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Characterisation of chicken farms in Vietnam: A typology of antimicrobial use among different production systems

Chloé Bâtie[a,b,c,*], Le Thi Thu Ha[g], Etienne Loire[a,b,f], Dinh Bao Truong[d], Ha Minh Tuan[c], Ngo Thi Kim Cuc[c], Mathilde Paul[e], Flavie Goutard[a,b,c,f]

[a] CIRAD, UMR ASTRE, Hanoi, Viet Nam
[b] ASTRE, CIRAD, INRAE, Univ. Montpellier, Montpellier, France
[c] National Institute of Animal Sciences, Hanoi, Viet Nam
[d] Faculty of Animal Science and Veterinary Medicine, Nong Lam University, Ho Chi Minh, Viet Nam
[e] IHAP, ENVT, INRAE, Université de Toulouse, Toulouse, France
[f] National Institute of Veterinary Research, Hanoi, Viet Nam
[g] InterRisk Program, Faculty of Veterinary Medicine, Kasetsart University, Bangkok, Thailand

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ABSTRACT

The usage of antimicrobials in livestock production is a driver for antimicrobial resistance worldwide. Reducing the use of antibiotics in the animal sector is a priority and requires a change in practices. Vietnam has diverse husbandry and antimicrobial use practices. The objective of this study was to determine the socio-economic and technical factors associated with antibiotic usage patterns on chicken farms in the north and south of Vietnam. Semi-structured interviews (n = 34) and on-farm questionnaires (n = 125) were conducted to collect socio-economic, technical, biosecurity, health management, and antibiotic usage data. Using Multivariate Corresponding Analysis, we identified three production systems (A, B, C) and three patterns of antibiotic usage (1, 2, 3). Group A raised indoor exotic chickens in an intensive setting and was associated with group 1, which used antibiotics according to company recommendations for both treatment and prevention. Group C raised free-range chickens for their own consumption and was associated with group 2, which used antibiotics according to drugstore advice for treatment. Finally, group B was a market-oriented, semi-confined system associated with group 3, which practiced experience-based antibiotic use and overuse. Farms in the south of Vietnam were associated with group 3 and those in the north with group 2. The prediction of antibiotic usage patterns based on farming practices could lead to the identification of a group of farms to be targeted in order to foster the more prudent use of antibiotics in Vietnam.

1. Introduction

Vietnam is subject to rapid demographic and economic growth, which in turn has led to an increase in animal production. Even though pork remains the main meat consumed by the Vietnamese, chicken accounts for 27% of the total meat consumed and is increasing (shown by Cesaro et al., 2019), with the total number of chickens reaching 383 million heads in 2020 (GSOV, 2020a). To meet the increased demand, the Vietnamese government has promoted more industrial production methods in the agricultural restructuring plan for 2021 – 2025 (Prime Minister, 2021). Even so raising less than 100 chickens still represents 95.40% of household raising chickens (GSOV, 2016), Vietnam is currently undergoing a shift towards a more industrial production system that varies across different regions (GSOV, 2020b). The north of Vietnam tends to have more familial production system while the south is more industrialized (Coyne et al., 2020; Cesaro et al., 2019). Intensification of practice led to an increased antibiotic consumption and a higher dependency to it. Transitioning farms towards intensive production are also more likely to demonstrate improper antibiotic usage (ABU) (Robinson et al., 2017). As antibiotic resistance (ABR), is mainly driven by the misuse and overuse of antibiotics in humans, animals, and in the environment (Holmes et al., 2016), it is necessary to promote a change of practice towards prudent ABU.

The quantity of antimicrobial active ingredients used per kilogram of

* Corresponding author at: CIRAD, UMR ASTRE, Hanoi, Viet Nam.
E-mail address: chloe.batie@cirad.fr (C. Bâtie).

