Biosecurity level assessment in commercial poultry farms of central Ethiopia

*Dejene Tadesse[1], Zerihun Aseffa[2], Abebe Wirtu[2] and Teshale Sori[2]**

[1]Bishoftu Bureau of Urban Agriculture, Bishoftu, East Shewa Zone

[2]Addis Ababa University, College of Veterinary Medicine and Agriculture, Department of Clinical Studies

**Corresponding author. E-mail: teshalesori2002@yahoo.com / teshale.sori@aau.edu.et*

Abstract

Proper biosecurity practice is crucial in poultry farming to reduce the risk of diseases. A study was conducted in Adama, Ada'a, and Lume districts, central Ethiopia, to assess the biosecurity measures of commercial poultry farms. A total of 51 farms were randomly selected, and their geographical locations were recorded using GPS devices. The biosecurity level of each farm was assessed using an observation checklist and a biosecurity score. The collected data were analyzed using Stata version 16 for binary data, and QGIS version 3.24.1 was used to map the farms. The results of the study showed that the farms were located close together within 5 km square, 3 km square, and 6 km square areas in Ada'a, Lume, and Adama, respectively. The average distance among the farms was 933.8 meters. The majority of the farms were located within 100 meters of residential areas. Only 58.8% of the farms had adequate space between sheds; 60.8% did not have an adequate drainage system. Ninety-eight percent of the farms obtain chicken from certified breeding enterprises; 92.2% provide underground water for their chickens; 80.4% report frequent cleaning and disinfection of farms; and 82.4% disclose vehicle movement control. Nearly one-third (31.4%) of the farms practice isolation of sick birds but keep them within the same shed where healthy birds are kept. The assessment of biosecurity levels of the study farms revealed that 23.5% (n=12) of the farms had a good biosecurity score, while 76.5% (n=39) had a poor score. The biosecurity scores of the farms showed a statistically significant difference among the study districts (p=0.040), with the Lume district having higher biosecurity scores than Adama and Ada'a districts. The age of the farm owners was significantly associated with the biosecurity score (p=0.003); all farms (100%) owned by individuals aged 20 - 39 had good biosecurity scores, and 80% of those farms owned by individuals aged 40 - 59 had good biosecurity. Farms owned by individuals who have previous chicken-rearing experience had better biosecurity scores than those farms owned by non-experienced owners (p<0.001). Among the farms having professional consultants, 57.7% of them had good biosecurity scores, whereas only 12.0% of farms lacking professional consultants had good biosecurity scores (p=0.015). In conclusion, the study revealed that biosecurity measures were not adequately implemented in poultry farms in central Ethiopia. Farm owners, veterinarians, and livestock authorities must collaborate to implement biosecurity measures to minimize the risk of losses and public health.

Keywords: Biosecurity; commercial poultry farm; spatial distribution; central Ethiopia.

Introduction

Biosecurity is defined in the European Animal Health Law as: "the sum of management and physical measures designed to reduce the risk of the introduction, development and spread of diseases to, from and within: (a) an animal population, or (b) an establishment, zone, compartment, means of transport or any other facilities, premises or location". The Food and Agriculture Organization of the United Nations (FAO) defines biosecurity as the "implementation of measures that reduce the risk of the introduction and spread of disease agents; it requires the adoption of a set of attitudes and behaviors by people to reduce risk in all activities involving domestic, captive/exotic and wild animals and their products" (FAO/OIE/WB, 2010). The World Organization for Animal Health defines biosecurity in the Terrestrial Animal Health code as "a set of management and physical measures designed to reduce the risk of introduction, establishment and spread of animal diseases, infections or infestations to, from and within an animal population". According to these definitions at the farm level, biosecurity measures may focus either on reducing the risk of entry of new pathogens (external biosecurity) or on reducing the internal dissemination of pathogens (internal biosecurity). It became an integral part of several strategic policy documents in animal and public health and policy for livestock production (Vanlangendonck *et al.,* 2021).

