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Factors affecting highly pathogenic avian influenza vaccination practices at poultry farms in Tra Vinh, Vietnam

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ABSTRACT

Background: The increased number of cases of highly pathogenic avian influenza (HPAI) as a zoonosis has raised concerns in terms of poultry and human health. Farmers' preventive practices are an effective way of reducing zoonosis. However, this practice may have been affected by many factors, including production behaviors, awareness, and farmers' perceptions of farmers toward zoonosis.

Aim: This study was conducted on 166 poultry farms in Tra Vinh Province with 14,894 poultry heads to determine the socioeconomic profiles and production characteristics of poultry farms and analyze the effect of these factors on HPAI vaccination practices.

Methods: Respondents were selected from lists provided by government officers. Descriptive statistics were used to describe all variables, and factors affecting HPAI vaccination practices were analyzed using binary regression analysis.

Results: The results showed that most farmers raised poultry with other livestock using the free-range method, which is a semi-intensive system. The primary objectives of poultry farming are meat sales and augmenting household consumption, with farmers primarily raising chicks produced on their farms. The implementation of the vaccine was less than 50% on the surveyed farms, with a small number of farmers administering an HPAI booster dose. However, only 6% of the farmers confirmed that their livestock had been exposed to HPAI. In addition, HPAI vaccination and booster dose practices significantly increased when farmers had 4–6 family members and received HPAI prevention training. Moreover, increased poultry numbers have led to increased vaccination rates and the implementation of booster doses for poultry. The study also reported that the vaccination rate decreased when poultry was used for household consumption.

Conclusion: Sociodemographic characteristics and production behaviors can affect the implementation of HPAI vaccination on small poultry farms.

Keywords: Poultry farm, Vaccination, Farming system, Farmer practice, HPAI.

Introduction

The poultry industry has also developed in recent years. Poultry flocks, especially chicken flocks, have increased owing to an increase in the demand for meat. In addition, the industry is undergoing rapid changes (Delabouglise *et al.*, 2020). Currently, poultry farms are the most substantial source of animal proteins for humans. Although productivity in terms of quality has improved, production costs remain high and poorly competitive, making chicken production occasionally unprofitable.

Worldwide, poultry health is a primary management concern in smallholder chicken production systems. In the smallholder poultry value chain, the control and prevention of high-prevalence recurrent diseases depend not only on addressing biological and environmental issues but also on improving the socioeconomic behavior of producers, traders, and consumers (Sealy *et al.*, 2019). Disease and mortality of birds continue to be substantial constraints on production and productivity, particularly on farms that practice multispecies poultry production (Delabouglise *et al.*, 2020). Disease outbreaks are most prevalent during the brooding period, and mortality increases during the first 5–10 weeks (Carrique-Mas *et al.*, 2019). Highly pathogenic avian influenza (HPAI), Newcastle disease, fowl pox, infectious bursal disease, coccidiosis, and bronchitis are the most prevalent poultry diseases in Vietnam, particularly in the Mekong Delta region (Carrique-Mas *et al.*, 2019; Delabouglise *et al.*, 2020). Vietnam is a developing nation affected by HPAI (Delabouglise *et al.*, 2020). HPAI poses a significant threat to poultry production, trading, and consumption in some countries (Figué and Desvaux, 2015). Small-scale farms face a high risk of disease transmission between animals and humans owing to the high virulence of

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HPAI (Whelan *et al.*, 2021). In addition, these viruses can occasionally be transmitted to humans, allowing for the potential emergence of new diseases, including pandemics (Delabouglise *et al.*, 2020). Carrique-Mas *et al.* (2019) found that on average, 2.5% of poultry in small-scale flocks in a region died each week. Low hygiene and biosecurity standards, which are typical of small-scale poultry farms in the region, contribute to the prevalence of disease in these flocks (Van *et al.*, 2019). In Vietnam, where "backyard" poultry production is prevalent, HPAI is endemic (Khaw *et al.*, 2021). The Mekong River Delta in southern Vietnam stands out as one of the regions with the highest HPAI prevalence. In this area, numerous farmers engage in small-scale poultry farming and invest modestly in measures such as vaccination and sanitation to prevent diseases. However, none of these were relevant in describing behavioral uptake.

The behavior of chicken farmers may be affected by changes in outbreak risk or mortality risk; however, the mechanism and extent of these impacts remain unclear. Furthermore, it is unknown whether chicken producers respond to disease outbreaks in their flocks by increasing the use of disinfection techniques or increasing vaccination rates against HPAI. For all known livestock systems, changes in farm management prompted by variations in epidemiological risk have not been quantified, partly because of the absence of combined epidemiological and behavioral data in longitudinal studies of livestock diseases (Hidano *et al.*, 2018). Therefore, the objectives of this study were to determine the socioeconomic status and poultry production characteristics of small farms and to analyze the effect of these characteristics on HPAI vaccination practices.

