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Comparing Biosecurity Measures between Commercial Broiler and Layer Farms: Exploring Poultry Farming Biosecurity Practices in Gujarat

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Research Article

Keywords: Biosecurity measures, broiler, layer, Gujarat, antimicrobial resistance, food safety

Posted Date: November 5th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10940489/v1

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Additional Declarations: No competing interests reported.

Abstract

Background

Poultry farming is crucial to India's economy, but global trade and the movement of people and animals have raised concerns about disease transmission and antimicrobial resistance. Implementing biosecurity measures on farms can control the spread of infectious diseases and antimicrobial resistance. This study aimed to compare the biosecurity practices of commercial broiler and layer farms in Gujarat and provide insights into the measures adopted by farmers in the region.

Methods

A cross-sectional study was conducted using survey questionnaires collected from 74 commercial poultry farmers including 39 broiler and 35 layer farmers. The cleaned data was analyzed using descriptive statistics, factor analysis of mixed data, and hierarchical clustering on principal component.

Results

The four clusters, with each cluster having a predominant farm type were identified. The biosecurity measures significantly differentiated farms, were: type of farm, rearing system, production cycle per year, level of biosecurity knowledge, source of income, farm previously encountered the disease outbreak and mode of operation. Comparatively layer farmers are well educated, experienced, have good biosecurity knowledge and follow strict biosecurity protocol than the broiler farmers. Additionally, the 79.49% broiler and 71.43% layer of farmers were not knowledgeable about antimicrobial resistance and 38.46% broiler and 91.43% layer farmers were not maintaining records. The majority of farmers agreed that lack of knowledge, skilled manpower and investment limit the implementation.

Conclusions

The analysis findings can guide strategies to reinforce compliance with critical biosecurity practices by farm type. Educational programs, such as workshops and information sessions, are vital to raise awareness and compliance with biosecurity practices among farmers. Further, establishing a partnership between authorities and farmers can facilitate better implementation of biosecurity measures. This collaborative approach highlights the importance of biosecurity while empowering farmers, fostering a unified effort to prevent diseases in the poultry sector.

Introduction

Poultry farming stands as a cornerstone of India's agricultural landscape, holding pivotal significance for the nation's economy and food security. India boasts one of the world's largest poultry populations, with a staggering 851.81 million birds recorded in the 20th livestock census of 2019, marking a substantial 16.8% increase. Among these, commercial poultry alone comprises 534.74 million, reflecting a 4.5% rise from the previous census [1]. In Gujarat, the poultry population stands at 21.77 million, accounting for 2.56% of the total poultry population. Globally, India ranks third in egg production and sixth in chicken meat production, as per [2]. In the fiscal year 2022–2023, India exported a remarkable 664,753.46 million tonnes of chicken products, valued at ₹1,081.62 crores [3]. However, the surging global trade and the movement of people and animals have intensified concerns regarding disease transmission and antimicrobial resistance within the industry.

Biosecurity constitutes a pivotal framework encompassing principles and strategies designed to control and thwart the entry and dissemination of infectious diseases within poultry farms [4] [5]. External biosecurity measures, such as regulating vehicular traffic, optimizing farm entrances, managing manure, handling deceased birds, and safeguarding against wild bird contact, are instrumental in preventing pathogen ingress. Internally, biosecurity is upheld through meticulous cleaning,

disinfection, and hygiene management. The costs associated with comprehensive biosecurity implementation pale in comparison to the extensive losses incurred during disease outbreaks.

Recognized as a linchpin in the prevention of severe poultry diseases such as Newcastle Disease [6], high pathogenic avian influenza (HPAI) [7], salmonellosis [8], and infectious laryngotracheitis [9], biosecurity measures safeguard the health and well-being of avian populations and the human stakeholders within the industry. Horizontal transmission of infectious agents to people can occur through aerosol, food, direct contact, fomites, vectors (insects), and zoonotic pathways. Humans primarily contract the most common zoonoses, such as campylobacter and salmonella infection from consuming contaminated poultry meat [10]. The primary causes of harmful microorganisms in meat and related products are the animals, people who handle the products, equipment that comes in contact with the meat, environmental factors, and water used during preparation. The consumption of meat and its related products have been linked to numerous outbreaks of diseases in human consumers. It is imperative to raise awareness about these diseases' causative agents and educate individuals on the importance of implementing control hygienic measures [11]. The identification of a critical epidemiological node is essential for understanding how infections can enter and spread within a population.

It is important to be aware of the potential risks associated with antibiotic residues in food, particularly those found in meat and eggs. Antibiotic residues in food have been linked to a number of adverse effects, including toxicity (hepatotoxicity and bone marrow toxicity), nephropathy, immunopathological effects (allergy), mutagenicity, and, most significantly, the transfer of antibiotic resistance between commensal and multi drug resistant bacteria, which may contribute to the imbalance of the gut microbiota and pose risks to human health [12]. Lack of new antibiotics threatens global efforts to contain drug-resistant infections. Current literature demonstrates a clear relationship between the level of antibiotic use in livestock and the emergence of antimicrobial resistance (AMR). The poultry industry needs to start using antimicrobials wisely and sparingly in their operations. This rising knowledge of how antibiotic usage affects AMR is anticipated to guide future industry practices and aid in the global effort to tackle the AMR challenge [13]. Adequate implementation of biosecurity measures within farms not only curtails pathogen exposure but also enhances productivity [14]. Effective biosecurity practices are essential to prevent disease spread, reduce antimicrobial use, and limit the emergence of antimicrobial resistance, thereby improving food safety and poultry productivity. By reducing the reliance on antimicrobials and bolstering biosecurity measures, the industry should work toward promoting sustainable and safe poultry production practices [15].

Given the paramount importance of biosecurity and paucity of literature on biosecurity practices in Gujarat poultry farms, this study aims to compare biosecurity practices between commercial broiler and layer farms in Gujarat. The specific objective is to pinpoint areas of similarities and differences in biosecurity practices in commercial broiler and layer farms. The study also focuses on identifying the perception of farmers regarding the complexity of implementing biosecurity measures and the limitations that hinder the implementation of appropriate biosecurity practices. This endeavour promises to deepen our comprehension of the biosecurity practices adopted by commercial layer and broiler farmers in Gujarat, thus contributing to the ongoing discourse on poultry farming biosecurity.

Materials and methods

Study Area and Design

A cross-sectional study was conducted during the data collection from biosecurity training. A total of 86 farmer participated in training including 39 broiler and 47 layer farmer, out of them 39 broiler and 35 layer farmer responded to the questionnaire. The training details are given in Table 1.

Table 1
Details of biosecurity trainings

Sr. No.	Training name	Date of training	Place	No. of farmers
1.	Broiler farmer training	Feb 1st ,2023	Anand	39
2.	Layer farmer training-I	December 22nd ,2022	Anand	15
3.	Layer farmer training-II	June 21st ,2023	Mahuva	32
Total				86

The study encompassed 39 broiler and 35 layer farmers of two major poultry pockets in Gujarat i.e. Anand and Mahuva (Fig. 1). Anand is located on latitude and longitude coordinates of 22.5645° N and 72.9289° E, respectively, whereas Mahuva is on latitude and longitude coordinates 21.092159° N and 71.770462° E, respectively, at an elevation of 128 meters.

Figure 1: Study area map. A) Gujarat state with districts of study areas highlighted in yellow, B) Study area of Saurashtra region of Gujarat and C) Study area of central region of Gujarat. Created using QGIS Desktop version 3.34.3

In order to reach a wide range of farmers, a personalized survey was conducted, and direct communication was established with them. The farmers were personally invited to participate in the one-day biosecurity training programme. To ensure efficient communication of the training schedules to the poultry farmers, collaboration was established with private integration companies and local leaders. As part of the training process, pre- and post-training questionnaires, a biosecurity scorecard, and a task to identify epidemiological nodes within the poultry distribution network were provided to farmers. The data collected from these sources was subsequently utilized to evaluate the biosecurity measures. The farm was considered the primary unit of analysis, while the respondent/farm owner served as the source of information regarding farm-level practices and characteristics. The questionnaire responses therefore represented the characteristics and biosecurity practices of the respective farm.

Questionnaire Design

The structured questionnaires were designed in the native Gujarati language, to ensure that farmers could easily comprehend and respond to the questions. The questionnaire was developed for this study. The questionnaire comprised various types of questions, including dichotomous, requiring a "yes" or "no" response, Likert scale, multiple-choice selection, as well as open-ended in nature. The pre-training questionnaire was primarily designed to gather information related to the farmer's profile, farm profile, and biosecurity measures on the farms. The farmer profile comprises name, contact details, place of living, gender, age, education level, marital status, type of family, number of people in the family, land holding, sources of income, and approximate annual income. The farm profile includes the name of poultry farm, farm registration, type of farm, mode of operation, number of birds, production cycle per year, number of sheds, capacity of sheds, rearing system, investment type, and number of staff. The biosecurity profile includes knowledge about biosecurity, scale of knowledge, biosecurity measures present in the farm, frequency of cleaning and equipment used for cleaning, name of disinfectant used, cleaning of drinkers and feeders, water sanitation, rodent management, details of litter material and its management, details about visitations to the farm, biosecurity measures used by visitors, details about vehicle entry in the farm and its disinfection strategy, protective wears used by staff, disease encountered in farm, pest control strategy, vaccination program, antibiotics usage, veterinary services available to the farm, contacts with wild birds, natural water sources around the farm, poultry death and disposal system, etc.

