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# ASSESSMENT AND OPTIONS FOR IMPROVEMENT OF BIOSECURITY PRACTICES IN POULTRY PRODUCTION SECTORS OF CENTRAL ETHIOPIA

**MSc THESIS**

**BY**

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**COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE**
**DEPARTMENT OF ANIMAL PRODUCTION STUDIES**

**JUNE 2023**
**BISHOFTU, ETHIOPIA**

# ASSESSMENT AND OPTIONS FOR IMPROVEMENT OF BIOSECURITY PRACTICES IN POULTRY PRODUCTION SECTORS OF CENTRAL ETHIOPIA

**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**

**By**

**Mensur Sabir Mohammed**

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**BISHOFTU, ETHIOPIA**

**APPROVAL SHEET**

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As members of the Examining Board of the final MSc open defense, we certify that we have read and evaluated the Thesis prepared by: Mensur Sabir Mohammed, entitled Assessment and Options for Improvement of Biosecurity Practices in Poultry Production Sectors of Central Ethiopia" and recommend that it be accepted as fulfilling the thesis requirement for the degree of Masters of Science in Animal Production

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| | |
|---|---|
| CSA | Central Statistics Agency |
| DZARC | Debre Zeit Agricultural Research Center |
| FAO | Food and Agriculture Organization of the United Nations |
| HPAI | Highly Pathogenic Avian Influenza |
| IB | Infectious bronchitis |
| IBD | Infectious bursal disease |
| NBG | National Biosecurity Guide |
| NMA | National Meteorology Agency |
| OIE | Office International des Epizooties |
| SNNP | Southern Nations and Nationalities People Region |
| WHO | World Health organization |

**Assessment and options for Improvement of Biosecurity Practices in Poultry Production Sectors of Central Ethiopia**

By

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Major Advisor- Ashenafi Mengistu (PhD) and Co-advisor- Hika Waktole (MSc)

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## ABSTRACT

A cross-sectional study was conducted from November 2022 to May 2023 to determine poultry biosecurity measures, investigate existing policies and guidelines concerning biosecurity practices, and thereby suggest possible improvement strategies of biosecurity practices in the poultry sector of central Ethiopia. As part of the assessment of biosecurity practices, a total of 82 farms (Adama = 32, Bishoftu = 30, and Modjo = 20) were selected using the purposive sampling method, and data were collected using a Biocheck UGent data. The information were also collected from 13 feed processing plants, 4 Chicken slaughter house,13 live poultry markets, stakeholders and government offices. The data were analyzed using descriptive statistics and the chi-square test. Thus the results showed that the mean overall biosecurity score of farms was 56.39%.whereas the average external and internal biosecurity scores were 49.41% and 72.67%, respectively. From the external biosecurity scores, visitors and farmworkers had the highest point of (93.3%), and feed and water supply (28.2%) had the lowest scores. From the internal biosecurity score, cleaning and disinfection had the highest score (78.59%), and materials and measures between compartments had the lowest score. The study site ($p = 0.033$) and capacity of the farm ($p = 0.000$) had a significant association with biosecurity status. Sources of day-old chicks ($p = 0.000$) significantly depends on the study site. Only 61.53% of the feed processing plants had updated biosecurity plans. However the worst case in the live poultry market using common equipment of (100.0%).Nationally, our country has no legal basis for the implementation of biosecurity measures in veterinary legislation in guidelines, rules, policies and proclamations. Significant variations in the biosecurity scores and a lack of legal basis for biosecurity adoption are highly require options of improvements by making awareness, guideline rules, policies and proclamations and enforcing their implementation.

***Keywords****: Biosecurity, External biosecurity, Guideline, Internal biosecurity, Options for improvement, Policies, Poultry*.

# 1. INTRODUCTION

## 1.1. Background

Poultry production represents an important sector in the agricultural industry, particularly in developing countries where commercial and backyard systems are often extensive and intensive and are dominating the industry (Conan *et al*., 2012). Poultry production has paramount socioeconomic importance in Ethiopia through the provision of eggs and meat, which supports food and nutrition security at household, regional, and national levels. Moreover, it serves as a source of cash income for about 80% of the Ethiopian population and contributes nationally to the gross domestic product (Shapiro *et al*., 2015). Poultry production is quicker and cheaper than other meat sources (Fabrice *et al*., 2021). The production of both poultry meat and eggs certainly helped to close the gap in the supply of animal protein for human consumption for the rapidly growing population (Leta and Bekana, 2010).

Despite the benefits of raising poultry, there are significant problems facing the industry, including disease occurrence, expensive feed costs, and an inadequate level of biosecurity practices. Poultry farmers around the world face endemic disease challenges that threaten poultry health and the profitability of the poultry enterprise. Particularly in Ethiopia, diseases remain one of the principal threats to boosting poultry production. The most economically important poultry diseases, including Newcastle disease, infectious bursal disease, infectious bronchitis disease, Marek's disease, infectious coryza, salmonellosis, colibacillosis, clostridiosis, mycoplasmosis, coccidiosis, and parasitic diseases, prevail in different regions of Ethiopia (Girma *et al*., 2013).

Poultry diseases have substantial adverse economic and social impacts on individual enterprises and on the poultry industry as a whole due to the high mortality and morbidity of poultry, high medication costs, loss in production and market, and the fact that they can pose a risk to public health through zoonosis (Farooq *et al*., 2000; Wierup, 2012; Wubet *et al*., 2019). Due to the ongoing disease outbreaks in the poultry enterprise, it is important to promote and

maintain biosecurity to protect the animals from bio-risks and other agents that could cause disease (FAO, 2013).

The term "biosecurity" refers to any management techniques aimed at preventing or minimizing the possibility of disease transmission and spread to people, animals, or an environment that was previously free of the agents that cause disease (Halifa, 2008). According to FAO (2008), biosecurity is explained as management practices to keep diseases out of the flock through the design of a combination of systems and practices to prevent the adverse effects of disease. Strict biosecurity measures, prevention strategies, and policies are adopted to control contagious diseases under field conditions (Ameji *et al.,* 2012).

OIE (2018) states that veterinary services are in responsible of creating and upholding biosecurity protocols at many levels, namely farm, regional, and national levels. Farm-level poultry biosecurity practices focus on internal and external biosecurity measures to prevent the introduction and spread of pathogens at the farm site. Regional-level biosecurity measures are activities taken by transporters, poultry market enterprises, feed processing plants, district and regional agricultural offices, and relevant experts. National-level biosecurity measures are taken by the Ministry of Agriculture, mainly the livestock sector, the poultry association, government officials, policymakers, and the active participation of the communities in order to prevent the introduction and dissemination of poultry diseases..

The major advantages of implementing biosecurity practices in all levels are preventing the transmission of pathogens causing clinical and subclinical infection in a flock, reduction of disease occurrence and antimicrobial use and minimize the production costs (Laanen *et al.,* 2013; Postma *et al.,* 2016).Poor or absent of biosecurity practices in farms results in high levels of baseline mortality due to predators and infectious diseases (Abdelqader *et al*., 2007).Neglect of biosecurity practices in poultry farms can give rise to the occurrence of diseases and unprecedented situations like high mortality rate, reduced profit and loss of investment (Tasie *et al*., 2020).

Globally, there are ready-made and available packages of biosecurity guidelines, recommendations and policy frameworks for various poultry production systems. However, in developing countries like Ethiopia, biosecurity interventions are given very little attention, and there is no standardized practical biosecurity guideline, policy, or proclamation, thus resulting in significant economic loss in the sector (Abebe, 2006)

In Ethiopia, the application of poultry biosecurity measures is limited. Also, there is no enough information on current biosecurity status of commercial poultry farms. All the available literature tends to indicate that most of the farms found in Ethiopia have limited biosecurity practices, and the nationwide status of the poultry biosecurity practice has not yet been studied and documented (Birhanu *et al*., 2015; Melkamu *et al*., 2016; Wondmeneh *et al.,* 2017;.Atsbaha and Negassi, 2017; Abdulbari *et al.,* 2021; Alemayehu *et al.,* 2021).

For sustainable and successful poultry production, the devising and implementation of practical, holistic poultry biosecurity measures are important at the national and regional levels. Hence, this study addressed the various and interlinked stakeholders apart from the farms, including feed processing plants, chicken slaughterhouses, poultry markets, and relevant veterinarians or experts in district and regional agricultural offices that contribute to the hindrance of disease transmission.

### 1.2. Statement of the problem

In Ethiopia, the most common viral, bacterial, protozoan, and parasitic poultry diseases are endemic and widespread, particularly in central Ethiopia. The role of biosecurity is a key tool in order to prevent and control those diseases and, as a result, increase the production and productivity of poultry. It has been obvious that weak biosecurity practices on a given farm are the leading causes of the transmission and propagation of pathogens. Due to the poor biosecurity measures in the industry, the sector is facing a loss of significant number of birds as a result of the emergence of deadly diseases. In the year 2019/2020 alone, 18.61 million (38.01 percent) poultry died of diseases (CSA 2020).Severe financial losses to the level of closure of their farms This incident may have adverse socioeconomic effects, including the

shortage and high cost of poultry products, malnutrition in children and adults, unemployment directly or indirectly, This will escalate the inflation in the cost of poultry production. Maintaining and implementing appropriate biosecurity measures remain one of the key remedial solutions to safeguard the sector. Moreover, the availability and level of implementation of enabling and working policies, guidelines and other important documents should be assessed to propose options for improvements in biosecurity practices

### 1.3. Research questions

This study was conducted to answer the following research questions:

1. What are the biosecurity measures implemented in poultry farms, feed processing plants, slaughter house and poultry markets?
2. Are there policies, guidelines, rules and proclamations at the national and regional level dealing with poultry biosecurity practices?
3. Do options for improvement of poultry biosecurity practices available?

### 1.4. Objectives

The general objective of this study was determination of the biosecurity practices in poultry production sectors

The specific objectives of the study were:

- To assess the implementation of biosecurity measures at the commercial layer farms, feed processing plants, slaughter houses and poultry markets.
- To investigate the existing policies and rules concerning about poultry biosecurity measures.
- To suggest possible improvement strategies for poultry biosecurity practices in central Ethiopia.

### 1.5. Benefits and beneficiaries of the research work

The poultry sector will be the frontline beneficiary as implementation of adequate level of biosecurity practices in order to reduce the spread of pathogens that cause clinical and subclinical illness in poultry farms. Limit the use of antibiotics, and provide a disease-free environment for improved productivity and profitability. The research work provides pertinent information on the availability of policies, guidelines and proclamations and recommendations on options for improvement of biosecurity practices. The government, private sector small scale producers and the entire community will benefit from the boost in the productivity of the sector and socioeconomic improvement

## 2. LITRATURE REVIEW

### 2.1. Poultry production systems in Ethiopia

There has never been a comprehensive study of the situation of Ethiopian poultry production in general or the commercial system in particular. This knowledge is essential for creating treatments and supports that aim to increase the output of poultry meat and eggs. Based on the reports of CSA (2017) there are more than 60 million chickens in Ethiopia, Out of which indigenous breeds comprise about 94.33%, the remaining are crosses and exotic. According to Dawit *et al*. (2008) the poultry production systems in Ethiopia can be divided into four groups based on the goals, biosecurity levels, and quantity of poultry retained.(1) Large-scale commercial farms with a capacity of over 10,000 poultry and a high level of biosecurity, (2) Medium-scale commercial farms with a capacity of 1000 to 10,000 poultry with optimal biosecurity, (3) Small-scale commercial farms with a capacity of 50 to 1000 poultry and a minimal level of biosecurity and (4) A village or backyard production system with a small number of poultry and minimum to no biosecurity.

### 2.2. Portal of entry of disease agents to farms

Understanding the causing factor and the ways of transmission is crucial before advancing better strategies to prevent poultry diseases. Identifying the most important transmission channels is essential in order to prioritize biosecurity efforts around the highest risk factors. There are different ways in which disease agents may gain entry into a poultry farm. The risk of introducing a pathogen increases with the purchase of poultry (Dewulf and Immerseel, 2018). When there is a high density of nearby farms, diseases can spread through airborne transmission if the farm is located next to a slaughterhouse, a human residence, or stagnant waters (Dewulf and Immerseel, 2018). Visitors and employees of farms may act as mechanical and biological vectors for the transfer of infectious diseases. It is commonly known that contaminated individuals bring the great majority of infections to a farm (farm personnel, family members living on site; contractors, maintenance personnel, neighbors, servicepersons, visitors, through their hands, boots, clothing, and dirty hair) with significant risk of transmission for contagious diseases (Amass, 2005; Lister, 2008).Disease-causing pathogens

can be introduced in to the farm through contaminated farm tools and equipment (feeders, waterers, nests, debeakers, vaccinators, sprayers) and vehicles (feed trucks, product and waste collection vehicles, animal transporting vehicles, egg transporting vehicles) are shared between farms (Pritchard *et al*., 2005). Indirect transmission also occurs through contact with infected or contaminated inanimate objects like environmental fomites from contaminated soil, feed and water. Diseases can also be brought in through contaminated chicks, litter and pests such as wild birds and rodents, feral and domestic animals, pets, insects, domestic birds and dead bird disposals (Balvinder *et al*.,2014).The different transmission path way of pathogens in to farms is summarized in (Figure 1).

