

Assessment of Biosecurity Implementation Among Traders in Live Bird Markets in Bogor

Penilaian Implementasi Biosekuriti di Kalangan Pedagang di Pasar Burung Hidup di Bogor

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Article submitted: February 26, 2026, revised: April 16, 2026, accepted: April 20, 2026

Abstrak

Pasar burung hidup berfungsi sebagai titik agregasi untuk burung dari berbagai wilayah geografis, yang berpotensi memungkinkan sebagai tempat penularan penyakit. Tingginya tingkat pergerakan manusia dan burung hidup, rendahnya kesadaran kebersihan dan sanitasi, dan penerapan praktik biosekuriti yang tidak memadai dapat meningkatkan risiko penularan penyakit. Data empiris tentang penerapan praktik biosekuriti di tingkat pedagang di pasar burung hidup di Bogor masih terbatas. Penelitian ini bertujuan untuk mengevaluasi tingkat implementasi biosekuriti di kalangan pedagang di pasar burung hidup di Kota Bogor dan Kabupaten Bogor. Sebanyak 15 pedagang dipilih dan dinilai menggunakan daftar periksa yang diadaptasi dari Panduan Biosekuriti untuk Pasar Unggas Hidup yang diterbitkan oleh Organisasi Pangan dan Pertanian (FAO). Penilaian berfokus pada tiga komponen utama biosekuriti yaitu kontrol gerakan, isolasi, dan sanitasi. Tingkat biosekuriti dikategorikan sebagai tingkat baik, sedang, dan buruk berdasarkan hasil penilaian. Hasil penelitian menunjukkan bahwa tingkat biosekuriti di antara pedagang di pasar burung hidup sedang (100%). Namun, tingkat ketidakpatuhan yang relatif tinggi masih diamati di semua komponen biosekuriti. Kesenjangan utama termasuk kurangnya inspeksi kesehatan burung, tidak adanya kandang isolasi, kepadatan tebar yang tinggi, praktik kebersihan yang buruk, dan pengelolaan limbah yang tidak memadai. Temuan ini menunjukkan bahwa praktik biosekuriti di pasar burung hidup tetap tidak optimal dan memerlukan perbaikan melalui peningkatan pengetahuan dan kesadaran pedagang, peningkatan manajemen pasar oleh otoritas pasar, dan penegakan peraturan yang lebih kuat oleh pemerintah. Studi ini memberikan bukti praktis untuk menginformasikan pengembangan kebijakan nasional, khususnya dalam memperkuat standar biosekuriti, kerangka peraturan, dan intervensi yang ditargetkan untuk pengelolaan pasar burung hidup di Indonesia.

Kata kunci: kontrol gerakan; biosekuriti; isolasi; pasar burung hidup; sanitasi

Abstract

Live bird markets serve as aggregation points for birds from diverse geographic areas, creating potential hotspot for disease transmission. High levels of human and live bird movement, low hygiene and sanitation awareness, and inadequate implementation of biosecurity practices can increase the risk of disease transmission. Empirical data on the implementation of biosecurity practices at the trader level in live bird markets in Bogor remain limited. This study aimed to evaluate the level of biosecurity implementation among traders at live bird markets in Bogor City and Bogor Regency. A total of 15 traders were selected and assessed using a checklist a dapt Biosecurity levels were categorized as good, moderate, and poor level based on the assessment result. The result showed that biosecurity level among traders in live bird markets were moderate (100%). However, a relatively

high degree of non-compliance was still observed across all biosecurity components. Key gaps included lack of bird health inspection, absence of isolation cages, high stocking density, poor hygiene practices, and inadequate waste management. These findings indicate that biosecurity practices in live bird markets remain suboptimal and require improvement through enhancing traders' knowledge and awareness, improving market management by market authorities, and stronger regulatory enforcement by government. This study provides practical evidence to inform national policy development, particularly in strengthening biosecurity standards, regulatory frameworks, and targeted interventions for live bird market management in Indonesia.