Materials and Methods

Location

This study was conducted in Tra Vinh Province, Mekong Delta, Vietnam, and covered three districts: Cang Long, Tra Cu, and Cau Ngang. These districts were selected because they are the most dynamic areas for poultry production activities involving small farms. In addition, an increased risk of HPAI has been observed in these areas owing to low perception and prevention practices regarding the disease. The research locations are shown in Figure 1.

Data collection

The survey was conducted from March to June 2023 to obtain data from poultry farms. Data were recorded during the transition period from the dry season to the rainy season to acquire information during the most sensitive time for poultry husbandry because of the increased number of cases of infectious diseases among birds. A three-section questionnaire was used to record the data. The survey was conducted using the local

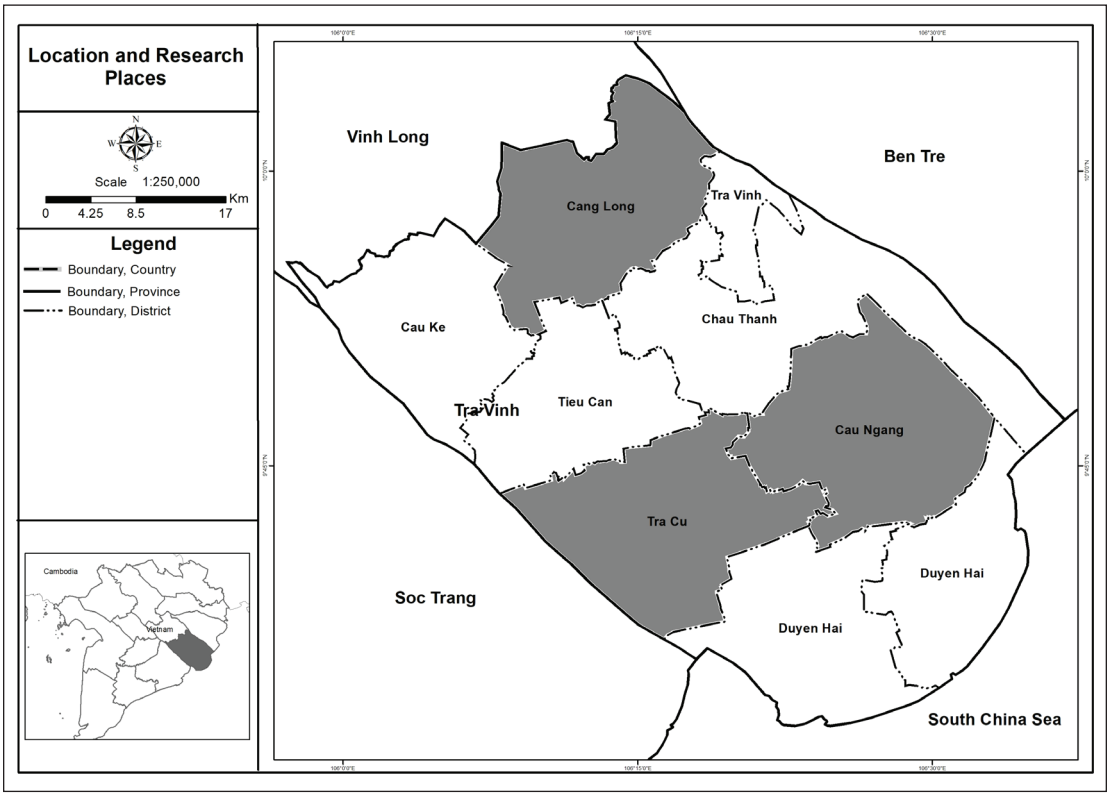

Fig. 1. The locations and research regions analyzed.

language (Vietnamese) with support from government officers (Qui *et al., 2*021).

In the first section, respondents were asked about their social profile, including age, gender, main occupation, formal education, number of family members in the household, labor, training for HPAI prevention, and income. Government officers visited the farms and filled out data from the information provided by the farm owners. In the second section, farming activities, including how farmers raised their livestock and their experiences with HPAI outbreaks, were recorded. In the third section, the farmers answered questions on production activities, such as the purpose of raising chickens and the number of chickens owned by the farm. The farmers' vaccination practices for birds were also discussed in this section. Notably, this study focused only on HPAI vaccination for birds. If farmers confirmed administrating the first dose of the vaccination, further questions were asked to check whether they had administered the second dose.

