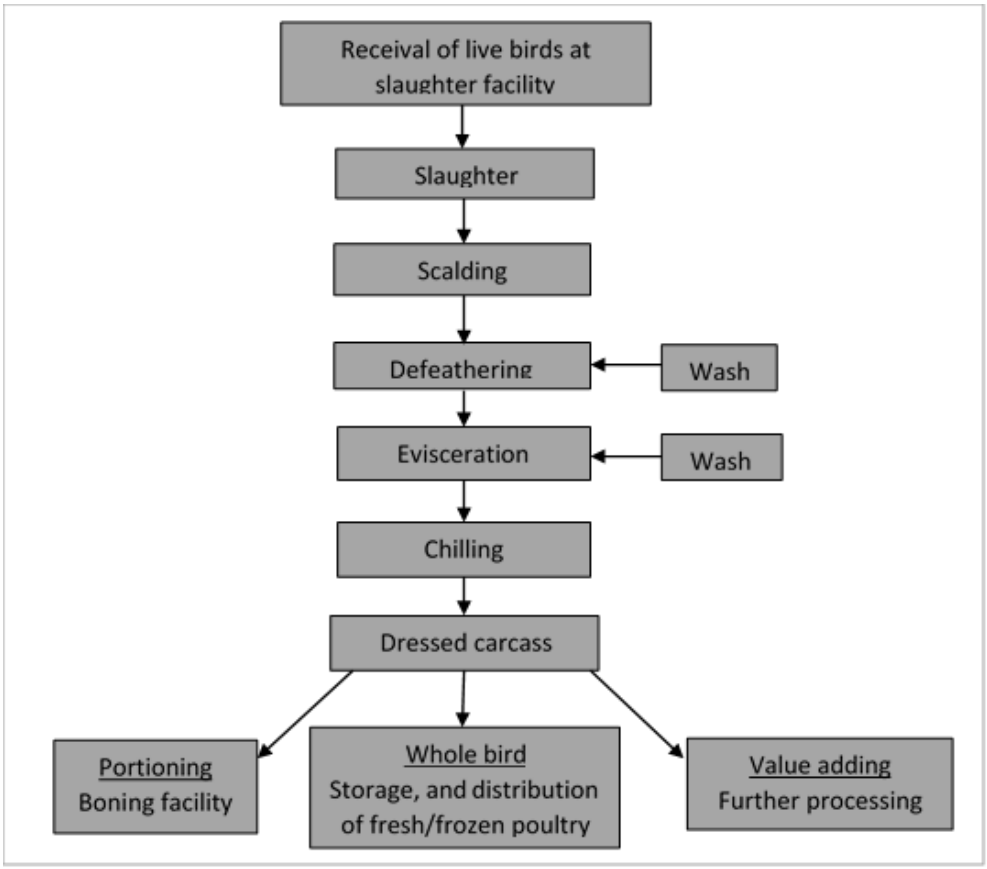


Figure 2. A flow diagram showing birds slaughtering and processing (adopted from FSANZ, 2005)

A study by Buhr *et al*. (2002) reported that reductions from the washing of 1.2-logs and 0.35-logs for carcasses where crops were removed intact and after rupturing, respectively. However, the efficacy of washing is dependent on other factors besides simply applying water to a carcass. It is also affected by the time taken to process the carcass. Attachment of *Salmonella* to the skin during processing may occur very rapidly, within 15 seconds, and can reduce the efficacy of washing. Besides, bacteria may also be protected via entrapment in feather follicles.

Evisceration: Evisceration is a process for removing the crop, gut and other internal organs. Some of these organs can be highly contaminated with pathogenic microorganisms. Most studies of the evisceration process show an increase in the prevalence of *Salmonella* after evisceration of between 2 to 5-fold, although one study in the US showed little effect of evisceration on the prevalence of *Salmonella* (FAO/WHO, 2002).

Feed withdrawal is critical in controlling the amount of intestinal spillage that occurs during evisceration. The time for off-feed ranges from 8 to 12 hours. Poorly controlled processes will result in considerable contamination of the carcass via rupture of the intestines. Besides, equipment used to eviscerate should be thoroughly cleaned and sanitised between shifts to minimise the build-up of contamination.

Chilling and freezing: Chilling of chicken meat with a temperature less than 4^0C is important to limit the growth of microorganisms. In the European Union, there is no legislation governing the time required to chill a poultry carcass, only a maximum final meat temperature of 4^0C before transport or cutting is defined, to be achieved 'as soon as possible'. However, regulations in the United States require carcasses to be chilled to 4.4^0C or lower in 4, 6, or 8 hours for carcasses weighing less than 4, 4-8, or over 8 pounds, respectively (FAO, 2012; Nasir, 2017). Methods for carcass chilling include air-chilling, water immersion and spray chilling. Due to the risk of cross-contamination in immersion chilling, European countries have generally moved to air chilling of carcasses, whereas in Australia and the US immersion chilling is common (FSANZ, 2005). Effective chilling can result in a reduction in bacterial numbers. The study conducted by Northcutt *et al*. (2003) chilling of carcasses resulted in a $\log_{10}$ reduction of 1.4 and 0.5 for *E. coli* and Salmonella respectively. Russell (2002) recommended the following parameter settings for the control of *Salmonella* contamination during spin chilling; water pH (6.5-7.5), temperature (<5ºC), flow rate (approximately 5 liters per bird). Flow direction (counter current) and chlorine concentration can all impact on chiller performance.

2.6 Biosecurity measures at Broiler Chicken Farms in Ethiopia

Effective reduction of microbial populations on poultry carcasses begins on the farm to which pathogen free broiler chicks are introduced. Besides, implementing strict biosecurity practices is highly important as broiler chicks can become infected and colonised with pathogenic microorganism through their environment (Brena *et al*., 2015).

Biosecurity involves using all measures possible to control the spread of disease-causing organisms. An all-in-all-out program followed by a rigorous cleaning and disinfection program is recommended. Rodent control, especially while the premises are empty, is very important to prevent recontamination of the environment by *Salmonella*-infected rodents after cleaning and disinfection (Davies and Wray, 1997; FAO, 212). The restricted movement of birds, people and equipment, combined with good sanitation, helps to control the spread of disease-causing micro-organisms, and possibly zoonotic pathogens. An important element in disease prevention is to avoid contact between poultry and migratory waterfowl and to ensure that small birds cannot gain access to the poultry house (Keener *et al*., 2004).

In Ethiopia, there are limited incentives within the chain to implement biosafety measures. Existing biosecurity measures are largely controlled and exercised depending on the whims of each firm which may result in differential levels of risk. It is not mandatory for commercial farms to exercise any type of biosecurity measures legislated by public authorities. Biosecurity measures are particularly absent among small-scale producers (Gezahegn and Karl, 2010). Producers vaccinate their chicken against common poultry diseases such as Marek's, Infectious bursal disease (IBD), Newcastle disease, fowl typhoid and fowl pox. Despite the fact that there is no vaccination program against *salmonella* and *Escherichia coli* (NABC, 2012). Besides, most of the commercial chicken farms are located in residential areas were difficult to implement strict biosecurity (Alemayehu, 2015).

The waste management and disposal methods of small and medium scale commercial farms are poor. The study conducted by Alemayehu (2015) at Bishoftu town commercial chicken producers show that about 20 (28.5%) of the households were disposed slaughter by-products on roadsides and public spaces adjacent to their farm and 13 (18.6%) were also dispose of dead chicken through the same way.

2.7 Broiler Meat Quality and Safety in Ethiopia

In Ethiopia, studies reported that there is a prevalence of various public health pathogenic microorganism in livestock meat among which *salmonella* and *E. coli* are the most prevalent. The risk factors for the prevalence of these pathogenic microorganisms' ranges from the farm where chicken is raised to hygiene at processing plants and meat handling at retail shops (Dadi and Asrat, 2008; Brena *et al*., 2015; Duguma *et al*., 2017).

2.7.1 *Salmonella at chicken farms*

A survey was conducted to know *Salmonella* infection among chicken flocks in Jimma town. A total of 384 faecal samples collected from 232 exotic chicken flocks which were kept indoor and 152 local chicken flocks which were free ranging. The identification result proved the overall prevalence of *Salmonella* was 41.9% (Kindu and Addis, 2013). According to the study by Duguma *et al*. (2017) out of 270 samples collected from bedding, personnel hand swabs and chicken cloaca, at Bonga and Hawasa poultry multiplication centers of South Ethiopia, about 45 (16.7%) *Salmonella* isolates were identified. The prevalence on the basis of sample type was higher in the bedding (35.3%) and personnel hand swabs (33.3%) than in the chicken cloaca (14.8%), which demonstrates the poor biosecurity and personal hygienic practices in the centers. The other study by Aragaet *et al*. (2010) out of 380 chicken samples randomly selected from 3 commercial poultry farms to estimate the prevalence *Salmonella* at Hawassa, the infection of *Salmonella Gallium* or *Pullorum* was 0.8%. Tadesse (2018), also reported 4.7% of *Salmonella* prevalence in poultry farms in central Ethiopia (Ada'a, Addis Ababa, Barake and Sebeta). From a total of 205 samples in which 100 cloacal swabs, 75 fresh faeces, 10 litter samples, 8 chicken feed samples, 8 poultry drinking water and 4 chicken handlers' hand swab samples in and around Modjo town about 31(15.12%) isolates were detected (Abunna *et al*., 2017).

2.7.2 *Salmonella in chicken meat*

Salmonella: Of the total 378 samples examined from poultry processing plants and retail markets at Debre Zeit and Addis Ababa, Ethiopia, *Salmonella* was detected in 80 (21.1%) of the samples analysed. Among the samples examined high proportion of chicken meat (15.4%), liver (34.5%), gizzard (41.1%), heart (23.7%) and skin (7.7%) were contaminated with Salmonella. The same study confirmed that the prevalence of *Salmonella* infection among exotic chicken flocks was 44.2% (Molla and Mesfin, 2013).

2.7.3 *E. coli at chicken farms*

In the country, *Escherichia coli* is prevalent in chicken farms. According to the study conducted by Shecho *et al*. (2017), out of 194 cloacae samples examined,13.4% were found to be positive for *E. coli* O157: H7. The finding indicated differences in *E. coli* O157: H7 infection among the different risk factors. Chicken from Adele Poultry Farm showed higher *E. coli* O157: H7 infection than Haramaya University poultry farm and young birds had more infection than adult birds.

2.7.4 *E. coli in livestock meat*

According to the study conducted by Bekele *et al.* (2014) on the prevalence *Escherichia coli* O157: H7 in Addis Ababa Abattoirs and retailers, out of 384 meat samples examined, 10.2% (39/384) were positive to *E. coli* O157: H7. Among these samples examined, beef was the most frequently contaminated with *E. coli* O157: H7 with an overall prevalence of 13.3 followed by 9.4 sheep meat and 7.8% goat meat. With regard to the meat source, the prevalence rates of *E. coli* O157: H7 at the abattoir and the selected retail shops were 5.7 and 14.6, respectively. Similarly, Beyi *et al.* (2017) in their study at beef butcher shops and restaurants in central Ethiopia, 4.5% carcass swabs and 3.6% cutting board swab samples were positive for *E. coli* O157.

2.8 Broiler Chicken Processing Facility in Ethiopia

In Ethiopia, there are only three privately owned (ELFORA, Alema and Passion) poultry abattoirs which are located in and around Bishoftu town (NABC, 2012). According to Gezahegn and Karel (2010), there are three important issues pertaining to processing in the broiler sector. These are, first, processing facility requires a substantial investment which is not affordable small-scale farmers. Second, some farms lack sufficient workspace where slaughter can be undertaken since it requires its own separate and unique infrastructure. Third, almost all poultry farms (including those in the cities and towns) have very poor drainage and waste management systems, which is a critical pre-condition for setting up such processing facility.

The limitedness slaughtering facility results to small and medium scale farmers spend a substantial amount of money (7-10 ETB/bird), to get professional slaughtering service which contributes to increasing the costs of production (Gezahegn and Karel, 2010). Apart from this, the lack of institutionalized formal poultry abattoir results in multifaced challenges in one or

other way that contributes to food quality and safety risk. The involvement of veterinary experts to inspect the health status of birds and monitor the overall safety of the slaughtering process is limited. Although it is mandatory that slaughterers taking a medical examination, the practicability is very rear (Gezahegn and Karel, 2010).

Small and medium scale commercial broiler chicken producers slaughter their birds in open spaces within the rearing farm compound using local equipment. They process their chicken on a floor covered with a plastic mat. The method of washing is too unhygienic through the water used in meat processing is entirely pipe water (Alemayehu, 2015). The method of washing a carcass is immersion washing where water stored in a container may use to wash a number of chicken carcasses one after the other. The use of stagnant rather than running water for carcass rinsing is a potential cause of the microbial build up that leads to cross-contamination of all subsequent carcasses (Gezahegn and Karl, 2010).

3. MATERIALS AND METHODS

The materials employed and the methods followed in selecting study locations and households, collecting data and laboratory samples, laboratory analysis and data analysis, during the implementation of the study period are presented in the following sub-sections.

3.1 Description of the Study Areas

The study was conducted at Bishoftu and in Addis Ababa. Bishoftu was considered to collect information related to broiler chicken production and processing, whereas Addis Ababa was considered to collect information related to broiler meat handling at the retail market.

Bishoftu town is a home of many governmental organizations which provide different services that help to enhance commercial chicken production. Among which, Debre Zeit Agricultural Research Center, AAU-College of Veterinary Medicine and Agriculture, National Veterinary Institute (NVI), Ethiopian Meat and Dairy Industry Development Institute (EMDIDI), and Ethiopian Poultry Producers and Processors Association (EPPPA) are located in the area. Besides, integrated big poultry farms such as Elfora, Alema, Genesis, and Elere farms serve as input supplier for commercial chicken businesses that are also located in the area (Alemu and Tadelle, 1997; NABC, 2012).

Addis Ababa is a capital City of the country and a residential area for the local and international organization. There are supermarkets supplying consumable items including broiler meat for hotels, restaurants and catering services providers located in the city. As a

result of facilitated road infrastructure and geographic vicinity, Addis Ababa City is a market destiny for poultry products produced from the Bishoftu area (Gezahegn and Karl, 2010; NABC, 2015).