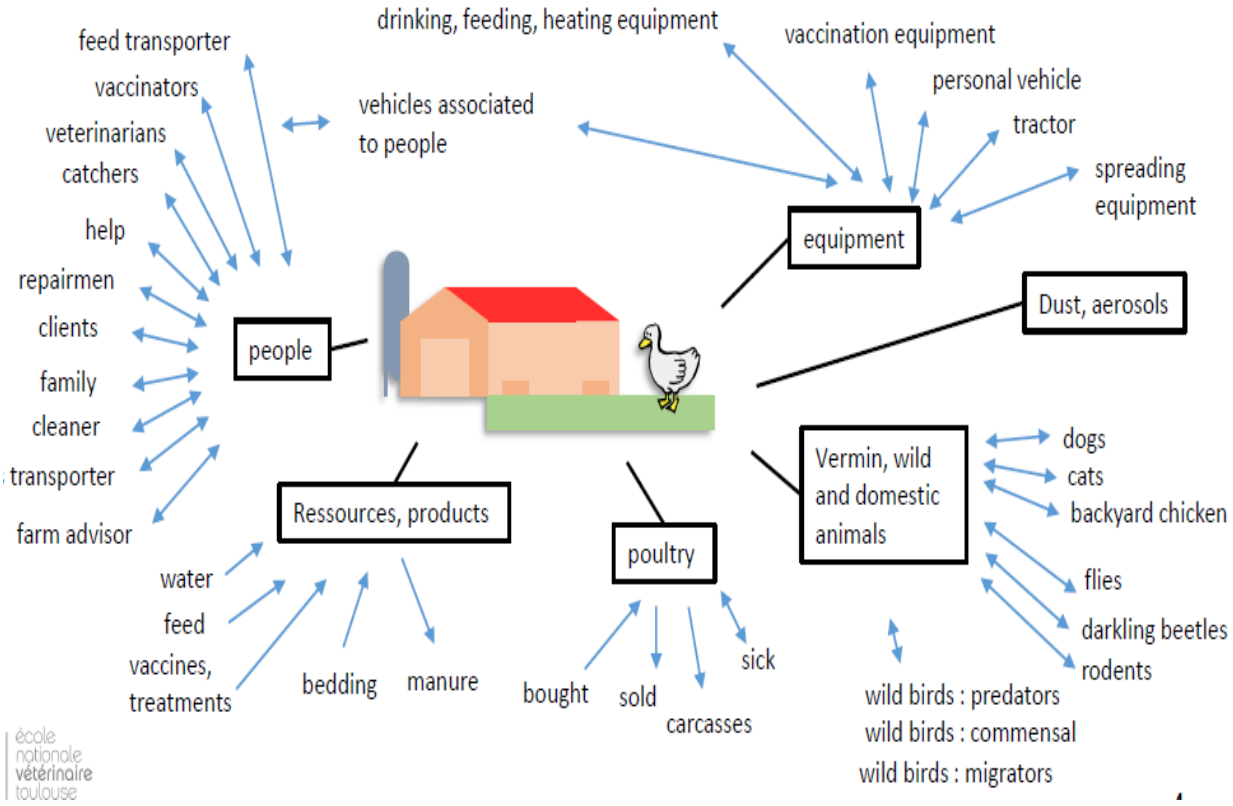


**Figure 1: On-farm pathways of pathogen transmission**.

Source (Jannat *et al.*, 2021)

### 2.3. The current understanding and definition of biosecurity

In poultry farming biosecurity is a package of preventive measures designed to preventing introduction (bio-exclusion) and spread (bio-containment) of pathogens at the farm site especially in organized poultry sector that may have animal health, food safety, and economic consequences. Disease transmission between farms depends on the integration of individual bio-exclusion practices and bio-containment measures (Beach *et al*., 2007; Dorea *et al*., 2010; Patrick and Jubb, 2010; Fasina *et al.*, 2011).Biosecurity practices designed to minimize the transmission of infectious diseases between and within farms is an important component of modern flock health programs. The activities range from simple, low cost to higher investment (Henson and Jaffee, 2005; Permin and Detmer , 2007).Biosecurity is a shared duty between the governments and other stakeholders. It is a strategic and integrated concept that analyzes and manages risk in food safety, public health, animal life and health, as well as linked environmental risk (WHO. 2005; FAO. 2007). As part of the one health concept, biosecurity is particularly important to minimize the impact of infectious diseases on public, animal and plant health, as well as the economy, the environment and society in general (OIE-FAO., 2009). The holistic approach of biosecurity is indicated in (Figure 2).

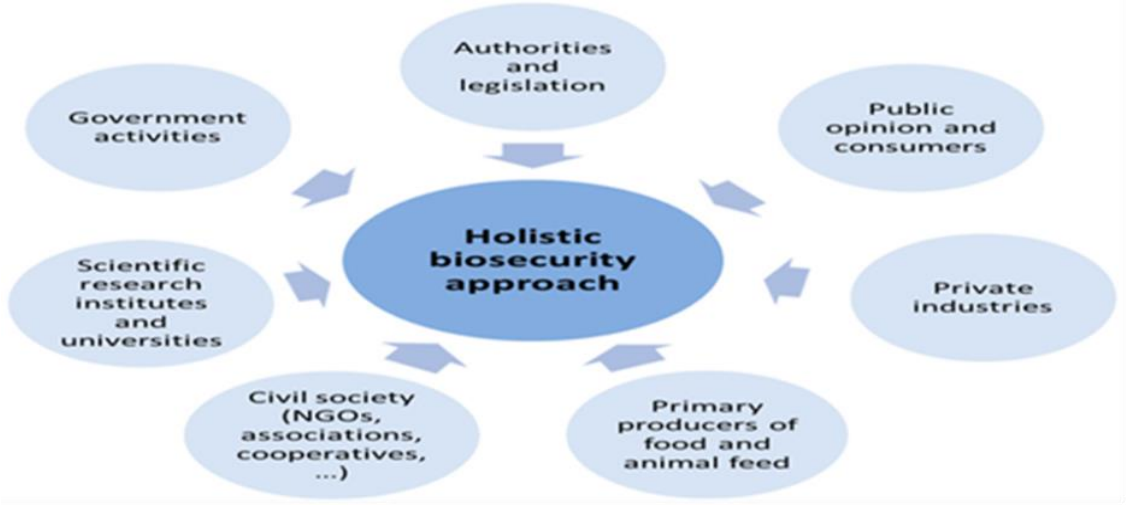


**Figure 2: Sector interests that are important to a holistic approach of biosecurity**

Source: (FAO, 2007)

## 2.4. Levels of biosecurity

The three levels of poultry biosecurity are conceptual, structural and procedural biosecurity: Conceptual biosecurity: this is the primary level of biosecurity revolves around the location of the poultry shed and their various components. Ideally, farms should not be located in close proximity to other farms or public roads, especially when the area has a high density of farms or next to slaughterhouses and markets (Lister, 2008).To reduce the likelihood of air borne transmission between poultry farms, the distance to nearest poultry farm should be at least 1000 meters away in case of breeder farm and 500 meters in case of commercial layer and broiler farms (Chowdhury *et al*., 2017). Structural biosecurity: it is the secondary level of biosecurity and deals with physical factors, such as house design and farm layout, perimeter fencing, drainage, location of changing rooms, presence of showers, air filtration systems, enclosed load-outs, and consider on-site movement of vehicles, equipment, and animals; traffic patterns; and feed delivery and storage (FAO, 2007). Procedural/operational biosecurity: it is the tertiary level of biosecurity which deals with routine procedures to prevent introduction (bio-exclusion) and spread (bio-containment) of infection within an equipment's including taking a shower, changing footwear, wearing farm dedicated clothes, dipping footbath before entry into the farm, washing hands, and disinfecting equipment at the point of entry (Elniema *et al*., 2018).

## 2.5. Measures of biosecurity

There are multiple ways to prevent poultry diseases, including excellent sanitation, medication, vaccination and the implementation of strict biosecurity measures (Okoli, 2004). Biosecurity measures implemented in poultry farms include segregation/isolation, traffic controlling and sanitation (Bizimenyera *et al.,* 2001). Isolation refers to the technique of separating infected birds from healthy ones as well as those belonging to various age and sex groups. According to FAO (2008) Isolation is the practice of keeping different bird species separately, preventing birds from having contact with potential sources of diseases, avoidance of mixing new birds from markets or neighbors with older flocks. quarantining those new birds for some time before joining them to the older flock, quarantining any bird that has gone

out for sale or returned from exhibition to join back into the same bird house, imported birds and preventing wild bird from having contact with the flocks. Traffic control in poultry production involves provision of fencing, doors and locking of gates, control of human and vehicle within and into the farm, notifying the visitors that flock areas are out of bound for people, control of the movement of machines, animals, equipment and products to and from the farm (Musiime, 2005).

Sanitation can be achieved through effective cleaning, disinfection and sterilization. Sanitation practically reduces the amount of pathogenic organism and reduces quantity of contaminating agents to its minimum level such that they pose no disease threat to birds through the practice of regular cleaning of equipment, washing of protective clothing and maintaining personal hygiene that will lead to destruction of disease organisms. It includes hand sanitizing, wearing of clothing exclusively made for the poultry house, using personal protective equipment like overalls, boots, and headwear. Cleaning of vehicle, houses and equipment, fumigation of poultry house, frequent washing of hands and feet before and after handling poultry materials (Nyaga, 2007).

Disinfection is the process of eliminating pathogenic organisms with the aid of agrochemicals referred to as disinfectants. Disinfectants are chemicals that are used for disinfection on inanimate objects only while antiseptic is mild form of disinfectant that is used externally on living tissues to destroy the activities of microorganisms. For instance, Sainsbury (2009) reported that limiting diseases spread in poultry farm, involves implementation of effective biosecurity that has a comprehensive range of clear procedure aiming at minimizing the possibility of introduction of undesired pathogen into the poultry production area. Sterilization is the process of eliminating all vegetative and spore forms of microorganisms, notably extremely resistant bacteria, fungi, and viruses (Musiimi, 2005).

### 2.6. Principles of poultry biosecurity

The fundamental principles of poultry biosecurity encompass procedures that reduce the probability of disease outbreaks and the principles of biosecurity include the following

components: Controlling poultry quarantine and poultry movements: Manage the introduction and movement of poultry in a way that minimizes the risk of introducing or spreading infectious disease (Eric and Jill, 2017).Keeping people, equipment and vehicle hygiene: People, equipment and vehicles entering the village, enterprise or country are controlled to minimize the potential for property contamination. Feed and water safety: Quality of stock feed and water is fit for purpose, especially purchased feed that is free from contaminants, untreated will and/or restricted poultry material (Fasina *et al*., 2011). Poultry health management, surveillance and reporting: Prevent and control poultry disease by using appropriate vaccination programs, regularly monitoring for disease and immediately reporting outbreaks (Dewulf and Immerseel, 2018). Creating public awareness: All farmers, traders, agency staff and contractors, understand the importance of the biosecurity requirements for the village, enterprise or country in which they work and can implement the agreed practices for which they are responsible (Windsor, 2017).

### 2.7. Importance of poultry biosecurity

Biosecurity increasingly gains importance for the health management of poultry flock. The application of biosecurity measures is crucial in preventing the spread of poultry diseases that result in clinical and subclinical infection on poultry. It ensures a disease-free environment, decreases the need for antibiotics, and increases production and profitability (Laanen *et al.*, 2013; Postma *et al*., 2016). High pathogen load increases mortality and negatively affects performance, resulting in large losses. Pathogen introduction is decreased in the production of poultry by using proper biosecurity procedures. However, a higher prevalence of disease is associated with lower levels of biosecurity, poultry production parameters and biosecurity have a very strong positive correlation (Laanen *et al.,* 2013; Postma *et al*., 2016) and between biosecurity and farm profitability (Corrégé *et al.,* 2012; Rojo-Gimeno *et al.,* 2016). Drinking water is a major cause of illness and birds need high-quality water to stay in the best possible condition. Good flock performance is strongly correlated with increased water sanitation. The economics of biosecurity are completely logical. All economic models indicate that disease prevention is always less expensive than illness treatment; therefore, the cost of adopting a biosecurity system is negligible when compared to the potential financial gain from output.

Consequently, the key component of the most effective disease control is adequate biosecurity (Postma *et al*., 2016).

## 2.8. Factors affecting biosecurity adoption on poultry farms

It was noted that the factors that influence the applying level of biosecurity activities or desire to implement a better level of biosecurity activities. They can be associated with respondents' characteristics and farm characteristics (Van Steenwinkel, 2011 and Siekkinen *et al*., 2012).

### *2.8.1. Farmer characteristics:*

Age of the household head: the age of the decision maker is an important factor influencing the adoption of biosecurity practices. Generally, the household head is responsible for the decisions made in poultry farms. Older farmers set more in their ways and less prepared to change or invest in new practices. Education is an important factor on farmer adoption of biosecurity.it is expected that the higher the educational level of farmers, the greater their biosecurity implementation (Nyaga, 2007).Poultry farming experience: it may also be an important influence on biosecurity adoption.it is expected that the greater the experience in poultry farming, the greater the likelihood that farmers will implement biosecurity measures,

Poultry as main occupation for household head: If poultry is the main source of income, it may be that production and efficiency may be important to these households, hence, they may have higher levels of biosecurity, poultry management: (Dorea *et al*., 2010). Farm ownership type: It was found that the farm ownership status of respondents could be defined as; owner; manager; owner and manager; and other, Non-poultry income: The importance of family income derived from non-poultry sources. Influence the priority to invest in poultry farm infrastructure and management changes. If non-poultry income is high there may be less priority for farmers to be concerned about poultry income and hence less investment in poultry activities (Van Steenwinkel, 2011 and Siekkinen *et al*., 2012).

*2.8.2. Farm characteristics*

Farm size and capacity: This includes the number of poultry farms and sheds, the total land area of farms, and the total and average shed capacity. These parameters have a negative influence on the implementation of biosecurity practices. The higher the number of poultry sheds, the higher the level of internal risk due to the need for more labor and transport (Soha and Dalia, 2018). The location of the farm also influences biosecurity adoption. The location includes the distance to other poultry farms, the altitude of sheds, the distance of sheds from main roads, residential areas, live chicken markets, wetlands, neighboring sheds, feed storage, offices, parking areas, and boundary fences. Social capital plays an important role in determining biosecurity adoption. and embedded in social interaction and attitudes among communities and may affect a community's response to disease-related risks (Sri Hery *et al*., 2011; Soha and Dalia, 2018).

## 2.9. Available biosecurity policies and proclamations in Ethiopia

The only biosecurity document available at the then Ministry of Agriculture and Rural Development was the one developed by the FAO's cooperation is the prevention and control strategy against Avian Influenza. This policy was a crucial component of the nation's strategic readiness and response strategy for the threat of an avian influenza pandemic. It was designed specifically for the animal health component of the strategic plan with a focus on biosecurity, movement control and market limitation, surveillance and diagnosis, disposal of carcasses and possibly infectious materials, vaccination, and compensation (FAO, 2006).This national biosecurity strategic plan is made up of several functional units, such as surveillance and epidemiology, which produce pertinent and timely data to assess the level of risk of an outbreak of highly pathogenic avian influenza and develop plans for counter measures to effectively stop the disease's spread and examines the variables influencing the prevalence and dissemination of HPAI, associated socioeconomic implications and efficiency of intervention methods, laboratory services: make sure that samples obtained for monitoring activities, diagnosing disease outbreaks and monitoring vaccination response have effective diagnostic capability and testing skills. Strengthening of infrastructure includes disease management,

ensuring prompt and appropriate responses to HPAI outbreaks to prevent occurrence and minimize spread, communication and public awareness and ensuring effective communication mechanisms and strategies with stakeholders and communities (FAO, 2006).

## 3. MATERIALS AND METHODS

### 3.1. Description of study areas

The present study was conducted in selected areas of, central Ethiopia. The areas were purposively selected on the bases of availability and accessibility of poultry breeder farms, high numbers of commercial poultry farms, nearby sources of feed processing plants, markets, and other inputs. Three towns namely Adama, Bishoftu and Modjo, as shown in the map of study area (Figure 3)

Adama town is located at 8.54°N and 39.27°E, at an elevation of 1712 m a.s.l., has an average annual temperature of 20.7 °C, and is located about 99 kilometers southeast of Addis Ababa. Farmers in the vicinity of Adama district practice a mixed crop and livestock farming system. Livestock production is very common, including cattle, sheep, goats, donkeys, and camels, and the area is the major supplier of beef cattle to domestic markets (Abdisa *et al.*, 2020). There are also a number of small- and medium-scale commercial and backyard poultry farms, poultry multiplication centers, feed processing plants, and markets (Addisu *et al.*, 2012).