Initially, purposive sampling was used to select respondents. The criteria for respondents were as follows: (1) chickens were available on the farm, (2) the farmers owned at least 20 chickens on their farms, and (3) the farmers had at least 3 years of experience raising birds on farms. Poultry farmers who have at least 3 years of experience in raising, trading, and raising poultry during the HPAI epidemic were selected as respondents. This criterion ensured that participants possessed valuable insights into accessing information related to prevention practices and addressing challenges on their farm. Based on these criteria, a list of 300 farms was selected by veterinary officers and used as the sampling framework for this study. However, only 166 farms met the sample selection standards used in this study. This numerical value satisfied the minimum recommended sample size required to achieve a statistical power of 80%. In addition, Levine and Stephan (2010) showed that, for an unknown population, the number of respondents (at least 30) was sufficiently large.

Data analysis

Data were analyzed through descriptive and binary regression analyses using the Statistical Package for the Social Sciences (IBM SPSS) 26.0 (IBM Corp, Armonk, NY). Binary logistic regression (BLR) was used to determine the relationship between vaccination practices or booster doses of HPAI and other variables (Hidano *et al.*, 2018), including social profile and production characteristics. All variables, including types, categories, and descriptions of the farms, are presented in Table 1. Notably, this study used the same independent variables, namely social profiles and production characteristics, for both dependent variables, analyzing the relationships between practices. Each dependent variable was analyzed individually. The model used in this study is illustrated in Figure 2. Equation (1) expresses the BLR formula employed

$$Y(Y_1/Y_2) = \log\left(\frac{p}{(1-p)}\right) = a + b_1 X_1 + b_2 X_2 + ... + b_n X_n \quad (1)$$

where *Y* is the dependent variable, Y_1 is the HPAI vaccine, and Y_2 is the booster dose. The independent variables included social profiles (X_1 = age; X_2 = gender; X_3 = main occupation; X_4 = formal education; X_5 = family members in the household; X_6 = labor; X_7 = training; X_8 = income) and production characteristics (X_9 = farming system, X_{10} = raising methods, X_{11} = chick source, X_{12} = raising purpose, X_{13} = number of poultry animals, X_{14} = HPAI availability, X_{15} = type of livestock, and X_{16} = first dose of HPAI vaccine). In addition, regression analysis ensured that the dependent variable could be predicted as accurately as possible from the set of independent variables when calculating the weights (a, b_1,…, b_n,). In this study, it was expected that changes in social profiles and production characteristics would change HPAI vaccination and booster dose practices.

Results

The social characteristics of poultry farmers in Tra Vinh province, Vietnam

The results in Table 2 show that poultry farmers over 40 years of age accounted for 77.1% of the total population, and most farmers were men. The farmers had a basic education (mostly primary and secondary school; no respondents reached the graduate level) and worked in livestock husbandry as their main job (more than 50%). In addition, more than 50% of their household family members participated in farming activities, with monthly incomes derived from these activities falling below $100. Moreover, the surveyed farmers noted that they disliked participating in training activities (52.4% of the total respondents).

Production system and characteristics of poultry farmers in Tra Vinh province

Among the surveyed farms, poultry was not the main livestock (Table 3), as farmers usually raised poultry in combination with other livestock (>67%). A total of 32.5% of the farmers confirmed that they raised only poultry, with an average of more than 80 heads per farm. However, chickens constituted the predominant type of poultry raised on most surveyed farms (>75%). As shown in Table 3, household consumption and the sale of broilers were the main reasons for raising poultry. Almost 90% of the respondents preferred a semi-intensive poultry system. The findings also confirm that the free-range faring method (>80%) was applied by most farms in Tra Vinh Province compared to other methods. In addition, Table 3 shows that in small farms in Tra Vinh Province, almost 85% of the respondents preferred to raise their own chicks.

Among the farms, the surveyed farmers reported that they rarely purchased chicks from external sources. The study also found that only 6% of the farmers faced HPAI challenges (Fig. 2). In terms of prevention

Table 1. Variable types.