Biosecurity at a poultry farm comprises all measures and actions implemented to reduce the risk of introduction and spread of disease agents and keep poultry and people healthy. By applying these biosecurity measures and improving the efficiency of management, the chickens are protected against a range of infectious diseases (Dewulf *et al.,* 2020). Globally, the poultry sector has evolved from a small-scale to an industrial production over the years. The aim is to have a thorough production through the optimization of components such as nutrition and genetics (Sahlström *et al.,* 2014; Alawneh *et al.,* 2014). However, higher densities of animals per production site and associated contact and operational structures have been incriminated as drivers for the occurrence of infectious diseases (Tenorio, 2022), which are responsible for substantial economic losses. The most effective and economically feasible method to prevent and control poultry diseases is the implementation of biosecurity measures (Butcher and Miles, 2012). Biosecurity aims to prevent infectious diseases and their spread to animals (both domestic and wildlife) and humans (Gilbert *et al.,* 2020). That is, it curtails the impact of infectious diseases on the economy, society, and environment to safeguard health and wellbeing. Biosecurity became one of the essential components of the One Health concept (Renault *et al.,* 2022).

Implementation of biosecurity measures resulted in several consequences in addition to minimizing risks for disease outbreaks. Studies have shown that biosecurity is positively associated with increased production, such as daily growth and reduction in mortality in broilers (Wijesinghe *et al.,* 2017). Additionally, the application of biosecurity measures dramatically reduces the use of antibiotics (Nöremark, 2010; Laanen *et al.,* 2013), which in turn reduces the development of antibiotic resistance and improves both animal and human health (Conan *et al.,* 2012). In contrast, high mortality and morbidity of chickens, high medication costs, loss of production, denied access to the market, and a high risk of public health from zoonotic diseases have been associated with farms that did not implement biosecurity measures (Wubet *et al.,* 2019). Diseases such as Newcastle disease, salmonellosis, fowl cholera, coccidiosis, and fowl pox were reported to cause high morbidity and mortality in village and commercial chicken (Wubet *et al.,* 2019) where biosecurity measures were not implemented properly (Cardona and Kuney, 2002; Mazengia *et al.,* 2012).

In Ethiopia, the evolution of the poultry sector from scavenging to small-scale and industrial systems has led to an increased need for biosecurity measures to prevent disease outbreaks that can have a significant impact on farm profitability and the national poultry sector. However, information on the levels of biosecurity measures exercised in commercial poultry farms is limited. Therefore, the objective of this study was to provide spatial maps of commercial poultry farms and quantify the biosecurity levels practiced in central Ethiopia.

Materials and methods

Study area

The study was conducted on medium and large-scale commercial poultry farms located in three districts in central Ethiopia, namely Ada'a (47 km southeast of Addis Ababa), Adama (100 km southeast of the capital, Addis Ababa), and Lume (73 km southeast of Addis Ababa). Figure 1 depicts the geographical locations of the study districts. These districts are located in the mid-Rift valley along two highways: one connecting Ethiopia to Kenya and the other connecting Ethiopia to Djibouti. The area is endowed with a number of creator lakes serving as recreational centers. As a result, there is high human traffic in the areas. Based on data acquired from the Ministry of Agriculture, these districts have emerged as significant contributors to the poultry industry, representing the majority of poultry production in the country. The districts were selected due to the presence of a high number of poultry farms, proximity to the commercial centers, and increased commercial activities.