3.2 Research Design

The research design for this study was cross-sectional study design; take a one-time snapshot approach of data collection. The population from which samples were selected for the purpose of this study were small and medium scale broiler chicken producers and processors, and broiler meat retail markets. To determine the physicochemical quality of meat such as pH, color, water holding capacity, tenderness and chemical composition and microbial quality (*Salmonella* and *Escherichia coli),* laboratory analysis was conducted. While to assess the broiler farm biosecurity, broiler processing and meat handling practices, analysis of survey and observation data is applied.

3.3 Sampling Method

Poultry production is a spontaneous activity practiced formally in areas specified by the town administration and informally at residential areas in homesteads sharing with people (Gezahegn and Karl, 2010). Besides, the majority of poultry rearing households are informal (practicing without trade license) which makes difficult to access their list from the office of Urban Agriculture and Ethiopian Poultry Producers and Processors Association (EPPPA).

Sampling of broiler rearing and processing farms: In consultation with the Office of Urban Agriculture and EPPPA, three specific locations such as Kajima, Genesis and Babogaya areas were selected using purposive sampling method based on their production potential. To select study households (both broiler rearers and backyard broiler processors), the snowball sampling method was applied. Snowball sampling is a method where existing subjects are asked to refer further subjects known to them and is applied when a sampling frame is difficult to identify (Lewis-Beck *et al*., 2003). From every location nine broiler producers and nine backyard broiler processing households, a total of 27 producers and 27 processors were selected, and survey and observation data were collected. With regard to microbial and physicochemical data from every location 4 farms a total of 12 farms, were selected using a simple random sampling method.

Retail market sampling: The major retail market areas in Adds Ababa were clustered into the three groups as follows: 1) Lebu, Mebrat Hail, Jemo and Bisrate Gebrel areas 2) Meskel Square, Arat Killo and Piaza areas 3) and Megenagana Round About, Gurd Sholla and CMC

areas. From each cluster 9, a total of 27 supermarkets were purposely selected and survey and observation data were collected on meat handling practices and hygiene of meat handlers. Among the supermarkets from which survey data were collected, a total of eight, that is two supermarkets from the first cluster and 3 supermarkets from each of the second and the third clusters were purposely selected based on the high keeping ability of chicken meat in display or storage freezer. Then from each retail market three, a total of 24 carcasses; either cooled or frozen and whole or part was purchased based on availability.

3.4 Methods of Data Collection

The survey questionnaire and observation checklists were developed and both quantitative and qualitative data were collected from broiler chicken rearing households, backyard processors and retail markets.

3.4.1 *Survey and observation*

For the purpose of this study, questionnaire (semi-structured questionnaire) and observation checklist were prepared and relevant data were collected through interviewing poultry farmer and at the same time observing the real situation at broiler rearing farms, backyard slaughtering sites and retail markets.

To evaluate the carcass damage at backyard slaughtering sites, from every slaughtering site selected for the study 40, a total of 480 carcasses were randomly picked and scored against the parameters such as bone breakages, bruising, blood engorged in vein and blood spot. At the same time, interview and observation were done what are the causes of the damage happened.

3.4.2 *Laboratory sample collection*

Faeces and carcass swab: From every broiler rearing farm, a total of 120 faeces (10 faeces sample/farm) were collected using systematic random sampling (equal amount of faecal sample from every batch of evisceration done the same day at the same slaughtering site) from the caecum of slaughtered birds. Similarly, from the slaughtering site, a total of 60 carcass swabs (5 swab sample per slaughtering site) were also collected after evisceration and inside-outside wash of the carcasses following the same method. The samples were kept and transported using a cool box with an ice bag and stored in a refrigerator at 4^0C for about 8-10 hours until submitted to the laboratory for bacteriology analysis. With regard to sample at the retail market, from every retail market considered in the study, 3 whole or parts (breast)

frozen carcass was purchased and transported to the laboratory using a cool box with an ice bag. The frozen carcasses were stored in the refrigerator at 4^0C for 12 hours to get thawed and a swab sample was collected.

Both faecal and carcass swab sample collections were done according to the WHO (2007) protocol using a clean pair of latex gloves, and the samples were put in a sterilized universal sample bottle which is labelled with relevant information stating sampling place, date and purpose of the analysis and was submitted to the National Veterinary Institute (NVI) microbiology laboratory for microbial analysis.

Meat sample: A total of 72 carcasses collected from both backyard slaughter site and retail market that is 48 carcasses (4 carcass from every 12 slaughtering sites) and 24 carcasses (3 carcasses per retail markets) were randomly selected and purchased. The fresh carcass from backyard slaughtering site was portioned into parts and chilled for 24 hours at a temperature of 4^0C to let the meat finish rigor mortis and prevent microbial contamination. Similarly, the frozen carcasses were purchased from retail markets and thawed in the refrigerator at 4^0C were also portioned and assigned for both physical and nutritional analysis considered in the study.

The parts of the carcass assigned for chemical analysis such as breast fillets (half), drumstick and thigh muscles were stored in a deep freezer at a temperature of - 20^0C until the analysis is conducted. The other half of the breast fillet was assigned for color, pH and drip loss measurement.

3.5 Laboratory Analysis

3.5.1 *pH*

Ultimate pH (pH_{24h}) were measured using a portable meat pH-meter (HI99163, HANNA instruments, UK) having a sharp penetrating blade over the electrode, and calibrated with pH 4.1 and 7.1 buffer solutions. The procedure was done according to the manufacturers' instruction. The probe was cleaned with distilled water between each measurement and three reading at different locations per sample were taken and averaged.

3.5.2 *Color*

For the color measurement, the internal face of the cranial position of the filleted breast meat samples was freshly exposed on the flat surface of white background in the measuring room

and allowed to bloom for about 30 to 45 minutes at ambient temperature. Then, meat color parameters [CIE values, lightness (L*), redness (a*) and yellowness (b*)] were obtained using a digital colorimeter (Hunter Lab MiniScan EZ, Washington, DC, USA) calibrated with black and white standardized plates between each measurement (Hunt et al., 2012) and three readings at different locations per sample were taken and averaged.

Different scholars have suggested that lightness (L*) values could be used as an indicator of poultry breast meat quality for further processing and for evaluating the incidence of pale and dark condition in poultry (Qiao et al., 2001; Woelfel and Sams, 2001; Barbut, 2009; Soares *et al*., 2009; Kralik *et al*., 2018). However, there are a slight variation with reference to the L* values to discriminate the color groups as dark, normal and pale. For the purpose of this study, the limit values established by Soares *et al*. (2009) were adopted and the breast fillet meat was classified into three color groups as follows: dark ($L^* \leq 44$), normal ($44 < L^* < 53$) and pale ($L^* \geq 53$).

3.5.3 *Water holding capacity (WHC)*

The drip loss of the breast meat sample from the processing farms and the retail markets was measured using a plastic drip method according to the procedure of Honikel (2009). From 25 - 35 gram of meat sample was excised and cut perpendicular to the fiber direction in the widest part of breast muscle. The samples were hanged in an inflated plastic bag and stored in the refrigerator at 4^{o}c for 24 hours and reweighed. The drip loss (%) was calculated as [100 × (Initial sample weight ‒ final sample weight/initial sample weight)].

3.5.4 *Tenderness*

For the meat tenderness analysis, the frozen breast fillets were transported to Jimma University College of Agriculture and Veterinary Medicine, post-harvest management laboratory using a cool box with an ice bag. The samples were thawed in the refrigerator at a temperature of 4^{0}C for 12 hours then packed with a plastic bag and cooked in a water bath until reaching an internal temperature of 75^{0}C. Then the sample was taken out from the cooker, cooled with ice for 30 minutes, and strips of meat were cut parallel to muscle fibers at 10 mm x 10 mm width and thickness (100 m^2) having 30 mm length. A texture analyser (Stable Micro System, TA-XT Plus, U.S.A.) was calibrated at 62 mm distance, 2 kg load cell, and 2.0 mm/s and 10.0 mm/s pre-test speed and post-test speed, respectively. From every sample, 3-4 measurements were sheared with the Warner Brazler shear blade (WB-blade) and averaged result was recorded.

3.5.5 *Meat chemical composition*

The meat samples for proximate analysis were kept frozen until the analysis is conducted. The frozen samples of broiler breast, thigh and drumstick meat cuts were separately dried, minced and homogenized and analysed for moisture, crude protein, fat ash and fiber following Association of Official Analytical Chemist methodology (AOAC, 2010) (See Appendix 2).

3.5.6 *Microbiological Test*

Isolation of salmonella

The isolation of Salmonella was done according to the technique recommended by the International Organization for Standardization (ISO-6579, 2002). Detection of Salmonella requires four successive stages: pre-enrichment in non-selective liquid media, enrichment in selective liquid media, selective plating on selective solid agar presumptive suspected isolates were identified and confirmed through screening against 4 biochemical tests (WHO, 2010).

Pre-enrichment in non-selective liquid media:1gram of faeces (1:10ml ratio BPW) were transferred to a sterile stomacher bag and mixed with buffered peptone water (BPW) (OXOID, Basingstoke, England) in 1:9 ratios. The mixture was homogenized using a laboratory stomacher (Thermo Scientific, USA) at high speed for 2 minutes and was directly incubated aerobically at 37^0C for 18-24hrs. Besides, the meat swab was taken in non-selective pre-enrichment liquid media, then transferred to a selective media; Rappaport vassilidis medium.

Enrichment in selective liquid media: 0.1ml of the incubated samples in pre-enrichment in non-selective liquid media were inoculated in Rappaport Vassiliadis medium (HIMEDIA, Mumbai, India) and incubated at 41.5^0C for 24-48 hrs. to finally confirm the sample was negative for *Salmonella* species. The blue media color will change to greyish white.

Plating out and identification: This procedure was done on xylose lysine desoxycholate (XLD) agar (HIMEDIA, Mumbai, India, 2002). A loop full culture which was enriched by a selective media were streaked onto plating out media. Then plates were incubated aerobically at 37^0C for 24 hrs. Then the selected colonies were transferred to Nutrient agar (HIMEDIA, Mumbai, India) in which they are let to develop and incubated at 37^0C for 24 hrs. for further confirmation on the biochemical test.

Biochemical confirmation: Colonies were further tested by Triple Sugar Iron (TSI) agar slants (HIMEDIA, Mumbai, India), Simmons citrate utilization test (HIMEDIA, Mumbai, India),

indole test (HIMEDIA, Mumbai, India), Methyl red - Voges-Proskauer (HIMEDIA, Mumbai, India) were conducted accordingly Quinn *et al.* (2002).

Isolation of E. coli

Isolation and identification of E. coli were performed by standard bacteriological methods. All the samples were cultured primarily in at 37ºc for 18-24 hrs. on Tryptone soya broth Samples were inoculated on Mac Conkey agar (HIMEDIA, Mumbai, India) which is a selective and differential medium for *E. coli*. A pink colony was picked and subcultured on Eosin Methylene Blue (EMB) agar (HIMEDIA, Mumbai, India) to obtain pure colony with a characteristic of metallic green sheen on EMB.

Biochemical confirmation: After isolation of the organism on the selective media and differential screening, the isolates were subjected to different biochemical tests according to (Quinn *et al.*, 2002) such as Triple sugar iron test (TSI) (HIMEDIA, Mumbai, India) and Indole production test (HIMEDIA, Mumbai, India), methyl red- Voges-Proskauer (HIMEDIA, Mumbai, India) and citrate utilization (HIMEDIA, Mumbai, India) test (Islam *et al.*, 2014).

3.6 Method of Data Analysis

The survey data and observation information collected from rearing farms, backyard slaughtered sites and retail markets were entered into SPSS software package version 20, and descriptive statistics such as frequency and percentage were computed followed the narration of the observation noted. With regard to microbiological laboratory data, percentage and frequency were computed and Pearson's Chi-square (χ 2) was used to determine the extent of *Salmonella* spp. and *Escherichia coli* contamination among broiler value chain components. The physical and nutritional broiler meat qualities, particularly the chilled meat, the one-way ANOVA and correlation analysis were performed on SAS, version 9.4 [Statistical Analysis Systems (SAS) Institute Inc., Cary, NC, USA)] software and statistical significance value were considered when $P< 0.001$and $P<0.001$.

4. RESULTS

4.1 Biosecurity Practices at Broiler Poultry Farms

Biosecurity practices were grouped into three categories following the results of survey work and observation information as 1) Isolation, 2) Hygiene, 3) Flock health care.

4.1.1 *Isolation practices*

The results of the present study (Table 1) showed that commercial broiler poultry keeping households did not implement the required isolation practices strictly. The majority of the farms had a fenced farm compound, separate living room for farm workers and implement all-in-all out practices. But, they located in inappropriate areas and did not have a separate room for feed storage and isolating sick birds.