No	Variables	Types of data	
Independent variables			
1	Age refers to the age of the members in the household	Categorical	1 = 18–40 years old; 2 = >40–60 years old; 3 = >60 years old
2	Gender refers to the respondents' gender	Dummy	1 = Men; 0 = Women
3	Main occupation refers to the primary activities that farmers engage in for the majority of their time	Categorical	1 = Horticulture; 2 = Animal husbandry; 3 = Business; 4 = Officer
4	Formal education refers to the highest level of schooling that respondents have completed	Categorical	1 = Primary school; 2 = Secondary school; 3 = High school; 4 = Bachelor; 5 = Graduate
5	Family members refer to the total number of individuals living together in the household	Categorical	1 = 1–3; 2 = 4–6; 3 = >6
6	Labor signifies the number of people from the family who actively participate in farming activities	Categorical	1 = ≥50% family members; 0 = <50% family members
7	Training refers to training activities relating to livestock farming that farmers engage in	Dummy	1 = Yes; 0 = No
8	Income refers to how much they earn from poultry farming activities monthly	Dummy	1 = <$100; 0 = ≥$100
9	Poultry heads refer to the number of poultry animals available at the farm	Continuous	-
10	Chick source indicates the source from which farmers acquire chicks	Categorical	1 = Chicks produced at the farm; 2 = Hatchery; 3 = From other farms; 4 = From companies
11	Raising purpose describes the intended use of the output products from poultry farming	Categorical	1 = For selling meat; 2 = For selling eggs; 3 = For consumption; 4 = Mixed
12	Farming system delineates the duration for which farmers keep their birds at the farm—whether throughout the entire year or only for several months	Categorical	1 = Seasonal farming; 2 = Semi-intensive farming 3 = Mixed
13	Raising methods specify how birds are raised on the farm, including whether they have free access to the ground or are kept in cages	Categorical	1 = Free-range farming; 2 = Semi-free-range farming; 3 = Caging farming
14	Type of livestock refers to which types of animals are kept at the farm	Categorical	1 = Poultry; 2 = Mixed livestock
15	HPAI at the farm refers to the historical exposure of livestock to HPAI	Dummy	1 = Yes; 0 = No
Dependent variables			
1	HPAI vaccine implementation refers to the implementation of HPAI vaccination by farmers	Dummy	1 = Vaccinated; 0 = Not vaccinated
2	Booster dose for HPAI vaccine refers to the implementation of a booster dose by farmers	Dummy	1 = Yes; 0 = No

HPAI: Highly pathogenic avian influenza.

practices, less than 40% of farmers vaccinated their poultry, and only 20% of farmers provided a second dose of vaccination against HPAI (Fig. 3).

Socioeconomic factors affecting vaccination practice against HPAI

Table 4 shows the logistic regression results, which were used to ascertain the effects of age, gender, occupation, education, number of household family members, and training on the likelihood of respondents engaging in vaccination practices against HPAI. The results showed that the number of household family members (up to 4–6 members) and training activities (performed together) had significant effects on vaccination practices. The model explained 32.5% (*Nagelkerke* R^2) of the variance

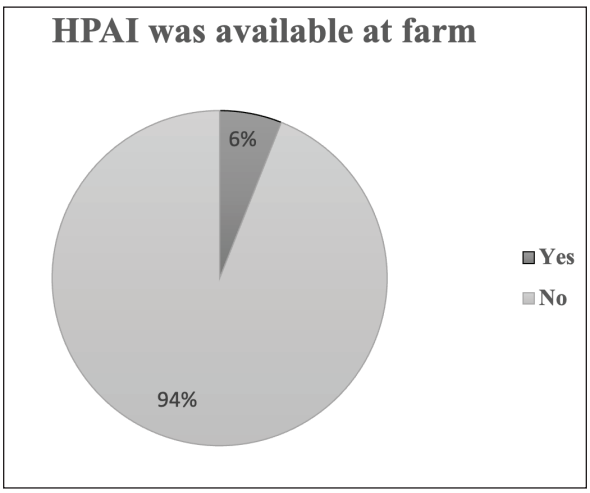

Fig. 2. The prevalence of HPAI at the farms (n = 166).

in vaccination and correctly classified 77.5% of cases. In addition, it accounted for 49.4% (*Nagelkerke* R^2) of the variance in booster dose administration practices and correctly classified 50.6% of cases. In particular, farmers with 1–3 family members in their households were less likely to administer HPAI vaccinations than farmers with 4–6 family members ($p < 0.05$), while other variables remained constant. Showing the same trend, the likelihood of administering vaccinations and booster doses increased when farmers participated in training activities compared to those who did not participate in training for HPAI prevention ($p < 0.01$).

Production characteristic factors affecting vaccination practices against HPAI

As shown in Table 5, a logistic regression model was used to ascertain the effects of the type of livestock, overall poultry count, chick source, raising purpose, type of farm, raising method, and HPAI availability on the probability of respondents engaging in HPAI vaccination and booster dose practices. Furthermore, it investigated how administering the first dose of vaccination influenced the likelihood of subsequently providing a booster dose. The model explained 57.4% (*Nagelkerke* R^2) of the variance in vaccination and correctly classified 46.6% of the cases. It also explained 78.3% (*Nagelkerke* R^2) of the variance in booster dose administration practices and correctly classified 21.7% of the cases. The results showed that the overall poultry count positively affected vaccination practices and booster doses of HPAI ($p < 0.05$). In particular, an increase in the overall poultry count was associated with an increased likelihood of engaging in vaccination practices and administering a boosted HPAI vaccination dose.