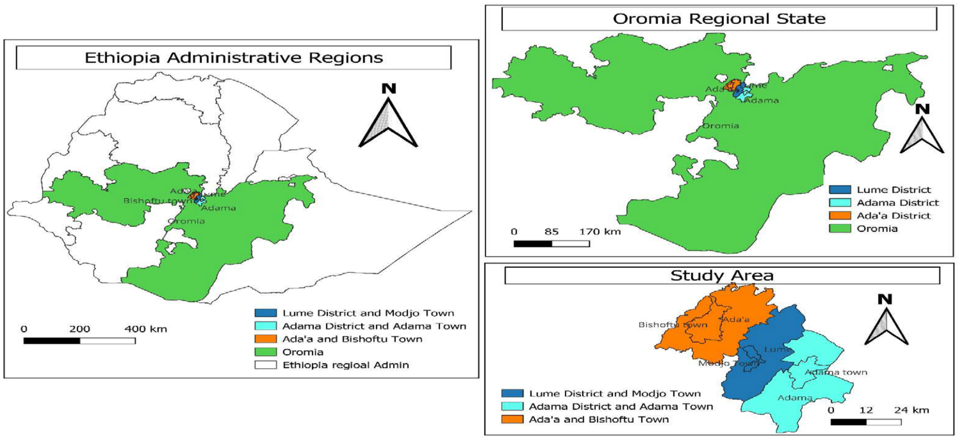

Figure 1. Map of Ethiopia and Oromia Regional State displaying the locations of study districts

Study design

This study utilized a cross-sectional study design. The study population comprised chickens raised under medium and large-scale poultry farms located in the Ada'a, Adama, and Lume districts. Data obtained from the agricultural offices showed that there were 378 (303 layer and 75 broiler) registered commercial poultry farms in the study districts. Out of these, ten broiler farms (5 small, three medium, and two large scale) and 64 layer farms (48 small, 12 medium, and four large scale) were in Adama. In Ada'a district, there were 57 broiler farms (22 small, 30 medium, and five large scale) and 187 layer farms (100 small, 78 medium, and nine large scale). A total of 52 layer farms (40 small, 10 medium, and two large scale) and eight broiler farms (5 small and three medium scale) were registered in the Lume district. For this study, 51 medium and large-scale poultry farms were randomly selected. GPS was used to collect coordinates of the farms, nearby residence areas, highways, open water sources, and live bird markets. Data collection was carried out using semi-structured questionnaires comprising both closed and open-ended questions to gather all the information regarding biosecurity measures and farm characteristics. The questionnaire was pretested before the final survey on a few farms in order to make the necessary refinements for better clarity and completeness. A face-to-face interview was conducted with farm owners, managers, or attendants. Biosecurity measures in each farm were evaluated using Chowdhury *et al*. (2020) poultry farm biosecurity scoring system, which categorized indicators and definitions of biosecurity scores at conceptual, operational, and structural levels.

Data collection

Data on the house design and orientation, types of construction, availability of enough spaces, hygiene status, frequency of cleaning and disinfection, traffic control, health management, and other biosecurity measures of the commercial poultry farms studied were collected using questionnaires and observations. In addition, measurements of variables such as distance among the farms, distance of the farms from main roads, and distance of the farms from residential areas were taken. Information on the demographic features of the farm owners and managers was also collected. All variables collected were categorized.

Operational definition

Large-scale poultry farm: A farm having ≥ 10,000 chicken
Medium-scale poultry farm: A farm rearing 5,000 – 9999 chicken
Small-scale poultry farm: A farm holding less than 5000 chicken
Good biosecurity: when the biosecurity score is above 50%
Poor biosecurity: when the biosecurity score is less than 50%

Data management and analysis

Data were analyzed using STATA version 16, and descriptive and analytical statistics were used. These include frequency summary, proportion, and Pearson's chi-square test, which were used to estimate associations between farm characteristics, demography of farm owners, and biosecurity status. The overall biosecurity status was estimated using the poultry farm biosecurity score system described by Gelaude *et al.* (2014), with farms scoring over 75% of the total score (>33) considered standard and farms scoring less than or equal to 33 considered "below standard." A significance level of $p < 0.05$ was used. Finally, spatial queries of QGIS version 3.24.1 were used to address environmental biosecurity issues, such as proximity to lakes, roads, and live poultry markets.