The post-training questionnaire was centred on feedback on the training, how they will improve biosecurity on the basis of knowledge shared during the training and constraints in observing the biosecurity measures. The question types include multiple choice and Likert scale questions. The questionnaire comprised inquiries related to updates in their knowledge with regards to disease transmission routes, organs of the immune system, antimicrobial resistance, and carcass disposal

facilities. The Likert scale was used to assess farmers' perception of individual biosecurity measures and the complexity experienced during implementation and to suggest areas where improvement is needed. The detailed questionnaires are provided as supplementary files in English language.

Statistical Data Analysis:

The data collected from the questionnaires were entered into a Microsoft Excel© datasheet, after which it was carefully checked for errors and any such errors were corrected. The final, cleaned data was then subjected to further statistical analysis. The quantitative variables in the study were analyzed using descriptive statistics, including measures of central tendency, such as the mean and measures of variation, such as the standard error. The quantitative data were further check for normal distribution pattern using appropriate test of normality like Kolmogorov-Smirnova test. The majority of data was not following the normal distribution, so means were compared using non-parametric independent-samples Mann-Whitney U Test. For categorical variables, frequencies and percentages were used to summarize the distribution of responses. Associations between categorical variables were assessed using Fisher's exact test. This test was selected because several contingency tables contained small cell frequencies (≤ 5), making Fisher's exact test more appropriate than the chi-square test for assessing associations under conditions of sparse data. These comparison of all the statistical data between layer and broiler farms was performed using IBM SPSS Statistics (Version 27). To gain a deeper understanding of the relationships and similarities between variable categories factorial analysis of mixed data (FAMD) was performed, using the FactoMineR package and graphically visualized using the Factoextra package in RStudio version 4.2.2. Factor analysis of mixed data was performed on 36 important selected variables comprising both categorical and quantitative characteristics of the poultry farms. The first 15 dimensions, which collectively explained 72.81% of the total variance, were retained for subsequent analysis. The FAMD reduced the dimensionality of the mixed dataset by representing the original variables in a common space of principal coordinates while preserving the major patterns of variation. These retained dimensions were subsequently used as input for hierarchical clustering on principal components (HCPC) to identify distinct groups of farms based on similarities in their characteristics and biosecurity practices. The clustering results were visualized using the first two FAMD dimensions. The Likert scaled answers were graphically represented using Likert's graph, made using Microsoft Excel©. In all the statistical analyses p value of less than 0.05 was considered significant.

Data source and distinction from previous publication

The data regarding biosecurity measures implemented in broiler farms from this study have been previously published by our group [16]. However, in the present study, these data were further utilized for a comparative evaluation of biosecurity practices between broiler and layer farms, with the aim of providing a better understanding of the similarities and differences in biosecurity implementation across the two production systems. The incorporation of layer farms and the comparative framework, together with FAMD and hierarchical clustering, enables the present study to address research questions that were not addressed in the previous publication.

Results

A total of 39 broiler and 35 layer farmers have filled the questionnaires. So, data from those were analyzed.

Farmer Profile

In the analysis of the farmer profile, Tables 2 and 3 presents the various socioeconomic characteristics of the farmers. The majority of the farmers were male, accounting for 100% in the broiler segment and 97.1% in the layer segment. Significant differences were observed in the age group and education variables between layer and broiler farmers. A higher proportion of layer farmers were found to be older (> 35 years: 82.9%) compared to broiler farmers (> 35 years: 48%). Moreover, layer farmers exhibited higher levels of education. The majority of the farmers were married and resided in joint family setups. A significant percentage (61.5% broiler, 65.7% layer) relied solely on poultry farming as their source of income. It was also noted that layer farmers had greater experience in poultry farming (> 10 years: 45.7%) compared to broiler farmers (> 10 years: 28.2%). The

mean poultry farming experience for layer farmers was 14 years, significantly higher than the mean poultry farming experience of 9 years for broiler farmers.

Table 2
Statistics of qualitative variables of farmer profile

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n = 39)		Layer (n = 35)		
Frequency	Percentage %	Frequency	Percentage %			
Gender	Female	0	0.0%	1	2.9%	0.4730
	Male	39	100.0%	34	97.1%	
Age group (in years)	20–35	16	41.0%	6	17.1%	0.0296
	35–50	18	46.2%	17	48.6%	
	Above 50	5	12.8%	12	34.3%	
Education	Diploma	0	0.0%	1	2.9%	0.0038
	Graduation	11	28.2%	16	45.7%	
	Higher secondary	5	12.8%	6	17.1%	
	Not educated	0	0.0%	1	2.9%	
	Post graduation	3	7.7%	5	14.3%	
	Primary	0	0.0%	2	5.7%	
	Secondary	20	51.3%	4	11.4%	
Marital status	Married	37	94.9%	33	94.3%	1.0000
	Single	2	5.1%	2	5.7%	
Family members group (in numbers)	1–5	31	79.5%	21	60.0%	0.0884
	6–10	6	15.4%	13	37.1%	
	Above 10	2	5.1%	1	2.9%	
Type of family	Joint	37	94.9%	35	100.0%	0.4946
	Nuclear	2	5.1%	0	0.0%	
Source of income	Poultry farm	24	61.5%	23	65.7%	0.7889
	Poultry farm and agriculture	13	33.3%	10	28.6%	
	Poultry farm and job	1	2.6%	0	0.0%	
	Poultry farm and share market	0	0.0%	1	2.9%	
	Poultry farm, agriculture and fish farming	0	0.0%	1	2.9%	
	Poultry farm, agriculture and Job	1	2.6%	0	0.0%	
Experience (in years)	< 5 (low)	14	35.9%	7	20.0%	0.22
	5–10 (medium)	14	35.9%	12	34.3%	
	> 10 (high)	11	28.2%	16	45.7%	

Characteristics		Type of farm			Fisher's Exact Test (P Value)
		Broiler (n = 39)		Layer (n = 35)	
Frequency	Percentage %	Frequency	Percentage %		
P value < 0.05 indicates statistically significant relationship between category of variable with farm type					

Table 3
Statistics of quantitative variables of farmers' profile

Characteristics	Type of farm		Independent-Samples Mann-Whitney U Test (P Value)
	Broiler	Layer	
Age (in years)	37.82	46.14	0.003
Land holdings (in acers)	4.12	4.50	0.037
Annual Income (in Rs.)	441923.08	386000.00	0.418
Experience of poultry farming (in years)	9.06	14.00	0.047
P value < 0.05 indicates statistically significant differences for variable between farm type			

Farm Profile

In the assessment of the farm profiles, significant variations in variables such as rearing system, mode of operation, presence of sanitizing facilities at the entry point for vehicles, consideration of location in the design of poultry farms, and prevention of entry of wild birds were observed between broiler and layer farms (Table 4). All layer farms were proprietor-owned, while 30.77% of broiler farmers operated under a contracted farming system. The utilization of deep litter rearing systems was exclusive to broiler farmers, whereas 57.14% of layer farmers utilized both cage and deep litter rearing systems. The majority of both broiler and layer farmers reported having foot baths and rodent-proof store rooms, as well as fenced surroundings and disposal facilities. Notably, 97.14% of layer farms were situated beyond a 500-meter radius of any canal, lake, or river, and wild bird entry was restricted in 97.44% of broiler farms.

Table 4: Statistics of qualitative variables of farm profile

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n=39)		Layer (n=35)		
		Frequency	Percentage %	Frequency	Percentage %	
Mode of operation	Contracted farm	12	30.77%	0	0.00%	0.000
	Own farm	27	69.23%	35	100.00%	
Rearing system	Both	0	0.00%	20	57.14%	0.000
	Cage system	0	0.00%	15	42.86%	
	Deep litter	39	100.00%	0	0.00%	
Investment type	Bank loan	5	12.82%	3	8.57%	0.359
	Loan from money lender	2	5.13%	2	5.71%	
	Own money	29	74.36%	21	60.00%	
	Own money and bank loan	3	7.69%	7	20.00%	
	Own money and loan from money lender	0	0.00%	1	2.86%	
	Own money, bank loan and loan from money lender	0	0.00%	1	2.86%	
Presence of storeroom	No	3	7.69%	1	2.86%	0.617
	Yes	36	92.31%	34	97.14%	
Rodentproof store room	No	11	28.21%	9	25.71%	1.000
	Yes	28	71.79%	26	74.29%	
Presence of foot bath for each house/shed	No	3	7.69%	9	25.71%	0.056
	Yes	36	92.31%	26	74.29%	
Presence of sanitizing facility at entry point for vehicles	No	21	53.85%	7	20.00%	0.004
	Yes	18	46.15%	28	80.00%	
Presence of fencing	No	2	5.13%	3	8.57%	0.662
	Yes	37	94.87%	32	91.43%	
Presence of disposal facility at farm	Yes	39	100.00%	35	100.00%	-
Presence of canal/ lake/ river within 500 meters of radius	No	31	79.49%	34	97.14%	0.030
	Yes	8	20.51%	1	2.86%	
Presence of trees around the farm	No	2	5.13%	5	14.29%	0.245
	Yes	37	94.87%	30	85.71%	
Location and design of poultry farm	No	27	69.2%	5	14.3%	0.000
	Yes	12	30.8%	30	85.71%	

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n=39)		Layer (n=35)		
		Frequency	Percentage %	Frequency	Percentage %	
Wild birds can enter inside the farm	No	38	97.44%	26	74.3%	0.005
	Yes	1	2.56%	9	25.7%	

P value < 0.05 indicates statistically significant relationship between category of variable with farm type

The quantitative variables, including the number of birds, sheds, managerial staff, labor staff, and shed capacity, were found to be significantly higher in layer farms compared to broiler farms. The average production cycle per year was 5.13 for broiler farms and 1 for layer farms (Table 5).