Chicken head counts experienced a respective increase of 1.021-fold with vaccination and 1.025-fold with booster doses. The results also demonstrated that farmers raising poultry for consumption purposes were less likely to administer vaccinations than those raising poultry for meat sale, while the other variables remained constant. This study also found that the first dose of vaccination increased the likelihood of administering a booster HPAI dose ($p < 0.05$).

Table 2. Poultry farmer's profiles in survey areas.

No	Criteria	Categories	Results	
			Freq.	%
1	Age	18-40 years old	38	22.9
		> 40-60 years old	90	54.2
		> 60 years old	38	22.9
2	Gender	Male	110	66.3
		Female	56	33.7
3	Main occupation	Horticulture	58	34.9
		Animal husbandry	89	53.6
		Business	14	8.4
		Officer	5	3.0
4	Formal education	Primary school	65	39.2
		Secondary school	68	41.0
		High school	25	15.1
		Bachelor	8	4.8
		Graduate	-	-
5	Family member	1-3	77	46.4
		4-6	88	53.0
		> 6	1	0.6
6	Labor	≥ 50% family members	106	63.9
		< 50% family members	60	36.1
7	Training	Yes	79	47.6
		No	87	52.4
8	Income	< $100	142	85.5
		≥ $100	24	14.5

Res.: Respondent(s); $ refers to USD, 1 USD is equal to 24.000 VND in this study; Freq.: Frequency.

Discussion

Zoonosis is particularly dangerous to people raising livestock. Zoonosis can start and spread if livestock farmers lack basic knowledge, ignore biosecurity precautions, and do not take care of their health (Cediel *et al.*, 2012). In addition, various factors, including people's histories, experiences, access to information sources, social environments, and individual interpretations may affect how people perceive the risk of contracting a disease (Hinjoy *et al.*, 2023). Notably, Guntoro *et al.* (2023) stated that social profiles should be carefully examined to determine appropriate farm practices, as understanding production systems is an important factor in determining how farmers practice

Table 3. Poultry production characteristics.

No	Criteria	Categories	Results	
			Freq.	%
1	Number of poultry	Heads	89.72 ± 220.6	
2	Kind of livestock raising at the farm	Poultry	54	32.5
		Mixed livestock	112	67.5
3	Raising purpose	For selling meat	85	51.2
		For selling egg	2	1.2
		For consumption	72	43.4
		Mixed	7	4.2
4	Farming system	Seasoning farm	12	7.2
		Semi-intensive farm	148	89.2
		Mixed	6	3.6
5	Raising methods	Free-range farming	134	80.7
		Semi-free-range farming	25	15.1
		Caging farming	7	4.2
6	Chick source	Chicks produced at farm	141	84.9
		Hatchery	17	10.2
		From other farms	7	4.2
		From companies	1	0.6

Freq.: Frequency.

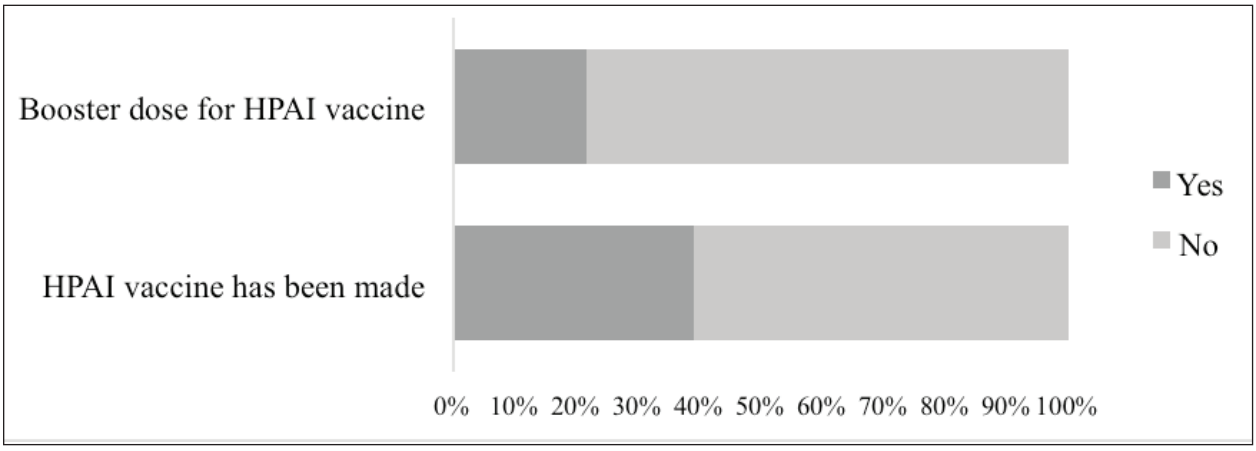

Fig. 3. HPAI vaccination practices at the farms (n = 166).

disease prevention. Accordingly, the social profile results in this study were consistent with those of previous studies (Delabouglise *et al.*, 2020; Qui *et al.*, 2020, 2021).