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animal is estimated to be 1.6 times higher in Vietnam than European countries (Carrique-Mas et al., 2020). Antibiotics are widely used as prophylactics (Choisy et al., 2019) and a high percentage of farmers self-medicate their animals (Pham-Duc et al., 2019), which is facilitated by easy access to drugs without diagnosis and prescriptions (Phu et al., 2019). Following the adoption of the national action plan (NAP) in 2017 (MARD, 2017), new legislations have been enforced as the ban of antimicrobials growth promoters (AGP) (National Assembly of the Socialist Republic of Vietnam, 2018), the ban of antibiotic in the feed for prophylaxis by 2025 (The Government of the Socialist Republic of Vietnam, 2020), and making the prescription mandatory (MARD, 2020). The new NAP (MARD, 2021), published in 2021, highlights the need for better enforcement of the recent regulations due to the low compliance rate of farmers (MARD, 2021). Providing an evidence-based study is thus necessary for policy makers to ensure better implementation and reduce ABU.

In this way, reducing antibiotic usage at the farm level requires a precise understanding of the system in which the strategy is implemented. Building a typology is a way to classify groups of farms that are approximately homogenous and for which the same recommendations can be made (Castel et al., 2010; Delpont et al., 2018). In Vietnam, three or four types of chicken production systems are usually described (backyard, semi-intensive and intensive farms) (Burgos et al., 2007; Desvaux et al., 2008; Duc and Long, 2008), but more complexity may be required to properly describe chicken farming diversity. Previous studies have determined heterogeneity in the amounts of antimicrobials used in different systems (Carrique-Mas et al., 2015) and in practices surrounding their usage (Kim et al., 2013; Luu et al., 2021). However, few studies have compared the usage between the 3 production systems at the same time.

The objectives of this study were to analyse technico-economic, socio-demographic and animal health management data on chicken farms in Vietnam, in order to characterise chicken farming systems, and explore associations between socio-economic, technical and antibiotic usage.

2. Material and methods

2.1. Local expert knowledge

To answer the research question, we conducted semi-structured interviews using participatory approaches (Catley et al., 2012) with experts specialised in chicken production or the veterinary drugs distribution chain in Vietnam between November 2019 and April 2020.