Keywords: biosecurity; isolation; live bird market; movement control; sanitation

Introduction

Poultry meat consumption in Indonesia was dominated by chicken meat which it reached 12.58 kg per capita per year and generally increased at an average rate of 7.44% per year. The demand for chicken meat in Java Island is particularly high, making it the main center of poultry population contributing a total of 62.89% in 2023. West Java has the largest contribution (23.72%) then followed by Central Java (19.33%), East Java (13.63%), and Banten (6.21%), as it also functions as a buffer zone for supplying broiler chicken meat to the capital city, DKI Jakarta, which receives poultry commodities from surrounding areas including Bogor, Depok, Bekasi (Bodetabek), and Banten (Kementan, 2024). This situation is also influenced by Peraturan Daerah (Perda) concerning about the Control, Rearing, and Distribution of Poultry, under which the DKI Jakarta Provincial Government prohibits food poultry farming (Perda, 2007).

Data on chicken meat consumption in Bogor are limited. However, based on the latest available data from the Badan Pusat Statistik (BPS), in 2023 Bogor was the region with the highest poultry meat production in West Java, reaching 215.6 tons. This production was predominantly composed of broiler chicken meat, followed by layer chicken meat, native chicken meat, and duck meat (BPS Jawa Barat, 2023). In 2025, Bogor remained the leading region for layer chicken meat production in West Java, reaching 15 tons (BPS Jawa Barat, 2025). However, it should be noted that data for other poultry commodities in 2025 were not available, and therefore direct comparison with the 2023 total poultry production should be interpreted with caution. These data nevertheless indicate the significant role of Bogor as a key poultry production hub in West Java.

Live bird markets have an essential role in bird marketing systems, particularly in low- and middle-income countries including Indonesia, as they remain important for daily consumer needs. These

markets serve as aggregation point for different birds species, such as free range chickens (local), broilers, male layer chickens, spent laying hens, ducks, and Muscovy ducks originating from diverse geographic areas, this allows them to facilitate and accelerate the transmission, evolution, and dissemination of diseases from birds (Offeddu *et al.* 2015). Direct contact between birds and humans can increase the risk of zoonotic transmission when biosecurity practices are inadequately implemented (Moyen *et al.*, 2021). Several previous studies have demonstrated that live bird markets can act as hotspots for disease outbreaks in various countries. For example, the human H5N1 outbreak at 1997 in China and the SARS outbreak at 2003 in China were both linked to live bird markets due to poor hygiene practice, lack of biosecurity measure, and high density of birds and activity of human (Guan *et al.*, 2003; Gao, 2014). The presence of H5N1 virus in live bird markets raises concerns regarding viral evolution, reassortment, and spillover events. Human H5N1 infections resulting from contact with birds in live bird markets have been documented in multiple countries, including Bangladesh, Vietnam, Indonesia, China, and Cambodia (Islam *et al.*, 2023; Chinh and Tan, 2018; Henning *et al.*, 2019; Wan *et al.*, 2011; Horm *et al.*, 2016).

Live bird markets are unlikely to be eliminated despite their recognized role as potential sources of disease transmission because their ability to fulfil consumer demands. Factors such as taste preferences, cultural preference for the consumption of freshly slaughtered birds, and long-standing religious traditions play a more influential role in sustaining these markets (Cardona *et al.*, 2009). Improving biosecurity in live bird markets to reduce viral circulation and prevent transmission to other animals and humans is therefore essential. In the context of disease prevention and control, three key biosecurity components play a critical role in limiting disease spread: movement control, sanitation, and

isolation (Siagian and Pratama, 2024). Most live bird markets still lack adequate biosecurity standards. For example, a study by Suartha *et al.*, (2010), reported that improper biosecurity practices were still common, including keeping birds in the market for more than one day, mixing different types of birds in a single cage, failure to clean cages, and lack of environmental disinfection. Another study by Basri *et al.*, (2013), also found that the slaughter of sick birds was still frequently carried out by traders. Live bird markets should implement several measures including temporary market closure, periodic rest days, overnight depopulation, and improved hygiene and disinfection practices, in order to mitigate the risk of zoonotic disease transmission (Offeddu *et al.*, 2016).