Bishoftu (Ada'a) district has an altitude of 1500–2250 m.a.s.l. and is located 47 kilometers southeast of Addis Ababa. The lives of the households highly depend on mixed crop and livestock production practices. Bishoftu is popularly known as the 'poultry village' of the country. There are many commercial and small-scale farms in this area, which are usually potential sources of poultry farm inputs, including fertile eggs, day-old chicks, and pullets, feed, and serving farms in other parts of the country. There are also feed processing plants, poultry slaughter houses, markets, and institutions working on the improvement of the poultry sector, including NVI, the College of Veterinary Medicine, and the Debre Zeit Agricultural Research Center (DZARC, 2006; NMA of Ethiopia, 2010).

Modjo (Lume) district is located 70 kilometers from Addis Ababa in the East Shewa zone of Oromia Regional State. The lives of the population in the vicinity mainly depend on mixed crop and livestock production. Vegetables are an important cash crop in the area. Currently, this district serves as a strategic center for newly emerging poultry farms.Poultry production is

widely practiced in this area, ranging from backyards up to large-scale commercial farms. There are also poultry feed processing plants and poultry markets (CSA, 2005; Abdisa *et al*., 2020).

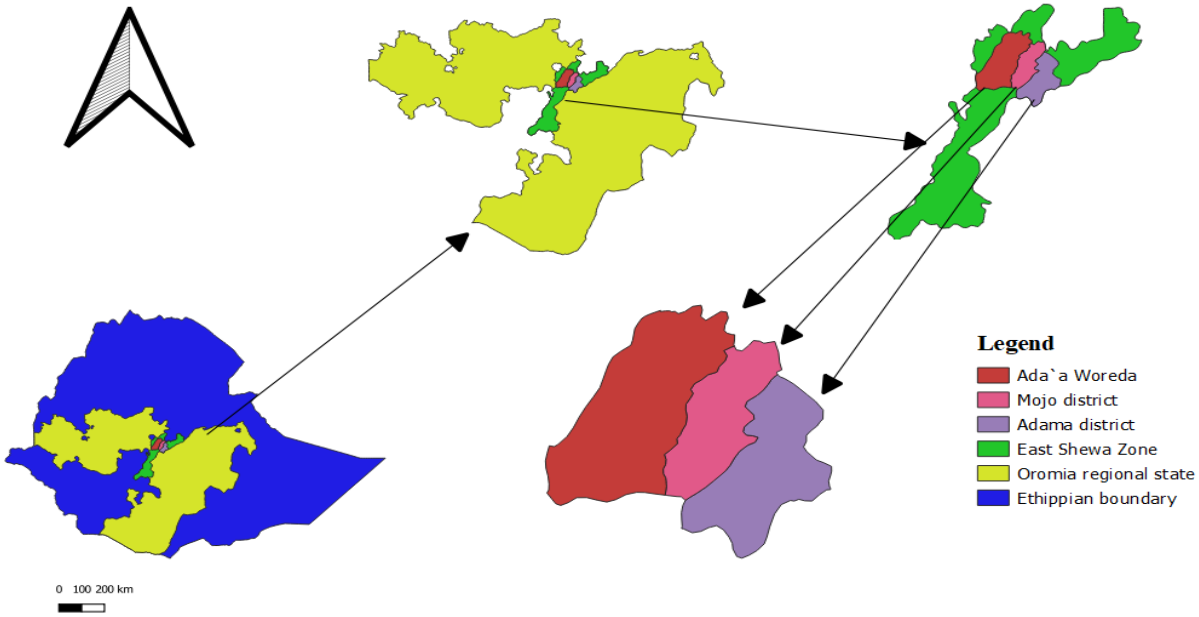


**Figure 3: Map of the study area**

### 3.2. Study design and population

A cross-sectional study was conducted from November 2022 to May 2023 to determine the biosecurity measures in poultry production sectors including poultry farms, feed processing plants, chicken slaughter houses, live poultry markets, and the stakeholder relevant governmental offices. The target Population of the study were commercial layer farms found in the three districts that raise exotic breeds of poultry.

### 3.3. Sampling methods

In the current study the poultry farms were purposively selected based on their practical criteria including farm type, ease of accessibility, geographical proximity and the willingness to participate in the study. Accordingly, a total of 82 (32 from Adama, 30 from Bishoftu and 20 from Modjo) commercial layer farms were selected and data were collected using the pretested Biocheck UGent questionnaires during actual visit of the farms.

For the assessment of holistic poultry biosecurity practices data were collected from interlinked companies including 13 feed processing plants, 13 poultry markets,4 poultry slaughter houses and 5 stakeholder government offices which are located in the selected areas of Central Ethiopia.

### 3.4. Biosecurity Assessment Tool

The Biocheck.UGent tool is the largest database on biosecurity in animal production and used to quantify and describe the biosecurity practices at the farm level. It is a risk-based scoring tool developed by the Ghent University, Belgium (https://biocheckgent.com/en).The tool is available online free of charge. It was based from the initial work of (Gelaude *et al*., 2014). The tool has its own structured online questionnaire which has 120 closed questions. All possible disease transmission ways were included such as airborne transmission, food-borne transmission, and vector-borne transmission like personnel. Wild birds, insects, litter, equipment, rodents or pets and environment like cleaning and disinfecting the poultry house.

The scoring system is separated into 2 main categories, external and internal biosecurity. External biosecurity comprises all measures preventing the introduction of off-farm pathogens and is subdivided into 10 subcategories (purchase of day old chicks, purchase of pullets, depopulation and transport of poultry, transport of eggs, feed and water supply, removal of manure and dead birds, material supply, visitors and farmworkers, infrastructure and biological vectors and location of the farm).Internal biosecurity includes all measures that aim at preventing the within-herd spread of pathogens and is subdivided in to 4 subcategories

(disease management and vaccination, cleaning and disinfection, materials and measures between compartments and egg management).The answer to every question results in a score between zero (when this measure is not implemented at all or worst scenario) and one (when the measure is fully implemented or best scenario).Depending on the importance of a particular biosecurity measure, the score for each question was multiplied by its weight factor. This score is subsequently multiplied by the weight of the specific question to obtain the relative result of the question. Next, all the results of the individual questions within a subcategory are summed up and divided by the maximum score that can be obtained in the subcategory. This proportional result of the subcategory is then multiplied by the weight of the subcategory to obtain the subcategory score. The subcategories were also assigned a specific weight factor equal to their determined relative importance for disease transmission (Laanen *et al.,* 2013; Gelaude *et al*., 2014).

The final score for both internal and external biosecurity can range from zero (indicating a total absence of the described biosecurity measures) to 100 (indicating a full application of the described measures).The overall biosecurity score was the sum of the external and internal biosecurity score. Due to the different relative weight, the external biosecurity score counts for 70% and the internal counts for 30% in the total biosecurity score. For ease of interpretation of the results, category and subcategory scores were recalculated each time to a score of 100 and presented as a percentage in the reports (Gelaude *et al*., 2014). A score of 100 means that all the biosecurity measures are all in place and that a score of zero means no measure is installed in the farm. The higher score indicates the better biosecurity status of the farms. Technically, a 50% biosecurity score means that half of the biosecurity measures are implemented and another half is not.

## 3.5. Methods of data collection

### *3.5.1. Data Collection procedures at the Farm level*

The Biocheck.UGent questionnaire was translated into the local dialect orally for ease of understanding and administration. The researcher personally visited each farm and conducted an interview with a contact person, who was typically the farm owner, employee, and veterinarian, in order to reduce interviewer bias. Before providing the questionnaire, the farmers were given a brief explanation of the study's purpose and given the opportunity to provide verbal informed permission. All participants in one district were completed first before moving to the next district. The majority of interviews took place within farm offices, while some others conducted outside farm gates. Actual visits to each farm were made to validate the survey results. Yet some farmers are opposed to entering the farm because of the risk of introducing a disease. The results were entered into the Biocheck.UGent online database once the paper copy of the questionnaire was completed at the farms as a result individual farm reports were generated. As final scores for each biosecurity subcategory were obtained for each farm and the obtained data were collected in Microsoft Office Excel format for further statistical analysis (Van Limbergen *et al*., 2014).

### *3.5.2. Data collection procedures in institutions*

The data for the feed processing plants, the chicken slaughter houses and the poultry markets were collected by self-prepared questionnaires. The contact personnel in the feed processing plant and chicken slaughter houses were professionals. The respondents in the poultry market were farmers, merchants and brokers.

### *3.5.3. Assessment of existing policies, guidelines and proclamation*

To collect the data required to provide answers on the topics identified a questionnaire was developed and a survey was conducted by actual visiting of the responsible government office obviously the Ministry of Agriculture specifically the livestock and fisheries division. Data were also collected from relevant stakeholder agricultural offices located in the study areas

*3.5.4. Options for improvement of biosecurity practices*

The options for the improvement for the biosecurity status strategies were given after all the real data on the ground was obtained as a result .Areas that need improvement options were categorised in to: (i) Farm inputs: including chickens, water, visitors, vermin and insects, animals, bedding material, Feed, vehicle and equipment, (ii) Farm outputs: include Eggs, Dead birds, Meat Product, litter and manure, Machinery, People and Vehicles, (iii) Biosecurity records**:** include Deliveries like feed, Visitors, vaccinations and medications, water usage, Feed consumption, Shed conditions**,** Mortalities, Movements of the chickens, Sales, Control of pests and rodents**,** Staff training

## 3.8. Data Management and Analysis

The collected data were stored in Microsoft Excel spread sheets and then statistically analysis was performed through SPSS version 20.0. For the socio-demographic characteristics of the respondents' summary of biosecurity levels, frequencies and percentages were computed. Due to the small number of participating feed processing plants, live poultry markets, and veterinarians, there was a limited amount of data; therefore, the statistical analysis was narrowed down to descriptive statistics only. The quantitative variables like the capacity of the farm, the age of the newest and oldest chicken building, years of experience in poultry farming, and the number of workers on the farm were summarized by minimum, maximum and mean. The percentages of the external, internal, and overall average biosecurity scores were calculated by using the Biocheck UGent tool. For the associations and dependency, the Chi-square test was performed.

## 4. RESULTS

### 4.1. Results at the poultry farm level

*4.1.1. General characteristics of the households*

Characteristics of the household (Table 1) revealed that the proportions of male respondents were higher than females in all the study sites, and the producers had a wide range of educational backgrounds, from primary to higher education.

**Table 1: Socio- economic characteristics of the contacted households**

| Variable | Categories | Adama N=32 | | Bishoftu N=30 | | Mojo N= 20 | |
|---|---|---|---|---|---|---|---|
| | | № | % Age | № | % Age | № | % Age |
| **Role of responden** | Employee | 6 | 7.3% | 4 | 4.9% | 3 | 3.7% |
| | Farm owner | 26 | 31.7% | 26 | 31.7% | 17 | 20.7% |
| **Sex** | Male | 19 | 23.2% | 20 | 24.4% | 14 | 17.1% |
| | Female | 13 | 15.9% | 10 | 12.2% | 6 | 7.3% |
| **Age** | 26-35 | 14 | 17.1% | 6 | 7.3% | 6 | 7.3% |
| | 36-45 | 11 | 13.4% | 14 | 17.1% | 8 | 9.8% |
| | >45 | 7 | 8.5% | 10 | 12.2% | 6 | 7.3% |
| **Educational status** | Primary School | 11 | 13.4% | 7 | 8.5% | 2 | 2.4% |
| | Secondary School | 12 | 14.6% | 7 | 8.5% | 5 | 6.1% |
| | Above Secondary school | 9 | 11.0% | 16 | 19.5% | 13 | 15.9% |

*4.1.2. General characteristics of the studied poultry farms*

From the total layer farms that participated in this study, the majority of them were medium-scale farms with a mean flock size of 2280 birds, and all of the farms use deep litter housing systems for poultry management (Table 2).

**Table 2: Characteristics of the studied poultry farms**

| Variables | Responses | Adama N= 32 | Bishoftu N=30 | Mojo N= 20 |
|---|---|---|---|---|
| **Number of layers** | Minimum | 440 | 540 | 756 |
| | Maximum | 7000 | 12000 | 15000 |
| | Mean | 1964.13 | 2555.50 | 2321.450 |
| **Years of experience** | Minimum | 2 | 2 | 3 |
| | Maximum | 9 | 21 | 16 |
| | Mean | 5.16 | 8.070 | 8.200 |
| **Number of workers** | Minimum | 1 | 1 | 1 |
| | Maximum | 9 | 22 | 8 |
| | Mean | 1.970 | 2.770 | 1.950 |
| **Capacity of the farms** | Small scale | 10 | 3 | 6 |
| | Medium scale | 22 | 26 | 13 |
| | Large scale | 0 | 1 | 1 |
| **Presence of other animals** | Yes | 7 | 16 | 3 |
| | No | 25 | 14 | 17 |

### 4.2. Biosecurity levels recorded in the study areas

The vast majority of the surveyed farms would not satisfy the requirements for the biosecurity levels, and in all the assessed farms, vermin were often a problem (Table 3).

**Table 3: Biosecurity levels recorded in the study areas**

| | Responses | Adama N= 32 | | Bishoftu N=30 | | Mo N= 20 | |
|---|---|---|---|---|---|---|---|
| | | No | % | No | % | No | % |
| Conceptual biosecurity | | | | | | | |
| Farm distance with neighboring chicken farm | <500 meters | 26 | 81.25% | 30 | 100.0% | 20 | 100.0% |
| | >500 meters | 6 | 18.75% | 0 | 0.0% | 0 | 0.0% |
| Stagnant/ running water in 1km radius | Yes | 0 | 0.00% | 6 | 20.0% | 0 | 0.0% |
| | No | 32 | 100.0% | 24 | 80.0% | 20 | 100.0% |
| Animal transport in nearest road | Yes | 5 | 15.6% | 13 | 43.3% | 12 | 60.0% |
| | No | 27 | 84.4% | 17 | 56.7% | 8 | 40.0% |
| Structural biosecurity | | | | | | | |
| Egg storage room | In chick house | 14 | 43,8% | 11 | 36.7% | 6 | 30.0% |
| | Separate room | 18 | 56.2% | 19 | 63.3% | 14 | 70.0% |
| Presence of hygiene lock | Yes | 15 | 46,9% | 18 | 60.0% | 12 | 60.0% |
| | No | 17 | 53.1% | 12 | 40.0% | 7 | 35.0% |
| Presence of functional foot bath | Yes | 22 | 68.75% | 27 | 90.0% | 18 | 90.0% |
| | No | 10 | 31,25% | 3 | 10.0% | 2 | 10.0% |
| Operational biosecurity | | | | | | | |
| Visitors and workers wear farm clothes | Yes | 18 | 56.2% | 23 | 76.7% | 12 | 60.0% |
| | No | 14 | 43.8% | 7 | 23.3% | 8 | 40.0% |
| Practice of hand wash before entry of farm | Yes | 5 | 15.6% | 4 | 13.3% | 1 | 5.0% |
| | No | 27 | 84.4% | 26 | 86.7% | 19 | 95.0% |
| Presence of functional foot bath | Yes | 22 | 68.8% | 27 | 90.0% | 18 | 90.0% |
| | No | 10 | 31.2% | 3 | 10.0% | 2 | 10.0% |

### 4.3. The major findings of the biosecurity measures

The majority of the assessed poultry farms consistently used the all-in-all-out approach for depopulating and restocking chickens, and 13.4% of them disposed of dead birds by throwing them outside their farms. The majority of farms lack house hygiene locks and some of the farms do not follow proper cleaning and disinfection procedures, which are the most crucial biosecurity measures as indicated in (Table 4).