Table 5: Statistics of quantitative variables of farm profile

Characteristics	Type of farm		Independent-Samples Mann-Whitney U Test (P Value)
	Broiler	Layer	
Average No. of birds	20579.49	38004.29	0.000
Average Production cycle per year	5.13	1.00	0.000
Average No. of sheds	5.49	6.86	0.000
Average Capacity of sheds	30653.85	67691.43	9.763E-08
Average Managerial staff	1.62	2.03	0.013
Average Labour staff	6.10	11.11	0.000
Average Distance from other poultry farm (in meters)	1155.43	675.29	0.379

P value < 0.05 indicates statistically significant differences for variable between farm type

Biosecurity Profile

Knowledge about biosecurity: The layer farmers exhibited a higher level of knowledge about biosecurity compared to broiler farmers. The majority of farmers had not received any training on biosecurity. A significant proportion of layer farmers (97.14%) demonstrated an understanding of disease transmission by pests, flies, and insects, which differed significantly from broiler farmers. Additionally, the 79.49% broiler and 71.43% layer of farmers were not knowledgeable about antimicrobial resistance (Table 6).

Cleaning and disinfection: All farmers consistently engaged in cleaning and disinfecting their poultry sheds, as well as implementing pest control measures. Additionally, all farmers ensured the sheds cleanliness before the placement of day-old chicks. A majority of layer farmers (77.14%) and broiler farmers (71.79%) utilized water sanitization practices (Table 6). The mean frequency of cleaning sheds per week in layer farms was 2.97, while in broiler farms, it was 1.44. All farmers consistently cleaned the feeders and water drinkers (Table 7).

Isolation and quarantine: The majority of farmers implemented isolation and quarantine measures for new birds, and all farmers isolated sick birds. Furthermore, most broiler farmers kept the shed empty for 10 days between two batches, while layer farmers maintained a 21-day gap (Table 6).

Restricted access: A higher percentage of layer farmers (74.29%) restricted the entry of vehicles, while broiler farmers restricted the entry of visitors. Precautionary measures were taken by visitors to most farms, and wild birds were effectively prevented from entering the majority of the farms (Table 6).

Dead bird, waste and manure management: The majority of farmers utilized the burial method for disposing of dead birds, with some layer farmers employing both burial and incineration methods, and a small proportion using only incineration. Additionally, the majority of farmers kept dead birds outside the shed and did not store poultry manure. Furthermore, a greater number of broiler farmers utilized vehicles to transport the manure (Table 6).

Health management: The majority of farmers adhered to guidelines for ensuring good nutrition, taking proper action during disease outbreaks, implementing vaccination programs, and procuring high-quality day-old chicks while refraining from adopting ethnoveterinary practices. All broiler farms had experienced disease outbreaks in the past. Additionally, both broiler and layer farmers sought advice from veterinarians, with significantly more comprehensive documentation and records maintained in layer farms (91.43%) compared to broiler farms (61.54%). Protective attire was consistently utilized by workers in all farms (Table 6).

Table 6: Statistics of qualitative variables of biosecurity profile

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n=39)		Layer (n=35)		
		Frequency	Percentage %	Frequency	Percentage %	
Farmers knowledge about biosecurity						
Knowledge of biosecurity	No	0	0.00%	2	5.71%	0.220
	Yes	39	100.00%	33	94.29%	
Level of biosecurity knowledge	Excellent	1	2.56%	9	27.27%	0.000
	Good	10	25.64%	14	42.42%	
	Poor	7	17.95%	7	21.21%	
	Very good	5	12.82%	2	6.06%	
	Very poor	16	41.03%	1	3.03%	
Undergone any training on biosecurity	No	24	61.54%	20	57.14%	0.814
	Yes	15	38.46%	15	42.86%	
Idea about the transmission of diseases by pests /flies/insects	No	17	43.59%	1	2.86%	0.000
	Yes	22	56.41%	34	97.14%	
Awareness about AMR	No	31	79.49%	25	71.43%	0.588
	Yes	8	20.51%	10	28.57%	
Cleaning and disinfection						
Cleaning and disinfection of poultry shed	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	
Use of water sanitizer	No	11	28.21%	8	22.86%	0.790
	Yes	28	71.79%	27	77.14%	
Adoption of pest control	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	
Ensure shed cleanliness before placing the DOC (Day old chicks)	No	0	0.00%	4	11.76%	0.043
	Yes	39	100.00%	30	88.24%	
Isolation and quarantine						
Isolation and quarantine of new birds	No	5	12.82%	7	20.00%	0.531
	Yes	34	87.18%	28	80.00%	
Minimum required period to keep shed empty between two batches	0 day	1	2.56%	0	0.00%	0.000
	10 days	22	56.41%	5	14.29%	
	21 days	16	41.03%	29	82.86%	
	Not required	0	0.00%	1	2.86%	
Isolation of sick birds	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n=39)		Layer (n=35)		
		Frequency	Percentage %	Frequency	Percentage %	
Restricted access						
Restriction on vehicle entry in the farm	No	27	69.23%	9	25.71%	0.000
	Yes	12	30.77%	26	74.29%	
Record keeping for vehicle entry	No	16	59.3%	4	44.4%	0.470
	Yes	11	40.7%	5	55.56%	
Restriction on visitors' entry	No	18	46.15%	23	65.71%	0.106
	Yes	21	53.85%	12	34.29%	
Preventive follow-up by visitors	No	2	11.11%	4	17.39%	0.679
	Yes	16	88.89%	19	82.61%	
Wild birds can enter inside the farm	No	38	97.44%	26	74.29%	0.412
	Yes	1	2.56%	9	25.71%	
Dead bird, waste and manure management						
Dead bird disposal method	Burial	38	97.44%	28	80.00%	0.020
	Burial and incineration	0	0.00%	5	14.29%	
	Incineration	1	2.56%	2	5.71%	
Place where dead birds are kept	Inside the shed	2	5.13%	4	11.43%	0.413
	Outside the shed	37	94.87%	31	88.57%	
Storage of poultry manure	No	31	79.49%	28	80.00%	1.000
	Yes	8	20.51%	7	20.00%	
Method of storing manure	Away from the farm	2	25.00%	0	0.00%	0.323
	Inside the tank	1	12.50%	0	0.00%	
	Open farm area	5	62.50%	7	100.00%	
Vehicles are employed to lift the manure	No	2	5.13%	11	31.43%	0.005
	Yes	37	94.87%	24	68.57%	
Health management						
Good nutrition	No	8	20.51%	3	8.57%	0.198
	Yes	31	79.49%	32	91.43%	
Documentation and record keeping	No	15	38.46%	3	8.57%	0.003
	Yes	24	61.54%	32	91.43%	

Characteristics		Type of farm				Fisher's Exact Test (P Value)
		Broiler (n=39)		Layer (n=35)		
		Frequency	Percentage %	Frequency	Percentage %	
Action during disease outbreak	No	11	28.21%	8	22.86%	0.790
	Yes	28	71.79%	27	77.14%	
Vaccination	No	0	0.00%	1	2.86%	0.473
	Yes	39	100.00%	34	97.14%	
Good quality day old chicks	No	2	5.13%	3	8.57%	0.662
	Yes	37	94.87%	32	91.43%	
Use of protective wears by workers	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	
Farm previously encountered disease outbreak	No	0	0.00%	4	11.43%	0.046
	Yes	39	100.00%	31	88.57%	
Use of antimicrobial/antibiotics in farm	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	
Adoptions of EVM	No	32	82.05%	28	80.00%	1.000
	Yes	7	17.95%	7	20.00%	
Advise from veterinarian	No	0	0.00%	0	0.00%	NA
	Yes	39	100.00%	35	100.00%	
P value < 0.05 indicates statistically significant relationship between category of variable with farm type						
NA: Test cannot be performed because of zero percentage in one category						

Table 7: Statistics of qualitative variables of biosecurity profile

Characteristics	Type of farm		Independent-Samples Mann-Whitney U Test (P Value)
	Broiler	Layer	
Frequency of cleaning the sheds in a week	1.44	2.97	0.008
Frequency of cleaning water drinker in a day	1.41	1.34	0.457
Frequency of cleaning feeder in a week	5.85	4.17	0.008
No. of persons are involving in poultry farming activity from family apart from labourers	1.46	1.49	0.769
P value < 0.05 indicates statistically significant differences for variable between farm type			

Factorial Analysis of Mixed Data

The variables that made the highest contributions to the variations observed were the type of farm, production cycle per year, rearing system, level of biosecurity knowledge, source of income, previous disease outbreaks on the farm, level of education, and number of birds.