Ethical clearance

This study was approved by the ethical review board of Addis Ababa University, College of Veterinary Medicine and Agriculture (Certificate Ref. No: VM/ERC/08/02/14/2022). The owners or managers of each farm were informed about the aim of the study, and verbal informed consent was obtained from each respondent. Participation in the study was voluntary, and respondents were free to withdraw from the study at any time. Their consent was recorded (marked) on the questionnaire paper, the interview was anonymous, and data remained confidential throughout the study.

Results

Spatial distribution of commercial poultry farms in the study areas

The farms were found in clusters within areas of 5, 3, and 6 square km in the Ada'a, Lume, and Adama districts, respectively. In Ada'a, the majority of the commercial poultry farms were located in the central, northwest, and eastern parts of the district. Similarly, in Adama, the farms were located in the central and northeastern parts of the district. In contrast, almost all of the farms in Lume district were situated in the northern parts of the district. The relative locations of the commercial poultry farms are depicted in Figure 2.

The average distance between poultry farms in the three districts was 933.8m, with a median of 205.4m. Distances between farms ranged from 16.39 to 4920.67 meters. The average distance between farms in Ada'a was 544.08m, the average distance in Lume district was 1991.59m, and it was 265.88m in

Adama. The study revealed that poultry farms in the selected districts were clustered in some areas of the districts and were located very close to each other. The majority of the farms were within 100 meters of residential areas, with only 9.8% located farther than 100 meters away from residential areas. In terms of proximity to main roads, 19.61% of the poultry farms were located within 300 meters of the main roads, while the rest (80.39%) were situated farther than 300 meters away from the main roads. In Lume district, however, none of the farms were located within 300 meters of the main road (Figure 2).

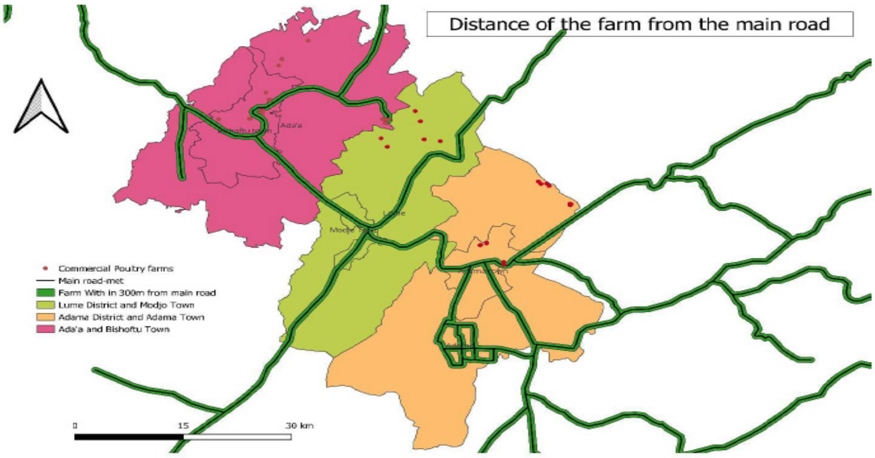

Figure 2. Map of the three study districts depicting the locations of the poultry farms. The top is the Ada'a district, the middle one is the Lume district, and the bottom is the Adama district. The poultry farms are indicated with red dots. The green bold lines represent the main roads.

Biosecurity measures adopted by poultry farms

House design and orientation

The orientation of the poultry houses in the majority of the farms (78.43%) was east-west, while the rest were oriented north-south. The medium-scale farms did not have well-defined physical boundaries. All of the farms were accessible to dogs, cats, and vermin. Although all of the farms had sick bird isolation rooms, the isolation rooms are located within the farms and have the potential to spread disease agents. More than half of the farms did not have washable housing surfaces, although all (100%) of them had concrete floors. More than half (62.75%) of the farms had adequate space between sheds, while the remaining 37.25% did not have adequate space. The results also showed that 21.57% of the farms had no restrictions on the entrance of humans, vehicles, and animals, while 37.25% of the farms had room for their staff inside the farm compound. Table 2 presents the details of the relative farm location and house design.