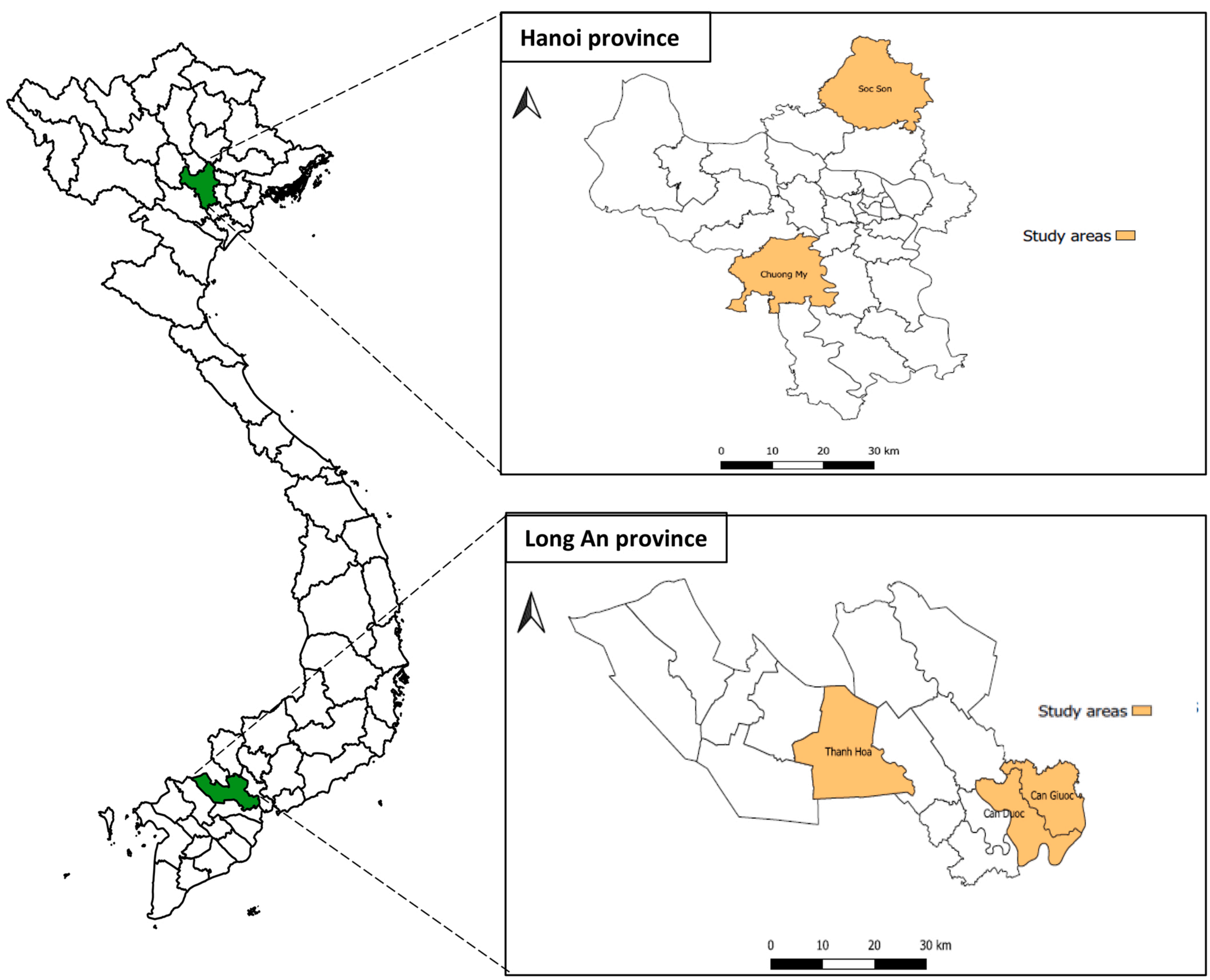

Fig. 1. Map of the study areas with the division into 63 provinces and zoom on Hanoi and Long An provinces. Hanoi and Long An provinces are represented in green. The five surveyed districts are represented in orange: Soc Son and Chuong My in Hanoi and Thanh Hoa, Can Duoc and Can Giuoc in Long An (Quantum GIS version 3.10.11).