In this study, it was noted that the traditional raising method persisted in Tra Vinh Province. Farmers raise poultry for household consumption using free-range raising methods, which can increase the risk of disease outbreaks owing to the lack of prevention practices. This method is predominantly employed by small farmers, with poultry production typically ranging from 80 and 200 heads (GSO, 2017), accounting for 90% of the farms observed in the current study. Notably, backyard poultry consumption is unsafe for human health and poses environmental problems. Furthermore, the poultry value chain in Tra Vinh Province has traversed various channels, with poultry primarily being fed agricultural byproducts, which could be a source of infectious diseases (Qui and Tho, 2023).

According to Ritter *et al.* (2017), every farmer has an individual combination of demographic characteristics (such as gender, age, and education), past experiences,

Table 4. Effects of socioeconomic status on HPAI vaccination practices.

Variables	Vaccination practices [a] (*n* = 166)			Booster dose practices [b] (*n* = 166)		
	Coef.	Odds ratio	Sig.	Coef.	Odds ratio	Sig.
Age						
40–60 years old	-	-	-	-	-	-
18–40 years old	−0.026	0.974	0.958	0.934	2.544	0.113
− >60 years old	−	0.399	0.189	−0.435	0.648	0.587
Gender	−					
Men	-	-	-	-	-	-
Women	0.172	1.188	0.681	−0.109	0.897	0.859
Occupation						
Animal husbandry	-	-	-	-	-	-
Horticulture	1.060	2.888	0.508	−1.061	0.346	0.520
Business	2.062	7.860	0.213	0.019	1.020	0.991
Officer	2.514	12.354	0.150	−1.778	0.169	0.418
Education						
Secondary school	-	-	-	-	-	-
Primary school	0.058	1.060	0.894	−0.255	0.775	0.670
High school	0.511	1.667	0.405	0.378	1.460	0.596
Bachelor	1.058	2.879	0.431	−0.218	0.804	0.876
Number of household family members						
4–6 members	-	-	-	-	-	-
1–3 members	**−1.386****	0.250	0.002	−0.504	0.604	0.380
>6 members	−21.698	0.000	1.000	−18.025	0.000	1.000
Percentage of family members engaged in labor						
<50% family members	-	-	-	-	-	-
≥50% family members	0.770	2.159	0.105	0.404	1.498	0.511
Training						
No	-	-	-	-	-	-
Yes	**1.101****	3.007	0.008	**3.075****	21.646	0.000
Income						
<100$ per month	-	-	-	-	-	-
≥100$ per month	0.867	2.380	0.112	0.973	2.645	0.115
Constant	−1.687	0.185	0.026	−3.153	0.043	0.005

Coef: coefficient; Sig: significant. **, significant at $p < 0.01$. The *Nagelkerke* R^2 for HPAI vaccination practices was 32.5%, while that for boosted HPAI dose practices was 49.4%. [a] For HPAI vaccination practices, the baseline was set as "vaccinated," where "vaccinated" includes 65 respondents and "not vaccinated" includes 101 respondents. [b] For HPAI booster dose practices, the baseline was set as "Yes," where "Yes" includes 36 respondents and "No" includes 130 respondents.

personality, routines, objectives, and cultural, economic, and family influences. These unique traits affect farmers' perceptions of preventive measures, animal health, management techniques, and decision-making. In this study, neither gender nor age trends among participants in any group were linked to their decisions regarding livestock vaccination. Despite the prominence of male poultry farmers in Tra Vinh

Table 5. Effects of farming characteristics on HPAI vaccination practices.