**Table 4: Major findings of the biosecurity measures (I)**

| Biosecurity measures | Responses | Adama N= 32 | | Bishoftu N=30 | | Mojo N= 20 | |
|---|---|---|---|---|---|---|---|
| | | No | % | No | % | No | % |
| Manure storage on the farm | Yes | 2 | 6.2% | 5 | 16.7% | 6 | 30.0% |
| | No | 30 | 93.8% | 25 | 83.3% | 14 | 70.0% |
| Separate dead bird storage room | Yes | 14 | 43.8% | 17 | 56.7% | 13 | 65.0% |
| | No | 18 | 56.2% | 13 | 43.3% | 7 | 35.0% |
| Dead bird protected from vermin and pets | Yes | 8 | 25.0% | 12 | 40.0% | 9 | 45.0% |
| | No | 24 | 75.0% | 18 | 60.0% | 11 | 55.0% |
| Ways of dead bird disposal | Throw outside farm | 8 | 25.0% | 0 | 0.0% | 3 | 15.0% |
| | Collected by rendering company | 2 | 6.2% | 3 | 10.0% | 0 | 0.0% |
| | Burned or buried | 22 | 68.8% | 27 | 90.0% | 17 | 85.0% |
| Obligation of visitors to register | Yes | 17 | 53.1% | 29 | 96.7% | 18 | 90.0% |
| | No | 15 | 46.9% | 1 | 3.3% | 2 | 10.0% |
| Visitors and workers wear farm cloth | Yes | 16 | 50.0% | 23 | 76.7% | 10 | 50.0% |
| | No | 16 | 50.0% | 7 | 23.3% | 10 | 50.0% |
| Presence of farm perimeter fence | Partially | 1 | 3.1% | 2 | 6.7% | 4 | 20.0% |
| | Completely | 31 | 96.9% | 28 | 93.3% | 16 | 80.0% |
| Vermin is problem at the farm | Sometimes | 4 | 12.5% | 4 | 13.3% | 4 | 20.0% |
| | Often | 28 | 87.5% | 26 | 86.7% | 16 | 80.0% |
| Outside of farm paved and clean | Partially | 7 | 21.9% | 7 | 23.3% | 9 | 45.0% |
| | Completely | 25 | 78.1% | 23 | 76.7% | 11 | 55.0% |
| Disinfection of feed transport vehicles | Yes | 8 | 25.0% | 10 | 33.3% | 2 | 10.0% |
| | No | 24 | 75.0% | 23 | 66.7% | 18 | 90,0% |
| Feed room sealed against water, vermin | Yes | 20 | 62.5% | 12 | 40.0% | 5 | 25.0% |
| | No | 12 | 37.5% | 18 | 60.0% | 15 | 75.0% |

**Table 4:** Major findings of the biosecurity measures (II)

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| House soaked with water before cleaning | Never | 1 | 3.1% | 0 | 0.0% | 2 | 10.0% |
| | Sometimes | 4 | 12.5% | 1 | 3.3% | 3 | 15.0% |
| | Always | 27 | 84.4% | 29 | 96.7% | 15 | 75.0% |
| House dry before disinfection | Sometimes | 11 | 34.4% | 10 | 33.3% | 11 | 55.0% |
| | Always | 21 | 65.6% | 20 | 66.7% | 9 | 45.0% |
| Disinfection of egg storage room | Yes | 24 | 75.0% | 21 | 70.0% | 11 | 55.0% |
| | No | 8 | 25.0% | 9 | 30.0% | 9 | 45.0% |
| Disinfection of loading and unloading areas | Yes | 22 | 68.8% | 30 | 100.% | 18 | 90.0% |
| | No | 10 | 31.2% | 0 | 0.0% | 2 | 10.0% |
| Disinfecting watering system after first production cycle | Never | 0 | 0.0% | 1 | 3.3% | 1 | 5.0% |
| | Sometimes | 0 | 0.0% | 0 | 0.0% | 2 | 10.0% |
| | Always | 32 | 100.% | 29 | 96.7% | 17 | 85.0% |
| Practice of regular vaccination | Yes | 27 | 84.4% | 30 | 100.% | 19 | 95.0% |
| | No | 5 | 15.6% | 0 | 0.00% | 1 | 5.0% |
| Farm work from young to old chicken | Yes | 27 | 84.4% | 18 | 60.0% | 16 | 80.0% |
| | No | 5 | 15.6% | 12 | 40.0% | 4 | 20.0% |
| Presence of functional foot bath | Yes | 22 | 68.8% | 27 | 90.0% | 18 | 90.0% |
| | No | 10 | 31,2% | 3 | 10.0% | 2 | 10.0% |
| Practice of house disinfection protocol | Yes | 26 | 81.2% | 24 | 80.0% | 19 | 95.0% |
| | No | 6 | 18.8% | 6 | 20.0% | 1 | 5.0% |
| Presence of house hygiene lock | Yes | 15 | 46.9% | 21 | 70.0% | 8 | 40.0% |
| | No | 17 | 53.1% | 9 | 30.0% | 12 | 60.0% |
| Presence of multiple houses | Yes | 10 | 31.2% | 19 | 63.3% | 14 | 70.0% |
| | No | 22 | 68.8% | 11 | 36.7% | 6 | 30.0% |
| Practice of all- in all- out system | Sometimes | 3 | 9.4% | 5 | 16.7% | 2 | 10.0% |
| | Always | 29 | 90.6% | 25 | 83.3% | 18 | 90.0% |

### 4.4. The external subcategory biosecurity scores of the study site.

The overall external biosecurity score for all farms was 49.41%. Among the external biosecurity scores, visitors and farmworkers had the highest scores, and feed and water supply had the lowest scores. Visitors and farmworkers, infrastructure and biological vectors, and material supply score marginally higher than the global average, as indicated (Table 5).

**Table 5: The external subcategory biosecurity score of the study sites.**

| Subcategories | Adama | Bishoftu | Modjo | Overall | Global average |
|---|---|---|---|---|---|
| **External biosecurity** | | | | | |
| **Purchase of day-old chicks** | 50.03% | 37.9% | 36% | 41.31% | 55 % |
| **Purchase of pullets** | 62.81% | 57.9% | 56.58% | 59.09% | 72 % |
| **Depopulation and transport of chickens** | 56.44% | 47.8% | 50% | 51.41% | 56 % |
| **Transport of eggs** | 35.13% | 31.9% | 31.6% | 32.88% | 41 % |
| **Feed and water supply** | 37.4% | 29% | 18.2% | 28.2% | 50 % |
| **Removal of manure and dead birds** | 31.88% | 47.5% | 35.6% | 38.33% | 46 % |
| **Material supply** | 68.6% | 75.6% | 67.3% | 70.5% | 62 % |
| **Visitors and farmworkers** | 87.5% | 92.3% | 100% | 93.3% | 70 % |
| **Infrastructure & biological vectors** | 75.2% | 71.6% | 68% | 71,6% | 65 % |
| **Location of the farm** | 53.8% | 44.6% | 47.2% | 48.5% | 64 % |
| **Subtotal of external biosecurity** | **53.2%** | **50.23%** | **44.8%** | **49.4%** | **57 %** |

### 4.5. The internal subcategory biosecurity scores of the study site.

The overall average performance in internal biosecurity was 72.67%. From the internal biosecurity score, cleaning and disinfection received the highest score, and materials and measures between compartments received the lowest score. Three-fourths of the marginal internal biosecurity scores were better than the global average (Table 6).

**Table 6: The internal subcategory biosecurity score of the study site.**

| Internal biosecurity subcategories | Adama | Bishoftu | Modjo | Overall | Global average |
|---|---|---|---|---|---|
| **Disease management and vaccination** | 75.75% | 63.87% | 73.73% | 71.12% | 71 % |
| **Cleaning and disinfection** | 80.4% | 80% | 75.37% | 78.59% | 66 % |
| **Materials and measures** | 42.63% | 52.96% | 28.63% | 41.4% | 63 % |
| **Egg management** | 66.84% | 65.77% | 66% | 66.2% | 60 % |
| **Subtotal of internal biosecurity** | **75%** | **72%** | **71%** | **72.67%** | **66 %** |

### 4.6. Biosecurity Scores of Central Ethiopia

The overall biosecurity score of the present study was found to be 56.39% and this finding was lower than the corresponding global average score (62%). The farms in Adama district had the highest score followed by Bishoftu (Table 7)

**Table 7: Overall biosecurity scores of the study sites**

| Biosecurity scores | Adama | Bishoftu | Modjo | Overall | Global average |
|---|---|---|---|---|---|
| **Internal biosecurity** | 75% | 72% | 71% | 72.67% | 66 % |
| **External biosecurity** | 53.2% | 50.23% | 44.8% | 49.41% | 57 % |
| **Overall** | **59.74%** | **56.76%** | **52.66%** | **56.39%** | **62 %** |

### 4.7. Associations and dependency results

*4.7.1. Association between biosecurity scores and farm characteristics*.

The farms and farmers characteristics have different significant associations with the biosecurity score. Flock size and study site had a significant association with the biosecurity scores. (Table 8).The individual farm biosecurity score was generated from Biocheck Ugent tool and according to their biosecurity score poultry farms were ranked as >80 % very good, 60 – 79 % = good, 50- 59% weak, <50% minimum (Chowdhury *et al.*, 2017).

**Table 8: Association between biosecurity scores with farms and farmer characteristics**

| **Variable** | | **Biosecurity score** | | | | **P=Value** |
|---|---|---|---|---|---|---|
| | | Very good | Good | Weak | Poor | |
| **Study site** | Adama | 23 | 1 | 0 | 7 | 0.033 |
| | Bishoftu | 17 | 5 | 1 | 8 | |
| | Modjo | 6 | 1 | 1 | 11 | |
| **Gender** | Male | 2 | 30 | 19 | 2 | 0.117 |
| | Female | 0 | 17 | 7 | 5 | |
| **Education status** | Primary school | 0 | 7 | 9 | 4 | 0.123 |
| | Secondary school | 1 | 17 | 6 | 0 | |
| | Above Secondary school | 1 | 23 | 11 | 3 | |
| **Capacity of the farm** | Small scale | 1 | 9 | 9 | 0 | 0.000 |
| | Medium scale | 0 | 38 | 16 | 7 | |
| | Large scale | 1 | 0 | 1 | 0 | |

### *4.7.2. Site dependent parameters of biosecurity measures*

All the internal subcategory biosecurity scores were independent of the study sites, while some external subcategory biosecurity scores were site-dependent, as indicated. (Table 9)

**Table 9:Chi-square test for site dependent parameters**

| **Site dependent parameters of external biosecurity** | **p-value** |
|---|---|
| **Sources of day-old chickens** | 0.000 |
| **Vehicle free from visible dirt before entering farms** | 0.015 |
| **Vehicle disinfection when entering the chicken farms** | 0.033 |
| **Driver have access to the egg storage room and handling facilities** | 0.049 |
| **Eggs being sold at the farm** | 0.026 |
| **Feed storage room sealed against water and vermin.** | 0.024 |

### 4.8. Findings at the feed processing plants

In the current study, all the surveyed feed processing plants purchase feed inputs from accredited suppliers, and some of the biosecurity measures show a great performance gap, as indicated in (Table 10).

**Table 10: Biosecurity practices in feed processing plants (N=13)**

| **Biosecurity activities** | **Yes responses** | |
|---|---|---|
| | No | Percentage |
| **Purchase of feed ingredients from the same station** | 12 | 92.3% |
| **Availability of suitable quality water** | 13 | 100.0% |
| **Good level of minimizing the risk of introducing diseases** | 12 | 92.3% |
| **Purchasing feed inputs from accredited supplier** | 13 | 100.0% |
| **Minimize risk of contaminants by employees** | 10 | 76.92% |
| **practice of personnel wearing clean clothes each day** | 5 | 38.46% |
| **Wear boots outside the feed mill** | 11 | 84.61% |
| **Wearing dedicated cloth and footwear** | 3 | 23.07% |
| **Use of hand sanitizer** | 8 | 61.53% |
| **personnel have access to chicken farms** | 8 | 61.53% |
| **Presence of updated biosecurity plan** | 8 | 61.53% |
| **Staff awareness about transmission of diseases** | 7 | 53.84% |
| **Restricting entry of non-feed mill vehicles** | 12 | 92.3% |
| **Presence of dedicated parking area** | 13 | 100.0% |

### 4.9, Findings at the chicken Slaughter house

The result shows that in all the assessed slaughterhouses, the biosecurity practices were encouraging.

| No | Biosecurity practices in the slaughter house | Frequency | Percentage |
|---|---|---|---|
| 1 | Availability of slaughter facilities | 4 | 100% |
| 2 | Good Personal hygiene of the employee | 4 | 100% |
| 3 | Suitable Water quality in the slaughter house | 4 | 100% |
| 4 | Presence of a cold room | 4 | 100% |
| 5 | Use of suitable packaging facilities | 4 | 100% |
| 6 | Presence of proper offal disposal system | 4 | 100% |
| 7 | Possibly of access of visitors to the slaughter house | 4 | 100% |
| 8 | Regular cleaning and disinfection of equipment | 4 | 100% |
| 9 | Sources of chicken only from disease free stocks | 4 | 100% |
| 10 | Slaughter facility is isolated from chicken farms | 4 | 100% |

### 4.10. Findings at the poultry markets

The current survey of biosecurity practices in the live poultry market shows there is a high risk of disease introduction and dissemination in the live poultry market (Table 11).

Table 11: Biosecurity practices in the live poultry markets.

| **Biosecurity practices** | | **Study site** | | | | | |
|---|---|---|---|---|---|---|---|
| | | Adama | | Bishoftu | | Modjo | |
| | | Count | % | Count | % | Count | % |
| **Practice of using common equipment** | Yes | 15 | 100.0% | 15 | 100.0% | 5 | 100.0% |
| **Decontamination of used equipment** | No | 5 | 33.3% | 1 | 6.7% | 2 | 40.0% |
| | Yes | 10 | 66.7% | 14 | 93.3% | 3 | 60.0% |
| **Use of rent or public vehicles to transport poultry** | No | 2 | 13.3% | 2 | 13.3% | 0 | 0.0% |
| | Yes | 13 | 86.7% | 13 | 86.7% | 5 | 100.0% |
| **Presence of refrigerator in the market** | Yes | 15 | 100.0% | 15 | 100.0% | 5 | 100.0% |
| **Practice of using cold room vehicles** | Yes | 15 | 100.0% | 15 | 100.0% | 5 | 100.0% |
| **Package chicken meat** | Yes | 15 | 100.0% | 15 | 100.0% | 5 | 100.0% |

### 4.11. Findings at the stakeholder agricultural offices

The numbers of poultry health specialists were limited in all the assessed agricultural offices, and there was no regular training of staff on biosecurity in that sector (Table 12).