Table 2. Results of assessment of the relative farm location and house design of the commercial poultry farms in the three selected districts

Variable	Category	Number of farms	Proportion
Residential areas	None within l00m	5	9.80
	Located within 200m	14	27.45
	Located within 100m	32	62.75
Backyard poultry (chicken, ducks, pigeons)	None within 200m	38	74.51
	Present within 100m	13	25.49
Orientation	East–West direction	40	78.43
	North–South direction	11	21.57
Public Places (Schools, Bazar, Bridge, etc.)	None within 200m	48	94.12
	Present within 200m	3	5.18
Staff rooms	Present inside the Farms	19	37.25
	None inside the Farms	32	62.75
Adequate Space	Present between sheds	32	62.75
	Not present between sheds	19	37.25
Width of sheds	>30 Feet	51	100.00
Floor-type	Concrete	51	100.00
Farm Environment	Vegetation around the shed	36	70.59
	None	15	29.41
Entry restriction	Yes	40	78.43
	No	**11**	21.57

Sources of farm inputs

The majority of the poultry farms (96.08%) in the selected districts obtained their feed from registered companies; 92.16% of the farms provided underground water to their chickens. Nearly all (98.04%) of the farms sourced their chickens from reliable, certified breeding centers and conducted health inspections upon receipt. However, 37.25% of the farms did not have stores for poultry feed. It was found that 39.22% of the farms implemented bait and traps as a rodent control strategy; 23.53% used feed spill-outs, while the remaining farms used both methods (Table 3). None of the farms studied traced poultry trucks and had very loose control over the transport routes.

Cleaning and disinfection

Most of the farms did not clean and disinfect their farm compounds regularly. Many of them (80.39%) had footbaths at the gates, although none of them regularly cleaned the bath and replenished the disinfectants. The cleaning and disinfection method used by the farms was also not appropriate. It consisted of removing dirt followed by application of disinfectants. The frequency of cleaning and disinfection was low, mainly covering only a portion of the premises. Most (60.78%) of the farms did not have an adequate drainage system (Table 3). The results also showed that none of the farms had a written biosecurity plan or records of vaccination, surveillance, and disinfection for each batch of chickens.

Table 3. Sanitation status, cleaning frequency of sheds, and sources of farm inputs for the commercial poultry farms studied

Parameter	Category	Number of farms	Percentage
Source of feed	Feed Company	49	96.08
	Prepared on farm	2	3.92
Source of water	Underground water	47	92.16
	Rain, nearby spring	3	5.88
	Surface water	1	1.96
Health check on recipient of chicks	Yes by veterinarian	50	98.04
	No	1	1.96
Waste /litter Management	Use for compost	1	1.96
	Stored and sold	28	54.90
	Contracted to farmers	22	43.14
Cleaning and Disinfection	Foot bath	41	80.39
	None	10	19.61
Feed management	Good storage system	32	62.75
	Poor storage system	19	37.25
Water management	Plastic material	51	100.00
Drainage Management	Adequate	20	39.22
	Inadequate	31	60.78
Waste disposal	Vermicomposting	6	11.76
	Composting in a pit	2	3.92
	Sale	43	84.31
Pest control	Bait and traps	20	39.22
	Feed spills out	12	23.53
	Both	19	37.25
Cleaning and disinfection of farm compound	Clean and disinfect the whole compound every week	10	19.61
	Clean and disinfect part of the compound regularly	16	31.37
	Clean and disinfect occasionally	23	45.10
	Not done	2	3.92
Cleaning and disinfection of utensils and shed	Done regularly	12	28.53
	Done when required	17	33.33
	Done sometimes	21	41.18
	Not done	1	1.96