Table 1. Measures to control movement in the broiler chicken farms in Bishoftu

Variables	Responses	Frequency and percentage
Farm location	At areas specified for the activity	6 (22.2)
	At residential areas and share with a residential compound	4 (14.8)
	At residential areas but in a separate compound	17 (63.0)
A fenced farm compound	Yes	24 (88.9)
	No	3(11.1)
A sign of restricting entrance into the farm	Yes	7 (25.9)
	No	20 (74.10)
Do not share equipment between poultry farms	Yes	23 (85.2)
	No	4 (14.8)
Separate living room for workers	Yes	27 (100)
	No	0 (0.0)
Separate room for feed storage	Yes	13 (48.1)
	No	14 (51.9)
Apply all-in all-out	Yes	22 (81.5)
	No	5 (18.5)
Isolation pen for sick birds	Yes	3 (11.1)
	No	24 (88.9)
The distance from other poultry farms (≥ 500 meters)	Yes	9 (33.3)
	No	18 (66.6)

4.1.2 *Hygiene and sanitation practices*

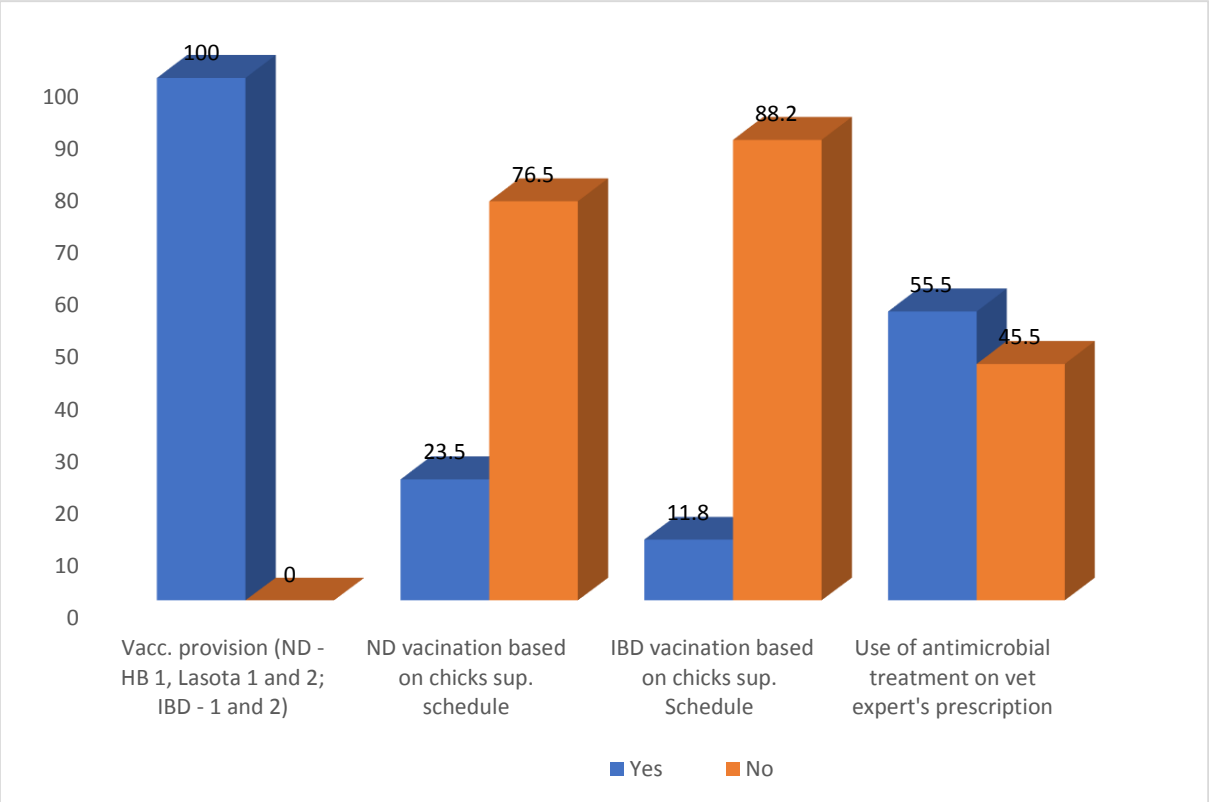
Hygiene and sanitation practices included pest management, disinfection, and dead bird disposal practices and all broiler farms (100%) practice cleaning and disinfection of poultry houses between successive batches of chicken and cleaning and disinfection of watering and feeding troughs. But these farmers do not put in place the other important hygiene practices such as footbath, tire bath, hand washing detergent, rodent and wild bird proof, appropriate dead bird disposal method, and dry and appropriate bedding (Table 2).

Table 2. Hygiene and sanitation practices in the broiler farms

Variables	Responses	Frequency and percentage
Source of water	Tap-water	19 (70.4)
	Deep-well	8 (29.6)
Foot bath	Yes	14 (51.9)
	No	13 (48.1)
Tire bath	Yes	12 (44.4)
	No	15 (55.6)
Hand washing detergent	Yes	8 (29.6)
	No	19 (70.4)
Bathroom for workers and visitors	Yes	17 (63.0)
	No	10 (37.0)
Overall and boats	Yes	18 (66.7)
	No	9 (33.3)
Wild birds' access to the chicken house	Yes	18 (66.7)
	No	9 (33.3)
Rodents access to the chicken house	Yes	12 (44.4)
	No	15 (55.6)
Cleaning and disinfection of poultry house between successive batches of chicken	Yes	27 (100)
	No	0 (0.0)
Cleaning and disinfection of feeding trough	Yes	27 (100)
	No	0 (0.0)
Cleaning and disinfection of watering trough	Every day	27 (100)
	Every other day	0 (0.0)
	Weekly	0 (0.0)
Dry and appropriate bedding	Yes	10 (37.1)
	No	17 (62.9)
Dead birds' disposal	Burned and buried	14 (51.0)
	Put in the rubbish pile	6 (22.2)
	Throw away on open space and roadside	4 (14.8)
	Give to pet animals	3 (11.1)

4.1.3 *Flock health care practices*

The flock health care practices implemented by broiler rearing farmers in the present study were vaccination and treatment (Figure 3). All broiler chicken keepers (100%) provide Newcastle disease (HB - 1, Lasota - 1 and 2) and Infectious bursal disease vaccination (IBD - 1 and 2) vaccination for their chicken. But do not follow the vaccination schedule provided by chick suppliers. Almost half of the broiler rearing households report that they providing antimicrobial treatment without the prescription of veterinary experts.



ND = Newcastle disease and IBD = Infectious bursal disease

Figure 3. The vaccination and disease treatment practice of chicken rearing households

4.1.4 *The incidence of disease and mortality of chicken*

Majority 17 (63%) of the broiler rearing respondents in this study reported that there was disease incidence in their farm. With regard to mortality, about 7 (36.8%) of respondents reported that five and less percent of chicken death whereas the rest 12 (63.2%) reported 6 - 15% of chicken death (Figure 4).

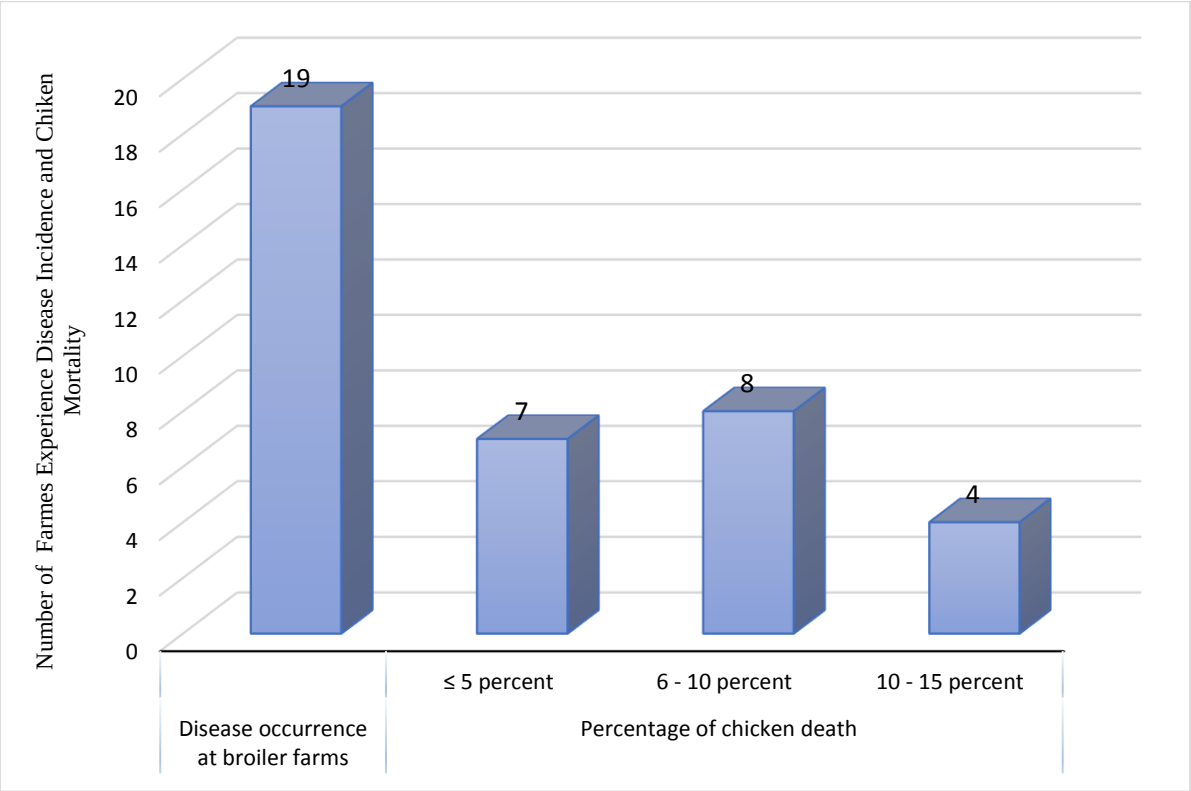


Figure 4. The incidence of disease and chicken mortality at broiler farms

4.2 Broiler Processing at the Backyard Slaughtering Sites

4.2.1 *Broiler processing practices*

The basic procedures in the processing of chicken meat in the present study are presented in Table 3. As the results revealed that all backyard broiler slaughtering sites (100%) were practiced the required procedures prior to slaughtering like feed withdrawal, anti-mortem and post-mortem inspection, stunning, proper killing (by severing the jugular vein) and proper bleeding. Besides, all the procedures are operated manually, hand defeathering and immersion carcass washing using non-flow water in a tank. Furthermore, the processors do not wash the carcass immediately after defeathering and chill the carcass which is a relevant step to decrease the temperature of the carcass which helps to hinder the microbial multiplication.

Table 3.Broiler processing practices at backyard slaughtering sites in Bishoftu

Variables	Responses	Frequency	Percent
Age of the chicken slaughtered	< 45 days	5	18.5
	45 - 55 days	22	81.5
Feed withdrawal (8 -12 hours)	Yes	0	0.0
	No	27	100
Anti-mortem inspection	Yes	0	0.0
	No	27	100
Post-mortem inspection	Yes	0	0.0
	No	27	100
Stunning	Yes	0	0.0
	No	27	100
Methods of killing	By cutting the neck	27	100
	By severing the jugular vein	0	0.0
Proper bleeding[a]	Yes	0	0.0
	No	27	100
Do you change scalding water in between the process	Yes	0	0.0
	No	27	100
Methods of defeathering	Mechanically (plucking machine)	0	0.0
	Manually (hand defeathering)	27	100
Washing of carcasses immediately after defeathering	Yes	0	0.0
	No	27	100
Methods evisceration	Manually using hand	27	100
	Mechanically by machine	0	0.0
Methods of carcass washing after evisceration	Immersion washing using non-flow water in a tank	27	100
	Immersion washing using flow water	0	0.0
Carcass chilling[b]	Yes	0	0.0
	No	27	100

[a]: Bleeding using a cutting cone for about 2- 3 minutes (CAC/GL 78-2011); [b]: Reducing the temperature of the carcass up to 4^0C using a refrigerator in the chiller room [ESA (ES 2790:2006. Rev. 2011)]

4.2.2 *Hygiene of the processing area and processing line*

The result of the present study indicates that the slaughtering process is carried out at open space in the same compound where the chicken was raised. Besides, all processing activities such as bleeding, evisceration to washing and packing of the carcass were carried out unhygienically in the same place. There was no separate place for each processing activity which helps to minimize the contamination of carcass with dirty matters (Table 4).

Table 4. The hygiene status of the broiler processing area and processing line

Variables	Responses	Frequency and percent
Separate processing area	Yes	0 (0.0)
	No	27 (100)
Clean processing area	Yes	18 (66.6)
	No	9 (33.3)
Disinfected processing area	Yes	5 (18.5)
	No	22 (81.5)
Domestic animals (dogs and cats) at the processing area	Yes	22 (81.5)
	No	5 (18.5)
Slaughtering/processing line	All process is carried out at the same place	27 (100)
	A clearly defined area for every activity	0 (0.0)
Slaughter waste disposal method	Dump at the town waste dumping area	16 (59.3)
	Dump at the nearby free area around the slaughtering site	11 (40.7)

4.2.3 *Hygiene of service utensils*

The hygiene practice of service utensils used in broiler processing such as cutting knives, plastic mat, scalding and carcass washing tanks are not in a proper hygiene status (Table 5).

Table 5. The hygiene of service utensils employed in broiler processing

Service utensils	Variables	Yes	No
Cutting knives	Clean, stainless steel and free from corrosion	23 (85.2)	4 (14.8)
	Disinfected	11 (40.7)	16 (59.3)
Plastic mat	Clean and new/not worn-out	25 (92.6)	2 (7.4)
	Disinfected	6 (22.2)	21 (77.8)
Scalding tank	Clean, and free from corrosion	10 (37.0)	17 (63.0)
	Disinfected	0 (0.0)	27 (100)
Washing tank	Cleaned and free from corrosion	27 (100)	0 (0.0)
	Disinfected	15 (55.6)	12 (44.4)

4.2.4 *Hygiene of the slaughterers*

The hygiene measures carried out by slaughter persons are presented in (Table 6). The result depicts that the slaughter persons do not practice most of the hygiene requirements contribute to ensuring the quality and safety of broiler meat.

Table 6. Hygiene measures by broilers slaughterer persons'

Variables		Yes	No
Cloth	Overall	2 (7.4)	25 (92.6)
	Head gears	0 (0.0)	27 (100)
	Aprons	1 (3.7)	26 (96.3)
	Hand gloves	0 (0.0)	27 (100)
	Plastic boot	5 (18.6)	22 (81.5)
	Mouse mask	3 (11.1)	24 (88.9)
Wash hands after touching or in contact with waste and garbage		6 (22.2)	21 (77.8)
Being free from any wounds, bruises or injuries on their hand		18 (66.7)	9 (33.3)
Health certificate for being free from any communicable disease		0 (0.0)	27 (100)

4.2.5 *Carcass damage*

The present study shows that Carcass damage was observed at the backyard slaughtering sites. It was also noted and processors set out that the possible reasons the damages (Table 7).