The variables most significantly associated with the construction of the first and second dimensions are presented in Figure 2. Figure 3 illustrates the relationships between various quantitative variables. The number of sheds, labour staff, and birds exhibited positive correlations with each other; further age and land holding also showed a positive correlation. Furthermore, land holdings and age demonstrated a negative correlation with the production cycle per year.

Cluster Analysis

The hierarchical clustering on principal components (HCPC) of the data resulted in the identification of four distinct partitions within the dendrogram, indicating the presence of four different clusters (Figure 4). The variables that made the most significant contributions to the variation in the data were found to be strongly associated with the formation of these clusters. Detailed significant quantitative and qualitative variables related to farmer profile, farm profile, and biosecurity practices observed within each cluster are presented in Table 8 and 9.

Table 8: Cluster statistics for significant qualitative varibles

Variable=Category	Cla/ Mod[a]	Mod/Cla[b]	Global[c]	v.test[d]
Cluster 1				
Rearing system=Deep litter	87.18	100.00	52.70	8.13
Type of farm=Broiler	87.18	100.00	52.70	8.13
Level of biosecurity knowledge=Very poor	94.12	47.06	22.97	4.61
Education=Secondary	79.17	55.88	32.43	3.93
Restriction on vehicle entry=No restriction on vehicle entry	66.67	70.59	48.65	3.43
Presence of sanitizing facility for vehicles=No sanitizing facility	67.86	55.88	37.84	2.89
Required period to keep shed empty between two batches (in days)=10 days	66.67	52.94	36.49	2.65
Wild birds can enter inside the farm=Wild bird cann't enter	51.56	97.06	86.49	2.43
Documentation and record keeping=No record keeping	66.67	35.29	24.32	1.96
Documentation and record keeping=Record keeping	39.29	64.71	75.68	-1.96
Level of biosecurity knowledge=Good	29.17	20.59	32.43	-1.96
Dead bird disposal method=Burial and incineration	0.00	0.00	6.76	-2.05
Education=Graduation	29.63	23.53	36.49	-2.09
Wild birds can enter inside the farm=Wild bird can enter	10.00	2.94	13.51	-2.43
Required period to keep shed empty between two batches (in days)=21 days	33.33	44.12	60.81	-2.65
Presence of sanitizing facility for vehicles=Sanitizing facility	32.61	44.12	62.16	-2.89
Level of biosecurity knowledge=Excellent	0.00	0.00	13.51	-3.24
Restriction on vehicle entry=Restriction on vehicle entry	26.32	29.41	51.35	-3.43
Rearing system=Cage system	0.00	0.00	20.27	-4.24
Rearing system=Both	0.00	0.00	27.03	-5.17
Type of farm=Layer	0.00	0.00	47.30	-8.13
Cluster 2				
Mode of operation=Contracted farm	41.67	100.00	16.22	4.06
Presence of store room=No store room	50.00	40.00	5.41	2.30
Rearing system=Deep litter	12.82	100.00	52.70	2.10
Type of farm=Broiler	12.82	100.00	52.70	2.10
Type of farm=Layer	0.00	0.00	47.30	-2.10
Presence of store room=Store room	4.29	60.00	94.59	-2.30
Mode of operation=Own farm	0.00	0.00	83.78	-4.06
Cluster 3				
Farm previously encountered disease outbreak=No disease outbreak	75.00	100.00	5.41	4.01
Level of biosecurity knowledge=No knowledge	100.00	66.67	2.70	3.26
Rearing system=Cage system	20.00	100.00	20.27	2.70

Variable=Category	Cla/ Mod[a]	Mod/Cla[b]	Global[c]	v.test[d]
Place where dead birds are kept=Inside the shed	33.33	66.67	8.11	2.40
Source of income=Poultry farm and agriculture	13.04	100.00	31.08	2.21
Education=Diploma	100.00	33.33	1.35	2.05
Source of income=Poultry farm	0.00	0.00	63.51	-2.00
Place where dead birds are kept=Outside the shed	1.47	33.33	91.89	-2.40
Farm previously encountered disease outbreak=Disease outbreak	0.00	0.00	94.59	-4.01
Cluster 4				
Type of farm=Layer	91.43	100.00	47.30	8.61
Rearing system=Both	100.00	62.50	27.03	6.26
Required period to keep shed empty between two batches (in days)=21 days	62.22	87.50	60.81	4.14
Mode of operation=Own farm	51.61	100.00	83.78	3.48
Presence of sanitizing facility for vehicles=Sanitizing facility	58.70	84.38	62.16	3.43
Documentation and record keeping=Record keeping	53.57	93.75	75.68	3.20
Rearing system=Cage system	80.00	37.50	20.27	3.13
Wild birds can enter inside the farm=Wild bird can enter	90.00	28.13	13.51	3.12
Level of biosecurity knowledge=Excellent	90.00	28.13	13.51	3.12
Restriction on vehicle entry=Restriction on vehicle entry	60.53	71.88	51.35	3.04
Dead bird disposal method = Burial and incineration	100.00	15.63	6.76	2.50
Education=Graduation	59.26	50.00	36.49	2.05
Dead bird disposal method=Burial	37.88	78.13	89.19	-2.55
Restriction on vehicle entry=No restriction on vehicle entry	25.00	28.13	48.65	-3.04
Wild birds can enter inside the farm=Wild bird cann't enter	35.94	71.88	86.49	-3.12
Education=Secondary	16.67	12.50	32.43	-3.20
Documentation and record keeping=No record keeping	11.11	6.25	24.32	-3.20
Presence of sanitizing facility for vehicles=No sanitizing facility	17.86	15.63	37.84	-3.43
Mode of operation=Contracted farm	0.00	0.00	16.22	-3.48
Level of biosecurity knowledge=Very poor	5.88	3.13	22.97	-3.66
Required period to keep shed empty between two batches (in days)=10 days	11.11	9.38	36.49	-4.30
Rearing system=Deep litter	0.00	0.00	52.70	-8.61
Type of farm=Broiler	0.00	0.00	52.70	-8.61
a: Percentage of farmers following corresponding category are also part of that cluster				
b: Percentages of farmers present in particular cluster following corresponding category				
c: Overall percentage of farmers following that category				
d: Positive value indicates over-expression of category in cluster, while negative value indicates				

Variable=Category	Cla/ Mod[a]	Mod/Cla[b]	Global[c]	v.test[d]
under-expression of that category in cluster				

Table 9: Cluster statistics of significant quantitative variables

Variable	v.test[a]	Mean in category	Overall mean	SD[b] in category	Overall SD
Cluster 1					
Production cycle per year	6.68	5.00	3.18	0.84	2.15
No. of sheds	-3.21	2.12	6.14	1.37	9.86
Labour staff	-4.67	2.76	8.47	2.54	9.63
No. of birds	-5.65	9194.12	28820.95	7177.58	27357.74
Cluster 2					
No. of birds	5.82	98000.00	28820.95	19390.72	27357.74
No. of sheds	5.19	28.40	6.14	26.66	9.86
Labour staff	4.86	28.80	8.47	11.70	9.63
Production cycle per year	3.02	6.00	3.18	0.00	2.15
Age (in years)	-2.12	30.80	41.76	6.11	11.90
Cluster 4					
No. of birds	3.19	40504.69	28820.95	17174.68	27357.74
Experience in poultry farming (in years)	2.72	15.00	11.40	11.07	9.88
Labour staff	2.59	11.81	8.47	8.57	9.63
Age (in years)	2.27	45.38	41.76	12.81	11.90
Production cycle per year	-7.54	1.00	3.18	0.00	2.15
a: Positive value indicates over-expression of category in cluster, while negative value indicates under-expression of that category in cluster					
b: Standard deviation					

The HCPC resulted in the formation of four distinct and separate clusters, with clusters 1 and 2 comprising primarily of broiler farms, and clusters 3 and 4 primarily consisting of layer farms. The majority of broiler farms were categorized within cluster 1, with a smaller representation in cluster 2. Similarly, the majority of layer farms were classified within cluster 4, with a smaller representation in cluster 3 (Figure 4).

The variables that best describe the clusters are presented in Table 8 and 3.8, with the most influential variables listed at the top. More detailed view of overexpressed and under-expressed categories for each cluster can be seen Table 8, in which the positive value of the v.test indicates that a category is overexpressed, while a negative value indicates that a category is under-expressed. Automatically the categories which describe the cluster least are under-expressed at present at the bottom in Table 8.