This study was conducted to evaluate the implementation of biosecurity practices among traders in live bird markets in Bogor. Previous studies have highlighted the role of live bird markets as potential hotspots for infectious disease transmission by focused on pathogen detection. There remains a critical gap to understanding how biosecurity measures are implemented at the individual trader level. By applying a structured questionnaires about non-compliance-based assessment across key biosecurity components, this study provides a trader-level evaluation of operational practices. The findings of this study provide baseline information on the current conditions of live bird markets in Bogor and may serve as a base for developing strategies to improve biosecurity implementation to prevent the spread of zoonotic diseases originating from these markets. The existing strategies remain relatively general, such as requiring markets to provide designated zones for live bird sale and slaughter, loading and unloading areas for live animals, and vehicle disinfection facilities for poultry transportation (BSN, 2015). But that strategies were removed in the revised BSN regulation issued in 2021 (BSN 2021). These general provisions need to be further strengthened to support more effective implementation of biosecurity practices.

Materials and Methods

This study was conducted in June 2025 in collaboration with Perumda Pasar Tohaga for the selection of markets in Bogor Regency and Perumda Pasar Pakuan Jaya for the selection of markets in Bogor City, to represent the diversity of markets in the Bogor area. The markets proposed by these

two authorities included Pasar Bogor and Pasar Jambu Dua in Bogor City, as well as Pasar Parung, Pasar Leuwiliang, and Pasar Citeureup in Bogor Regency. These five markets were selected because they are known to trade large volumes of live bird trading and receive supplies not only from within Bogor but also from other regions. In addition, these markets actively redistribute birds into several other markets across Bogor. From each market, traders were selected based on the following criteria: (i) active involvement in live bird trading, (ii) on-site slaughter, and (iii) sourcing live birds from both within and outside the Bogor area, and (iv) willing to participate in observations and interviews. Traders who met these criteria were then selected using simple random sampling, with at least three traders chosen from each market due to the limited number of live bird traders in each market. During implementation, several traders declined to participate; therefore, the final sample size in this study was 15 traders. In addition, this constitutes a limitation of the study, as it is geographically restricted to Bogor and involves a relatively limited number of respondents.

Data were collected through interviews and direct on-site observation using a structured checklist adapted from the Biosecurity Guide for Live Poultry Markets (FAO, 2015), with adjustments to reflect actual field conditions based on expert consultations from the Division of Veterinary Public Health and Epidemiology, School of Veterinary Medicine and Biomedical Sciences, IPB University. These adaptations resulted in the selection of key indicators directly associated with zoonotic disease transmission in live bird markets. The biosecurity assessment focused on three main components: movement control, isolation, and sanitation (Siagian and Pratama, 2024). These components were operationalized into a total of 28 assessment indicators were used, consisting of 6 items related to movement control, 9 items related to isolation, and 13 items related to sanitation practices, which are further presented under each respective aspect in the Discussion section.

The level of biosecurity implementation was determined based on the number of non-compliant events. Each of the 28 indicators was scored as 1 if a non-compliant event was observed and 0 if no non-compliance was identified. Thus, the maximum possible score was 28, while the minimum was 0. Biosecurity implementation levels were then classified as poor when the score was >20 , moderate

when the score ranged from 10 to 20, and good when the score was <10. Biosecurity implementation was categorized into predefined levels, as presented in Table 1.

Table 1. The category of biosecurity levels for live bird traders.

Biosecurity Level	Non-compliant on Biosecurity Implementation
Good	<10
Moderate	10–20
Poor	>20

All collected data were analyzed using Microsoft Excel 365 and SPSS Statistics 21. Descriptive statistics were used to summarize the data and were presented in tabular and graphical formats to facilitate interpretation and comparison across the assessed sites. Results were presented as mean with standard deviation (SD) and frequencies where appropriate to explore differences in biosecurity implementation across trader characteristics. Spearman's rank correlation analysis was used to assess associations between continuous or ordinal variables and total biosecurity non-compliance scores. The Mann–Whitney U test was applied to compare non-compliance scores between categorical groups. The significance was set at $p < 0.05$.

The relatively small sample size ($n = 15$) and low number of trained traders ($n = 2$) was the limitations of this study. These limitations limit the statistical power of comparative and bivariate analyses. As a result, the findings should be interpreted with caution and the absence of statistical significance does not necessarily indicate the absence of meaningful relationships. In addition, the use of non-parametric tests and descriptive comparisons restricts the ability to draw causal inferences. Future studies with larger sample sizes and more balanced group distributions are needed to confirm these observed trends and provide more robust inference.