**Table 12: Biosecurity practices related with veterinarians and sectors (N=5)**

| Focus points | Yes responses | Percentage |
|---|---|---|
| **Practice of veterinary supervision** | 5 | 100% |
| **Training of staff on biosecurity** | 0 | 0.00% |
| **The number of poultry health specialists are limited** | 5 | 100% |
| **Practice of visiting different poultry farms frequently** | 5 | 100% |
| **Practice of unauthorized access to the farms** | 0 | 0.00% |
| **Availability of biosecurity plane** | 0 | 0.00% |
| **Availability of biosecurity rules and policies** | 0 | 0.00% |

### 4.12. Results with existing policies, guidelines and proclamation on biosecurity practices.

The result shows that our country has no legal basis for the implementation of biosecurity measures in veterinary legislation, particularly in the poultry sector, which includes poultry biosecurity guidelines, rules, policies, and proclamations. There were no possible partnerships between different stakeholders for the implementation of biosecurity measures, no evaluation for the implementation of biosecurity levels, no accreditation (certification) of farms with an appropriate level of implementation of biosecurity measures, no national subsidies for certified farms, no new technology developed in support of the evaluation or implementation of biosecurity. However, most recently, the Ministry of Agriculture started providing national attention to support the implementation of biosecurity measures in different production sectors.

### 4.13. Results with options for improvement of biosecurity practices

Options for the improvement of the biosecurity status strategies were given after all the real data on the ground was obtained as a result there were significant gap observed in the external biosecurity practices.

## 5. DISCUSSIONS

The current study addressed the level of implementation of poultry biosecurity measures and investigated the available policies and guidelines and possible options for strategies to improve poultry biosecurity and combat the impacts of disease and boost productivity in the study areas and beyond. General characteristics of poultry farming revealed that the majority of poultry farmers (64.6%) were men. This finding was in agreement with Rimi *et al.* (2018) where 81% of the farmers were male. The main reason for male-dominated commercial poultry farming practices could be due to the fact that it requires capital for initial investment and demand. On the other hand, women are mostly engaged in backyard and small-scale poultry production systems as opposed to men (Tadelle *et al*., 2003).

In terms of farm size, the majority of poultry farms found in the three studied areas were medium-scale, accounting for 73.17%. Large-scale farms are very limited in number and also restrict the entrance of personnel for research or other purposes. Previous reports also revealed that medium-scale poultry farms predominate (Eltholth *et al.*, 2016; Rehman *et al.*, 2017; Abdulbari *et al.*, 2021), in line with the findings of the current study. Medium-scale poultry production has become a profitable industry for many reasons, including minimum maintenance requirements, fast financial outcomes, easy marketing, and easy control through the application of a small number of preventive measures(Essam and Mona, 2020).

The current study disclosed that the vast majority of the assessed farms failed to satisfy the required criteria for the conceptual, structural, and operational levels of biosecurity. From the results, about 92.68% of the poultry farms were located less than 500 meters from neighboring poultry farms. Similar situations were reported where 100% and 88.64% of the poultry farms were established in less than 500 meters (Mustafa *et al*., 2018; Abdulbari *et al*., 2021). This result deviates from the standard distance set between two farms, particularly in Bishoftu and Modjo, where 100% of the farms were located less than 500 meters from the neighboring poultry farms. This scenario makes them vulnerable to disease outbreaks. This implies that the higher the poultry farm density available in a specific area, the greater the chance of pathogen

transmission among the farms. This may happen due to the negligence of the local government for the random establishment of poultry farms.

In the structural biosecurity aspect of biosecurity level, 46.34% of the farms do not have house hygiene locks. 37.8% of farms have no separate egg storage room, and 18.29% do not have functional footbaths. A similar report was noted by Abah *et al.* (2017) and Rahman *et al.* (2017). This may be due to a lack of knowledge of structural biosecurity levels. The procedural biosecurity measures were also poor. For instance, 79.26% of the farms do not disinfect vehicles for feed transport. This result agrees with Elniema *et al*. (2018). This may be due to the negligence of the farmers to implement biosecurity measures

According to the current study, the majority of farms remove dead birds through burning or burring at the farm's appropriate site. However, 13.4% of the farms were throwing dead birds outside their farms. About 57.14% of the farmers were removing dead birds by throwing outside the farms in Bangladesh (Shiraz *et al.,* 2020).Improper disposal of dead birds will lead to the spread of infections, cause major pollution problems, attract pets and pests, and cause aesthetic problems (Nutsch and Kastner, 2008; Mustafa *et al*., 2018).

Only few (21.95%) of the farms mandated visitors and staff to wash their hands with disinfectant before and after entering the farmyards. Farm visitors and workers could serve as mechanical vectors for the dissemination of infectious poultry diseases, especially when personnel have contact with sick birds. As much as possible, farms should limit the number of people obtaining access to their facilities, and their stay inside the farm should be as short as possible because they can serve as mechanical vectors for disease transmission (Carey, 2005; Lister, 2008).

Rodents damage the poultry industry and result in financial losses for poultry breeders all over the world (Rao, 2015).The findings of the current study indicated in 85% of the farms, noted that vermin were often to be a problem. Only 52% of the farms applied rodent control programs. Similar results were reported (Balvinder *et al*., 2014; Abah *et al*., 2017).Vermin cause major economic loss in poultry farms as they are reservoirs of different bacteria, including E. coli, Mycoplasma, Pasturella, and Salmonella. Vermin also consume poultry,

feed and damage equipment, annoying chickens and damage to feed bags, resulting in feed wastage (Mohan and Sakthivel, 2015).

The average overall biosecurity score of the commercial layer farms in Central Ethiopia was 56.39%, with Adama having the highest score. As compared to the global average biosecurity score of 62%, the current result is slightly lower. On the contrary, previous studies carried out in the Philippines (65.9%) and Sierra Leone (67%) indicated an overall biosecurity score greater than the global average (Tanquilut *et al*., 2011; Abdulrahman, 2022).Similar results were also reported by (Gelaud *et al*., 2014)..

In each of the study sites, the average internal biosecurity score was higher than the average external biosecurity score. The average biosecurity scores for the external and internal subcategories were 49.41% and 72.67%, respectively. This result agrees with (Racicot *et al*., 2012;Tanquilut *et al.*,2011 and Abdulrehman ,2022). This difference between the external and internal biosecurity scores emanated from the fact that fewer preventive measures were invested in the external biosecurity measures in comparison with the internal biosecurity measures. In general, the internal biosecurity scores are higher than the external biosecurity scores, in contrast to the swine industry, where the external biosecurity scores are on average higher than the internal biosecurity scores (Laanen *et al*., 2013).

The result also shows that flock size (P = 0.000) and study site (P = 0.033) had significant influence on the implementation of biosecurity measures. In agreement with the current result (Geidam *et al.,* 2011) noted that the greater number of flocks, the higher biosecurity score and Poultry farms with low flock sizes were more at risk than large flock-size farms On the contrary (Dorea *et al*., 2010; Fabric *et al*., 2021) on their report flock size did not significantly affect the implementation of biosecurity measures.. On the other hand, owners' education level (p = 0.123) and sex (p = 0.112) had no significant influence on the practice of biosecurity measures. The finding that sex had no significant impact on the adoption of biosecurity measures is at contradiction with that of Obisesan (2014), who discovered that sex substantially and positively influenced Nigeria's biosecurity adoption. The observation that education has no significant influence on the use of biosecurity measures is surprising since it

is expected that a high literacy level will help farmers analyze and understand the rationale of using biosecurity measures. Similar information was noted that the owner's education level had no significant association with the biosecurity measures (Mignouna *et al.*, 2011; Lavison, 2013; and Namara *et al.*, 2013).

All the internal biosecurity parameters were independent of the study sites, while some external biosecurity parameters were site-dependent. In one-day-old chicken purchasing practice, the sources of day-old chicks significantly depend on the study site ($p = 0.000$). In depopulation and transport of chickens, the practice of keeping vehicles free from visible dirt ($p = 0.015$) and vehicle disinfection when entering farms ($p = 0.033$) significantly depend on the study site.

Through the use of contaminated ingredients during receiving at the feed manufacturing site during processing, packaging, storage, loading, and delivery by delivery vehicles both incoming and outgoing, as well as delivery personnel, feed contamination with disease-causing microorganisms can be introduced at various levels throughout the manufacturing process up to consumption (FAO, 2010; NBG, 2018). In the current study, of the assessed feed processing plants, the majority (92.3%) purchase feed ingredients from different processing stations and preferred and approved suppliers that maintain an accredited quality assurance program that includes biosecurity. This activity is encouraging. and almost all of the factories have good levels of minimizing the risk of introducing or spreading diseases, pests, and weeds while purchasing grains, roughage, additives, and feed ingredients. More than half (61.54%) of personnel working in the assessed feed processing plants have access to poultry farms. This area needs improvement because when personnel working in feed processing plants enter contaminated poultry farms, the chance of feed and feed ingredients contamination is high (FAO, 2010).

The assessment reveals that only 61.5% of staff was aware of the potential for the introduction and transmission of diseases by visiting vehicles and machinery. This situation again needs improvement before implementing biosecurity measures in feed processing plants. Awareness creation about the routes for entry of contaminants into feed and feed ingredients by personnel

working in feed mills is prioritized. The result also shows that only 61.5% of the feed mills had an updated biosecurity plan implemented by their staff. In addition to the more common endemic disease threats to poultry production, numerous foreign poultry diseases associated with feed ingredients have been identified at the global level. Preventing the entry and transmission of diseases should be a goal for any updated biosecurity program (FAO, 2010). Due to the lack of studies in this area with related topics to discuss and compare with the results, only scientific justification was forwarded.

The current assessment reveals that even though the numbers of modern poultry slaughter houses are limited, the biosecurity practices are encouraging. All of the biosecurity aspects expected from a poultry slaughterhouse, including the preparation, slaughtering, processing, and proper packaging of products, were fully practiced. This result deviates from Muhammad *et al*. (2020) study on biosecurity application in small-scale poultry abattoirs in Indonesia. They noted that all aspects of biosecurity score less than fifty percent except main building construction, which scores 85%.. The basis of the variation may be that Muhammad *et al.* (2020) conducted their survey on small-scale chicken abattoirs, while the current survey was conducted on modern poultry slaughter houses. In Central Ethiopia, even though the poultry slaughter is highly regulated at the poultry slaughter houses, most slaughter takes place on the farms where there is limited investment in slaughtering facilities, no inspecting officers, and poor sanitation and disinfection, which contribute to the transmission of infectious poultry diseases (Barlow *et al*., 2015; FAO, 2022).

In the assessed live poultry markets, all of the farmers and merchants use common equipment like crates for poultry transportation. When the number of people using common equipment is high, the chance of disease transmission is also high. Among them, 73.2% of the farmers and merchants decontaminate the crates before using them, while 91% of them rent common transport vehicles, and 40% of them mix poultry from different sources. These activities are all contributing factors to the transmission of chicken infectious diseases from infected to healthy chickens. Chicken diseases can be transmitted in live bird markets through contaminated equipment, the mixing of birds from different sources, the use of unclean crates and vehicles,

the improper disposal of dead birds, and the mixing of sick birds that have been brought to the market (FAO, 2022).

According to the current assessment in the local agricultural offices, there were discouraging results for all the activities related to poultry biosecurity measures. There were no poultry biosecurity rules that were implemented, no training of staff on biosecurity, weak linkages among the various stakeholders, and almost wholly absent coordination in the sector to support the poultry farmers. Disagreeing with the current result in Indonesia, before starting the poultry business, the local government provides training on poultry biosecurity (Patrick *et al*., 2010). In Nigeria, the veterinary officers from the local agricultural offices provide significant information on biosecurity to the poultry farmers on a regular basis (Diarra and Usman 2008).

It has been obvious that implementation of the existing rules, policies, and proclamations of poultry biosecurity practices results in healthy poultry and poultry products (East, 2007). Providing biosecurity legislation and working for the implementation of biosecurity practices have a great impact on the biosecurity status of a country (Ian, 2019). According to the current biosecurity assessment in the Ministry of Agriculture, our country has no legal basis for the implementation of biosecurity in veterinary legislation, specifically for the poultry production sector. There are no governing biosecurity guidelines, rules, policies, or proclamations at the local, regional, or national levels. The government only implemented a few biosecurity rules on the poultry enterprise, such as forced quarantine periods for chickens imported from other countries (Chaka and Bekele, 2009). However, this legislation's ability to prevent the spread of disease is severely hampered because there are no restrictions governing the packaging materials or containers used to import hens (Gezahegn and Karl, 2010)

As part of the biosecurity plan, there is no regular training of staff on biosecurity at the local regional and National level also there are a few poultry health specialists. Most recently, the Ministry of Agriculture started provision of national funds to support the implementation of biosecurity measures in different production sectors. In Ethiopia, due to a lack of biosecurity guidelines, the biosecurity measures employed in the poultry sector are decided by individual

firms and are variable in application (Gezahegn and Karl, 2010). On the contrary, globally developed countries have their own poultry biosecurity guidelines, rules, policies, and proclamations (Akinwumi and Ajewole, 2014). Even in Australia, the implementation of biosecurity at the government and other stakeholder levels is formalized in the inter-governmental agreement (Gary, 2021), and the Generic Farm Biosecurity Manual was presented to the industry with separate jurisdictional representative offices.

Based on the current findings during the observation of the poultry production sectors demonstrates substantial disparity in the execution of the external biosecurity measures and biosecurity levels specifically in the study site. This gap needs improvement options in all the sectors. At the farm level the following improvement options for biosecurity practices should put into practice: (1) Plane farm location and design, (2) Keep visitors to farms to a minimum, (3) Limit visitations to other (4) practice an effective rodent and insect control programs,(5) Avoid contact with non-commercial poultry or wild birds (6)Documentation and Record keeping

The improvement options of the other poultry production sectors linked with the government policies, rules and proclamations. The stakeholder government body makes biosecurity guideline for each sector and support by rules and work for implementation.

## 6. **CONCLUSION AND RECOMMENDATIONS**

According to this study there were significant variations in the average external and internal biosecurity scores of the poultry farms, and the overall biosecurity score was less than the global average score, which provides a clear picture of the level of biosecurity measures in the commercial layer farms in Central Ethiopia as well as the interlinked stakeholders, including the feed processing plants, As per the present finding the overall biosecurity practices of the central Ethiopia were encouraging whereas the live poultry markets biosecurity practices were need serious attention to be improved. Additionally the current study revealed that there were no or very limited biosecurity rules policies and proclamations at farm, local, regional and National levels. This implies that the biosecurity measures in the poultry sectors specifically in the study areas of Central Ethiopia and country at large requires significant options of improvement strategies.