Table 7. The occurrence of carcass damage at backyard slaughtering sites and its possible causes (number of carcasses checked = 480)

Types of carcass damage	Occurrence of the cases (No. and %)	Possible Causes
Bone breakage	139 (29.0)	Inappropriate transportation of chicken from the rearing farm to slaughtering area (Appendix 1: Fig. C)
Bruising	45 (9.4)	Inappropriate slaughtering, not using appropriate bleeding cone (Appendix 1: Fig. F)
Engorged or haemorrhage wing veins	55 (11.5)	Improper processing, lack of care of slaughterers while pulling out the viscera
Blood spot	33 (7.00)	Improper management during rearing (damage occurred during the rearing period)

4.3 Broiler meat Receiving and Handling Practices at the Retail Markets

4.3.1 *The source of broiler meat for retail markets*

The result of the study revealed that the sources of broiler meat for retail markets in Addis Ababa were local production (both poultry abattoirs and backyard slaughtering sites) and import from other countries (Table 8).

Table 8. The source of broiler meat for retail markets in Addis Ababa

Source of meat		Response		Percentage of cases*
		N	Percent	
Locally produced	Poultry abattoirs	13	26.5	48.1
	Backyard slaughter sites	27	55.1	100.0
Imported		9	18.4	33.3
Total		49	100.0	181.5

* Multiple response variables. Most respondents at the retail market (N=27) answered more than one times for the questions presented

4.3.2 *Controlling the quality and safety of the broiler meat received from the suppliers*

The report also showed that the majority of the retail markets did not check the quality and safety of the meat against the required parameters while receiving the meat from suppliers. However, they reported that they check the meat cleanness, packaging quality and freshness (Table 9).

Table 9. Types of information that retail markets in Addis Ababa recorded on the broiler meat receiving from suppliers

Information recorded at a time of broiler meat receiving	Yes	No
Cold chain (means of transportation)	8 (29.6)	19 (70.4)
Temperature (< 4^0C)	0 (0.0)	27 (100)
Bone breakage	6 (22.2)	20 (77.8)
Bruising	0 (0.0)	27 (100)
Engorged or haemorrhage wing veins	2 (7.4)	25 (92.6)
Blood spot	8 (29.6)	19 (70.4)
Skin color	11 (40.7)	16 (59.3)
Cleanness	15 (55.6)	12 (44.4)
Freshness	23 (85.2)	4 (14.8)
Packaging (bag thickness and not being tired out)	18 (66.7)	9 (33.3)

4.3.3 *The practice of meat handling and storage*

Retail market respondents report that they were implementing most of the required meat handling and storage practices (Table 10).

Table 10. Meat handling practices at the retail markets in Addis Ababa

Meat handling practices	Responses	Frequency and percentage
Keeping broiler meat in a separate display/storage freezer	Yes	18 (66.7)
	No	9 (33.3)
First-in-first-out	Yes	24 (88.9)
	No	3 (11.1)
Storage or display temperature	$\leq$ -18^{0}C	17 (63.0
	$\geq$ -18^{0}C	10 (37.0))
Cleaning of a freezer between a batch of meat stored	Yes	20 (74.1)
	No	7 (25.9)
Duration of storage for a batch of broiler meat	1 - 10 days	12 (44.4)
	10 - 20 days	12 (44.4)
	20 - 30 days	3 (11.1)

4.3.4 *Hygiene of meat handlers*

Although meat handlers do not wear all the required clothing, it was noted that they wear some clothing such as gown and hairnet. Besides, they also reported that they are a holder of health certificate from the concerning organization to work on food items (Table 11).

Table 11. Clothing and hand washing practices, and health of the meat handlers

Category	Subcategory	Responses (N, %)	
		Yes	No
Clothing	Apron/gown	22 (81.5)	5 (18.5)
	Hairnet/cape	14 (51.9)	13 (48.1)
	Gloves	10 (37.0)	17 (62.9)
	Mask	3 (11.1)	24 (89.9)
	Wearing of appropriate clean gown*	9 (40.9)	13 (59.1)
Hygiene & health of meat handlers	Availability of hand washing tap at meat handling area	9 (33.3)	18 (66.6)
	Always wash hands before and during meat handing	11 (40.7)	16 (59.3)
	Having health certificate	19 (70.4)	8 (29.6)

* Calculated on the basis of the retail markets where meat handlers wearing apron/gown

4.4 The Level of Bacterial Contamination of Broiler Chicken Farms, Backyard Slaughtering Sites and Retail Markets

The extent of contamination of broiler farms, backyard slaughtering sites and retail markets by *Salmonella* spp. is presented (Table 12).

Table 12. The status of *Salmonella* spp. infection along the broiler chicken value chain

Sample Type	Examined (No.)	Positive (No., %) *Salmonella* spp.	$\chi 2$	P value
Faeces (broiler chicken farms)	120	17 (14.2)		
Carcass swab from slaughtering sites	60	9 (15.0)	40.494	0.000
Carcass swab from retail markets	24	17 (70.8)		
Total	204	43 (21.1)		

The extent of contamination of broiler farms, backyard slaughtering sites and retail markets by *Escherichia coli* is presented (Table 13).

Table 13. The status of *Escherichia coli* infection along the broiler chicken value chain

Sample Type	Examined (No.)	Positive (No., %) *Escherichia coli*	$\chi 2$	P value
Faeces (broiler chicken farms)	120	33 (27.5)		
Carcass swab from slaughtering sites	60	28 (46.7)	24.377	0.000
Carcass swab from retail markets	24	19 (79.2)		
Total	204	80 (66.7)		

4.5 Physicochemical Qualities of Broiler Chicken Meat

4.5.1 *Characteristics of chilled meat based on lightness values*

Out of the total 48 broiler breasts (*pectoralis major)* subject for the color **tes**t, the majority were normal. Besides, the parameters such as color values (L*, a* and b*), pH, drip loss and tenderness were also evaluated among the row breast meat groups and categorized based on lightness values as presented in (Table 14 and 15).

Table 14. Broiler breast meat color category on the basis of CIE lightness value

Category of breast meat color	Frequency	Percentage (%)
Paler/lighter than normal	7	14.6
Normal	35	72.9
Darker than normal	6	12.5

The color (L*, a* and b*), pH, drip loss and shear force values of the three different color groups of raw broiler breast meat are presented in (Table 15).

Table 15. Color, pH, drip loss and tenderness value of the normal, dark and pale chilled broiler meat groups

Variables		Dark (n=4)	Normal (n=37)	Pale (n=7)
Color	L*	39.50 ± 4.12^{c}	47.46 ± 1.69^{b}	55.14 ± 2.12^{a}
	a*	4.41 ± 1.03^{a}	3.60 ± 1.03^{a}	3.08 ± 1.69^{a}
	b*	6.19 ± 1.53^{b}	9.53 ± 1.21^{a}	9.07 ± 1.25^{a}
pH_{24h}		6.83 ± 0.10^{a}	5.69 ± 0.67^{b}	5.24 ± 0.40^{b}
Drip loss (%)		3.45 ± 0.76^{b}	3.63 ± 0.19^{b}	4.06 ± 0.76^{a}
Tenderness (N)		32.50 ± 6.84^{b}	33.80 ± 6.33^{b}	41.35 ± 4.50^{a}

$^{a-c}$ Means within a row with no common superscript are significantly different at $P<0.001$

L* = Lightness; a* = Redness and b* = Yellowness

The Pearson correlation coefficients and the probabilities between the CIE color values, pH, drip loss and tenderness are indicated in (Table 16).

Table 16. Pearson correlation coefficient and probabilities of broiler breast meat lightness (L*), redness (a*), yellowness (b*), pH, drip loss and tenderness.

	L*	a*	b*	pH	Drip loss	Tenderness
L*	1	-0.1358	0.4127*	-0.6581**	0. 5180*	0.4574*
a*		1	0.0365	0.1207	0.1329	-0.1461
b*			1	-0.1978	0.1267	-0.2424
pH_{24h}				1	-0.7143*	-0.2174
Drip loss					1	0.2527
Tenderness						1

****, *** Means statistically different at P <0.001and P<0.05, respectively

4.5.2 *Physical qualities of frozen chicken breast meat*

The mean values of color, ultimate pH, drip loss and tenderness of the frozen breast meat in this study are presented in (Table 17).

Table 17. Color, pH, drip loss and tenderness of the frozen chicken breast meat (n=24)

Parameters		Min.	Max.	Mean	Std. D.
Color	L*	43.00	54.00	48.40	2.61
	a*	2.11	6.93	4.19	1.27
	b*	5.70	14.20	10.55	2.26
PH_{24h}		4.60	5.00	4.76	0.11
Drip loss (%)		3.70	10.00	5.96	2.25
Tenderness (N)		34.70	48.60	40.23	4.81

N=Newton; Min.= Minimum; Max.= Maximum and Std.D.= Standard deviation

4.5.3 *Chemical composition of breast, thigh and drumstick broiler meat*

The chemical composition of the breast, thigh and drumstick broiler meat cuts in the dark, normal and pale broiler meat groups are presented in (Table 18).

Table 18. The proximate composition of the prime cuts of the normal, dark and pale chilled broiler meat color groups (Mean±SD, n=6)

Parameters	Breast			Thigh			Drumstick		
	Normal	Dark	Pale	Normal	Dark	Pale	Normal	Dark	Pale
Moisture (%)	74.72±0.82[b]	76.09±0.72[a]	73.15±0.75[c]	75.32±4.851	75.92±1.86	75.77±0.42	77.47±1.15	78.47±0.23	76.98±0.90
Crude protein (%)	20.75±2.02	21.60±1.85	19.90±0.89	17.46±1.40	17.64±0.03	17.15±0.95	17.71±0.11[b]	18.90±0.94[a]	16.57±0.18[c]
Crude fat (%)	2.43±0.61	1.62±0.55	1.29±0.65	5.39±0.09	5.69±1.62	5.28±0.09	4.85±0.47	5.00±0.13	5.20±0.04
Crude ash (%)	1.19±0.049	1.44±0.42	1.23±0.25	1.13±0.12	1.13±0.03	1.43±0.11	1.10±0.04	0.89±0.06	1.07±0.01
Crude fiber (%)	0.30±0.20	0.30±0.17	0.35±0.21	0.37±0.07	0.28±0.8	0.26±0.08	0.31±0.24	0.28±0.23	0.38±0.021
Energy (Kcal)	104±13.53	97.95±13.27	94.23±1.53	118.26±4.71	119.81±18.35	118.14±0.69	119±7.82	111.29±1.92	117.61±0.82

[a-c] Means within a row of prime cuts with no common superscript differ (P<0.05)

The proximate composition of frozen meat cuts such as breast, thigh and drumstick collected from the retail market is presented in (Table 19).

Table 19. The proximate composition of the frozen chicken meat cuts (Mean±SD, n=4)

Parameters	Breast	Thigh	Drumstick
Moisture (%)	76.5±1.85	75.25±0.28	77.14±0.22
Crude protein (%)	20.1±1.80	19.10±1.21	17.61±2.24
Crude fat (%)	5.20±1.54	7.30±1.50	4.90±0.18
Crude ash (%)	1.80±0.75	1.18±0.46	1.19±0.25
Crude fiber (%)	0.38±.025	0.54±0.19	0.38±0.02
Energy (Kcal)	98.72±10.53	115±8.65	114±10.67

5. DISCUSSION

5.1 Survey and Observation

5.1.1 *Broiler farm biosecurity*

Isolation practices: The study depicted that only few broiler farms (22.2%) are located at the areas specified for the purpose whereas the majority 77.8% are at residential areas either in the same or separate compound with resident people. Besides, it was noted that most of the farms 66.6% are located at the nearest distance (<500 meters) from another poultry farm. About 88.9% and 85.2% are in the fenced compound and do not share equipment with other poultry farms, respectively. All broiler farms 100% have a separate living room for farm workers. The study also revealed that about 48.1% and 81.5% of the farms have a separate room for feed storage and implement all-in all-out practices, respectively. But about 74.10% do not have a sign of restricting entrance into the farm. The result of this study showed that the practice of farmers was implementing an all-in-all-out system and is reported by Duguma *et al*. (2016), where all farms did not implement the practice. However, in both studies, poultry producers were sharing equipment within and between poultry farms. With regard to location, the result of this study showed that majority (77.8%) of the broiler chicken farms are located at residential areas which is comparable with the result reported by Kouam *et al*. (2018); 88.2%, 14.7% and 3.9% of the commercial farms commercial broiler chicken farms in Western Highlands of Cameroon were located at the nearest distance to the main road, close to other commercial poultry farms and at livestock operations, respectively.

The survey and observation data generated from this study were comparable with the findings of Maduka *et al*. (2016), who reported 84.6%, 94.9%, 97.4% and 89.6% commercial broiler farms were having a fenced compound, separate feed storage unit, a separate isolation room for the sick birds and implement all-in all-out management practices, respectively in Nigeria. Donado-Godoy *et al*. (2012) also reported that in Colombia about 78.6% and 62.9% of the farmers had a fenced compound and the sign of restricting access, respectively which is similar to the present finding. The result of this study also showed that 59.5% of the farms share equipment from other poultry operations.

*Hygiene and sanitation practices at broiler farms***:** The hygiene and sanitation practices of the broiler farms are presented in (Table 2). The result indicates that about 70.4% of the broiler farms use tap water as a water source for their chicken. Besides, about 51.9%, 44.4% and 29.6% used footbath, tire bath and hand washing detergent respectively. All the farms were

implemented cleaning and disinfection of the chicken house, watering and feeding troughs, Besides, 63.0%, 66.7% and 58.9% of the farms have a bathroom, overall and boats, and appropriate dray bedding, respectively. Furthermore, 51.8% of the farms implement appropriate dead birds' disposal method. However, 66.7% and 45.4% of the poultry houses were accessible to wild birds and rodents, respectively.

The studies conducted by other scholars report variable results on chicken farm hygiene and sanitation practices. With regard to the water source, the result of the present study agrees with the finding reported by Addis *et al*. (2014), 70% of small-scale intensive poultry farms at Bahir Dar city have access to tap water for their farm. With regard to a footbath and the wearing of protective cloth, the findings of the present study agree with Yitbarek *et al.* (2016), who reported 77.6% and 63.3% of the commercial poultry farmers at Debre Markos use footbath and protective clothing, respectively.