Results and Discussion

Respondent Characteristics

All respondents were male, most of whom were under 40 years old. Most respondents (80%) had more than five years of experience in live bird trading. Based on interview results, the average number of birds sold was 127 birds per day. Most respondents (86.7%) sold more than one bird species at their market stalls, such as free-range

chickens (local), broilers, male layer chickens, spent laying hens, ducks, and Muscovy ducks. Among all respondents, only two traders (13.3%) had received formal biosecurity training. The training was provided by the market management authority in Bogor City in 2019.

Table 2. Characteristics of live bird traders in Bogor City and Bogor Regency.

Respondent Characteristic	Number of Respondents	Percentage (%)
Gender:		
• Male	15	100
• Female	0	0
Age:		
• Young (<40 years)	9	60
• Old (≥ 40 years)	6	40
Education Level:		
• No formal education	1	6.7
• Elementary school or equivalent	3	20
• Junior high school or equivalent	4	26.7
• Senior high school or equivalent	7	46.7
Experience in live bird trading:		
• Early (<1 year)	0	0
• Moderate (1–5 years)	3	20
• Long (>5 years)	12	80
Biosecurity training:		
• Yes	2	13.3
• No	13	86.7
Selling more than one bird species:		
• Yes	13	86.7
• No	2	13.3
Number of birds sold per day:		
• Low (<50 birds)	3	20
• Moderate (50–100 birds)	7	46.7
• High (>100 birds)	5	33.3

Biosecurity Implementation Level

The level of biosecurity was determined based on the number of non-compliance identified during observation. The biosecurity level and corresponding amount of non-compliance for each trader are presented in Tables 3 and 4. Based on this non-compliance, all traders operating in live bird markets in Bogor City and Bogor Regency were classified as having a moderate level of biosecurity implementation (100%).

Table 3. Number of non-compliant identified among live bird traders in Bogor City and Bogor Regency

Trader Code	Non-compliant	Compliant	Biosecurity Level
CT 01	18	10	Moderate
CT 02	18	10	Moderate
CT 03	12	16	Moderate
PB 01	13	15	Moderate
PB 02	12	16	Moderate
PB 03	14	14	Moderate
JD 01	13	15	Moderate
JD 02	11	17	Moderate
JD 03	15	13	Moderate
LE 01	17	11	Moderate
LE 02	17	11	Moderate
LE 03	16	12	Moderate
PR 01	16	12	Moderate
PR 02	14	14	Moderate
PR 03	18	10	Moderate

Notes: CT= Pasar Citeureup; PB= Pasar Bogor; JD= Pasar Jambu Dua; LE= Pasar Leuwiliang; PR= Pasar Parung.

Table 4. Biosecurity levels among live bird traders in Bogor City and Bogor Regency

Biosecurity Level	Number of Respondents	Percentage (%)
Good	0	0
Moderate	15	100
Poor	0	0
Total	15	100

Movement Control Aspects

The observed movement control aspects are shown in Table 5. Most traders (93.3%) allowed direct contact between consumers and live bird. Only one trader (6.7%) transported bird mixed with more than one species; however, this practice still poses a potential risk for disease transmission in live bird markets. A large proportion of traders (73.3%) did not conduct any form of health inspection of bird upon entry into the market.

Table 5. Movement control aspects among live bird traders in Bogor City and Bogor Regency

Component	Non-compliant	Percentage (%)
Mixed-species bird transport	1	6.7
Unscheduled bird arrival	11	73.3
Lack of bird health inspection	11	73.3
Direct human–bird contact	14	93.3
Inter-trader bird movement	3	20
Presence of other animals	15	100
Average non-compliant		61.1

Isolation Aspects

The evaluated isolation aspects are shown in Table 6. Notably, most traders (73.3%) maintained high stocking densities within individual cages, and 26.7% continued to mix different bird species. Most live bird traders (73.3%) lacked isolation cages to separate sick birds; consequently, some traders (26.7%) kept sick bird in the same cages with healthy birds.