Variables	Vaccination practices [a]			Booster dose practices [b]		
	Coef.	Odds ratio	Sig.	Coef.	Odds ratio	Sig.
Types of livestock						
Poultry	-	-	-	-	-	-
Mixed livestock	0.418	0.658	0.412	1.547	4.696	0.150
Number of chickens	**0.020***	1.021	0.018	**0.025***	1.025	0.021
Chick sources						
Chicks at the farm	-	-	-	-	-	-
Hatchery	−39.824	0.000	0.999	−35.181	0.000	0.999
From other farms	−39.007	0.000	0.999	−36.381	0.000	0.999
From companies	−39.405	0.000	0.999	−20.386	0.000	1.000
Raising purpose						
Selling meat	-	-	-	-	-	-
For selling eggs	28.881	3.490e+12	1.000	55.964	2.019e+24	1.000
For consumption	**-1.244***	0.288	0.021	-3.372	0.034	0.088
Mixed	−21.49	0.000	0.999	−17.10	0.000	0.999
Farming system						
Seasonal farming	-	-	-	-	-	-
Semi-intensive farming	−40.334	0.000	0.991	−15.118	0.000	0.999
Mixed	21.093	1.446e+6	0.998	16.744	1.870e+4	0.999
Raising methods						
Free-range farming	-	-	-	-	-	-
Semi-free-range farming	−2.271	0.103	0.124	32.177	9.422e+10	0.999
Caging farming	−2.401	0.091	0.133	32.628	1.479e+11	0.999
HPAI availability						
No	-	-	-	-	-	-
Yes	0.635	1.887	0.452	−2.063	0.127	0.079
Vaccination						
No vaccination	-	-	-	-	-	-
First dose of vaccination	-	-	-	**3.069****	21.527	0.008
Constant	−1.730	0.177	1.000	−37.44	0.000	0.998

Coef.: co-efficiency; Sig.: significant. *, significant at $p < 0.05$; **, significant at $p < 0.01$. The *Nagelkerke* R^2 for HPAI vaccination practices was 57.4%, and for HPAI, the boosted dose practice was 78.3%. [a] For HPAI vaccination practices, the baseline was set as "vaccinated," where "vaccinated" includes 65 respondents and "not vaccinated" includes 101 respondents. [b] For HPAI booster dose practices, the baseline was set as "Yes," where "Yes" includes 36 respondents and "No" includes 130 respondents.

Province and their greater influence on household decisions, given that they do not usually participate in household work, male farmers have more free time after farming activities than female farmers. This allows them to interact with extension officers and exchange information about disease prevention (Qui *et al.*, 2021). In addition, although men occasionally have greater control over larger animals and women have more control over smaller animals (such as chickens and small ruminants), such conditions are not universally applicable (Ransom *et al.*, 2017).

The dominant proportion of males on the surveyed farms was similar to that reported by Guntoro *et al.* (2023). However, this study did not note any effects of gender on vaccination practices. According to Guntoro *et al.* (2023), farmers with limited education are less likely to be familiar with animal disease-control techniques. In contrast, owners who receive education are more informed, which enables them to prevent illness and eliminate poor habits (Seid *et al.*, 2020). Notably, in the current study, although most farmers in Tra Vinh Province attended primary and secondary schools

and had basic knowledge, they lacked practicing HPAI vaccination. However, as farmers' experience increased, there was a corresponding improvement in their understanding and ability to prevent diseases. Importantly, veterinarians most frequently cite farmers' ignorance and lack of understanding as reasons why clients may not adopt various biosecurity measures (Pritchard *et al.*, 2015), including vaccination. In addition, according to Cui *et al.* (2019), the duration of experience in poultry farming is significantly correlated with the implementation of personal safety and biosecurity prevention practices.

Regarding the number of household family members, this study found that an increase in the number of family members in the household led to increased vaccination practices. Notably, the presence of more people at home people at home facilitates farmers in organizing and implementing vaccination procedures. This may be attributed to the fact that having additional help allows them to efficiently arrange their farming activities and allocate more time to vaccination. In addition, as previously mentioned, the number of family members in the household affected the farmers' willingness to adopt technologies or innovations at their farms, including vaccination practices (Gao *et al.*, 2017).

Previous experience with HPAI has been noted to affect the ratio of poultry vaccinations (Ritter *et al.*, 2017). Furthermore, access to an efficient and safe vaccine and previous exposure to the disease are important factors that may influence farmers' vaccination decisions (Zhang *et al.*, 2017). However, the current study did not record this information due to the low proportion of farmers in Tra Vinh Province with experience in the HPAI outbreak, constituting less than 6%. Moreover, poultry volumes did not contribute substantially to the farmers' income, which is typically the focus of most small farmers. This finding aligns with the results of Whelan *et al.* (2021), revealing no significant results in connecting past experiences with HPAI vaccination practices. This finding is likely due to the small number of farmers with HPAI experience. Another influencing factor is the acknowledgment that perceived importance is a key mediating variable between past experiences and the adoption of behaviors (Whelan *et al.*, 2021). However, this study did not analyze "mediation," which can be a worthy subject in future research.