However, the present study showed that farmers who are raising broiler chicken were poorly implementing most of the farm hygiene measures as compared with other countries. In Nigeria, the hygiene practices implemented by the commercial poultry farms were use of foot bath (56.4%), use of tire bath (22.3%), having tap water in the farm (98.7%), implementing appropriate carcasses disposal method (97.5%), using dry bedding (98.5%), having bathroom for farm workers (82.3%) and practice cleaning and disinfection of watering and feeding troughs (97.4%) (Yitbarek *et al*., 2016) which is little better than the practices observed in the study. The other study by Donado-Godoy *et al*. (2012) also reported that the status of commercial broiler chicken farmers in implementing hygiene and sanitation practices at Colombia were rodent management (97.1%), restricting wild birds' access, and cleaning and disinfection poultry facility (house, feeder and drinker) (100%) and appropriate dead birds' disposal by composting (80%) and are better than the finding of this study.

*Flock health care practices***:** All commercial broiler chicken rearers implement vaccination against Newcastle and Gumboro diseases. However, the result of the present study showed that the majority of the respondents 88.2% and 76.5% were following the suppliers' vaccination program for Newcastle disease and infectious bursal disease (IBD) respectively, whereas, the rest were following their own arbitrary schedule (Fig. 3). The result of this study is almost in agreement with the finding Sambo *et al.* (2015) who report that 80% of semi-intensive poultry producers around Bishoftu town were administered vaccination by themselves using varying schedules and dilutions contrary to the manufacturers' recommendations. The result of this study also depicted that, only 55.5% of the producers

used antimicrobial treatment following vet expert's prescription (Fig. 3). The result of the present study also showed that the use of antibiotic treatment better than reported by Duguma *et al*. (2016) where all commercial poultry farms in South Western Ethiopia were using antibiotic treatment without veterinarian prescription. In Colombia, 57.5% of the commercial broiler chicken farms were also frequently providing antimicrobial treatment for their chicken without veterinarian prescription (Donado-Godoy *et al*., 2012) which is in support of the present study.

*The rate of mortality***:** The rate of mortality record in the present study was ranging from 3.5 - 13.6% (Fig. 4) which is by far lower than the 5.05-23.27% morality range occurred commercial in poultry farms in Central Ethiopia (Addis *et al*., 2014) and the 36% morality level reported in small-scale intensive poultry farms in Bahir Dar city (Chanie *et al*., 2009).

Generally, the biosecurity practices in broiler chicken farms in the study area were poor as compared with the OIE (2018) standard which recommends a strict application of biosecurity measures mentioned above and other practices. The pathogens in poultry farms such as *Salmonella, E. coli* and other microbial diseases are prevented and controlled through hygiene and appropriate implementation of farm biosecurity measures (White, 1997; Chanie *et al.*,2009; Margaret, 2013; Duguma *et al.* 2016). This is explained by study Raseta *et al.* (2015) that they established an effective application of on-farm biosecurity measures could reduce the *Salmonella* contamination level from 55% to 10%.

In developed countries, in addition to strict farm biosecurity programs, commercial poultry farms should practice vaccination against S*almonella* and E. coli infections (Donado-Godoy *et al*., 2012; Margaret, 2013). However, in Ethiopia, the broiler chicken vaccination program is not inclusive of these pathogens. According to the National Veterinary Institute, Department of Vaccine Quality and Assurance, the national vaccine development program is based on the national coverage and transmission level of the diseases; a vaccine is developed for the diseases which their transmission level is known, and not controlled through hygiene and treatment. According to the interviewee in the NVI, unlike viral disease such as Newcastle and Gumoboro, etc, these pathogens can be prevented or controlled through good hygiene and biosecurity practices, and antimicrobial treatment (Personal communication). However, antimicrobial administration without the veterinary expert's diagnosis and drug prescription continuous to be the major challenge for microbial drug resistance in the Ethiopian poultry sector (Chanie *et al*., 2009; Duguma *et al*., 2016).

5.1.2 *Meat quality and hygiene practices at the processing sites*

The hygiene practices carried out at the processing sites and retail markets were poor (Table 4). These practices are against the standards recommended by the Ethiopian Standard (ES 2790: 2006, Rev. 2017) and the Codex Alimentarius Commission (CAC/GL 78-2011) and CAC (CAC/RCP 58-2005).

Chicken transportation: In the study area it is observed that the number of chickens was put into the sack and transported by human carry from the rearing house to the slaughtering areas. It was also noted such transportation cause the chicken to be suffocated, unconscious and finally die (Appendix 1: Fig. D) which results in meat quality defects. Inappropriate transportation of broiler chicken is one of the major factors causing carcass damage.

Feed withdrawal: All the broiler processors did not implement feed withdrawal and aware about the importance of feed withdrawal in meat quality and safety before slaughtering, although some of them were explained its economic benefit to save the feed. Despite, the CAC (CAC/GL 78-2011) states that the slaughtering chicken flock should be starved for about 8-12 hours in order to reduce the likelihood of contamination of the carcass by faecal material and ingesta during processing as most of *Salmonella* spp. and E. *coli* are enterobacteria embedded in the gastrointestinal content of the chicken (Hertanto *et al*., 2018). From the meat quality point of view, standard feed withdrawal period prior to slaughter reduces stress with positive effects on slaughter yield and tenderness of meat (Bilgili, 2002). Feed withdrawal can enhance meat quality by reducing the amount of total carbohydrate available for post-mortem conversion of glycogen to lactic acid.

Ante-mortem and Post-mortem Inspection: The animal to be slaughtered should be subjected to ante-mortem inspection, with the competent authority determining the procedures and the tests to be used; so that the animal is either passed for slaughter or condemned for public health reasons. These practices help to prevent moribund, unhealthy or otherwise unsuitable chickens should not be processed and thereby reduce possible meat-borne hazards, occupational health hazards, or likelihood of unacceptable contamination of the slaughter and dressing environment following slaughter [CAC (CAC/GL 78-2011)]. The Commission also states that, following the ante-mortem inspection, if the flock presented for slaughtering is positive for instance for *Salmonella*, this should be done in a manner that minimises cross-contamination to other flocks. Similarly, the Ethiopian Standard Agency (ES 2790: 2006, Rev. 2017), states that to maintain the good hygienic condition and to prevent hazards to the

consumer, all poultry shall undergo antemortem and post-mortem inspections, which shall be carried out by the appropriate official agency, under veterinary supervision. Despite the fact that the result of this study showed that all backyard broiler processors (100%) did not carry out both ante-and post-mortem inspection. Furthermore, they slaughter and sold the chicken when their flock gets diseased. Given unhygienic processing, the nearest distance between farms and inappropriate slaughtering by-product disposal method, exacerbate the pathogen transmission into other poultry farms in the area. What makes the situation worse is that 18.5% of the broiler chicken rearers were reported that they slaughtered their chicken at an early age before attaining the required weight as a result of disease incidence at their farm. This practice might contribute to the downgraded (underweight) meat enter into the market. In addition, it may have an effect on other meat quality and safety aspects which needs to be investigated through further research.

*Stunning***:** The result of this study showed that none of the broiler processors stunned chicken while slaughtering. However, the OIE (2018) legislation under the Welfare of Animals (Slaughter or Killing) regulation 1995, states that all animals that are to be slaughtered are required to undergo pre-stunning, unless and otherwise religious slaughter. The same organization also stated that if stunning is not done properly, this too can also negatively affect the carcass and meat quality causing conditions such as PSE (pale, soft and exudative) or DFD (dark, firm and dry). It happens as non-stunned chicken are involved in high muscular activity while struggling to death which accelerates glycolysis, causing the accumulation of lactic acid in the muscle tissue and thus lowering pH and increasing toughness of the meat (Wong and Ashton, 2015). In the present study, it is identified that non-stunned slaughtering is among the major causes of broiler carcass damage.

Killing, bleeding and scalding: The result of the present study showed that broiler processors were carried out the improper methods of killing and bleeding. They kill the chicken by hanging the neck upside, support at the mouth of the barrel and then entirely cut it and throw into the barrel wherein all the slaughtered birds let to ‘bleed’ (Appendix 1: Fig. E and F). Holding of the bleeding chicken by overlapping one over the other, apart from hindering proper bleeding results to carcass damage (during struggling to death) and microbial cross-contamination (Appendix 1: Fig. M). Broiler processors in the study area do not use bleeding cone which helps to facilitate good bleeding.

According to the CAC (CAC/GL 78-2011), to ensure good bleed out, the bird should let to bled from 2-3 minutes. This practice also helps to prevent inhalation of scalding water and to

reduce the amount of blood entering the scaldler. Furthermore, it was observed that the other chickens to be slaughtered next are observing the process. This situation put the chicken to experience fear, pain, panic and other adverse effects which potentially affect the meat quality, such as the inhalation of blood because of bleeding into the trachea which can potentially affect the meat quality (Wong and Ashton, 2015).

The slaughterers scalded the chicken without checking the water temperature using a thermometer. But it was observed they tried to manage the water temperature by adding cold water or reducing the power of the fire. The processors were also asked that what they do if the carcass is over scalded and became red out of their capacity. They responded that they recover the problem by socking the carcass into the cold water immediately after defeathering. If the problem is not yet fixed, they further sock the carcass in cold water with ice following the final washing (Appendix 1: Fig. J).

Hygiene during meat processing and handling: According to the Ethiopian Standard Agency, code of hygiene practices for poultry processing, Ethiopian Standard (ES 2790:2006, Rev. 2017), areas where birds are received or stored shall be so separated from areas in which final product preparation and packing is conducted as to preclude contamination of the finished product. Similarly, the CAC (CAC/RCP 58-2005) also states that to minimize cross-contamination, stunning and bleeding areas, and scalding and defeathering areas should be separated with each other and also from dressing areas (either physically or by distance). The processing area and any equipment/service utensils used for carcass processing should properly be cleaned and disinfected using appropriate disinfectant. This organization also states that any food animal once slaughtered, should be eviscerated without delay and effectively cleaned of dust, feathers and other contaminants by the application of tape water.

However, in the study area, it was observed that all the broiler processing was carried out within the same compound where the chicken is grow-out. Although, about 66.6% of the processing areas were clean (free from dust, mud and other rubbish matters) and only 18.5% are disinfected. Besides, it is noted that pet animals such as dog and cat were at 81.5% of the processioning sites. It was also noted that all stages of processing such as killing, scalding, and defeathering (called dirty stages of processing), and evisceration, carcass cleaning (washing) and even packing were carried out at the same place.

The slaughterer man massively kills a number of birds, ranging from 50-100 at a time using a barrel open underneath and stand on the plastic mat where all other dressing processes were also done. The dead carcass left aside for a couple of minutes until scalded and the follow-on

steps performed. The blood of the chicken is flow on the plastic mat and when it is over they sometimes remove it. Then, the women in charge of scalding randomly pick the carcass among the other. During this time, the only thing what she does is that being sure the chicken to be put into the scalding tank is dead. This situation affects the scalding process in such a way that the late killed to be early scalded. It is also observed that a single scalding tank is used throughout the whole slaughtering process without changing the water and cleaning in between the process. As noticed during the study, the scalding water is changed into a bloody color and get dirty by feather and other rubbish matter (Appendix 1: Fig. H).

Almost all slaughterers or individuals involved in chicken processing do not wear protective cloth such as overall, headgears, aprons, hand gloves and plastic boot and medical examination for being free from any communicable disease. Broiler processors were a wash or clean equipment and utensils used for processing the carcass such as cutting knives, plastic mat, scalding tank and washing tank. But, they did not disinfect these equipment or utensils using appropriate disinfectant. Respondents also reported that they own some of the processing equipment such as barrel opened underneath (serve as a cutting cone) and cutting knives which move anywhere with them when they call for slaughtering service. This could be a potential risk factor for the transmission of disease pathogens from one processing area to other process area and to the poultry farm itself.

All broiler processors carried out both defeathering and evisceration manually by hand. A team of slaughterers was sequentially set down by forming a circle on the plastic mat laid over the ground on the basis of the job assigned in the dressing process such as defeathering, leg and neck cutting and evisceration. Every individual assigned for the given activity mentioned above performs accordingly. As mentioned above, all the dressing process is carried out at the same place including giblet processing.

Eviscerations of broiler were done in an improper way by hands, the worker opens the body cavity and removes the internals out at the same time the workers were involved in other carcass processing activities without using gloves or washing his or her hand with disinfectant or soap. It was observed that the person who was processing giblet and doing defeathering also involved in other activities for instances transporting the carcass to washing tanks. It was also noted that the feather is not removed frequently so that it makes a pile on the processing area adjacent to the plucked carcass. Besides, the carcass is not cleaned immediately after slaughtering. This could be effective in carcass contamination with internal parts microbes and the external environment.

The person in charge of washing has washed the carcass using sequentially arranged washing tanks (usually 3-4) filled with non-flow water. The washing is done starting with the first tank where most of the dirty matters including feathers and faeces adhered on the carcass are removed and ends with the last tank by rinsing (Appendix 1: Fig. J). The water in the washing tanks, particularly the water in the first tank was less frequently changed. It was also observed that the amount of water used in carcass washing is not enough to wash out of pathogenic microbes. However, the CAC (CAC/GL 78-2011), states that the inside and outside of all carcasses should be thoroughly washed, using pressure sufficient water to remove visible contamination.

At the end of the final washing, the carcass is put into a big barrel until a few hours left for packing. Then the carcass gets out from the tank and laid on the plastic mat to let the water drain out for about 1:30 - 2:00 hours. Finally, the carcass is packed with plastic bag pierced at different places so as to enhance the water to drain out still in it. The plastic bag used for packing the carcass did not labelled with the necessary information that helps to maintain the product quality and safety such as production date, expiry date, keeping and cooking instructions. Besides, a pierced plastic packaging is a potential route through which pathogenic microorganisms get into the carcass and contaminate it. Furthermore, the giblets do not separately wrap, rather put into the abdominal cavity from which gastro-intestinal tract is drawn out. This will be the potential risk for microbial contamination while these organs are not well cleaned during washing.

The slaughtering processing mostly started early in the evening, around 6:00 - 7:00 P.M and continue the whole night and ends early at the morning (5:30 - 12:00 A.M). It is easy to imagine how long the slaughtering process is! The extended processing time makes the carcass to be left outside for a long time up to 11:00 hours in the contaminated environment without cooling and chilling. Furthermore, what makes the situation worse is that most (85.2%) of the carcass is transported to the retail market with goods transporting mid-busses where the cold chain is not put in place (Appendix 1: Fig. O).