Table 6. Isolation aspects among live bird traders in Bogor City and Bogor Regency

Component	Non-compliant	Percentage (%)
Failure to segregate newly arrived bird	10	66.7
Mixing of different bird species	4	26.7
Inadequate spacing between cages	11	73.3
Vertical stacking of cages with mixed species	6	40
High stocking density per cages	11	73.3
Failure to isolate sick bird	4	26.7
Failure to separate dead bird	0	0
Absence of FIFO system	15	100
Lack of isolation cage	11	73.3
Average non-compliant		60

Sanitation Aspects

The observed sanitation aspects are shown in Table 7. Most traders (86.7%) did not wash their hands with water and soap after contact with bird. This practice was likely influenced by the limited availability of soap (66.7%) and disinfectant materials (77.3%) at trading stalls. In general, bird cages and the environment were poorly maintained and not routinely cleaned. Waste management practices were also inadequate across most traders operating in live bird markets in Bogor.

Table 7. Sanitation aspects among live bird traders in Bogor City and Bogor Regency

Component	Non-compliant	Percentage (%)
Traders working while ill	0	0
Lack of personal protective equipment (PPE) use	15	100
Failure to perform regular hand hygiene	13	86.7
Lack of access to clean water	0	0
Absence of soap	10	66.7
Absence of disinfectant	11	73.3
Poor cage and environmental sanitation	10	66.7
Accumulation of fecal matter in cages	11	73.3
Inadequate cleaning of equipment	6	40
Insufficient waste disposal containers	9	60
Failure to segregate solid and liquid waste	3	20
Improper disposal of solid waste in public areas	9	60
Direct discharge of liquid waste into waterways	15	100
Average non-compliant		57.4

Recapitulation of All Assessment Aspects

A summary the main biosecurity aspect is shown in Figure 1. Overall, the highest level of non-compliance was observed in the movement control aspect (61.1%), followed by the isolation and sanitation aspect. In general, all three biosecurity aspects exhibited substantial non-compliance, indicating weaknesses in biosecurity implementation within live bird markets.

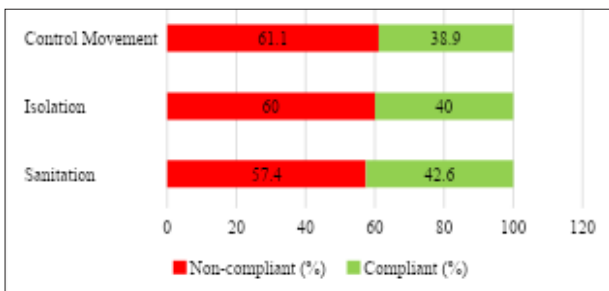


Figure 1. Recapitulation of non-compliance assessment in every aspect in live bird traders in Bogor.

Comparative and Bivariate Analysis of Trader Characteristics

Association between trader characteristics and total biosecurity non-compliance with Spearman correlation analysis showed not statistically significant associations between individual trader characteristics and total of biosecurity non-compliance scores (Table 8). A moderate negative

correlation was observed for education level ($\rho = -0.481, p = 0.069$), indicating a tendency toward lower non-compliance among more educated traders, although this did not reach statistical significance.

Table 8. Association between traders' characteristics and biosecurity non-compliance

Variable	ρ (Correlation)	p-value
Trader's age	-0.020	0.944
Trader's education level	-0.481	0.069
Experience in live bird trading	-0.320	0.245
Number of birds sold per day	-0.134	0.635

Comparative analysis using the Mann-Whitney U test (Table 9) also showed not statistically significant in total non-compliance scores between trained and non-trained traders ($p = 0.392$). However, non-trained traders have higher mean scores and mean ranks, suggesting a tendency toward poorer biosecurity practices. Similarly, no significant difference was observed between traders selling single species with multiple bird species ($p = 0.732$).

Differences in biosecurity non-compliance by market location were observed between city and regency LBM across all biosecurity components (Table 10). Traders in regency LBM consistently showed higher non-compliance scores compared to those in city LBM. The difference was statistically significant for sanitation ($p = 0.044$) and total non-

Table 9. Comparison of biosecurity non-compliance by training and type of birds sold

Variable	Group	Mean \pm SD	Mean Rank	p-value
Training	Trained	13.50 \pm 0.71	5.50	0.392
	Not trained	15.15 \pm 2.51	8.38	
Type of Birds Sold	Single species	14.50 \pm 3.54	7.00	0.732
	Multiple species	15.00 \pm 2.38	8.15	