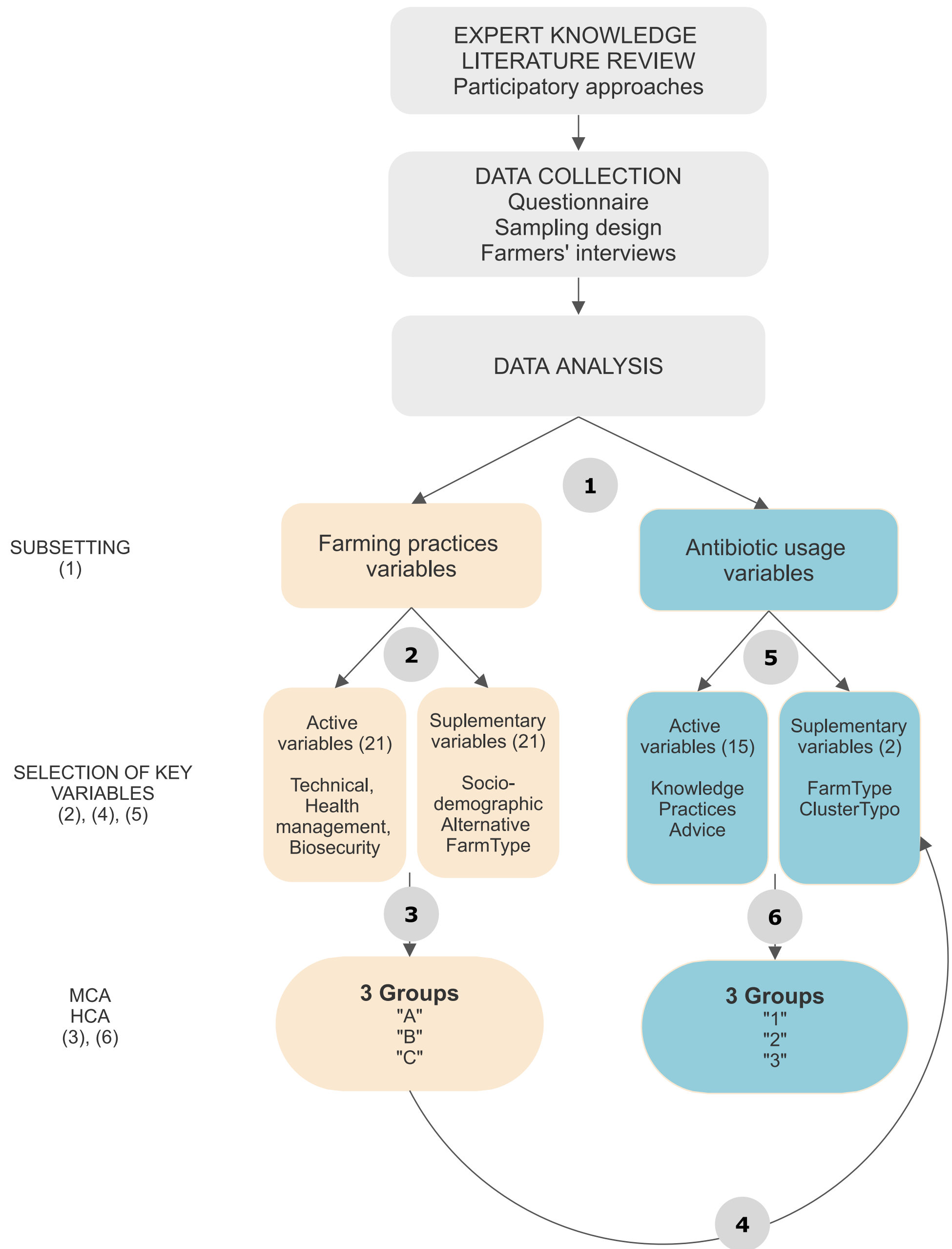

Fig. 2. Framework of the methodological process for typology of farming practices and antibiotic usage patterns.
Adapted from (Alvarez et al., 2018).

Experts were selected based on a list of contacts obtained for a previous study (Bordier et al., 2018) and through snowball sampling. Interviews were conducted by one or two researchers face-to-face, or over the phone, in the north and south of Vietnam. The average duration of each interview was 60 min and Vietnamese, English, or French languages were used. Data were collected by note-taking and the flowchart of each production system described by the participant was drawn. Respondents were free to directly modify the flowchart during the interview when conducted face to face. All the flow charts were compiled in a single one and transcripts were analysed.

2.2. Sampling and data collection

To assess the diversity of farming practices and antibiotic usage across Vietnam, we selected two provinces: Hanoi in the Red River Delta (RRD) region and Long An in the Mekong Delta (MD) region, respectively in the north and south of Vietnam. The RRD has the largest chicken population accounting for nearly 24,1% of the national population and the MD for 14,0% (GSOV, 2020a). The two surveyed provinces were selected based on their number of chickens, diversity of production and ease of access. Moreover, they play an important socioeconomic role in both regions due to their proximity to two important cities: Hanoi and Ho Chi Minh City. According to the census data, Hanoi has the highest number of poultry (27,7%) while Long An ranks second (12.4%) in the total population of chicken of RRD and MD regions respectively (GSOV, 2020a).