Cluster 1 primarily consisted of broiler farms utilizing the deep litter system for rearing. The 94.12 % of all farmer having very poor biosecurity knowledge also belonged to clusters 1. The 47.06% of farmers exhibited very poor biosecurity knowledge. Additionally, more than half of the farmers in cluster 1 had completed education up to the secondary level only. In cluster 1,

70.59% of farmers did not restrict vehicle entry into the farm, and 55.88% of farms lacked sanitizing facilities at the entry point for vehicles. The average production cycle per year in cluster 1 was 5. The average number of sheds, labor staff, and birds in each cluster is detailed in Table 9 as quantitative variables of the clusters. The different categories like deep litter rearing system, broiler farms, very poor level of biosecurity knowledge and secondary level of education of farmers are overexpressed, while layer farms, cage type rearing system and restriction of vehicle entry inside the farms are under-expressed as compare to other.

Cluster 2 also comprised broiler farms, but all the farms in this cluster operated under a contracted system. Additionally, all the farms in cluster 2 utilized the deep litter system. The number of birds, sheds, and labor staff was significantly higher in cluster 2 compared to cluster 1, leading these farms to form a distinct cluster from cluster 1. In the mode of operation contracted farming is overexpressed, while its alternate option own type of farming system is under-expressed.

Cluster 3 comprised three layer farms that had not encountered any previous disease outbreaks. Within cluster 3, 66.67% of farmers had no knowledge regarding biosecurity measures. All the farmers in cluster 3 had poultry farming and agriculture as their sources of income, and 66.67% of farmers within this cluster kept dead birds inside the shed. Naturally these most defining categories of cluster 3 are overexpressed, while keeping dead bird outside the shade and previous disease encounter in the farms are under-exprssed.

Cluster 4 consisted of layer farms, and all the farmers who adopted both cage and deep litter systems of rearing were categorized within this cluster. Within cluster 4, 87.5% of farmers kept their sheds empty between two batches for 21 days, 93.75% of farms maintained documentation and record-keeping, 84.36% of farms had sanitizing facilities at the entry point for vehicles, and 71.88% of farms restricted the entry of vehicles inside the farm. Again these categories in cluster 4, we can say overexpressed, while other categories like, broiler farms and deep litter type of rearing system are under-expressed

Farmers Perceptions

The study evaluated farmers' perceptions of the compexities associated with implementing biosecurity measures and the constraints related to adopting such measures by utilizing the Likert scale. Farmers expressed difficulties in managing the location design of poultry farms, handling actions during disease outbreaks, and controlling rodent pests. Furthermore, a majority of farmers acknowledged that the implementation of biosecurity measures is hindered by factors such as insufficient knowledge, control, awareness, manpower, financial resources, and skilled labor (Figure 5 & 6).

Discussion

This pioneering study offers a comprehensive overview of broiler and layer farm biosecurity practices in a major poultry-producing region of Gujarat. The research provides insights into the characteristics of poultry farmers, farm, biosecurity practices, and highlights key differences for improvement in biosecurity measures between broiler and layer farms. The data gathered allows for a comparative analysis of biosecurity profiles.

Farmer Profile

The most of poultry farmers were male. Studies in various regions, including, India [16], Nigeria [17], and Ethiopia [18], consistently demonstrate that poultry farm ownership is predominantly male. This gender imbalance reflects inequalities in access to financial resources, entrepreneurial opportunities, and the influence of socio-cultural factors. Furthermore, limited access to education and cultural barriers faced by women can hinder their entrepreneurial endeavors in this sector. A significantly larger percentage of layer farmers (82.9%) were older than 35 years, compared to just 48% of broiler farmers. This suggests that layer farming may attract or retain an older demographic, possibly due to factors such as established experience, land ownership, or different risk tolerances. Conversely, broiler farming appears to involve a younger cohort, perhaps reflecting a greater willingness to adopt newer technologies, access to different financing options, or a different set of career goals. Coupled with the age disparity, the observation that layer farmers generally possess higher education levels and experience further distinguishes the two groups. The educational levels observed in this broiler are comparable to those

reported in Cameroon by [19], and in India by [16], where farm owners mostly possessed a secondary education. This higher educational attainment among layer farmers could contribute to several differences in farm management practices, including biosecurity. More educated farmers may be more likely to understand and implement complex biosecurity protocols, access and interpret information about disease prevention, or adopt innovative farming techniques [20]. This potential link between education and biosecurity practices warrants further investigation, as it could inform targeted interventions to improve biosecurity in the broiler sector. For example, educational programs tailored to younger farmers and addressing specific biosecurity challenges relevant to broiler production could be beneficial. This greater experience among layer farmers could contribute to their observed higher adoption of biosecurity measures. Longer exposure to the industry may provide a deeper understanding of disease risks and the importance of preventative measures.

Farm Profile

All layer farms were owned by the farmers themselves, while nearly a third (30.77%) of broiler farms operated under contract. This difference in ownership structure may influencemanagement practices and investment in biosecurity. Contract farming in broilers has become a significant model for poultry production in India. It involves agreements between farmers and companies, where companies supply inputs like chicks and feed, and farmers raise the birds per company standards. This model reduces risks for farmers by guaranteeing market access and stabilizing prices while providing them with technical support and training. For companies, it ensures a reliable supply of quality broilers, allowing them to focus on processing and marketing [21]. Broiler farms exclusively used deep litter systems, while over half (57.14%) of layer farms employed a combination of cage and deep litter systems, other layer farms only followed cage system. This type of rearing system was also observed in study of [22]. Deep litter systems suit broiler farms due to their body weight and short production cycles (up to six weeks), allowing multiple cycles annually. However, shared space and litter contact increase disease risk if not managed properly, requiring frequent cleaning and replacement, which can be costly and labour-intensive. Cage systems offer biosecurity advantages by separating birds, but present challenges in maintaining cage hygiene and preventing disease spread between cages [23]. Majority of broiler as well layer farms have rodentproof store room, footbath, fencing and disposal facility, essential for maintaining biosecurity, protecting resources, and ensuring the overall health of the poultry. These results are in consistent with the earlier studies of [16],[19] and [24]. Rodent-proof store rooms are critical in preventing contamination and loss of feed and other supplies. Footbaths reduce the risk of disease transmission into poultry houses and minimizes the risk of introducing diseases from external sources. Fencing plays a role in protecting poultry farms from various external threats, including predators and unauthorized access. Layer farms typically have higher values in various quantitative measures such as the number of birds, sheds, and staff (both managerial and labour). This suggests that layer farms are more extensive in terms of scale and resources compared to broiler farms. In general, layer farming requires more infrastructure and labour for the continuous production of eggs, which is contributing to these higher numbers. The average production cycle reveals a significant disparity: broiler farms have an average production cycle of 5.13 ± 0.13 per year, while layer farms have only 1. The average production cycle per year for broilers exceeds the findings of [19], who reported a mean of 3.89 ± 1.10 for the production cycle. This suggests that broiler farms can produce multiple batches of birds within a single year, allowing for quicker returns on investment [16]. In contrast, layer farms typically operate on a longer cycle, focusing on egg production, which is more continuous but less frequent in terms of different flocks. Together, these points indicate that layer farms are designed for long-term, sustainable egg production and require a more significant setup and ongoing workforce [25]. In contrast, broiler farms operate on a faster turnover model, producing chickens more rapidly but potentially with fewer resources per cycle. The availability of sanitizing facilities for vehicles at the entry points is notably greater in layer farming operations compared to broiler farming. This indicates a stronger emphasis on sanitation and biosecurity measures in layer facilities.

Biosecurity Profile

Knowledge of Biosecurity

Layer farmers tend to have higher education levels and more experience in the industry, which likely contributes to their greater knowledge of biosecurity practices compared to broiler farmers. This greater awareness is evident as a striking 97.14% of layer farmers understand how pests, flies, and insects can transmit diseases, illustrating their proactive approach to maintaining

flock health. These findings contrast with the study conducted by [24], which reported an overall high level of biosecurity compliance among meat chicken farms. However, most farmers, regardless of poultry type, lack formal training in biosecurity, which limits effective practices. Also, in the study of [16] and [19] significant portion of poultry farmers lack the exposure to technical training or workshops on biosecurity management in farms. Additionally, there is a significant gap in knowledge regarding antimicrobial resistance among the majority of farmers, highlighting the need for targeted education in both layer and broiler farming.

Cleaning and disinfection

All farmers actively participated in cleaning and disinfecting their poultry sheds, alongside implementing pest control measures to safeguard their flocks. Before placing day-old chicks, all broiler farmers ensured that their sheds were clean, reflecting their commitment to proper husbandry practices. Furthermore, all farmers made it a priority to regularly clean feeders and water drinkers, ensuring that the birds have access to a hygienic environment. In terms of sanitation, a significant portion of layer (77.14%) and broiler (71.79%) farmers adopted water sanitization practices, indicating a conscientious approach to maintaining water quality. The findings regarding the cleaning and disinfection practices on farms align closely with the study of [26].