Traffic control practices

The majority of the poultry farms (82.35%) had control measures in place for vehicle movement within the farm, including vehicle disinfection before and after visiting the farm. Almost two-thirds (64.71%) of the farms had a designated area for vehicle parking and cleaning. Most farms had strict control measures for human traffic, with only 3.92% of farms allowing visitors to enter freely. However, 15.69% of the farms did not have proper biosecurity inspections for farm attendants and other staff (Table 4). None of the farms had staff/workers training programs in biosecurity, and as a result, the staff/workers lacked a vigilant attitude towards its implementation. None of the farms studied had standard operating procedures for their workers.

Table 4. The cleaning and disinfection of the farm environment and traffic control status of the poultry farms in the study areas

Variable	Category	Number of farms	Percentage
Vehicle Movement	No movement	18	35.29
	Disinfection upon entry	24	47.06
	No control of the vehicle	9	17.65
Separate area for vehicles	Yes, for cleaning and disinfection	5	9.80
	Yes, only for cleaning	33	64.71
	Not effective	1	1.96
	None	12	23.53
Farm compound	Brick wall with a gate for recording visitors	19	37.25
	Porous wall with footwear and disinfection at the entrance	30	58.82
	No wall with free entrance	2	3.92
Human traffic control	Strict cleaning, disinfection, and PPE required	11	21.57
	Only disinfection	39	76.47
	None	1	1.96
Residence on the farm	Yes permanently	20	39.22
	None	31	60.78
Management of egg trays	Use and dispose	20	39.22
	Clean and disinfect after each use	19	37.25
	Clean and disinfect when dirt is visible	12	23.53

Isolation of sick and disposal of dead birds

The majority of the farms (88.24%) in the selected districts practice the proper disposal of dead birds and the isolation of sick ones. All farms disclosed that they practice vaccination of chickens following the recommendations of veterinarians and the instructions of vaccine manufacturers. However, none of the farms had records of vaccination over the years. About two-thirds (66.67%) of the farm owners were aware of the importance of biosecurity protocols. However, none of them had an epidemiological unit for tracing and monitoring diseases, including regulating the removal and disposal of dead birds or the isolation of sick ones. A separate disposal pit, use of an incinerator, and burning of dead birds were practiced by 84.31% of the farms, while the remaining 15.69% did not disclose their disposal system (Table 5). Most of these actions were taken without consulting veterinarians.

Table 5. Isolation of sick and disposal of dead birds by the selected farms in the study area

Variable	Category	Number of farms	Percentage
Disposal of dead and isolation of sick birds	Quick disposal and isolation	45	88.24
	Disposal of dead birds but keep sick ones in separate rooms in the shed	6	11.76
Vaccination	Yes	51	100.00
All in all, all-out practice	Yes	51	100.00
Awareness about the importance of biosecurity	Yes, all farmworkers	34	66.67
	Only some of the workers	17	33.33
Flock monitoring	Regularly by employed Vet. and government authority	6	11.76
	Only by employed Vet.	45	88.24
Facility for personnel hygiene	Shower facility and disinfection	12	23.53
	Hand wash and foot bath at the gate	1	1.96
	Foot bath and spray system at the gate	2	3.92
	Only foot bath	19	37.25
	None	17	33.33
Management of dead birds	Disposal pit /incinerator /burring	43	84.31
	Not disclosed	8	15.69
Management of sick birds	Isolation room away from shed	35	68.63
	Isolation room in the same shed	16	31.37