In light of the above conclusion the following recommendations are forwarded:

- The various actors in poultry sectors mainly farm owners and the responsible government offices and relevant stakeholders should make an effort to integrate the external biosecurity measures into laws and regulations that will motivate and inspire poultry producers to adopt the external biosecurity measures in and around farms
- Reform work in terms of regular training of staff and supervision of activities is required in feed processing plants with the aim of attaining standard biosecurity practices
- In the live chicken markets, the great gap was the use of common equipment for chicken transportation (crates and vehicles) and the lack of cleaning and disinfection of equipment. The practices in this regard should be improved through sustained support by way of awareness creation among merchants and farmers. Responsible authorities must envisage its proper implementation
- To reduce the risk of infectious disease occurrence due to on farm poor chicken slaughtering practices in the central Ethiopia, the government, producers and stakeholders work cooperatively by establishing multiple small scale poultry abattoirs,

providing legislations and working for the implementation that slaughtering takes place only in the abattoir

- Integrated biosecurity practices must be exercised at farm, regional and national levels to adopt the global requirements and accomplish activities as per the expected standards and
- The government in general and the Ministry of Agriculture in particular should develop a policy framework with detailed guidelines of poultry biosecurity for its implementation and law enforcement by responsible bodies.

## 7. REFERENCES


Abah H., Abdu P. and Assam A. (2017): Assessment of biosecurity measures against Newcastle disease in commercial poultry farms in Benue state. *Sokoto Jour.of Vet.Sci*., **3**: 32 – 37.

Abdisa H., Gezahegn M., Tilahun D. and Asalifewu N. (2020): Seasonal and annual climate profile of Adama district, East Shewa, Oromia, Ethiopia. *SSRG Inter. Jour. of Geo-informatics and Geological Science*., **6**:1-4.

Abdulbari I., Adem A., Shihun S., Asamenew T. and Yimer M. (2021): Assessment of biosecurity status in commercial chicken farms found in Bishoftu Town, Oromia Regional State, Ethiopia. *Vet. Med. Inter. Jour.,* **21**:5-9.

Abdulqader A., Gauly M. and Wollny C. (2007): Characterization of chicken production systems, status of biosecurity and their potential in different levels of management measures in Jordan. *Trop Anim Health Prod.,* **39:**155-164.

Abdurahman S. (2022): Biosecurity assessment of layer farms in Sierra Leone using Biocheck. UGent ScoringTool. *Inter. Jour. of Innovative Sci. and Res. Techn.,* **8**: 132-139.

Abebe W. (2006): Review on the new features of the Ethiopian poultry sector, biosecurity implications, and food and agriculture organization of the United Nations**.**, **2**:13-16.

Addisu A., Solomon M., Getachew L., Solomon A., Fantahun D., Duncan A. and Thorpe W. (2012): Beef and feed value chain analysis in Adama district, Ethiopia. Ethiopian Institute of Agricultural Research, Debre Zeit Agricultural Research Center, **3**: 12-17.

Adedayo,V.( 2012): Poultry waste management techniques in urban agriculture and its implications:.*Asian J. Agric. Sci*., **4**:258-263.

Akinwumi A. and Ajewole O. (2014): Awareness and practice of biosecurity measures in small scale poultry production in Ekiti State, Nigeria. *Jour.of Agri and Vet. Sci*.**11**: 24 – 29.

Alemayehu A., Misba A. and Tadiose H. (2021): Biosecurity status in small and medium scale poultry farms in Ethiopia.*Glob. Veteri.,* **2**: 85-91.

Amass S. (2005): Swine disease transmission and prevention.Diseases of Swine. *Blackwell Publishing Ltd*., Oxford,UK. 1075 – 1098.

Ameji O.,Abdu P., Sa'idu L. and Isa M.(2012): Knowledge of poultry diseases, biosecurity and husbandry practices among stakeholders in poultry production in Kogi State, Nigeria. *Jour. of Veter. Sci***. 2**:26-31.

Atsbaha H. and Negassi A. (2017): A review on current characteristics of chicken production system dynamics and bio-security implications in Ethiopia.*Adva.in Life Sci. and Techno.* **55**: 1-7.

Balvinder K., Manuja A.and Kumar S. (2014): Globalization and livestock biosecurity national academy of agricultural sciences. *Agric.Res.* **3:** 22-31.

Barlow S., Boobis A., Bridges J., Cockburn A.,Dekant W.,Hepburn P.,Houben G.,Konig J.,Nauta M.,Schuermans J and Bánáti D.(2015): The role of hazard-and risk-based approaches in ensuring food safety. *Food Sci Technol***. 2**:176-188.

Beach R.., Poulos C. and Pattanayak S. (2007): Agricultural household response to avian influenza prevention and control policies. *Jour. of Agri. and Appl. Econ.,* **39**: 301-311.

Birhanu H., Tehetna A., Yohannes H. and Awot T. (2015): Assessment of biosecurity condition in small scale poultry production system in and around Mekelle. *Eur. Jour. of Biol.Sci.,* **4**: 99-102.

Bizimenyera E., Nyaga P.and Oloya J. (2001): Multiple bacterial resistances against commonly used disinfectants for bacteria isolated from chicken hatcheries in Kenya

Carey B., Prochaska.F. and Jeffrey S. (2005): chicken equipment biosecurity, Agricultural life extension, Texas Agricultural Extension Service.,9-14.

Chaka H. and Bekele S. (2009): Assessments of the qualitative risks for the introduction of (H5N1) virus into Ethiopia via wild birds.Africa/Indonesia Team Working Paper No. 21, ILRI, Nairobi.21-37.

Chowdhury E., Das P., Islam M. and Yamage M.(2017): Quantification of biosecurity status in commercial poultry farms using a scoring system., department of Pathology, Bangladesh Agricultural University. *Jour. of Bangladesh Agri. University* **8**: 253-258.

Conan A., Goutard S. and Sirenda V. (2012): Biosecurity measures for backyard poultry in developing countries: a systematic review. *Vet Research jour.,* **8**:240-246.

Corrègė I., Fourchon P., Le Brun T. and Berthelot N. (2012): Biosécurité et hygiène en élevage de porcs: état des lieux et impact sur les performances technico-économiques. *Joumées Recherche Porcine.,* **44**:101-102.

CSA (Central Statistical Authority) (2005): Agricultural sample survey report on livestock and livestock characteristics. *Stati. Bulletin* **331**:1465-1473.

CSA (2017): Agriculture sample survey report on livestock and livestock characteristics, Addis Ababa Ethiopia., **2**:86-99.

CSA (2020): Agricultural sample survey, Statistical Bulletin No. 587.CSA, Addis Ababa, Ethiopia

Dawit A.,Tamirat D., Serge N. and Devesh R. (2008): Overview and background paper on Ethiopia's poultry sector: Relevance for HPAI research in Ethiopia, *Afri. Regi. Report*.**1**:47-54.

Dewulf J. and Van Immerseel F. (2018): General principles of biosecurity in animal production and veterinary medicine from principles to practice. *Springer Berlin,Heidelberg, Germany.*,**1**;3-31.

Diarra S. and Usman B.(2008): Prevalent economic diseases and mortality in layers. *Inter.Jour.of poult. Sci.,* **9**:304-310.

Dorea F., Berghaus R., Hofacre C. and Cole,J. (2010): Survey of biosecurity protocols and practices adopted by growers on commercial poultry farms in Georgia. *Avian Dis.,* **54** :1007-1015.

DZARC (DebreZeit Agricultural Research Center) (2006): Annual metrology reports. DZARC,Debrezeit, Ethiopia.21-34.

East, I (2007): Biosecurity principles and adoption of biosecurity practices in the Australian poultry industries. *Aust. Vet. Jour*.**85**:107–112.

Eihab M., Fatherahman A., ElAwad A., Yousif M., Yassir M., EltahirHussein H., Hassanin M., Elfatih M. and Dana L.(2020): Biosecurity preparedness analysis for poultry large and small farms in the United Arab Emirates; Abu Dhabi Agriculture and Food Safety Authority, Abu Dhabi, UAE *Agri. MDPI*., **10**: 1-19.

Elniema A., Haytham A. and Abdullkaream B. (2018): Evaluation of the efficacy of cleaning and disinfection in broiler farms between rest periods in Khartoum state Sudan.University of Bahri, College of Veterinary Medicine, Department of Preventive Medicine *jour. of pharm. and pharmaceu. Sci.,* **6**:109-119.

Eltholth M.,Mohamed R.,Elgohary F. and Elfadl E.(2016): Assessment of biosecurity practices in broiler chicken farms in Gharbia Governorate, Egypt, Alexandria. *Jour.of Vet. Sci*., **49**: 68–77.

Eric G. and Jill N. (2017): Official training on the NPIP Program standards biosecurity principles, **2**:2-11.

Essam S. and Mona S. (2020): Assessment of biosecurity measures in broiler's farms in the Suez Canal area Egypt using a seasonal prevalence of Salmonellosis. *Veterinary World*, **4**: 622-632.

Eze C., Chah J., Uddin I., Anugwa I. and Igbokwe E.(2017): Biosecurity measures employed by poultry farmers in Enugu State, Nigeria .*Jour. of Agri. Exten..*, **21**: 89- 104

Fabrice D., Tatfo K., Isabelle S., Bouelet N., Medoua N. and Germain K. (2021): Biosecurity practices and characteristics of poultry farms in three Regions of Cameroon. *J. World Poult. Res.,* **11**: 64-72.

FAO (Food and Agricultural Organization) (2007): Biosecurity principles and components. In FAO biosecurity toolkit; Food and Agriculture Organization of the United Nations: Rome, Italy.

FAO (2008): Biosecurity for highly pathogenic avian influenza: Issues and options.FAO, Vialedelle Terme di Caracalla, Rome, Italy.18-23.

FAO (2010): Good practices for the feed industry: implementing the Codex Alimentarius code of practice on good animal feeding.. **3**:3-19.

FAO (2013): World livestock changing disease landscapes Food and Agriculture Organization, Rome, Italy**.** *Vet. Clin. North Am. Food Anim. Pract.***18**: 515–547.

FAO (2022): Africa Sustainable Livestock: Biosecurity and public health practices along the poultry value chain in Kenya.Evidence from Kiambu and Nairobi City Counties., 2-21.

Farooq M., Durrani F., Faisal S., Asghar A. and Khurshid A. (2000): Incidence of infectious bursal disease among birds submitted to a diagnostic laboratory in NWFP, Pakistan. Pak *Vet. Jour*., **20**:77-80.

Fasina F., Ali A., Yilma J., Thieme O. and Ankers P. (2011): The cost-benefit of biosecurity measures on infectious disease in the Egyptian household poultry. Preventive veterinary medicine. **103**: 178-191.

Gary S., Hester M.,Johnny H., RuiZhou A. and Atibhav C.(2021):The Boundary of the Market for Biosecurity Risk.**41**:1448-1461.

Geidam Y.,Gambo H., Adamu S., Grema H., Dapchi A. and Sanda K. (2011): An assessment of the biosecurity measures in poultry farms in Borno and Yobe States. *Sahel Jour. Of Vet. Sci.*, **10**: 83-86.

Gelaud P., Scheper M.,Verlinden M., Laanan M. and Dewulif L.(2014): Biocheck.UGent: A quantitative tool to measure biosecurity at broiler farms and the relationship with technical performances and antimicrobial use.Poult.Scie.**93**:13-18.

Gezahegn A. and Karl M. (2010): Poultry value chains and HPAI in Ethiopia, Africa/Indonesia Team Working Paper.31 -43.

Girma M., Pal M., Dessie T., Esatu W., Mamo W. and Keskes S. (2013): Sero-prevalence of Newcastle disease in poultry under backyard system in villages of Bishoftu town, Ethiopia. *Res. J. Poult. Sci*., **6**:38-42.

Gussem M., Meddelkoop K.., Mullen K. and Veer E. (2013): Broiler Signals; A practical guide for broiler focused management *Rood Bont Publishers*., 34-51.

Halifa M. (2008): Good biosecurity practices in nonintegrated commercial and in scavenging production systems in Tanzania: FAO Study report, **12**:1-28.

Henson S. and Jaffee S. (2005): Afro-food exports from developing countries: the challenges posed by standards World Bank., 91-114.

Ian D.(2019): Disease Control, Prevention and On-Farm Biosecurity: The Role of Veterinary Epidemiology College of Veterinary Medicine, School of Veterinary and Life Sciences, Murdoch University.**18**:3-13.

Jannat H., Fatimah M., SaifulIslam A.., AmirulIslam S., Asadurahman A., Nishiyama S., Jayedul H. and Tanvir R. (2021): Review zoonotic significance and antimicrobial resistance in Salmonella in Poultry in Bangladesh. *Zoonotic Diseases*.,**1**: 3-24.

John C. and Teto K.(2013): Poultry waste management practices in selected poultry operations around Gaborone, Botswana. *Int. J. Curr. Microbiol. App. Sci*, **2**: 240-248.

Kasiiti J. (2007): Isolation of avian paramyxo viruses from village chickens and wild birds in Kenya, *Inter. Jour. of Bus. & Mgt. Sci*,,**3**: 2208-2190.

Kenea Y., Legesse D. and Alemu Y. (2003):chicken marketing structure, spatial variations and determinants of prices in Eastern Shewa Zone, Addis Ababa, Ethiopia., 69-80

Laanen M., Callens B., Dewulf J., De Jong E., Maes D., Persoons M., Ribbens S., Strubbe M.(2013):Relationship between biosecurity and production/antimicrobial treatment characteristics in pig herds. *Vet. Jour.*, **198**:508–512**.**

Lavison R. (2013): Factors Influencing the Adoption of Organic Fertilizers in Vegetable Production in Accra (MSc Thesis) Accra Ghana.*Jour.of Servi. Sci. and Mgt.*, **10:15-**17.

Leta S. and Bekana E. (2010): Survey on village based chicken production and utilization system in mid rift valley of Oromia, Ethiopia. *Glob. Vet.*, **5**: 198-203.

Lister A. (2008): Biosecurity in poultry management and poultry diseases. *IFAC Jour. of Sys. and Contr.*. **4**: 2468-6018

Melkamu B.,Berhan T. and Ashenafi M..(2016): Disease management and biosecurity measures of small-scale commercial poultry farms in and around Debre Markos, Amhara Region, Ethiopia. *Jour.of Vete. Medi.and Anim. Healt*., **8**:136-144

Mignouna B., Manyong M., Rusike J., Mutabazi, S. and Senkondo M. (2011): Determinants of adopting imazapyr-Resistant Maize Technology and its Impact on Household Income in Western Kenya., **3**: 158-163.

Mohan R. and Sakthivel P.(2015): Role of rodents in poultry environs and their management. *Jour. of Dair., Vete. & Anim. Res.*, **2**:107–114.

Muhammad T., Faisal F. and Elziyad p. (2020): Biosecurity Application of Small Scale Chicken Abattoir in Sidoarjo, East Java, Indonesia. Department of Physiology and Pharmacology, Faculty of Veterinary Medicine, Universitas Airlangga, Surabaya., **6**: 226 -229.