Within these two provinces, 10 communes in five different districts (Chuong My and Soc Son, in the north; Thanh Hoa, Can Duoc, and Can Giuoc, in the south) were chosen based on chicken density, diversity of farming practices, and prior approval from local authorities (Fig. 1). To capture farm diversity, we selected the farms using a stratified sampling method based on four strata defined by expert knowledge and stemming

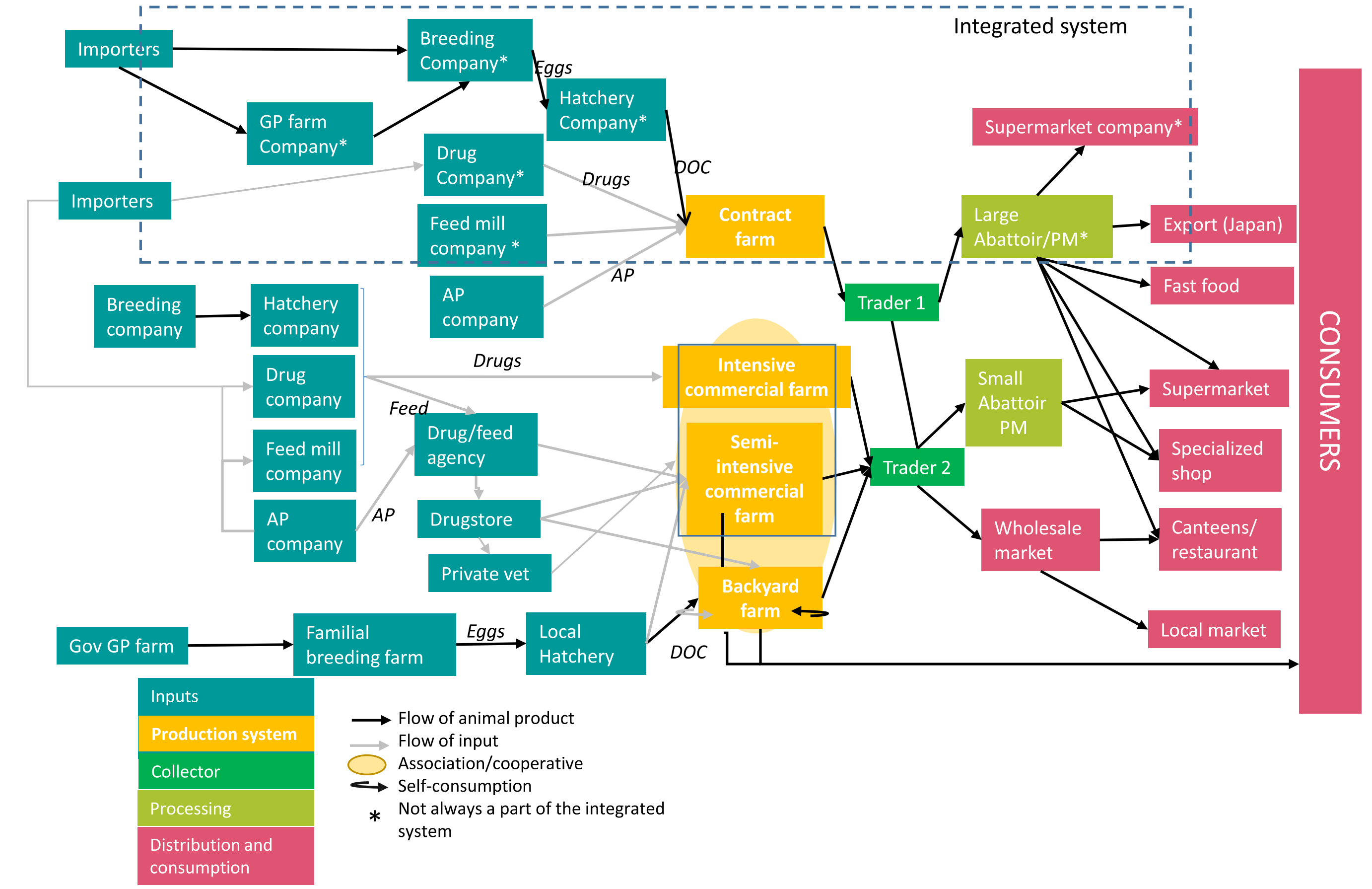

Fig. 3. Description of the chicken production value chain in Vietnam from stakeholders' interviews in 2020. AP: Alternative products; GP: Grandparents; PM: Process manufactory; DOC: day-old chicks.

from the literature review (Burgos et al., 2007; Desvaux et al., 2008; Duc and Long, 2008; Hanh et al., 2007). The four strata included backyard farms with fewer than 100 chickens, semi-intensive family commercial farms with between 100 and 2000 chickens, intensive family commercial farms with more than 2000 chickens, and contract farms with more than 2000 chickens that reared either broiler, laying hens, or roosters. We sampled 125 farms with an equal distribution between provinces and strata to maximise the diversity while taking technical constraints into account. Farms were randomly selected from a list drawn up by the communal veterinarians.