Carcass damage: The result of the present study also showed that carcass damage was observed at the broiler slaughtering sites. Out of the 480 carcasses checked against the parameters for carcass damage; 29.0% bone breakage, 9.4% bruising, 11.5% engorged or haemorrhagic wing veins 7.0% blood-spots were observed. It was also noted that the possible causes for the observed carcass damage were inappropriate transportation of chicken from the rearing farm to slaughtering area; inappropriate slaughtering, especially using of the barrel to

bleed the chicken; improper processing especially lacks care of the slaughterers while pulling out the gastrointestinal tract. Besides, the interviewers respond that improper management during rearing (damage occurred at the rearing period) is also among the possible causes of carcass damage. There is evidence in the literature that catching often results in injury, especially when a large number of birds are caught with maximum haste by the catching team identified and quantified losses when comparing both manual and mechanized catching (16.5 to 7%), respectively. The authors found bruising in thighs, legs, and breasts of up to 25% of the harvested birds due to handling, catching, transportation, and unloading at the processing area. However, most of the damages in the carcass were found during catching in the breast (11%), thighs (33%), and wings (38%) (Wong and Ashton, 2015).

5.1.3 *Meat handling and hygiene practices at the retail markets*

Inspection of the meat received from suppliers: Apart from local poultry abattoirs and imported from other countries, all retail markets reported that they also bought chicken meat from backyard slaughterers. The majority of the retail markets also reported that they do not check the meat against temperature (either the meat cooled up to the required temperature level or not) and carcass damages such as bone breakage, bruising, blood spot and blood engorged in vein. The majority (70.4%) of retail markets do not check whether the meat is transported in the cold chain or not. The action of retail markets being lenient on these aspects could be one of the contributing factors that the meat transporters still keep on using goods transporting mid-busses for the purpose. However, the majority of retail markets also reported that they were checking the observable and sensible physical qualities of meat by skin color, cleanness and freshness and quality of packaging (bag thickness and not being tired out). As stated in the above section, the meat packed by backyard slaughterers did not labelled with essential information which helps to handle the product and safety of the consumer. It was observed that the meat at the retail markets did not labelled with essential packaging information as any of them was repack and labelled the meat again.

Handling and hygiene practices: The result of this study highlighted that the majority of the retail market were implementing most of the safe meat handling practices such as keeping broiler meat in a separate display or storage freezer (66.7%), practicing first-in-first-out (88.9%), storing the meat with the recommended temperature (63%) and cleaned the storage freezer between a batch of meat stored (74.1%). Furthermore, the majority (88.8%) of the retail markets have stored the meat for less than 20 days. The shorter the storage duration the lesser the chance of spoilage as the meat kept with the required storage temperature. It was

also noted that most of the meat handlers or individuals in contact with the meat were wear clothes such as apron or gown (81.5%) and hairnet/cape (51.9%). However, only a few were wearing gloves (37%) and mask (11.1%), and the wearing of appropriate and clean uniform (40.9%) and always wash hands before and during meat handing (40.7%). However, the majority (70.4%) of the respondents were reported that they took the medical examination for being free from any communicable diseases. It was also noted that (33.3%) of the retail markets did not have hand washing tub at the meat handling areas.

5.2 Laboratory Examination

5.2.1 *The extent of contamination of broiler chicken rearing farms, backyard slaughtering sites, and retail markets by Salmonella and Escherichia coli*

Out of the total 204 samples 21.1% (43/204) and 39.2% (80/204) and were positive for *Salmonella* spp. and *Escherichia coli,* respectively. From the 120 faecal samples collected from broiler chicken rearing farms, 14.2% (17/120) and 27.5% (33/120) were positive for *Salmonella* spp. and *Escherichia coli,* respectively. Similarly, of the 60 carcass swab samples from backyard slaughtering sites 15% (9/60) and 46.7% (28/60) were positive for *Salmonella* spp. and *Escherichia* c*oli,* respectively. Furthermore, of the 24 carcass swab samples from the retail markets, 70.8% (17/24) and 79.2% (19/24) were *positive Salmonella* spp. and *E. coli,* respectively. Among all the broiler value chain components, the contamination of both *Salmonella* spp. and *E. coli* were significantly ($P<0.001$) higher at retail markets.

The *Salmonella* spp. isolates from faecal samples found in this research are similar to the (14.8%) incidence in poultry multiplication and commercial farms in North Western Ethiopia (Duguma *et al*., 2017). Though the result is higher than the 4.7% contamination in poultry farms in central Ethiopia (Ada'a, Addis Ababa, Barake and Sebeta), but lower than the 41.3% incidence in broiler chickens at Jimma, Western Ethiopia (Kindu and Addis, 2013). The *E. coli* contamination found in the present study is higher than the 13.7% prevalence in Adele and Haramaya University poultry farms, Eastern Ethiopia (Shecho *et al*., 2017), but lower than the 35.5% incidence in live-bird markets at Addis Ababa, Ethiopia (Gebeyehu *et al*., 2018). The incidence of both salmonella and *E. coli* are related to unavailability of strict biosecurity practices at poultry production farms. Keeping sick birds within the flock, poor hygiene and biosecurity measures, improper disinfection of houses, the absence of disinfect at the gates and the presence of pet, dairy cows, pigs and calves in the premises were identified as the major risk factors for *Salmonella* and *E. coli* outbreaks in the poultry farms (Chanie *et al*., 2009).

The *Salmonella* spp. contamination at backyard slaughtering sites found in this research is almost similar with the 7.8% in Northern Egypt (Moawad *et al*., 2017) but higher the 3.62% prevalence in Constantine, Algeria (Elgroud *et al*., 2008). The result of the present study also showed that *E. coli* contamination at the backyard slaughtering sites is higher than the 14.4% *E. coli* contamination in meat processing plants in the Northern Egypt (Moawad *et al*., 2017). The incidence of pathogenic microorganisms at the backyard slaughtering sites could be related to unhygienic traditional processing. The feather and skin of broiler chicken slaughtered for processing could be contaminated with faeces during the growing period, as both *Salmonella* and *E. coli* harbor in the gastrointestinal of birds. The level of *Salmonella* spp. contamination may be increased during evisceration (Hertanto *et al*., 2018). It was also noticed that intestines of the birds were damaged frequently as a result of inappropriate pulling of the viscera. Besides, the feather and blood were rarely removed from the processing area both of them cause the carcass to become contaminated with pathogenic microorganisms.

The extent of *Salmonella* spp. and *E. coli* contamination at retail markets investigated in this study was higher than the 56% and the 68% contamination at chicken meat retail markets in Alexandria, Egypt (Samaha *et al.*, 2012). The finding of the present study also higher than the 32% *Salmonella* and the 47.2% *E. coli* contamination in Oyo, Nigeria (Adeyanju and Ishola, 2014).

The higher level of bacterial contamination at the retail markets identified in this study could be due to the higher possibility of cross-contamination of the meat along the value chain as the meat is processed unhygienically and transported and handled inappropriate way.

5.2.2 *Physicochemical qualities of the broiler chicken meat*

Physical qualities of broiler meat: The result of this study showed that out of the 48 chicken breast fillets subjected for color measurement, the majority (72.9%) were normal, while the rest (14.6%) and (12.5%) were paler and darker than normal, respectively. The percentage of breast meat paleness found in this study is lower than the 28% reported in Canadian (Barbut, 1997), 37-47% in the USA (Woelfel *et al*., 2002) and 20% in England (Wilkins et al., 2000). The breast meat color values investigated in this study was different from the 69% (normal), 11% (pale) and 20% (dark) meat in Brazilian commercial flocks (Moreira *et al.*, 2018). These authors also stated that on the basis of cooking loss, chicken meat could be classified as of colors: 20.96% for PSE meat, 25.77% for normal meat and 21.32% for DFD meat.

The result showed that the average lightness (L*) values of row breast meat were significantly (P<.001) different among normal, dark and pale groups, while the pale group was significantly (P<0.001) different in yellowness value (b*) than both normal and dark groups. Besides, the pH value of the dark meat group was significantly (P<0.001) different than normal and light color groups. Furthermore, a significant drip loss (P<0.05) difference was observed in the pale row breast meat than in the normal and dark groups. Similarly, the pale group meat was significantly (P<0.05) different from the normal and dark color groups.

The color value results found in this study is almost similar to the findings of Kralik *et al*. (2014). The authors found that, L*a* and b* values for the dark, normal and pale color meat groups were 43.35, 2.03 & 7.89; 48.53, 1.87 & 9.63; and 56.76, 1.14 & 12.76, respectively. The L*color value for the dark, normal and pale meat color groups investigated in this study were lower than the 48.29, 53.51 and 57.53, respectively. However, the a* values for the three color groups of breast meat were higher than the 2.96, 2.05 and 1.63, respectively. Similarly, the b* value for the three color groups of the breast meat was also higher than the 1.07, 1.52 and 2.08, respectively (Petracci *et al*., 2004).

The pH_{24h} values for the Pale, Normal and Dark breast meat color groups found in the present study were almost in agreement with pH ranges established by Kralik *et al*. (2018); 5.61 - 5.83, 5.93 - 6.04, and 6.30 - 6.27 for the three color groups of the breast meat, respectively. The drip loss found in this study was similar to the 6.0% for pale and 3.34% for dark meat groups (Barbut, 1993). However, it was lower than the 6.52% and 4.04% for the pale and normal meat groups, respectively (Adzitey, 2011) and higher than the 1.50%, 2.11% and 3.45% for dark, normal and pale color groups, respectively (Kralik *et al*., 2014). The significant difference in the drip loss (the higher result of drip loss) in the pale meat groups is expected as there was a strong negative relationship between the pH_{24h} and drip loss.

The shear force value of the pale breast meat group was (41.35 N), and significantly greater than the normal (33.80 N) or darker (32.50 N) that were not different from each other. The finding of this study is almost similar to the 31.4 N, 33.3 N and 47.0 for the dark, normal and pale color meat groups, respectively (Petracci *et al*., 2004). However, it was higher than 23.5 N and 27.34 N for the normal and pale broiler breast meat groups (Carvalho *et al*., 2018). The higher the shear force, the lesser the breast meat tenderness is explained by the higher drip loss, the higher L* color value and the more the meat acidic.

The result of the present study also showed that there was a significant (P<0.05) positive correlation between L* values and b* (r = 0.4127), drip loss (r = 0.5180) (P<0.05), and tenderness (r = 0.4574). Besides, there was a significant (P<0.001) negative correlation between L* and pH (r = -0.6581) and the pH_{24h} and drip loss (r = -0.7143). The correlation coefficients between L* and b*, and L* and drip loss found in the present study were higher than reported by (Woelfel *et al*., 2002); the correlation of L* and drip loss, and the pH_{24h} and drip loss than the (r = 0.491) and the (r = 0.327), respectively. The correlations of L* and pH_{24h}, and L* and drip loss are also higher than the (r = -0.285) of the correlation of L* and pH_{24h}, and the (r = 0.353) correlation of L* and drip loss (Kralik *et al*., 2014). The moderate negative correlation between L* and pH_{24h} and pH and drip loss explain the lower moisture content in the pale breast meat color groups, as the pH decreases the moisture also decreases; drip loss increase then the meat becomes pale in color.

The mean L*, a* and b* color values of the frozen breast chicken meat were 48.40, 4.19 and 10.55, respectively. Besides, pH_{24h}, drip loss (%) and tenderness (N) were 4.76, 6.55 and 40.23 respectively. The result also showed that L* color value found in this study is almost similar with the 47.77 while the a* and b* values are higher than the values reported by Fernandes *et al*. (2016); a*=0.23 and b*=4.81. The pH_{24h} found in this study is almost similar to the 4.94 reported Hussain *et al*. (2016) but lower than the 5.90 (Fernandes *et al*., 2016). With regard to this, Barbut (1993) stated that chicken meat with low pH is associated with increased drip loss, and decreased tenderness.

The occurrence of pale meat color is due to the stress conditions to which the birds are subjected during handling (transporting) and slaughtering. Any stress shortly before or at slaughter was reported to cause PSE due to an increased rate of post-mortem metabolism, accelerated glycolysis, and premature onset of rigor mortis (Moreira *et al*., 2018; Nasir *et al*., 2017). High temperature and low pH in chicken meat will stimulate protein denaturation, which will further influence the lowering of the water holding capacity in the meat. If animals are exposed to longer stress before slaughtering, they will have less stored glycogen in muscles because of exhaustion. Reduced glycogen reserve affects post-mortem changes after slaughtering, meaning that the pH value remains high, which causes the occurrence of DFD meat. In this meat, protein denaturation and drip loss are slowed down (Adzitey, 2011).

Nutritional qualities of broiler meat: The moisture content of the breast meat was (74.72%) for the normal, (76.09%) for the dark and (73.15%) for the pale meat groups, all of which were significantly (P<0.05) different from each other. The moisture content of the dark breast

meat group found in this study agrees with the 78.23%, whereas lower than the 76.35% and 76.72% for the normal and pale meat groups, respectively (Qiao *et al*., 2001). The protein content of the drumstick meat was (17.71%) for the normal, (18.9%) and (16.57%) for the pale meat color groups, all of which were significantly ($P<0.05$) different from each other. However, there was no statistical difference in the moisture content of the thigh and drumstick meat among the three meat color groups. There was no statistical difference in the moisture content of the thigh and drumstick meat among the three meat color groups. The higher drip loss observed in the pale breast meat color group could be explained by the observed lower moisture content in the same meat groups (Table 16). Furthermore, it is explained by the low protein content in the pale meat group of drumstick meat which is resulting from protein denaturation because of the low pH.

The result of the present study also showed that the moisture content was highest in the drumstick (77.14%) than the breast and the thigh muscles having 76.5% and 75.3%, respectively. Higher protein (20.1%) was observed in the breast muscle followed by the thigh and drumstick muscles having an average protein content of 19.1% and 17.6%, respectively. Furthermore, higher (7.3%) fat was observed in the thigh muscle followed by breast and drumstick having an average fat content of 5.2% and 4.9%, respectively. The result also indicated that almost the same energy was observed in both thigh and drumstick muscles; 114 and 115 kcal, respectively while the energy in the breast meat was lower (98.7 kcal). The protein and fat content in the three meat cuts found in this study were almost within the range between 18.4 - 23.4% and 1.3 - 6.0%, respectively whereas, the ash content was a bit higher than the 0.8 - 1.2%, established by (Culioli *et al*., 2003).