Musiime J. (2005): The Kenyan poultry industry with particular reference to the Newcastle disease problems. Control with thermo stable oral vaccines Kuala Lumpur, Malaysia *Inter. Jour. of vet medicine*, **12**:167-175.

Mustafa A., Hamad M.,Elhassan M., Adil M., Salman A., Elsiddig M. and Lamyia M.(2018): Disposal of dead birds and manure in poultry farms under different production and management systems in Khartoum State Sudan ; Department of Food Safety and Veterinary Public Health, College of Veterinary Medicine, University of Bahri. *World jour.of pharma. and pharmace. Sci.***44**:61-70.

Namara E., Weligamage P. and Barker R. (2013): Prospects for adopting system of rice intensification in Sri Lanka: A socioeconomic assessment. Research report.

NBG (National Biosecurity Guide for the poultry feed Sector) (2018): Biosecurity for feed: guidance for developing biosecurity practices for feed and ingredient manufacturing animal nutrition association of Canada, Ottawa, **2**:32-43.

Ndem J. and Ogba E.(2017):Biosecurity measures needed by rural poultry farmers for effective disease prevention; Department of Technology and Vocational Education, Ebonyi State University; *Inter. Jour. of Advan. in Agri. Sci. and Techno*. **4**:17-20.

Newell D., Elvers K., Dopfer D., Hansson I., Jones P., James S., Gittins J., Stern N., Davies R., Connerton I., Pearson D..,Salvat G. and Allen V..(2011): Biosecurity-based interventions and strategies to reduce Campylobacter spp. on poultry farms. *Appl. Environ. Microbiol*; **77:** 8605-8614.

NMA (National Meteorological Agency of Ethiopia) (2010): Annual metrological reports of Ethiopia.

Nutsch A, Kastner J (2008): Carcass disposal Options. In: Voeller J (ed) Wiley Handbook of Science and Technology for Homeland Security. Wiley,New York.1959–1969.

Nyaga P.(2007):Good biosecurity practices in small scale commercial and scavenging production system in Kenya.*Rome FAO press.*18-21.

Obisesan A. (2014): Sex differences in technology adoption and welfare impact among Nigerian farming households, MPRA Paper No. 58920.3-7.

OIE-FAO (2009): Guide to good chicken farming practices and other animal production and health, Food Safety; FAO-OIE: Rome, Italy.87-91.

OIE (Office International des Epizooties) (2018): Application of biosecurity in different production systems at individual, country and regional levels Europe. OIE Regional Commission Bellini, 1-6.

Okoli I. (2004): Studies on antimicrobial resistance among E. Coli isolates from feeds and poultry production unit. PhD Thesis owerri Federal University of Technology.9-13.

Patrick I. and Jubb T. (2010): Comparing levels of biosecurity in smallholder broiler and layer farms in Bali and West Java. Towards the adoption of cost-effective biosecurity on NICPOS farms in Indonesia.

Patrick W.,Marshall G.Ambarawati I.and Abdurrahman M.(2015):Social capital and cattle Marketing chains in Bali and Lombok, Indonesia. ACIAR Technical Reports No. 7 Australian Centre for International Agricultural Research, Canberra.18-26.

Permin A. and Detmer A. (2007): Improvement of management and biosecurity practices in smallholder producers. Rome. 12-23.

Postma M., Backhans A., Collineau L., Loesken S., Sjölund M., Belloc C., Emanuelson U., Grosse E., Beilage K., Stark K. and Dewulf ,J. (2016): The biosecurity status and its associations with production and management characteristics in tarrow-to-finish pig herds., **10**: 478- 489.

Pritchard G.,Dennis I. and Waddilove J.(2005):Biosecurity reducing disease risks to pig breeding Herds in Practice **27**: 230 – 237.

Racicot M.,Venne D., Durivage A.. and Vaillancourt, J.(2012):Evaluation of strategies to enhance biosecurity compliance on poultry farms in Québec: effect of audits and camera. *Prev. Vet. Med*. **103**, 208–218.

Rahman M., Badhy. M., Islam M., Osmani E., Chowdhury P. and Islam R.(2017): A baseline survey on biosecurity practices of layer farmers in Bhaluka and Sakhipur upazila of Bangladesh: 15-21.

Rao A.(2015): Role of rodents in poultry environs and their management. *J Dairy Vet Anim Res.***2**:107–114.

Rimi N., Sultana R., Muhsina M.,Uddin B.,Haider N.,Nahar N., N. Zeidner N., K.Ramirez K., and Luby S.(2018): Biosecurity Conditions in Small Commercial Chicken Farms, Bangladesh; **2**: 244–258.

Rojo-Gimeno C., Postma M., Dewulf J., Hogeveen H., Lauwers L. and Wauters W. (2016): Farm economic analysis of reducing antimicrobial use whilst adopting improved management strategies on farrow-to-finish farms Preventive Veterinary Medicine. *Prevet.*, **129**: 74-87.

Sainsbury O. (2009): Poultry health and management, *Blackwell publishers.*18-23.

Shapiro B., Gebru G., Desta S., Negassa A., Nigussie K., Aboset G.and Mechal H. (2015): Ethiopia livestock master plan.In "ILRI Project Report. Nairobi, Kenya: International Livestock Research Institute (ILRI)". Agric *& Food Secur* 8- 9.

Shiraz M., Sogra M., Shajedurahman M., Mahfuza A. and Islam M. (2020): Investigation of biosecurity in commercial poultry farms of Dinajpur district. Department of Medicine, Surgery and Obstetrics, Hajee Mohammad Danesh Science and Technology University Dinajpur, Bangladesh. *International Journal of Natural and Social Sciences*., **7**: 14-20.

Siekkinen K., Heikkila N.Tammiranta D. and Rosengren H. (2012): Measuring the costs of biosecurity on poultry farms: A case study in broiler production in Finland. *Acta Vete. Scandin.*, **54**:844-866.

Soha M. and Dalia E .(2018): Factors affecting applying level of biosecurity activities in broiler farms in matrouh government Egypt., department of economic studies, socio-economic Studies division, Cairo, Egypt. *Egypt. J. Desert Res*., **68**:173-186.

Sri Hery S., Muhammad I., Ian P. and Tristan J. (2011): Factors influencing the adoption of biosecurity activities on broiler and layer farms in Indonesia, Australian Agricultural and Resource Economics Society National Conference Melbourne**.**

Tanquilut 1Ł., EspaldonŁ M.,, EslavaŁ D.,,AncogŁ R., Medina‖ C., Paraso M.and Domingo R.(2011): Biosecurity assessment of layer farms in Central Luzon, Philippines.3-11**.**

Tasie C., Wilcox G.and Kalio A.. (2020): Adoption of biosecurity for disease prevention and control by poultry farmers in imo state Nigeria. *Jour. of Agri. and Food Scis.* **18**: 85-97.

Tegla,W., Mohamoud M. and Chadha, H.(2016): Assessment of biosecurity initiatives on broiler farms in Khartoum, Sudan; *Afric Jour. of Poult. Farmin.* **4**:159-165.

Van Limbergen, T., Dewulf, J. and Klinkenberg, M. (2014): Scoring biosecurity in European conventional broiler production. *Poult. Sci*.**1**:74–83.

Van Steenwinkel S. (2011): Assessing biosecurity practices, movements and densities of poultry sites across Belgium, resulting in different farm risk-groups for infectious disease introduction and spread, Preventive Veterinary Medicine. *Poult. Sci*. **98**: 259-270.

WHO (World Health organization) (2005): International Health Regulations., 64-81.

Wierup M. (2012): Principles and strategies for the prevention and control of infectious diseases in livestock and wildlife, in ecology and animal health. *University Press.*, **13**:143-154.

Windsor A. (2017): How to adopt biosecurity practices and the role of government and private sector Asia- OIE Regional Commission.3-4.

Wondmeneh E., Alemayehu A., Bewket S., Tsigereda F. (2017):Status of commercial poultry production in Ethiopia, Ministry of livestock and fisheries, Addis Ababa, Ethiopia., 22-35

Wubet W., Bitew M., Mamo G., Gelaye E., Tesfaw L., Sori H., Zewdie T. and Abayneh T. (2019): Evaluation of inactivated vaccine against fowl cholera developed from local isolates of Pasteurella multocida in Ethiopia. *Afri Jour.of Micro. Res.,* **13**:500-509.

## APPENDIXES

### Apendix 1: Questionnaire format for poultry farm

1. General characteristics of farm and respondent

1.1. Date of Interview (Date/month/year) _____

1.2. Name of the farm (if known by name): _____

1.3 Role of Respondent on the farm a) Farm owner b) Employee c) Owner relative

1.4 Age of farm respondent [should be more than 18 years to be eligible]

a) 18-25 b) 26-35 c) 36-45 d) >=46

1.5 Gender of the respondent a. Male b. Female

1.6 Up to which grade have you attended school?

a) None, no formal education b) Primary school c) Secondary school d) above secondary

**Farm characteristics**

I. How many laying hens are there on the farm?

II. How many years of experience in keeping poultry does the person in charge have?

III. How many people are working on the farm?

IV. How old (in years) is the oldest building in which poultry is being kept?

Va. Are there, besides the laying hens, any other farm animals present at your farm? A) Yes B) No

Vb what other animal(s) is (are) present at your farm? A) Pet B) Horses C) Cattle D) Sheep/goats

VI. How old (in years) is the newest building in which poultry is being kept?

VII. What type of housing system is used on the farm?

A) Cages B) Enriched cages C) flooring system D) Aviary E) Free-range system

**A. Purchase of one-day-old chicks**

1. Is there a rearing facility present on the farm? A) Yes B) No

2. Are your one-day-old chicks (during the last 2 years) always bought from the same original Source? A) Always the same supplier B) Sometimes a different supplier

3. Are they bought one-day-old chicks first delivered at your farm, i.e. before other farms are

Supplied by the same transport vehicle? A) Always B) Sometimes C) Never

4. Are the transport vehicles (including the transport crates and containers) cleaned and Disinfected before the one-day-old chicks are loaded? A) Always B) Sometimes C) Never

**B. Purchase of laying hens**

5. Are your laying hens (during the last 2 years) always bought from the same riginal source? A) Always the same supplier B) Sometimes a different supplier

6. Whenever laying hens are bought from another farm, is proof requested to ensure that the Sanitary statute and health management of the farm of origin is equal or higher than your own Farm? A) Yes B) No

7. Are they bought laying hens first delivered to your farm, i.e before other farms are supplied by the same transport vehicle? A) Always B) Sometimes C) Never

8. Are the transport vehicles (including the transport crates and containers) for poultry cleaned and disinfected before the laying hens are loaded? A) Always B) Sometimes C) Never

9. What happens with the laying hens after their first production cycle?

A) The laying hens are always slaughtered

B) The laying hens are sometimes kept for a second production period after molting

C) The laying hens are always kept for a second production period after molting

**C. Depopulation and transport of hens**

10. Is the transport vehicle (including the transport crates and containers) for poultry empty on arrival at the farm? A) Always B) Sometimes C) Never

11. Is the transport vehicle (including the transport crates and containers) for poultry free from Visible dirt on arrival at the farm? A) Always B) Sometimes C) Never

12. Is the transport vehicle (including the transport crates and containers) for poultry cleaned and disinfected on arrival at the farm? A) Always B) Sometimes C) Never

13. Do the driver and the catching team receive and wear farm-specific or disposable clothes during the loading of poultry? A) Always B) Sometimes C) Never

14. Do the driver and the catching team receive and wear farm-specific or disposable shoes during the loading of poultry? A) Always B) Sometimes C) Never

15. Do the driver and the catching team wash and disinfect their hands before entering the Poultry houses? A) Always B) Sometimes C) Never

16. Are the transport crates and containers loaded and unloaded from the transport vehicle

with farm-specific equipment (e.g. loader)? A) Yes B) No

17. Are the transport crates and containers transported in- and outside the poultry houses with farm- specific equipment (e.g. loader)? A) Yes B) No

18. Are the transport vehicles for poultry disinfected when entering the farm (e.g. driving through disinfection baths / spray system / etc..)? A) Always B) Sometimes C) Never

19. In how many steps does the depopulation of a poultry house take place?

A) In one step B) In two steps C) In more than two steps

**D. Transport of eggs**

20. Are the eggs that are ready for transport stored in a specific storeroom (i.e in a room Different from the egg room) ? A) Yes B) No

21. Does the driver have access to the egg facilities of the farm? A) Yes, but only to the egg room B) Yes, but only to the specific storeroom C) Yes, the driver has access to both the egg room and specific storeroom D) No, the driver doesn't have access at all

22. Is the transport vehicle for the eggs empty on arrival at the farm? A) Always B) Sometimes C) Never

23. Is the transport vehicle for the eggs cleaned and disinfected before entering the farm?

A) Always B) Sometimes C) Never

24. Are the transport vehicles for eggs disinfected when entering the farm (e.g. driving through Disinfection baths / spray system / etc..)? A) Yes B) No

25. Are eggs being sold at the farm? A) Yes B) No

26. Do people enter the farm to buy the eggs?

A) Yes, they enter the farm; but they stay outside the egg room or specific storeroom

B) Yes, they enter the farm and they go inside the egg room and/or specific storeroom

C) No, the eggs can be bought without entering the farm (e.g. from the public

**E. Feed and water**

27. Is the farm site divided into a clean and dirty area? A) Yes B) No C) I don't know

28. Are the clean and dirty area of the farm site clearly separated? A) Yes B) No

29. Can the feeding company fill up the silos/deliver feed without entering the clean area?

A) Yes B) Only some of them C) No

30. Are the transport vehicles for feed always disinfected when entering the farm (e.g. driving through disinfection baths / spray system / etc..)? A) Yes B) No

31. Does the feed supplier have access to the poultry houses and is direct contact with the poultry possible? A) Always B) Sometimes C) Never

32. Are the feed silos or the feed storage rooms (storage of complete feed or concentrate) Completely sealed against water, birds and vermin? A) Yes B) No

33. How often a year does the feeding company fills up the silos or delivers feed?

A) Less than 20 times a year B) Between 20 and 35 times a year C) More than 35 times a year

34. How often are bacteriological analyses of the drinking water performed?

A)At least once a year B) Every two years C) Less frequent than every two years D) Never

35. Where is the water sample for the bacteriological analyses taken? A) At the source

B) At the last drinker C) At both locations, i.e. at the source and at the last drinker

**F. Removal of manure and carcasses**

36. Is manure being stored on the farm? A) Yes B) No

37. Is the manure stored in a fully closed container or compartment? A) Yes B) No

38. Is the manure removed and disposed of appropriately through the dirty road? A) Yes B) No

39. Is there separate carcass storage? A) Yes B) No

40. Is the carcass storage space protected from vermin, cats and/or dogs?

A) Yes, it's completely protected B) It's only partially protected C) No

41. Is this carcass storage space cleaned and disinfected after each collection? A) Always B) Never

42. Is the carcass storage cooled? A) Yes B) No

43. What happens with the carcasses? A) The carcasses are composte B) The carcasses are buried/burned C) the carcasses are stored and collected by a rendering company