Table 10. Comparison of biosecurity non-compliance by market location

Variable	Group	Mean ± SD	Mean Rank	p-value
Movement Control	City	3.33 ± 0.52	6.33	0.213
	Regency	3.89 ± 1.05	9.11	
Isolation	City	4.00 ± 0.89	5.50	0.065
	Regency	5.33 ± 1.41	9.67	
Sanitation	City	5.67 ± 1.51	5.33	0.044
	Regency	7.00 ± 0.71	9.78	
Total of Non-compliance	City	13.00 ± 1.41	4.50	0.013
	Regency	16.22 ± 2.05	10.33	

Table 11. Correlation between biosecurity non-compliance components

Variable	ρ (Correlation)	p-value
Total of non-compliance vs movement control	0.454	0.089
Total of non-compliance vs isolation	0.824	<0.001
Total of non-compliance vs sanitation	0.669	0.006
Movement control vs isolation	0.251	0.366
Movement control vs sanitation	-0.208	0.456
Isolation vs sanitation	0.471	0.076

compliance ($p= 0.013$), indicating substantially poorer biosecurity conditions in regency markets.

Spearman correlation analysis (Table 11) revealed that total non-compliance scores were strongly associated with isolation ($\rho= 0.824$, $p<0.001$) and sanitation ($\rho= 0.669$, $p= 0.006$). Correlations between individual components were generally weak and not statistically significant.

Discussions

Most traders introduced live bird during regular market operating hours at 05.00 AM – 12.00 PM. This practice may increase the risk of zoonotic disease transmission due to intensified human–animal contact during peak market activity. In addition, the introduction of bird during trading hours can increase stress levels in birds. Stress-induced immunosuppression in bird has been shown to reduce immune function, thereby increasing susceptibility to infection and enhancing the risk



Figure 2. Unscheduled bird arrival and direct contact with humans.

of disease transmission among birds (Tamzil *et al.*, 2022; Brandl and Farine, 2024).

Mixed bird species within the same shipment should be avoided, as it increases the risk of disease transmission both between different bird species and across geographic areas. Mixed-species transport facilitates pathogen exchange and amplification (Bedi *et al.* 2022). Wild birds are known as the natural reservoir of avian influenza (AI) viruses, especially aquatic wild birds (WOAH, 2021). These birds can bring a wide range of AI subtypes, including both highly pathogenic avian influenza (HPAI) and low pathogenic avian influenza (LPAI) viruses (CFSPH, 2024). Several studies conducted between 2014 and 2019 in Java Island reported the circulation of HPAI viruses in live bird markets, with an overall prevalence of 22%, which is 53% from that were positive for H5 based on RT-PCR testing (Dharmayanti *et al.*, 2020). Mixing with unvaccinated birds can increase the risk of virus transmission in live bird markets. To mitigate these risks, bird entering markets should be verified as clinically healthy through health inspection at the point of entry (Basri *et al.*, 2013). Furthermore, FAO guidelines strongly recommend that bird sold in live bird markets originate from certified farms and accompanied by valid animal health certificates to reduce the introduction of infected birds into markets (FAO, 2015).



Figure 3. Mix of different bird species.

Control movement between consumer and bird should implemented to prevent direct contact between humans and animals. Access restriction systems should be implemented within selling areas by applying a one-directional flow or used glass partitions or other transparent materials, that allow customers to view the animals directly without physical contact. Transferring bird between stalls should be avoided cause this practice raises concerns regarding intra-market disease dissemination, particularly if the transferred birds are already infected disease (FAO, 2015). This is important because direct contact between animals and humans can facilitate the transmission of various zoonotic diseases. Movement control should also be implemented for animals in and around the trading area, as several pathogens, including avian influenza (AI) viruses, are known to be multispecies pathogens thereby increasing the risk of cross-species infection (Bedi *et al.*, 2022). Although it may be difficult to ensure complete from other animals, particularly rodents in live bird market environments, targeted control measures are necessary to reduce the risk of pathogen transmission.

High stocking density per cage was also commonly found in live bird traders. That condition can increase infection and facilitate disease transmission among bird (Haugan and Bjornson, 2010). Prolonged retention of bird in live bird markets promotes pathogen accumulation and persistence (Sheen *et al.*, 2024). Separation of newly arrived birds from those already present, combined with prioritizing the sale of birds that have been in the market longer can be implemented to reduce infection pressure. Furthermore, FAO guidelines recommend that live bird markets implement regular market rest days to allow thorough cleaning, sanitation, and disinfection of the market environment, thereby interrupting transmission cycles and reducing viral environmental persistence (FAO, 2015).