Isolation and quarantine

The majority of farmers adopted quarantine measures for newly introduced birds, which is essential for preventing the introduction of pathogens into established flocks. All farmers also isolated sick birds, a critical biosecurity practice that helps to curtail the spread of disease within the population [27]. Broiler farmers typically adhered to a protocol of keeping their sheds empty for 10 days between successive batches [16]. This practice is rooted in the need to break the transmission cycle of pathogens that may persist in the environment. However, layer farmers implemented a more extended empty period of 21 days, which may reflect their understanding of the longer incubation periods of certain pathogens and the importance of reducing the risk of disease transmission.

Restricted access

Majority of layer farmers implemented restrictions on the entry of vehicles to their farms, a practice that helps minimize the risk of disease introduction through contaminated equipment or personnel. In contrast, broiler farmers focused on restricting visitor access as a key biosecurity measure. This differentiation underscores the specific risks associated with each farming type, as layers may face greater vehicle-related threats due to supply deliveries. Most farms also enforced precautionary measures for visitors, ensuring that individuals entering the premises followed specific protocols, such as wearing protective clothing like mask, gloves, head caps or footwear. This further enhances biosecurity by reducing the potential for disease transmission through human contact. Additionally, successful measures were taken to prevent wild birds from entering the majority of farms. This is crucial as wild birds can act as carriers of pathogens that may negatively impact poultry health. By effectively controlling access points and minimizing interactions with wildlife, farmers can significantly reduce the risk of disease outbreaks, thereby safeguarding the health of their flocks [28].

Dead bird, waste and manure management

The management of dead birds and poultry manure is a crucial aspect of biosecurity in both layer and broiler farming. The majority of farmers opted for burial as the primary method of disposing of dead birds, which is a common practice due to its simplicity but it may cause the ground water pollution. Layer farmers, however, showcased a more diversified approach; some employed both burial and incineration methods for disposal. This might indicate a heightened awareness of biosecurity risks, as incineration can effectively eliminate pathogens that may linger in carcasses and is one of the safest method of carcass disposal [29]. This finding stands in contrast to the results reported by [22] which indicated that a significant proportion of farmers in Mexico utilized incineration as the primary method for carcass disposal. Most farmers kept dead birds outside the poultry sheds, a practice that minimizes the risk of contamination within the living environment. However, it's noteworthy that many farmers did not store poultry manure. The lack of storage could reflect a preference for immediate disposal or transport,

but it also raises questions about the potential for unintentional pathogen spread if the manure is not handled correctly. When it comes to manure management, broiler farmers demonstrated a greater tendency to utilize vehicles for transporting manure.

Health management

Most farmers followed guidelines to ensure good nutrition, effectively managed disease outbreaks, implemented vaccination programs, and procured high-quality day-old chicks. This observation aligns with the findings of [16] and [30]. All broiler farms reported past disease outbreaks, indicating a vulnerability that highlights the importance of strict biosecurity measures. Both broiler and layer farmers consulted veterinarians for guidance, but layer farms maintained significantly more comprehensive documentation and records. This thorough record-keeping may enhance their biosecurity and management practices. Additionally, workers across all farms consistently used protective attire, which helps reduce the risk of disease transmission through human contact. Overall, these practices illustrate the commitment of farmers to uphold biosecurity and health standards, with layer farms showing a more structured approach to managing their operations compared to broiler farms.

The significant variables identified, such as the type of farm, production cycle per year, rearing system, level of biosecurity knowledge, source of income, previous disease outbreaks, level of education, and number of birds, play crucial roles in differentiating the farming profiles. Each of these variables contributes uniquely to how farmers manage their operations, deal with biosecurity, and respond to the challenges they face.

Conclusions

Biosecurity practices are essential for preventing the introduction and spread of pathogenic microorganisms that cause diseases on poultry farms. The predominantly male farmer demographic reflects broader socio-cultural constraints, while the age and educational differences suggest that layer farming attracts more experienced and knowledgeable individuals, resulting in superior biosecurity practices. To improve comprehension and compliance with biosecurity protocols among poultry farmers, targeted educational initiatives, including workshops and informational sessions, are critical. These programs should be designed to deliver evidence-based information on the importance of biosecurity measures, the types of prevalent pathogens, and effective strategies for managing risks. Furthermore, establishing collaborative relationships between regulatory agencies and farmers is imperative for the effective implementation of biosecurity strategies. This synergistic approach not only reinforces the importance of biosecurity but also empowers farmers, leading to a more unified effort toward disease prevention within the poultry industry.

Abbreviations

AMR
Antimicrobial resistance
HPAI
high pathogenic avian influenza
FAMD
Factor Analysis of Mixed Data
HCPC
Hierarchical Clustering on Principal Components
SD
standard deviation. IRB:Institutional Review Board
IAEC
Institutional Animal Ethics Committee
UKRI
UK Research and Innovation
GCRF
Global Challenges Research Fund.

Declarations

Ethics approval and consent to participate

The study was conducted in compliance with the ethical principles for social science research involving human participants. Prior to data collection, the purpose and scope of the study were explained to all participating livestock farmers in their local language (Gujarati). Voluntary verbal informed consent was obtained from each respondent before proceeding with the questionnaire, and participants retained the right to withdraw at any stage of the interview. To ensure strict confidentiality and privacy, all collected data have been fully anonymized. No personally identifiable information or individual coordinates are disclosed in this manuscript, and data are presented solely in an aggregated format. Under Section 4 of the ICMR National Ethical Guidelines for Biomedical and Health Research involving Human Participants, this format typically falls under socio-behavioural study. The ICMR guidelines state that proposals presenting less than minimal risk can be made exempted from ethical review by committee. At the time of the study, formal review by a Human Research Ethics Committee/Institutional Review Board (IRB) was not sought because the study was considered as a minimal-risk, non-clinical questionnaire survey. Our institution has an Institutional Animal Ethics Committee (IAEC) for animal research; however, the present study did not involve experimental use of animals and therefore the study was not submitted to that committee either. No IRB approval or formal exemption/waiver certificate was therefore obtained. This study involved a voluntary, anonymous low risk questionnaire-based survey of adult poultry farmers and did not involve clinical intervention, collection of human biological samples, or experimental procedures involving human participants. The study was conducted with due consideration of ethical guideline principles to confidentiality and responsible handling of the information provided by the participants.

Consent for publication

Not applicable. The manuscript does not contain any individual person's identifiable data, images, or personal details.

Competing interests

The authors declare that they have no competing interests.

Limitations

This study has several limitations. The cross-sectional design limits the ability to establish causal relationships between farm characteristics and biosecurity practices. The relatively small sample size (n = 74) and voluntary participation may have introduced selection bias. As the study was conducted only in Gujarat, the results may not be directly applicable to poultry farms across India. Additionally, reported biosecurity practices were not independently validated through direct on-farm observation.

Funding

This work was conducted under the support of Kamdhenu University, Gujarat, and the One Health Poultry Hub, funded by the UK Research and Innovation (UKRI) Global Challenges Research Fund (GCRF).

Author Contribution

KR collected and curated the data, performed analyses, and drafted the manuscript. AG assisted with field coordination and data collection. BJ and PD contributed to questionnaire design, data cleaning, and manuscript editing. PK and HP conceived the study, supervised the work, coordinated farmer training activities, facilitated field logistics, supported data acquisition

guided data interpretation, and revised the manuscript. ASF and FT provided methodological guidance, scientific inputs, and critical review of the manuscript. SJ helped in publication.

Acknowledgements

The authors sincerely thank Kamdhenu University, Gujarat, and the Royal Veterinary College, UK, for institutional support and collaboration. Special thanks to the One Health Poultry Hub for technical guidance and resources. We gratefully acknowledge the poultry farmers of Anand and Mahuva for their valuable time and participation. We also thank the private integration companies and local coordinators who facilitated communication and farmer mobilization.

An abstract describing preliminary findings from this study was previously presented in UKRI-GCRF One Health Poultry Hub Final Hub Meeting and published in the Abstracts Handbook of the final hub meeting which was held at New Delhi in February 2024. The present manuscript provides the complete study methodology, detailed statistical analysis, results, interpretation, and discussion and substantially extends the information presented in the conference abstract.

Data Availability

The datasets generated and analyzed during the current study are available from the first author on reasonable request. Processed, anonymized data may be shared in compliance with institutional and ethical guidelines.

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PMID: 32475441.