44. Are the carcasses composted in a closed system?

A) Yes, they are composted inside a building that can be completely closed

B) Yes, they are composted outside, enclosed with plastic C) No

45. How are the carcasses buried/ burned? A) They are burned in an approved incinerator on the farm

B) They are buried in the appropriate soil on the farm C) Other

46. Can the carcasses be collected by the rendering company without entering the farm (e.g.

from the public road)? A) Yes B) No

47. Are carcasses manipulated with gloves, or are hands cleaned and disinfected after Manipulation of carcasses? A) Always B) Sometimes C) Never

48. Is the material used for the removal of dead birds out of the poultry houses (e.g.buckets wheelbarrow) cleaned and disinfected after each use? A) Always B) Sometimes C)Never

**G. Visitors and farmworkers**

49. Are visitors obliged to notify you of their presence before entering the poultry houses (e.g. visitor's register)? A) Yes B) No

50. Is a poultry-free period (longer than 12 hours) expected of all visitors before they are allowed to enter the poultry houses? A) Yes B) No

51. Is there a farm hygiene lock available and is it always used by visitors when they enter the poultry houses? A) Yes B)No

52. Are all poultry houses only accessible for visitors through the farm hygiene lock? A) Yes B) No

53. Is there a strict separation between the clean and the dirty area of the farm hygiene lock? A) Yes B) No

54. Is there a changing room with farm-specific clothes and shoes in the farm hygiene lock? A) Yes B) No

55. Do visitors and farmworkers have to wear farm-specific clothing before they are allowed to Enter the farm? A) Yes C) No

56. Do visitors and farmworkers have to wear farm-specific shoes/overshoes before they are allowed to enter the farm? A) Yes B) No

57. Do visitors and farmworkers have to wash and disinfect their hands before they are allowed to enter the farm? A) Yes B) No

58. How many times per year is access to the poultry houses granted to visitors?

A) Access is never granted B) Access is granted, but less than 12 times a year

C) Access is granted more than 12 times a year

59. Are there any farmworkers who also keep poultry or any other type of bird at home? A) Yes B) No

60. Are there any farmworkers who also work on other poultry farms? A) Yes B) No

**H. Material supply**

61. Is there any material being shared with other farms that enters the poultry houses and/or has contact with your poultry? A) Yes B) No

62. Are specific measures taken for the introduction of material (e.g. UV-disinfection unit, alcohol disinfection)? A) Yes B) No

**I. Infrastructure and biological vectors**

63. Does the poultry have access to the outside, i.e. the open air? A) Yes B) No

64. Is the outdoor area enclosed with nets on all sides (including the ceiling)? A) Yes B) No

65. Are there bird- and vermin-proof grids placed on the air inlets? A) Yes B) No

66. Is the farm fenced? A) Yes, it's completely fenced A) It's only partially fenced B) No

67. Is the outside of the farm (around the walls) paved and clean (e.g. removal of weeds, waste, …)? A) Yes, it's completely paved and clean B) It's only partially paved and clean C) No

68. Are vermin (i.e. rats) considered to be a problem at the farm? A) Often B) Sometimes C) Never

69. Is a rodent control program present on the farm? A) Yes, a professional pest control company has been hired B) Yes, I have established my own pest control programme C) No

70. Do pets have access to the poultry houses (including the hygiene lock and egg room)? A) Yes B) No

71. Is “backyard”-poultry or any other type of bird being kept? A) Yes B) No

72. Are any other farm animals being kept on the same farm site? A) Yes B) No

**J. Location of the farm**

73. Is there stagnant or running water within a 1-kilometre radius (0.6 miles) of the farm? A) Yes B) No

74. At what distance (straight-line) is the nearest neighboring poultry farm located?

A) Less than 500 metres (Less than 0.3 miles)B) Between 500 metres and 1 kilometre C) More than1km

75. Is manure from other poultry farms spread on the neighboring farmlands (within a 500-metre (0.3 miles) radius)? A) Often B) Sometimes C) Never

76. Does animal transport frequently occur (i.e. minimum once a day) via the public road (road less than 100 metres (328 feet) from your farm) where your farm is located at (e.g. due to the

location of a slaughterhouse in the neighborhood…)? A) Yes B) No

**K. Disease management and vaccination**

77. Is the poultry checked on a daily basis? A) Yes B) No

78. Is a poultry health management programme, for which regular farm visits (e.g. by your Veterinarian (s)) are performed, present on your farm? A) Yes B) No

79. Are autopsies of culled and dead birds systematically performed during these? visits? A) Always B) Sometimes C) Never

80. How often are the poultry houses checked to remove dead birds?

A) Twice or more a day B) Once a day C) Less frequent than once a day

81. Are there different age categories of poultry present on your farm?

A) Yes, there are different age categories within one poultry house

B) Yes, there are different age categories, which are sorted by poultry house C) No

82. Is farm work, per poultry house, performed from young to older birds? A) Yes B) No

**L. Cleaning and disinfection**

83. Are the poultry houses cleaned after each production cycle? A) Yes, dry and wet cleaning is performed after each production cycle B) Yes, however, only dry cleaning is performed C) No

84. Are the poultry houses soaked with water before the start of cleaning?

A) Always B) Sometimes C) Never

85. Is detergent added to the water during cleaning? A) Always B) Sometimes C) Never

86. Are the poultry houses disinfected after each production cycle? A) Always B) Sometimes C) Never

87. Are the poultry houses dry before the start of the disinfection? A) Always B) Sometimes C) Never

88. Is the efficacy of cleaning and disinfection checked, with for example a hygienogram, swabs, ..., after each production cycle? A) Always B) Sometimes C) Never

89. Are the central corridor and other common places cleaned after each production cycle?

A) Yes, dry and wet cleaning is performed after each production cycle

B) Yes, however, only dry cleaning is performed after each production cycle C) No

90. Are the central corridor and other common places disinfected after each production cycle?

A) Yes B) No

91. Is the egg room regularly cleaned? A) Yes, after each outgoing egg transport
B) Yes, after each production cycle C) No
92. Is the egg room regularly disinfected? A) Yes, after each outgoing egg transport
B) Yes, after each production cycle C) No
93. Is the material/machinery used for egg collecting regularly cleaned
A) Yes, after each outgoing egg transport B) Yes, after each production cycle C) No
94. Is the material/machinery used for egg collecting regularly disinfected?
A) Yes, after each outgoing egg transport B) Yes, after each production cycle C) No
95. Is the loading and unloading area cleaned and disinfected after each production cycle?A) Yes B) No
96. Is the drinking water system properly cleaned and disinfected both on the in- and outside after each production cycle? A) Always B) Sometimes C) Never
97. Are the feeding systems (e.g. storage bins, augers, hoppers and chain feeders) cleaned and Disinfected after each production cycle? A) Always B) Sometimes C) Never
98. Are the feed silos cleaned and disinfected on the inside?
A) Yes, after every one or two production cycle(s) B) Sometimes C) Never D) Silo's aren't used

**M. Materials and measures between compartments**

99. Are there multiple poultry houses present on the farm? A) Yes B) No
100. Is there a house hygiene lock present at every poultry house? A) Yes B) No
101. Is there a strict separation between the clean and the dirty area of the house hygiene lock? A) Yes B) No
102. Is there a changing room with poultry house-specific clothing and shoes in the house hygiene lock? A) Yes B) No
103. Do visitors and farmworkers have to wear poultry house-specific clothes before they are allowed to enter the poultry house? .A)Yes B)No
104. Do visitors and farmworkers have to wear poultry house-specific shoes/overshoes before they are allowed to enter the poultry house? A) Yes B) No
105. Do visitors and farmworkers have to wash and disinfect their hands before they are allowed to enter the poultry house? A) Yes B) No

106. Is there a disinfection bath/boot washer at the entrance of each poultry house? A)Yes B) No

107. Is the fluid of the disinfection baths/boot washers immediately changed when visually Contaminated? A) Yes B) No

108. Has clearly recognizable, separate material been foreseen for each poultry house?A) Yes B) No

109. Is there a protocol for the cleaning and disinfection of material after each production cycle and is this protocol abided by? A) Yes B) No

**N. Egg management**

110. Are the eggs collected in the poultry house itself, or does the collection take place in a separate room close to the poultry house (e.g. in connection with an automatic belt)? A) In the poultry house itself B) In a separate room next door

111. Do you have a fully automatic egg collection system or are people manually doing the Collection and/or transportation of the eggs to the egg room ? A) There is a fully automatic system

B) Manual collection and/or transportation of the eggs by farmworkers

112. Are the farmworkers active in the poultry houses, also working in the egg room?A) Yes B) No

113. Do the farmworkers, who collect and/or transport the eggs to the sorting/packaging room, take strict preventive measures between the egg sorting/packaging room and the poultry houses? A) Always B) Sometimes C) Never

114. Are dirty, cracked and/or broken eggs removed from the collection systems as early as possible and handled separately? A) Yes B) No

115. Are the egg belts, belt brushes and other egg handling equipment cleaned after each production cycle? A) Always B) Sometimes C) Never

116. Are the egg belts, belt brushes and other egg handling equipment disinfected after each production cycle? A) Always B) Sometimes C) Never

117. Are disposable egg trays being used to transport the eggs? A) Yes B) No

118. What are the egg trays made of? A) Plastic B) Cardboard

119. Are the egg trays regularly cleaned? A) Yes, after each egg transportation

B) Yes, after each production cycle C) No

120. Are the egg trays regularly disinfected?

A) Yes, after each egg transportation  B)Yes, after each production cycle  C) No

**Apendix 2: Questionnaire format for feed processing plants**

**ADDIS ABABA UNIVERSITY**

**COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE**

Dear respondents, the purpose of this questionnaire is to collect data in the assessment and improvement of biosecurity practices in chicken feed processing plants found Adama,, Bishoftu and Modjo in central Ethiopia. Responding to this questionnaire will have great contribution on the optional development strategies of chicken biosecurity practices. Therefore, you are kindly requested to respond these questions by writing "YES" or "NO" at the end of the question.

.Name of feed mill .Location

Respondent position date

1. Do you purchase feed ingredients from the same processing plants/station?

A) Yes B) No

2. Is the water used in the feed processing plant suitable quality? A) Yes B) No

3. Is the level of minimizing risk of introducing or spreading diseases, pests and weeds while purchasing grains, roughages, additives and feed ingredients good? A) Yes B) No

4. Do you purchase feed inputs from preferred and approved suppliers that maintain an accredited quality assurance program which includes a biosecurity component? A) Yes B) No

5. Is there a practice to minimize the risk of introduction and spread of disease or contaminants by feed processing plant employees or family? A) Yes B) No

6. Do feed processing plant personnel wear laundered clean clothes each day at the commencement of their work? A) Yes B) No

7. Does your staff take boots that are worn at the feed processing plant outside the feed mill?

A) Yes B) No

8. Are protective clothing and footwear worn in the feed mill area at all times and removed prior to exiting? A) Yes B) No

9. Are hands sanitized and disinfected on entering and leaving the feed mill?

A) Yes.. B) No

10. Do personnel working in feed processing have access to the poultry farms?

A) Yes B) No

11. Is there an updated biosecurity plan in the feed processing plant? A) Yes B) No

12.Are all staff aware of the potential for introduction and transmission of diseases by visiting vehicles and machinery? A) Yes B) No

13. Is the entry of non-feed mill vehicles, machinery and equipment into areas of the feed mill beyond the specified delivery areas restricted? A) Yes B) No

14. Is there a designated parking area for vehicles not entering the production area? A) Yes B) No

**Apendix 3: Questionnaire format for chicken slaughter house**

**ADDIS ABABA UNIVERSITY**

**COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE**

Dear respondents, the purpose of this questionnaire is to collect data in the assessment and improvement options of biosecurity practices in chicken slaughter house found in central Ethiopia. Responding to this questionnaire will have a great contribution on development of the improvement options and strategies on biosecurity practices. Therefore, you are kindly requested to respond these questions by writing "YES" or "NO" at the end of the question

Name of Slaughter house Date

Location Respondent position

Type of Slaughter house: A) Backyard B) Common slaughter house C) Individual slaughter house

1. Does slaughter facilities are available? A) Yes B) No

2. Is Personal hygiene of the personnel working in the slaughter house good? A) Yes B) No

3. Water quality in the slaughter house is suitable? A) Yes B) No

4.Is there a cold room ? A) Yes B) No

5. Do you use suitable packaging facilities? A) Yes B) No

6. Do you have proper offal disposal system? A) Yes B) No

7. Is it possible access of visitors to the slaughter house? A) Yes B) No

Thank you!!

**Apendix 4: Questionnaire format for the live poultry market**

**ADDIS ABABA UNIVERSITY**

**COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE**

Dear respondents, the purpose of this questionnaire is to collect data in the assessment of biosecurity practices and improvement strategies in the chicken markets of Adama, Addis Aaba, Bishoftu and Modjo, central Ethiopia. Responding to this questionnaire will have a great contribution on the development of optional chicken biosecurity strategies. Therefore you are kindly requested to respond confidentially while you are asked.

Please answer the following questions by putting "YES" or "NO" at the end.

Location of chicken market……..Date……

Status of respondent: A) Producer B) broker C) Veterinarian

D) Merchant Other specify…… Signature……

1. Do you use common equipment such as crate, tray for eggs and others?
   A) Yes B) No
2. Do you practice decontamination of used equipment? A) Yes B) No
3. Do you use public / rent vehicles to carry chicken and chicken products to the market?
   A) Yes B) No
4. Is there refrigerator in the market? A) Yes B) No
5. Do you use cold room vehicles? A) Yes B) No
6. Is the chicken meat packed properly? A) Yes B) No

   Thank you!!

**Apendix 5: Questionnaire format for the responsible Agricultural offices**

**ADDIS ABABA UNIVERSITY**

**COLLEGE OF VETERINARY MEDICINE AND AGRICULTURE**

Dear respondents, the purpose of this questionnaire is to collect data in the assessment and improvement options of chicken biosecurity practices in District and regional agricultural officers and veterinarians (Adama,, Bishoftu and Modjo) central Ethiopia. Responding to this questionnaire will have a great contribution on development strategies of biosecurity practices. Therefore, you are kindly requested to respond these questions by writing "YES" or "NO" at the end of the question.

Name of the district/regional office……..

date……..Location…….

Respondent's position……

1. Is there regular veterinary supervision from the district and/or regional agricultural office? A) Yes B) No

2. Is there regular training of staff on biosecurity from the district and/or regional agricultural office? A) Yes B) No

3. Are the veterinarians/poultry health specialists limited in number? a) yes B) No

4. Do they often visit the different poultry farms? A) Yes B) No

5. Is there unauthorized access to the farms by the veterinarians/poultry health specialists? A) Yes B) No

Thank you!!

## Apendix 6: Representative pictures during the survey