Sick bird should be removed from general cages and placed in isolation facilities. Therefore, the availability of isolation cages should be considered

a minimum biosecurity requirement for live bird traders (FAO, 2015). Sick or dead bird should not be slaughtered or sold, as this practice may facilitate pathogen transmission to other animals, humans, and the environment (Haugan and Bjornson, 2010). Dead bird should be disposed of in designated waste containers and must not be mixed with other types of waste. Appropriate solid waste management strategies, such as incineration or burial through controlled composting are highly recommended to ensure viral inactivation and prevent environmental dissemination (CFSPH, 2024). Liquid waste should not be discharged directly into open drainage channels. Liquid waste should be temporarily retained and treated to ensure the elimination of biological hazards prior to environmental release (FAO, 2015).

None of the traders used personal protective equipment (PPE) during trading activities. This practice poses a direct risk to both workers and the public. The use of basic PPE including gloves, aprons, masks, and face shields is recommended to reduce occupational exposure to pathogens (FAO, 2015). Soap and disinfectants for environmental sanitation should be readily available alongside clean water. Cleaning and disinfection should be carried out daily to reduces the probability of stalls becoming contaminated with various pathogens (Islam *et al.*, 2023). Hygiene and sanitation practices are also essential to minimize pathogen contamination in holding cages, as well as in slaughtering and handling equipment (Wahyuni *et al.*, 2022). In addition, personal hygiene practices, such as handwashing with water and soap, represent simple yet effective measures to reduce contamination (Bhatia and Narain, 2006). According to FAO guidelines, poultry stalls and surrounding environments should be cleaned daily, and disinfection should be conducted at least once per week to effectively reduce pathogen transmission pathways (FAO, 2015).



Figure 4. Poor environment sanitation and lack of PPE use.

The absence of statistically significant associations between trader characteristics and biosecurity non-compliance suggests that individual-level attributes are not the primary determinants of biosecurity practices in live bird markets. Despite these characteristics, only two of traders had received formal biosecurity training. The lack of observable differences between trained and non-trained traders raises questions about the effectiveness of training programs, especially since the program was only conducted once in 2019 without further evaluation. This finding indicates limited dissemination and uptake of biosecurity information among live bird traders in Bogor City and Bogor Regency. Limited dissemination of information to traders influences their behavior in implementing appropriate biosecurity practices (Kurscheid *et al.*, 2015). The knowledge about biosecurity had significant relationship to the attitude and practice of biosecurity in traders live bird (Wicaksono *et al.*, 2025). Training should be combination with incentives, supervision, infrastructure support, and regulatory enforcement to ensure effective biosecurity implementation in live bird markets (Turkson and Ekike, 2016). Therefore, it is necessary to evaluate the effectiveness of the training implementation.

Market location showed an association with biosecurity outcomes. Traders operating in regency markets showed higher non-compliance across all components, with statistically significant differences observed for sanitation aspect and total of non-compliance. Poor sanitation has been widely recognized as a critical risk factor for the persistence and transmission of pathogens in live bird markets (Biswas *et al.*, 2017). This pattern indicates that biosecurity implementation is strongly influenced by structural conditions at live bird market, including infrastructure, sanitation facilities, regulatory enforcement, and management systems. This is in accordance with FAO guidelines where environmental and institutional factors were found to play a more critical role than individual behavior in shaping disease risk (FAO, 2015). The weak correlations observed between biosecurity aspects suggest that practices are not implemented in an integrated manner. These findings indicate that improving biosecurity in live bird markets requires a system-level approaches interventions. Targeted interventions should prioritize sanitation and isolation practices, as these components appear to have the greatest influence on overall compliance.