Biosecurity scores of the farms

The assessment of biosecurity levels of the study farms revealed that 23.53% (n=12) of the farms had a good biosecurity score, while 76.47% (n=39) had a poor score. The biosecurity scores of the farms showed a statistically significant difference among the study districts (p=0.040), with the Lume district having higher biosecurity scores than Adama and Ada'a districts. The age of the farm owners was significantly associated with the biosecurity score (p=0.003); all farms (100%) owned by individuals aged 20 - 39 had good biosecurity scores, and 80% of those farms owned by individuals aged 40 - 59 had good biosecurity. Farms owned by individuals who have previous chicken-rearing experience, as was the previous chicken-rearing experience, had better biosecurity scores than those farms owned by non-experienced owners (p<0.001). Among the farms having professional consultants, 57.69% of them had good biosecurity scores, whereas only 12.00% of farms lacking professional consultants had good biosecurity scores (p=0.015). All (100%) of the large-scale farms had good biosecurity scores, while only 21.28% of medium-scale farms had good biosecurity scores. The result of the biosecurity scores of the study farms is given in Table 6.

Table 6. Association between biosecurity score and various variables studied in commercial poultry farms in the study areas

Variable	Category	Number of farms	Biosecurity level		Chi-square	p-value
			Poor	Good		
District	Adama	16	14 (87.50%)	2 (12.50%)	4.931	0.040
	Ada	29	21 (72.41%)	8 (27.59%)		
	Lume	6	4 (66.67%)	2 (33.33%)		
	Overall	51	39 (76.47%)	12 (23.53%)		
Age of owners (in years)	13-19	3	0 (0.00)	3 (100.00%)	11.3322	0.003
	20-39	40	8 (20.00%)	32 (80.00%)		
	40-59	8	6 (5.00%)	2 (25.00%)		
Sex of owner	F	20	15 (25.75%)	5 (25.00%)	0.0992	0.753
	M	31	9 (29.03%)	22 (70.97%)		
Owner's educational status	Primary	10	8 (80.00%)	2 (20.00%)	2.546	0.116
	Secondary	18	2 (11.11%)	16 (88.89%)		
	College	8	4 (50.00%)	4 (50.00%)		
	University	15	6 (40.00%)	9 (60.00%)		

Variable	Category	Number of farms	Biosecurity level		Chi-square	p-value
			Poor	Good		
Previous chicken-rearing experience	Yes	21	12 (57.14%)	9 (42.86%)	15.8035	≤ 0.001
	No	30	28 (93.33%)	2 (6.67%)		
Having professional consultant	Yes	26	11 (42.31%)	15 (57.69%)	5.8784	0.015
	No	25	22 (88.00%)	3 (12.00%)		
flock size	Large	4	0 (0.00%)	4 (100.00%)	5.978	0.011
	Medium	47	37 (78.72%)	10 (21.28%)		
House type	Deep litter	50	37 (74.00%)	13 (26.00%)	2.6957	0.101
	Cage system	1	1 (0.00%)	1 (100.00%)		

Discussion

Poultry production requires strict implementation of efficient biosecurity measures to prevent the entry of disease agents to manage a disease once it is on the premises. The goal is to minimize losses due to diseases, optimize production, and improve food security and safety. These measures can be split into bio-exclusion and biocontainment, covering a range of actions such as housing with appropriate ventilation, proper floor systems, sufficient and secure isolation areas, and effective traffic control, among others. Biosecurity practices have been proven effective and inexpensive in disease control measures in other parts of the world (Wijesinghe *et al*., 2017; Van Limbergen *et al*., 2018; Tasie *et al*., 2020). In Ethiopia, the Ministry of Agriculture has identified poultry production as a critical priority sector in its endeavors to enhance household food security and promote overall wellbeing (Hailemichael *et al*., 2016). However, infectious diseases are widespread on commercial farms, resulting in significant financial losses (Asfaw *et al*., 2021). This study revealed poor biosecurity scores among commercial poultry farms, highlighting the need for the implementation of biosecurity procedures to prevent the introduction and spread of infectious agents.