6. CONCLUSION AND RECOMMENDATION

6.1 Conclusion

From this research, it is possible to conclude that the poor broiler farm biosecurity and unhygienic slaughtering process are the major risk factors for the contamination of *Salmonella* spp. and *E. coli* along the broiler value chain.

The higher *Salmonella* spp. and *E. coli* at the retail market implies that once the contamination happened, the risk would progressively increase as the product goes through the value chain.

The significant difference in lightness, yellowness, muscle pH, drip loss and shear force values between the three color groups and the significant correlation between lightness, muscle pH, drip loss and shear force indicate that breast meat color could be used as a possible indicator of the functional properties of the meat.

The physical qualities of breast meat fillets were comparable with the findings of other studies. Furthermore, the proximate chemical composition of breast, thigh and drumstick meat cuts were in the range of the expected nutrient level.

6.2 Recommendations

Based on the above conclusions, the following recommendations are forwarded:

A. Further study in characterizing the serotype of pathogenic *Salmonella* spp. and *E. coli* should be conducted.

B. As *Salmonella* and *E. coli* are vertically and horizontally transmitted infections, further study on hatcheries, broiler parent stock farms, and other relevant value chain components should be conducted.

C. Tailor-made training and awareness creation of farm biosecurity, hygienic broiler processing, and meat handling should be given to broiler chicken rearers', processors and retail markets.

D. Integrated research that helps to enhance broiler meat processing and thereby contribute to ensuring broiler meat quality and safety should be conducted.

E. Since multiple entry points exist for pathogenic microorganisms, multifaceted intervention approaches are required to successfully control contamination of poultry during the growth period, the processing procedure of broiler chickens, and handling and retailing of meat.

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APPENDICES

APPENDIX 1. List of Figures Explaining Backyard Broiler Processing

Figure A. Broiler chicken in the rearing house

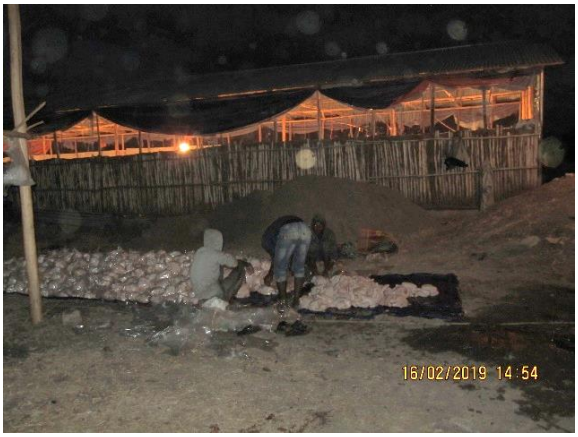

Figure B. Broiler slaughtering area

Figure C. Chicken transportation using sacks

Figure D. Chicken ready for slaughtering

Figure E. Slaughtering

Figure F. A barrel used as killing cone

APPENDIX 1: List of Figures Explainin (*Continue)*

Figure G. Scalding

Figure H. Scalding water hygiene

Figure I. Defeathering and evisceration

Figure J. Carcass washing

Figure K. Carcass at processing

APPENDIX 1: List of Figures Explainin (*Continue)*

Figure L. A carcass ready for packing

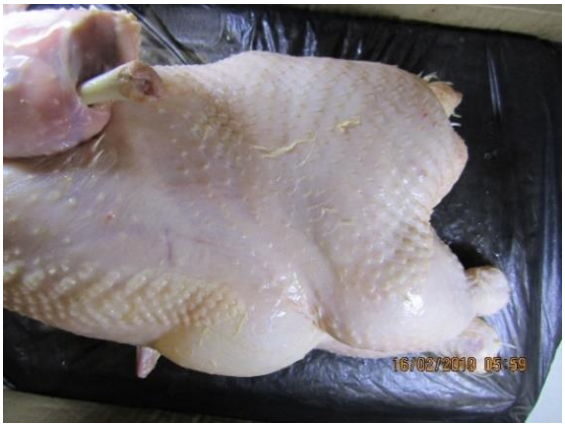

Figure M. Bone breakage at the wing

Figure N. Carcass at packing

Figure O. Vehicle using broiler meat transportation

APPENDIX 2. Questionnaire and Observation Checklist Used for Broiler Rearing Farms

Survey Questionnaire/Observation Check List for Collecting Information on Broiler Chicken Biosecurity Practices

---

1. General Information

1.1 Date of interview: _____

1.2 City/town: _____ Kebele/location: _____

1.3 Name of the household head: _____

1.4 Telephone Number: _____

1.5 Sex of the household head 1. Male ☐ 2. Female ☐

1.6 Age of the household head in years: _____

1.7 Educational status of household head

1. Illiterate 2. Read & write 3. Primary school 4. High school certificate 5. Diploma & above

1.8 Marital status? 1. Married ☐ 2. Single ☐ 3. Divorced ☐ 4. Widows ☐

2. Farm Biosecurity Practices

2.1 What is the location of the chicken house? 1. On areas purposely assigned for the activity 2. Share with residential compound 3. Residential area, but in separate compound

2.2 What is the size of your chicken house in meter square (meter square)? _____

2.3 What is the breed of your broiler chicken? Please specify _____

2.4 When you housed the chicken (DD/MM/YYYY): _____

2.5 What is the total number of chicks housed/stocked initially? _____

2.6 Do you receive documented information about the chicken (breed, vaccination status etc.) you purchased from breeder farms? 1. Yes ☐ 2. No ☐

2.7 Is the farm compound fenced? 1. Yes ☐ 2. No ☐

2.8 Is there any notice board restricting entrance into the farm? 1. Yes ☐ 2. No ☐

2.9 Do visitors allowed to enter the farm? 1. Yes ☐ 2. No ☐

2.10 Is there foot bath at the get of the farm? 1. Yes ☐ 2. No ☐

2.11 Tire bath at the get of the farm? 1. Yes ☐ 2. No ☐

2.12 Is there bath room for farm workers/visitors? 1. Yes ☐ 2. No ☐

2.13 Is there detergent to wash hands for workers/visitors? 1. Yes ☐ 2. No ☐

2.14 Is there separate cloth and shoes for farm workers and visitors? 1. Yes ☐ 2. No ☐

2.15 Do wild birds' access to the chicken house 1. Yes ☐ 2. No ☐

2.16 Do rodents access to the chicken house? 1. Yes ☐ 2. No ☐

2.17 Do you apply All-in All-out practice? 1. Yes ☐ 2. No ☐

2.17.1 Is there any poultry farm in the same compound/around 500 meters radius with your chicken farm? 1. Yes ☐ 2. No ☐

2.18 Is there any livestock farm (dairy, fattening, sheep, pig, goat etc.) in the same compound/around 500 meters radius with the chicken farm? 1. Yes ☐ 2. No ☐

2.19 What is the source of water for your chicken farm? 1. Tap water ☐ 2. River ☐ 3. Deep-well ☐

2.20 What is the source of feed for you chicken? Please specify: _____

2.21 Did you fed your chicken growth hormone? 1. Yes ☐ 2. No ☐

2.22 How often do you wash drinkers in a week? _____

2.23 How often do you wash water tank in a week? _____

2.24 How often do you wash feeders in a month? _____

2.25 Appropriate and dry bedding/litter? 1. Yes ☐ 2. No ☐

2.26 Do you vaccinate your chicken? 1. Yes ☐ 2. No ☐

2.27 Please fill the types of vaccine and date of administration in the table below

Types of vaccine	Age of birds (days)
Newcastle	
Newcastle	
Gumboro	
Gumboro	
Others (specify): _____	

2.28 Do provide prophylactic treatment for your chicken? 1. Yes ☐ 2. No ☐

2.29 Were your chicken get sick? 1. Yes ☐ 2. No ☐

2.29.1 If **yes**, do you provide antibiotic treatment? 1. Yes ☐ 2. No ☐

2.29.2 If yes, who provide the antibiotic treatment? 1. Myself ☐ 2. Veterinary expert ☐ 3. Others (specify): _____

2.29.3 When do you provide antibiotic drug before your chicken get slaughtered? (DD/MM/YYYY) _____

2.30 How do you dispose slaughter by-products of the farm? 1. Burned ☐ 2. Buried ☐ 3. Put in a rubbish pile ☐ 4. Throw away on open spaces/road side ☐ 5. Others (specify): _____

2.31 How do you dispose dead birds from your farm? 1. Burned ☐ 2. Buried ☐ 3. Put in a rubbish pile ☐ 4. Throw away on open spaces/road sides ☐ 5. Others (specify): _____

2.32 How do you dispose the chicken farm litter? 1. Burned ☐ 2. Buried ☐ 3. Put in a rubbish pile ☐ 4. Throw away on open spaces/road sides ☐ 5. Use/sale for compost 6. Others (specify): _____

2.33 Is there sharing of farm equipment's within/between poultry farms? 1. Yes ☐ 2. No ☐

2.34 Is there separate feed storage room? 1. Yes ☐ 2. No ☐

2.35 Is there separate living room for farm attendants 1. Yes ☐ 2. No ☐

2.36 Is there isolation pen for sick birds? 1. Yes ☐ 2. No ☐

2.37 If **yes**, type of isolation pen? 1, Partition within chicken house ☐ 2. Out of chicken house ☐

2.38 **Off-feed** (i.e. time duration between stop of offering & start of slaughtering) (hours): _____

2.39 Do you the importance of feed withdrawal for slaughtering chickens? 1. Yes ☐ 2. No ☐

2.39.1 If yes, ask their explanation from a view point of broiler meat quality and safety: _____

2.40 Poultry house disinfection before the chicken housed 1. Yes ☐ 2. No ☐

2.41 Is the poultry house cleaned between successive batches? 1. Yes ☐ 2. No ☐

2.42 Is the poultry house disinfected between successive batches of chicken? 1. Yes ☐ 2. No ☐

2.43 For how many days the house left evacuated until for the next batch of chicken _____

2.44 Poultry house equipment cleaned between successive batches of chicken? 1. Yes ☐ 2. No ☐

2.45 Poultry house equipment disinfected between successive batches of broiler? 1. Yes ☐ 2. No ☐

2.46 Have you ever obtained training on chicken production, meat processing, meat handling and related issues? 1. Yes ☐ 2. No ☐

2.46.1 If **yes**, please specify what was the theme/issue of training? _____

2.47 Do you have knowledge about food quality & safety? (broiler meat) 1. Yes ☐ 2. No ☐

2.47.1 If **yes**, ask their explanation from a view point of broiler meat: _____

_____

2.48 Do you have knowledge about the importance of feed withdrawal for slaughtering chickens?

1. Yes ☐ 2. No ☐

2.49 If yes, ask their explanation from a view point of broiler meat quality and safety: _____

"Thank you for Your Time"

APPENDIX 3. Questionnaire and Observation Checklist Used for Broiler Processing Sites

Survey Questionnaire and Observation Check List to Collect Information on Broiler Processing Practices

1 General Information

1.1 Date of interview: _____

1.2 City/town: _____ Kebele/location: _____

1.3 Name of the household head: _____ Mobile No: _____

1.4 Sex of the household head: 1. Male ☐ 2. Female ☐

1.5 Age of the household head in (years) _____

1.6 Educational status of household head:

1. Illiterate ☐ 2. Read & write ☐ 3. Primary school ☐ 4. High school certificate ☐ 5. Diploma & above ☐

1.7 Marital status? 1. Married ☐ 2. Single ☐ 3. Divorced ☐ 4. Widows ☐

2 Slaughtering/Processing Practices

2.1 What is the breed of broiler chicken? Please specify _____

2.2 Did you undertake ante-mortem chicken inspection? 1. Yes ☐ 2. No ☐

2.3 Do you apply stunning? 1. Yes ☐ 2. No ☐

2.3.1 If **yes**, what is the method of stunning? 1. Percussion ☐ 2. Electrical ☐ 3. Gas ☐

2.4 What is the method of killing?

1. By severing the jugular vein in one stroke cut ☐ 2. By severing the jugular vein more than one stroke 3. By cutting the neck ☐ 4. Halal ☐

2.5 The time of bleeding [average of sampled birds slaughtered] (minutes): _____

2.6 What is the method of scalding? _____

2.7 What is the carcass scalding water temperature? (^{o}C) _____

2.8 The time of scalding [average of sampled carcasses] (minutes) _____

2.9 Methods of defeathering? 1. Manually (hand defeathering) ☐ 2. Mechanically (plucking machine) ☐

2.9.1 If manual defeathering, washing hand between defeathering of each chicken? 1. Yes ☐ 2. No ☐

2.10 Do you wash the carcasses immediately after defeathering? 1. Yes ☐ 2. No ☐

2.11 If **yes**, what is the methods of washing?

1. Immersion washing ☐ 2. Washing using running water ☐ 3. Both ☐

2.12 Methods of evisceration? 1. Manually using hand ☐ 2. Mechanically by machine ☐

2.12.1 If manually evisceration, do you wash your hand between evisceration of each chicken?

1. Yes ☐ 2. No ☐

2.13 What is the method of washing the carcass after evisceration? Please explain (hot/cold, salt solution water, and flow of water/immersion) _____