The findings of this study are consistent with previous research, indicating that practices such as keeping birds in the market for more than one day, mixing different types of birds in a single cage, failing to clean cages, not performing environmental disinfection, slaughtering sick bird, not using soap when washing hands, not wearing personal protective equipment, disposing of bird feces into open drainage systems, and discarding carcasses in general waste bins are still commonly carried out by bird traders (Suartha *et al.*, 2010; Basri *et al.*, 2013; and Wicaksono *et al.*, 2025). Poor hygiene practices, weak biosecurity implementation, and high levels of bird and human movement create favourable conditions for transmission of multiple pathogens within live bird markets (Biswas *et al.*, 2017). The transmission not only affects bird but also poses potential health risks to market visitors and consumers who enter these markets.

Although biosecurity training has previously been conducted by market authorities in Bogor City, but have not shown into effective behavioural change among traders. Negative attitudes and a lack of awareness are among the factors contributing to the improper implementation of biosecurity practices. As reported by Wicaksono *et al.*, (2019), low levels of knowledge and predominantly negative attitudes are strongly correlated with poor biosecurity practices. Social, economic, and cultural perceptions also contribute to the ineffectiveness of the training, as traders tend to prioritize the income they earn (Kurscheid *et al.*, 2015). Pratiwi *et al.*, (2020), suggested that one factor supporting their findings in live bird markets is that inadequate biosecurity practices, combined with the absence of consistent supervision and enforcement by market management and government authorities, may transform live bird markets into persistent reservoirs and amplification points for infectious diseases. These findings suggest that comprehensive improvements across movement control, isolation, and sanitation are required to strengthen biosecurity practices and reduce disease transmission risks in live bird markets.

Live bird markets in Indonesia lack a standalone legal framework. Previously, live bird market management was partially addressed under the Indonesian National Standard (SNI) 8152:2015 about Traditional Markets. This standard requires markets to provide specific zones for live bird sale and slaughter, loading and unloading areas for live animals, and vehicle disinfection facilities for bird

transportation (BSN, 2015). These standards were consistent with the FAO biosecurity standards for live bird markets (FAO, 2015). However, in the revised SNI 8152:2021, regulatory requirements concerning live bird trading were removed from the criteria for market certification (BSN, 2021). As a result, compliance with biosecurity measures specific to live bird markets is no longer embedded within the national market standardization framework. Currently, the remaining regulation for live bird markets are contained in the Regulation of the Minister of Health of the Republic of Indonesia No. 17 of 2020 on Healthy Markets. This regulation mandates the provision of separate areas for live bird trading, routine disinfection of bird stalls at least once per month, the use of personal protective equipment, post-work hygiene practices such as bathing before leaving the market, and the maintenance of environmental hygiene and sanitation (Permenkes, 2020).

Conclusion

Live bird markets in Bogor City and Bogor Regency have not yet demonstrated adequate biosecurity measures to prevent the transmission of various pathogens. A high number of non-compliances were identified across the main biosecurity components of movement control, isolation, and sanitation. The absence of clear regulations and an effective market governance framework for biosecurity implementation can increase the transmission of multiple infectious diseases. Improving traders' knowledge and awareness of biosecurity must be accompanied by strengthened supervision and enforcement mechanisms, as well as improvements in market governance. Establishing clear, binding regulations is essential to support and sustain effective biosecurity practices in live bird markets.

Conflict of Interest

The authors declare that there is no conflict of interest with any parties involved in this research.

Funding Statement

This study was supported by Pendanaan Riset Pembangunan Berkelanjutan (PRPB) Lembaga Pengelola Dana Pendidikan (LPDP), Ministry of Education, Culture, Research and Technology, Republic of Indonesia.

Acknowledgement

The authors would like to express their sincere gratitude to Wageningen University & Research, Utrecht University, and IPB University for their support and collaboration in the NiCoHARPP project (Netherlands–Indonesia Consortium on Health Resiliency and Pandemic Preparedness). The authors also acknowledge Perusahaan Umum Daerah Pakuan Jaya of Bogor City and Perusahaan Umum Daerah TOHAGA of Bogor Regency for their institutional support of this study. In addition, the authors extend their appreciation to all live bird traders in Bogor City and Bogor Regency for their participation as respondents in this research.

Author's Contribution

The authors confirm their contribution to the paper as follows: study conception and design: ZM, TP, CB; data collection: ZM, CB; analysis and interpretation of results: ZM, TP, CB; draft manuscript preparation: ZM, CB.

Ethics Approval

This article does not involve animal subjects, so ethical approval for animal studies is not necessary in the present study.

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