The study found that commercial poultry farms were concentrated in certain parts of the districts and located very close to each other, mostly less than one kilometer apart. This proximity puts the farms at high risk for the introduction of pathogens from nearby farms, carried by vehicles, humans, farm implements, feral birds, or scavenging chickens. Previous studies have reported that the proximity of farms to neighboring same-species units and significant transport routes influence the risk of disease introduction (Gibbens *et al.*, 2001). Standard poultry operations require an isolated geographical location in relation to other poultry and livestock establishments' and wild bird concentrations (OIE, 2022), and the recommended relative locations of the farms are not followed (Gelaude *et al.*, 2014). The location of farms within 100 meters of residential areas puts them at high risk of the introduction of pathogens from surrounding waste, free-range chickens reared by households, and human movement. Moreover, this location is repulsive to residents and puts them at risk of contracting diseases (Iyiola-Tunji *et al.*, 2013). Observations during this study showed that several chicken farms were located within 0-20 meters of residential areas.

The majority of the farms lack adequate drainage systems, which favors the discharge of untreated wastewater or run-off into chicken habitats, creating favorable conditions for pathogen survival and multiplication on the farm and potentially contaminating chicken feed and/or water. Although most farms indicated that they frequently clean and disinfect their farms, the design and construction materials used are impervious, hindering efficient cleaning and disinfection. Areas surrounding the poultry houses were not paved with concrete or other waterproof material, making effective cleaning and disinfection difficult and putting the farms at risk of disease outbreaks. Disinfection requires proper cleaning and removal of all organic matter and the saturation of all surfaces, sticking to the five sequences of cleaning and disinfection (Kustritz, 2022). Similar observations were reported in northern Ethiopia, where the majority of farms practiced cleaning and disinfection of farms despite unsuitable house design and construction (Birhanu *et al.*, 2015). Effective removal of pathogens or niches favorable for their survival is critical to prevent disease spread to neighbors and maintain good hygiene.

Although the majority of the poultry farms in the study area reported practicing vehicle movement control, they did not pay due attention to farm workers and visitors, who were allowed to access the shed and flock without proper inspection. Personnel and visitors did not take showers, change their clothes, or wear provided footwear. The farms did not have a registry for the entry of visitors and vehicles. Hence, the traffic control practices reported by the farms were only for formality, and such practices put the farms at risk of the introduction and dissemination of pathogens. Coupled with the farms' proximity to one another and residence areas, loose traffic control is favorable for outbreaks of infectious diseases. Similar observations were reported in Sudan (Mustafa *et al*., 2018). Poor biosecurity can result in reduced financial gain, increased disease outbreaks, and negative impacts on the health and welfare of poultry (East, 2007; Fasina *et al*., 2013).

Disposal of dead birds and isolation of sick ones are practiced in the poultry farms in the study areas. Although some farms use disposal pits and incinerators, they are practiced by farm personnel and not supervised by veterinarians. Isolation of sick birds was done in a separate room in the same shed. The absence of a separate and secured isolation house for sick birds increases the risk of pathogen transmission to susceptible birds. Given the farms' proximity to one another, the spread of pathogens to neighboring farms is also possible. In contrast, the vaccination coverage reported in this study is higher than the reports of previous authors (Birhanu *et al*., 2015).

Interestingly, the majority of the farm managers and owners reported being aware of biosecurity issues such as cleaning and disinfection, traffic control, and isolation practices. However, none of them had a written biosecurity plan, and personnel did not receive training in biosecurity relevant to chicken health, human health, and food safety. In addition, there appears to be poor communication among personnel involved in the poultry production chain, such as farmers, veterinarians, and extension workers. This lack of communication and coordination can lead to inadequate disease surveillance, poor implementation of biosecurity measures, and ineffective disease control.

Conclusions

This study shows the prevalence of poor biosecurity levels in commercial poultry farms in the study areas. The farms did not have standard operating procedures for the implementation of biosecurity measures. Biosecurity score was statistically associated with the age of owners, chicken rearing experience of the owners, having a professional farm consultant, and flock size. Collaboration of farm owners and veterinary and livestock authorities is recommended to implement biosecurity measures to minimize the risk of losses and public health.

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