_____

2.13.1 If immersion washing, the average time that carcass remains in the immersion tank? (min.) ____

2.14 If **hot water** is used for washing the carcasses what is the temperature? (°C) _____

2.15 Do you undertake post-mortem inspection? 1. Yes ☐ 2. No ☐

2.16 Do you check weight of the carcasses for over and/or under-weight? 1. Yes ☐ 2. No ☐

2.16.1.1 Please explain why for both cases? _____

2.17 How do you drip/remove the water in carcasses? E*xplanation briefly* _____

_____

2.18 The time let the carcasses to drip/remove the water (hours) _____

2.19 Do you chill the carcasses after slaughtering? 1. Yes ☐ 2. No ☐

2.19.1 If **yes**, what is the method of chilling?

1. Air chilling ☐ 2. Water immersion chilling ☐ 3. Spray chilling ☐

2.19.2 A **brief note** about the process: _____

_____

2.19.3 If **yes**, at what temperature do you chill the carcasses? (°C) _____

2.20 Do you freeze the broiler carcasses until it is supplied to retail market? 1. Yes ☐ 2. No ☐

2.21 Do you further process the carcasses (cut into parts)? 1. Yes ☐ 2. No ☐

2.22 Methods of packing the carcass? (plastic, leak-proof or absorbent pads, etc.) _____

2.23 Labeling (production & expiry dates, and storage & cooking instructions)? 1. Yes ☐ 2. No ☐

2.24 Packing- separate wrapping for giblets? 1. Yes ☐ 2. No ☐

2.25 Is the slaughtering compound separate/different from production house? 1. Yes ☐ 2. No ☐

2.26 Is there any waste accumulation in the slaughtering compound/area? 1. Yes ☐ 2. No ☐

2.26.1 If **yes**, please take a note on the hygiene/cleanness of chicken slaughtering compound (e.g. availability of farm wastes (litter, other wastes etc.) _____

2.27 Do you disinfect/sanitize slaughtering processing surface/area using appropriate disinfectant?

1. Yes ☐ 2. No ☐

2.28 Exclusion of domestic animals (dogs, cats and other domestic animals from slaughtering area):

1. Yes ☐ 2. No ☐

2.29 Knives (stainless steel, free from corrosion, cleaned and disinfected): 1. Yes ☐ 2. No ☐

2.30 Do you use cutting board for carcass processing? 1. Yes ☐ 2. No ☐

2.31 Hygienic plastic mat (cleaned, new/not worn-out and disinfected) used for processing the carcasses: 1. Yes ☐ 2. No ☐ _____

2.32 Hygienic scalding tank (cleaned, corrosion free and disinfected): 1. Yes ☐ 2. No ☐

2.33 Hygienic washing tank (cleaned, corrosion free and disinfected): 1. Yes ☐ 2. No ☐

2.34 Others specify (_____); _____

2.35 Do personnel engaged in handling and processing of meat use protective clothing?

Over-all	1. Yes ☐	2. No ☐	Headgears:	1. Yes ☐	2. No ☐
Hand gloves:	1. Yes ☐	2. No ☐	Plastic boat	1. Yes ☐	2. No ☐
Mouse mask:	1. Yes ☐	2. No ☐	Aprons	1. Yes ☐	2. No ☐

2.36 Do chicken processors wash their hands if they touch or in contact with any waste/garbage?

1. Yes ☐ 2. No ☐

2.37 Take an observation note on the way chicken are handled immediately before slaughtering (from the view point of stress): _____

_____

2.38 Are slaughter persons medically certified being free from any communicable disease?

1. Yes ☐ 2. No ☐

2.39 Are slaughters free from any wounds, bruises or injuries on their hand? 1. Yes ☐ 2. No ☐

2.40 Duration (a time between slaughtering and cooling the carcasses) (hours)_____

2.41 What is the average time taken to complete the whole slaughtering process? (hrs.) _____

2.42 Do you take training on hygienic food/meat handling practices? 1. Yes ☐ 2. No ☐

2.43 Where do you dispose slaughter waste? 1. Dump at the town waste dumping area 2. Dump at nearby free space 3. Buried 4. Burned

2.44 Carcass damage occurred 1 Bone breakage: _____

2. Bruising: _____
3. Engorged or haemorrhagic wing vein: _____
4. Blood spot: _____

"Thank you for Your Time"

APPENDIX 4. Questionnaire and Observation Checklist Used for Retail Markets

Questionnaire and Observation Check list for collecting information on broiler meat handling practices at retail markets

---

1. General Information

1.1 Date of interview: _____

1.2 City/town: _____; Kebele/location: _____

1.3 Name of retail market: _____; Mobile No: _____

2. Retail Market Practices

2.1 What is your source for chicken meat? (√) *for all it applies*

1. Poultry Abattoirs ☐ 2. Backyard slaughter site ☐ 3. Imported from other countries ☐

2.2 Who are your customers for chicken meat? _____

2.3 Do you keep record of purchase and delivery origin of chicken meat? 1. Yes ☐ 2. No ☐

2.3.1 If yes, which types of information do you record? Please specify _____

_____

2.4 Do you check temperature of chicken meat received for your market? 1. Yes ☐ 2. No ☐

2.4.1.1 If yes, what is the required meat temperature at the time of receiving? (°C) _____

2.5 Do you check the meat you received against the following parameters visually? (√) *for all it applies*

1. Blood spot ☐ 2. Engorged or haemorrhagic wing veins ☐ 3. Skin color ☐ 4. Bruising ☐

5. Bone breakage ☐ 6. Cleanness ☐ 7. Others (specify) _____

2.6 Do you have packaging parameter to receive chicken meat from suppliers? 1. Yes ☐ 2. No ☐

2.6.1 If yes, explain what do you check with related packaging? _____

2.7 Is there any labelling (*name and address of producer, weight, production and expiry dates of the meat*)? 1. Yes ☐ 2. No ☐

2.8Do you check freshness of the meat you received? 1. Yes ☐ 2. No ☐

2.8.1 If yes, how do you check for its freshness? _____

_____

2.9 Do you check the way chicken meat is transported to your market (recommended van truck/do they have cold chain)? 1. Yes ☐ 2. No ☐

2.10 Do you re-pack chicken meat at your retail market? 1. Yes ☐ 2. No ☐

2.10.1 If yes, what is your method of packaging? 1. Air vacuum ☐ 2. Plastic bag ☐ 3. Others (specify) _____

2.11 Do you undertake special carcass cutting (cut up the carcass into parts)? 1. Yes ☐ 2. No ☐

2.11.1 Where you keep chicken meat at the super market? 1. In freezer ☐ 2. In cold room ☐ 3. Others (specify) _____

2.12 What is the temperature range you stored the chicken meat? (°C) _____

2.13 Do you keep chicken meat separate from other food items (including another animals' meat)? 1. Yes ☐ 2. No ☐

2.14 Do you practice *first in- first out* while selling chicken meat? 1. Yes ☐ 2. No ☐

2.15 What is the storage duration of a batch of chicken meat? (days) _____

2.16 Do meat handlers wear appropriate protective clothing/clean uniform? 1. Yes ☐ 2. No ☐

2.17 Do meat handlers wear hairnet/cape while working on the meat? 1. Yes ☐ 2. No ☐

2.18 Do meat handlers wear mask while working on the meat? 1. Yes ☐ 2. No ☐

2.19 Do you use gloves while handling/processing meat? ` 1. Yes ☐ 2. No ☐

2.20 Do meat handlers wash their hands before and during meat processing? 1. Yes ☐ 2. No ☐

2.21 Do meat handlers take medical examination/health certificate? 1. Yes ☐ 2. No ☐

2.22 Do meat handlers wash their hands if they touch/in contact with any waste item? 1. Yes ☐ 2. ☐

2.23 Is there insect and/or vermin occurrence in your market? 1. Yes ☐ 2. No ☐

2.24 Do you have insect trap at meat sale, display and storage area in the market? 1. Yes ☐ 2. No ☐

2.25 Do you arrange training on food safety and quality for your workers (meat handlers and processors) in your market? 1. Yes ☐ 2. No ☐

2.26 knowledge on food quality and safety? Please explain your general opinion with relation to raw meat? _____

2.27 Give chance to the respondent to reflect his/her opinion on the issue;_____

_____

_____

"Thank you for your time"

APPENDIX 5. AOAC Broiler Meat Laboratory Analysis Protocols

Sample preparation: The external fat on the meat samples were removed and dried in an oven at 92^{O}C for 6 hours and then well grinded with a miller until the particle size suitable to conduct the required proximate parameters.

Moisture: A clean crucible was dried at 92^{o}C in a forced air oven for 1 hour. The crucible was transferred to a desiccator and cooled for 30 minutes. The empty crucible was weighed (M_1) to the nearest 0.1 mg. The heating, cooling and weighing were repeated until the difference between two successive weighing was less than 5 mg. About 5 grams of sample was weighed accurately (M_2). The crucibles were placed in an oven and dried at 92^{o}C for 6 hours. The crucibles were removed from the oven and cooled in the desiccator for 30 minutes and weighed. The samples were further dried for 1 hour, cooled again in the desiccator and weighed (M_3). The heating, cooling and weighing were repeated until a constant weighed has been achieved.

The moisture content of each sample was calculated from the equation;

$$\%\, Moisture = \frac{(M2 - M3)}{(M2 - M1)}\, x\, 100$$

Where; M1: Weight of the dried crucible

M2: Mass of the dried crucible and the sample before drying

M3: Mass of the dried crucible and the sample after drying

Crude Protein: Around 0.5 grams of dried sample was weighed and transferred into the digestion tube. Then 6 ml of acid mixture (85% Orthophosphoric Acid and 98% Sulfuric Acid) and 3.5 ml of Hydrogen Peroxide solution were added into the digestion flask step by step. The tubes were shaken until the violate reaction disappeared. About 3 grams of the catalyst mixture containing 0.5 grams of Copper Sulfate and 100 grams of Potassium Sulfate was added into the digestion tube. The solution was then digested at 370 °C for 1 hour and 30 minutes by Kjeldahl digester (Gerhardt Kjeldatherm Digester, Germany) until a clear solution was obtained. Then 30 ml of water was added and shaken to avoid precipitation of Sulfate in the solution.

The digested sample was transferred into the sample compartment of the distillation apparatus (Gerhardt Vapodest 200, Germany). A 250 ml conical flask containing 50 ml of Boric Acid - Indicator Solution (10 drops of 75 mg Bromocresol Green and 50 mg Methyl Red in 100 ml of 99 % Ethanol) was placed under the condenser of the distiller with its tips immersed into

the solution and start the distillation. The distillate was titrated with 0.1N Sulfuric Acid standardized using tris (hydoxymethyl) aminomethane until the solution changes from green to violet or pink with the endpoint occurring when one drop of acid results in a color change from steel-blue to light pink.

The nitrogen content of each sample was calculated from the equation;

mg Nitrogen = Volume x Normality x 14 $\quad\quad$ $\% \, Nitrogen = \frac{mg\ N}{W\ (mg\ sample)}\ x\ 100$

The Crude Protein in the sample was calculated using the following formula;

% Crude Protein = % Total Nitrogen X 6.25

Crude Fat: An empty clean extraction flask was dried at 92ºC in a forced air oven for 1 hour. The crucible was transferred to a desiccator and cooled for 30 minutes. The empty extraction flask was weighed (W) to the nearest 0.1 mg. The heating, cooling and weighing were repeated until the difference between two successive weighings was less than 5 mg.

The bottom of an extraction thimble (Whatman) was covered with a 2 cm layer of cotton. About 5 grams of sample was weighed accurately to the nearest 0.1 mg (W1) in the thimble. The sample was covered with a layer of fat-free cotton and the thimble containing the sample was placed in the fat extraction chamber of the Soxhlet apparatus. About 150 - 200 ml of Petroleum Ether was added through the condenser to the weighed extraction flask. The water for the condenser was turned on along with the hotplate of the Soxhlet apparatus. The fat was extracted for four hours. The petroleum ether extract was dried in a forced air oven at 92ºC for 1 hour. The flask was cooled in a desiccator to room temperature for 30 minutes and weighed immediately. The heating, cooling and weighing process was repeated until the difference between two successive weighing is less than 5 mg (W2).

The Crude Fat content of each sample was calculated from the equation;

$$\% \, Crude\ Fat = \frac{(W2 - W)}{W1}\ x\ 100$$

Where; W: Weight of Flask (g)

W_1: Weight of Sample (g)

W2: Weight of Extraction Flask with Petroleum Ether Extract (g)

Crude Ash: Porcelain Crucibles were cleaned and dried in a muffle furnace at 550ºC for 1 hour. The crucibles were cooled in a desiccator for 30 minutes and weighed to the nearest 0.1 mg (W1). About 2.50 grams of the sample was weighed into each crucible (W2). Then the

samples were charred at low temperature on a hot plate under a fume-hood and slowly increased the temperature until smoking ceased and the samples became thoroughly charred. The crucibles were then placed in a furnace at about 550°C for 1 hour. The crucibles were then removed from the furnace and were cooled. 5 drops of deionized water were then added to each of the crucibles to moisten the ash and evaporated the water on the hot plate for 15 minutes and placed in the furnace at 550 °C for 30 minutes. Then they were removed from the furnace and placed in desiccators for 30 minutes. Finally, the mass of each crucible was weighed (W3).

The Crude Ash content of each sample was calculated from the equation;

$$\%\ Crude\ Ash = \frac{(W3 - W1)}{W2}\ x\ 100$$

Where; W1: Weight of Crucible (g)

W2: Weight of Sample (g)

W3: Weight of Ash + Crucible (g)

Crude Fiber: The test portion of about 1 gram (W1) was weighed and pre-treated by adding 30 ml Petroleum Ether to each crucible and filter with a vacuum. 150 ml volume of 0.13M Sulfuric Acid was added to each sample and boiled for about 30 minutes. The mixture was filtered through a crucible using a vacuum and washed several times with distilled water. The residue was transferred to a beaker and 150 ml 0.23M Potassium Hydroxide was added and boiled for about 30 minutes. The mixture was washed with 30 ml acetone and dried. The crucibles were put in an oven set to a temperature of 103 ± 2°C and for 4 hours. The crucibles were then placed in a desiccator to cool and weighed to the nearest 0.1 mg (W2). The crucibles were placed in a muffle furnace and incinerated to for 2 hours at a temperature of 550 ± 20°C. Finally, the crucibles were put in a desiccator and allowed to cool. The final weight (W3) was taken after removing to the nearest mg.

The Crude Fiber content of each sample was calculated from the equation;

$$\%\ Crude\ Fiber = \frac{(W2 - W3)}{W1}\ x\ 100$$

Where; W1: Weight of Sample (g)

W2: Weight of Crucible and Residue after Drying (g)

W3: Weight of Crucible and Residue after Incineration (g)