Training is also an indicator of increased vaccination practices on small poultry farms. According to Li *et al.* (2020), extension agencies arrange training to teach farmers how to use techniques efficiently and reduce performance uncertainty. According to Hahn and Truman (2015), education and the acquisition of new information contribute substantially to improving individuals' health knowledge. One strategy that aids in improving novice poultry producers' awareness and comprehension of the risks posed by HPAI is the creation of a community platform in which seasoned poultry farmers can exchange experiences and specific expertise. As part of the community mentorship program, government representatives or regional livestock officials should focus on the development of various forums to exchange knowledge and experiences (Hinjoy *et al.*, 2023), thereby increasing disease prevention methods. Thus, training is recognized as one of the effective communication channels that may increase prevention practices against HPAI, including vaccination, and thus increase the rate of HPAI vaccination for poultry on farms. However, as outlined by Mutua *et al.* (2019), given the difficulty in accessing services, the lack of well-trained veterinary staff has been recognized as a barrier to vaccine uptake. To address this issue, improving the educational system over time, fostering the younger generation's familiarity with technical advancements, and creating training programs to educate new farmers in the area emerge as potential strategies to improve vaccination rates on farms. Specifically, for senior farmers, participation in these training sessions may increase their awareness of zoonotic diseases (Moutos *et al.*, 2022), thereby increasing vaccination rates.

Traditionally, factors related to financial costs and rewards dominate the decision-making process. However, mounting evidence indicates that a number of additional elements, such as farmers' perceptions of risk, knowledge, control, incentives, emotions, and normative beliefs, can impact their actions (Doidge *et al.*, 2021). In this study, the consumption behaviors of farmers in Tra Vinh Province decreased the rate of poultry vaccination. Specifically, farmers tended to abstain from vaccination when raising poultry for household purposes. This practice might be rooted in the belief that livestock vaccination is unnecessary, as farmers often struggle to differentiate between vaccinated and unvaccinated animals (Mutua *et al.*, 2019). In addition, farmers' inclination to vaccinate their livestock varies depending on the type of livestock present on their farms, with farmers of cattle and small ruminants exhibiting greater enthusiasm for vaccination compared to their counterparts raising village chickens, possibly because of the diverse economic importance of various livestock species. In addition, the low number of poultry raised for consumption purposes disrupts vaccination efforts. Similarly, Rathod *et al.* (2016) reported that the level of commercialization plays a pivotal role in shaping attitudes toward immunization, with commercial farmers generally holding more favorable opinions of animal immunization than smallholder farmers.

The limited number of poultry on farms poses challenges to the feasibility of vaccination, as the associated costs outweigh the profits from poultry consumption. Consequently, the high cost of payment for vaccines compared to the relatively lower profits from poultry consumption renders vaccination financially unfavorable. This financial dilemma is highlighted by the findings of Ashfaq *et al.* (2020), who

discovered that many small- and medium-sized farmers struggled to control livestock diseases due to a lack of funding. Moreover, the predominant consensus among farmers in the species group is that the exorbitant costs associated with vaccines and other medications pose a formidable obstacle to effective disease control. This financial barrier could prevent farmers from applying the recommended treatment entirely. In addition, the vaccination status of small flocks is likely to be less closely monitored because they are less likely to be sold to larger towns, making vaccination less beneficial from the farmers' perspective (Delabouglise *et al.*, 2020).

Conclusion

The demographic profile of poultry farmers in Tra Vinh Province reveals a predominantly male population, mostly aged over 40, with animal husbandry as their primary occupation. Notably, these farmers were less likely to participate in farming training, and most did not administer HPAI vaccinations on their poultry farms. The prevailing poultry production system in the province remains small-scale, with an average of 80 heads per farm, primarily dedicated to household consumption. Specifically, a large number of farmers in the province raised their birds using a semi-intensive system employing the free-range method.

The adoption of HPAI vaccination practices was influenced by factors such as the number of family members in the household, engagement in training, and the overall poultry count. Furthermore, the administration of an initial vaccination dose increased the likelihood of the administration of a booster HPAI vaccination dose on poultry farms. As shown by these findings, training is a useful way to improve farmers' prevention practices, especially HPAI vaccination practices.

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Conflict of interest

The authors certify that there is no conflict of interest with any financial, personal, or other relationships with other people or organizations related to the material discussed in the manuscript.

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Author contributions

Qui, N. H. and Thu, N. T. A.: Research design; Linh, N. T.: Data analysis; Qui, N. H.: Methodology; Qui, N. H. and Thu, N. T. A.: Validation; Thu, N. T. A.: Investigation; Qui, N. H. and Thu, N. T. A.: Data curation; N.H.Q.: Writing-original draft preparation; N. H. Q., Linh, N. T. and Thu, N. T. A.: Writing—review and editing. All authors have read and agreed to the published version of the manuscript.

Data availability

All data are provided in the manuscript.

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