Figures

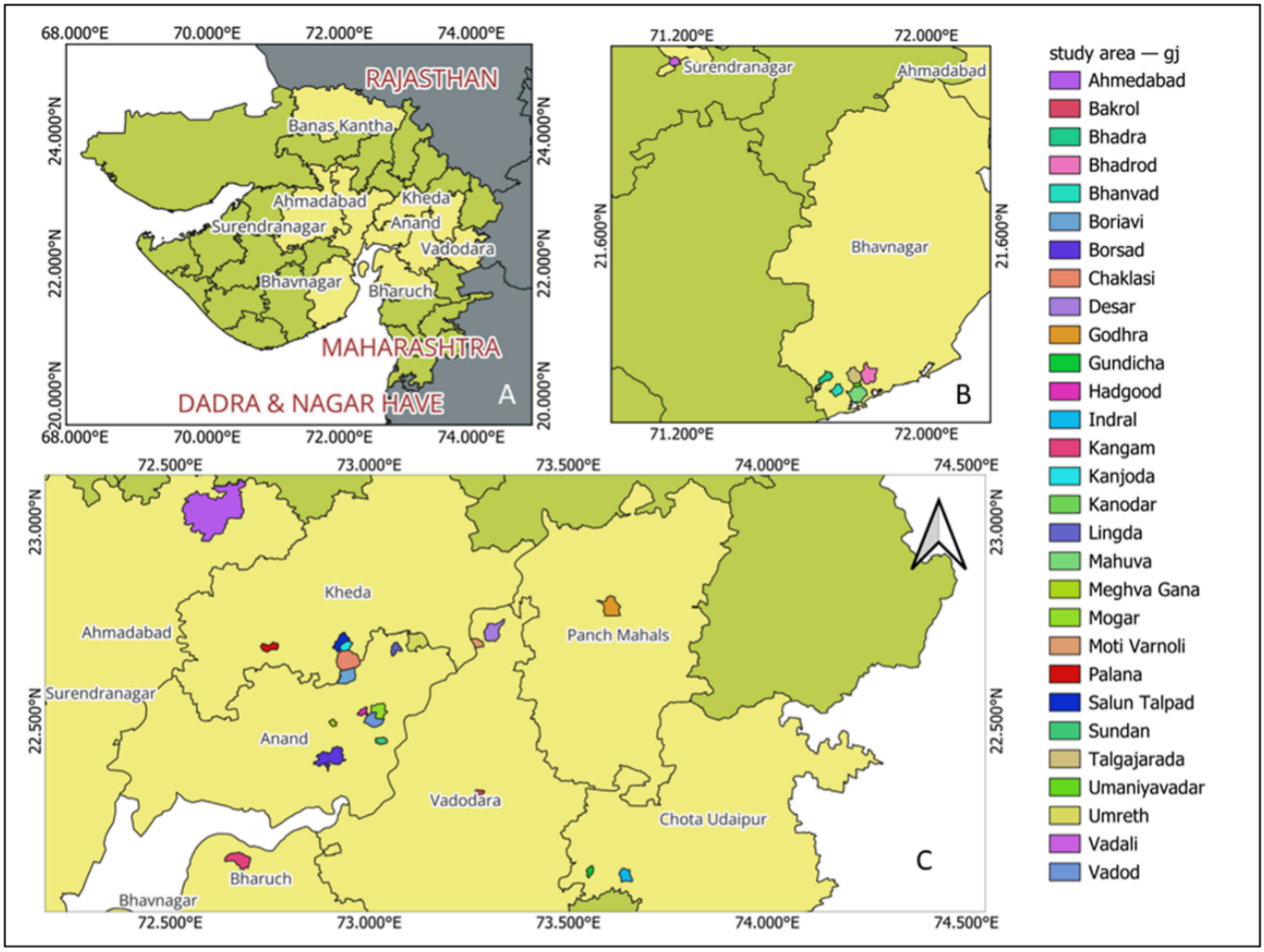


Figure 1

Study area map. A) Gujarat state with districts of study areas highlighted in yellow, B) Study area of Saurashtra region of Gujarat and C) Study area of central region of Gujarat. Created using QGIS Desktop version 3.34.3

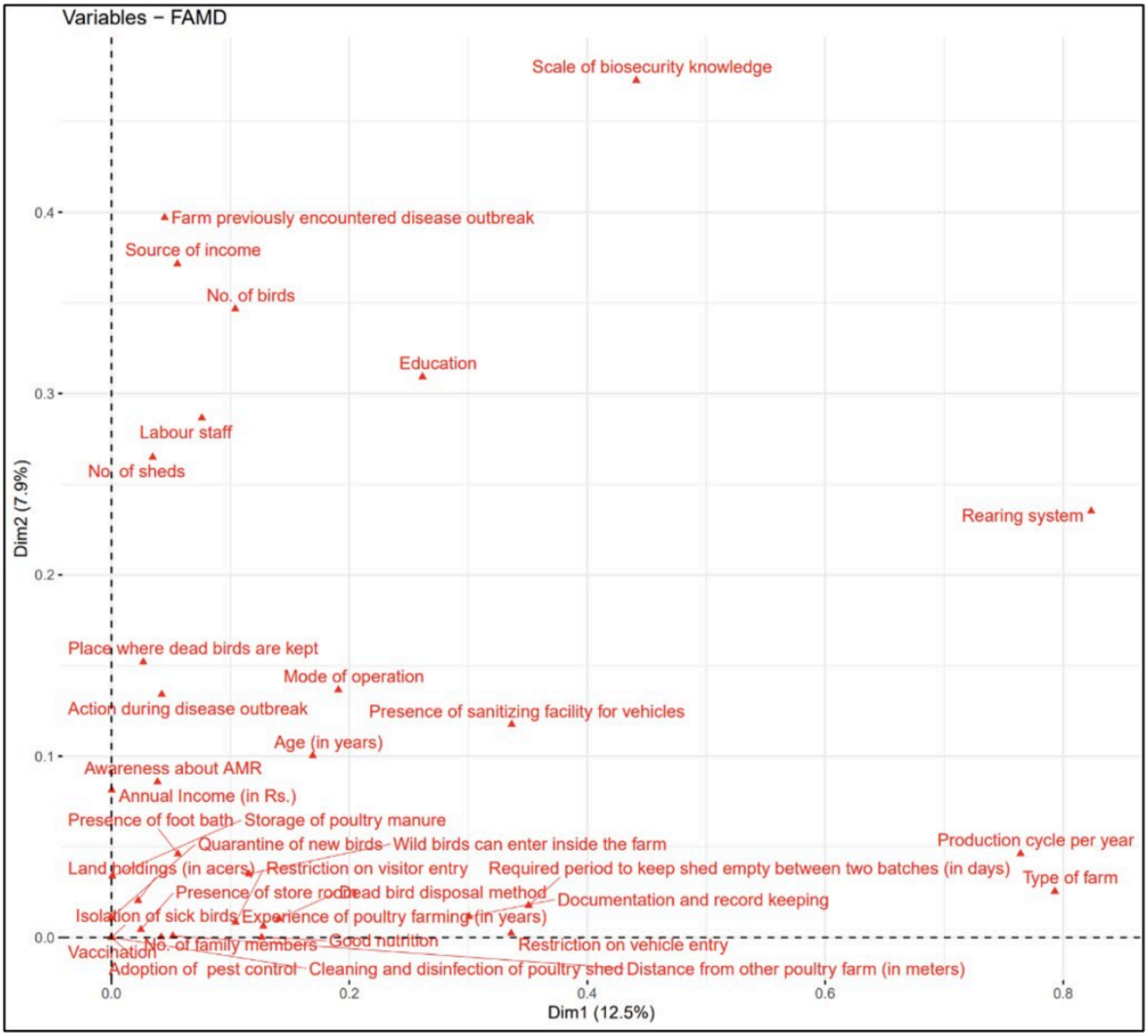


Figure 2

Variables used to perform FAMD and variables contributing to dimension 1 and dimension 2. Variables contributing more to the variation between farm type are located farther away from the origin.

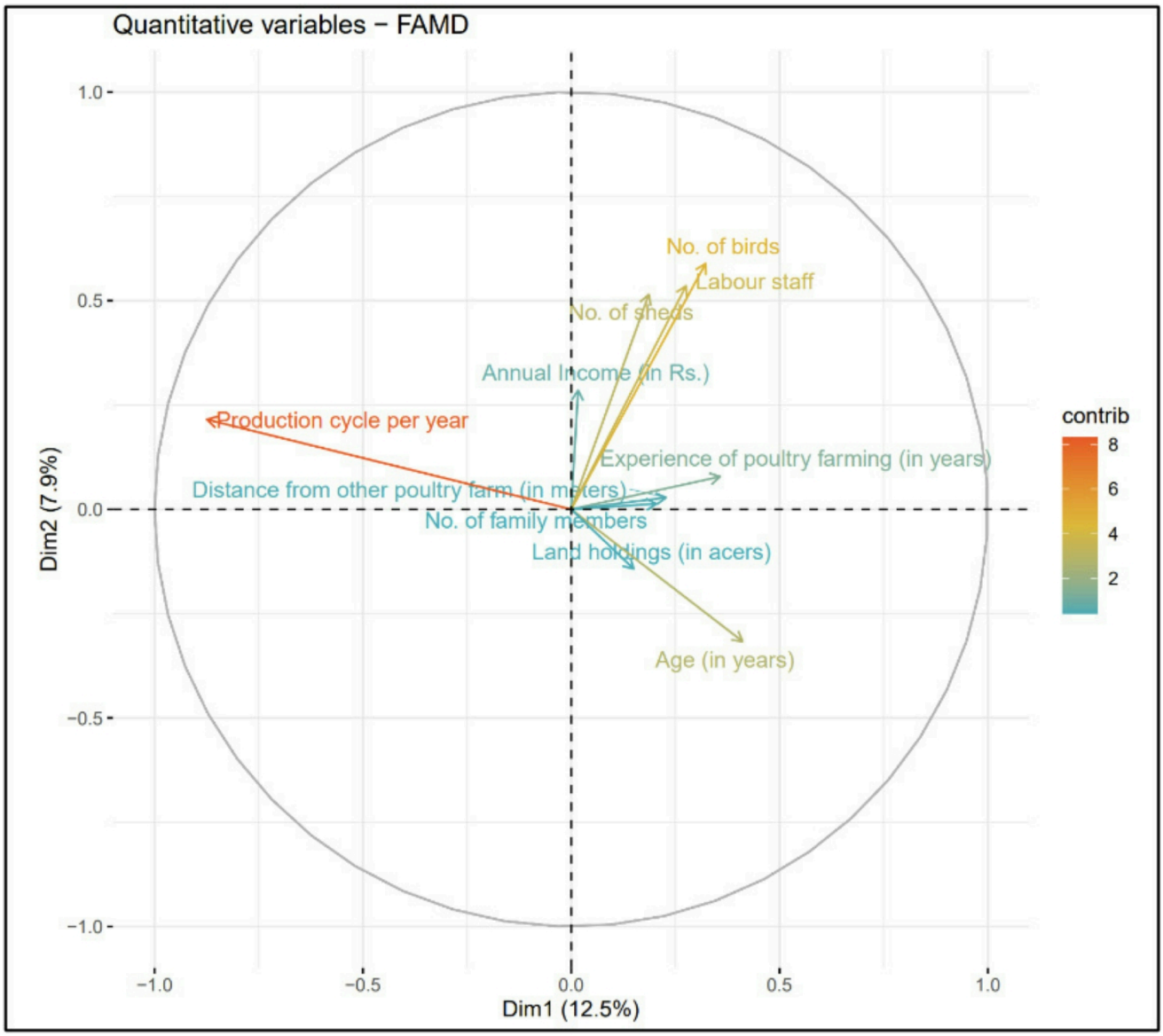


Figure 3

Relationships between quantitative variable in FAMD. Variables in same quadrant and also in same direction indicates positive correlation while variable in opposite direction indicates negative correlation.

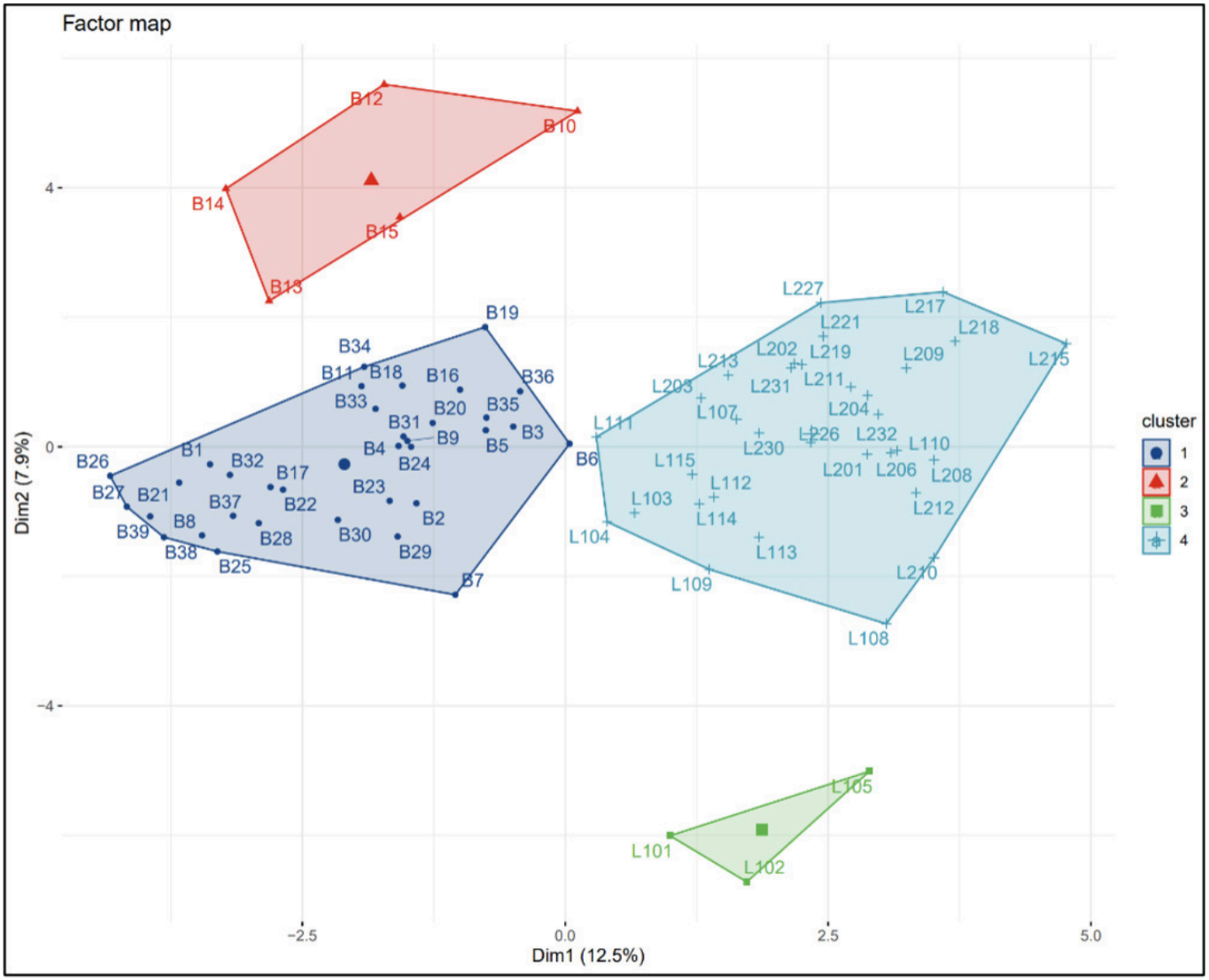


Figure 4

HCPC of farms. The “B” prefix and “L” prefix indicates broiler and layer farm respectively. Farms located nearer to each other are more similar and showing more common biosecurity pattern, than farms located farther away.



Figure 5

Likert's scale results showing perception of farmer regarding complexity of implementing biosecurity measures in broiler and layer farm

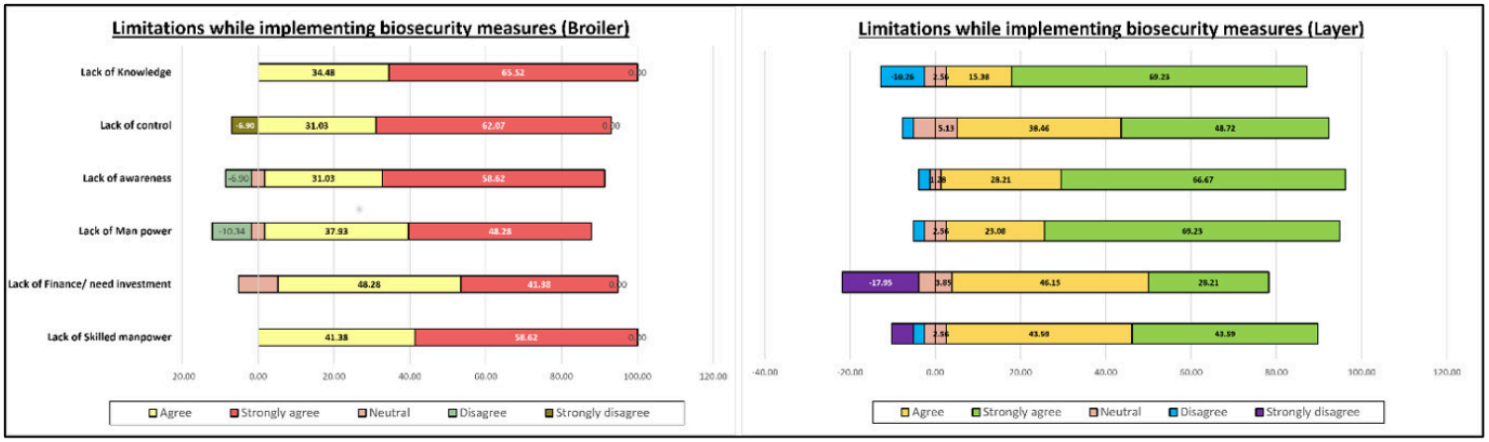


Figure 6

Likert's scale results showing perception of farmer on limitation while implementing biosecurity measures in broiler and layer farm

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- PosttrainingQuestionnaireBroiler.docx
- PretrainingQuestionnaireBroiler.docx
- PosttrainingQuestionnaireLayer.docx
- PretrainingQuestionnaireLayer.docx