A structured questionnaire including 110 close-ended questions was designed around four main sections: (i) socio-demographic and economic data; (ii) farm characteristics (technical characteristics, inputs, outputs, biosecurity); (iii) health management (disease management, training courses, records); (iv) antibiotic usage. Farm visits were conducted in June and July 2020 by two research teams of 3 researchers from the National Institute of Animal Science (NIAS) in Hanoi province and 2 students and 1 teacher from Nong lam University (NLU) in Long An province. The questionnaire was designed and addressed in paper version (Hanoi) and on a web interface – KoBoToolbox using tablets (Long An) (Pham and Vinck, 2020). Paper versions were then reported on the web interface. The questionnaire was tested and reviewed through three pilot studies, two in Hanoi and one in Long An. Both teams were trained on data collection.

The objectives of the survey were explained, and written informed consent was obtained from all farmers before each interview. This study was approved by the Ethics Review Board for biomedical research of Hanoi University of Public Health with the application number 020–150/DD-YTCC.

2.3. Data management and analysis

Data gathered through the Kobotool box were loaded onto a Microsoft Excel© datasheet and then cleaned using R software version 3.6.3. The "factoextra" (Kassambara and Mundt, 2020), "FactomineR" (Husson et al., 2020), and "Factoshiny" (Vaissie et al., 2021) packages were used for factorial and clustering analyses.

Farmers who did not answer the question "do you use antibiotics" were excluded from the dataset. Two sub-datasets were created: farmers who used antibiotics in which the multivariate analysis was conducted and farmers who did not use antibiotics.

A Multiple Correspondence Analysis (MCA) followed by a Hierarchical Cluster Analysis (HCA) were performed to classify farm groups displaying the same characteristics and antibiotic usages (Husson et al., 2017). We used the Principal Components (PC) that explained more than 50% of the total variance from the MCA for the HCA with consolidation according to Ward's method applied to individuals situated in a Euclidian space (Husson et al., 2017). The number of factors was determined based on the loss of within-group inertia and the interpretability of the classes. The similarity between individuals was explored by assessing the relationships between variables and then assigning them into farm groups (clusters) according to the pattern of variables (Husson et al., 2017).

We separated the 192 variables obtained from the questionnaire into 154 farming practice variables and 38 ABU variables.

To create the typology of farming practices, out of the 154 variables, we introduced 21 relevant variables in the first MCA/HCA as active variables and 22 as supplementary variables. The number of key variables is usually recommended to be 5 times less than the sample size (Alvarez et al., 2018). The other variables were removed because they

Table 1
Socio-demographic characteristics of the 111 Vietnamese chicken farms surveyed in 2020.

Variables		Total n (%)
Gender		
	Male	85 (76.6)
	Female	26 (23.4)
Age group		
	< 30	13 (11.7)
	30–45	28 (25.2)
	46–60	51 (46.0)
	> 60	19 (17.1)
Education		
	Illiterate/primary school	6 (5.4)
	Secondary school	49 (44.1)
	High school	38 (34.2)
	College or higher	18 (16.2)
Occupation		
	Owner	98 (88.6)
	Employee	13 (11.4)
Year farming experience		
	< 5	21 (18.9)
	5–10	34 (30.6)
	11–15	21 (18.9)
	> 15	32 (28.8)
Farm status		
	Family	87 (78.4)
	Contract/company	24 (21.6)
Type main of chicken		
	Broilers	70 (63.0)
	Laying hens	36 (32.4)
	Roosters	5 (4.6)
Chicken breed		
	Foreign	37 (33.3)
	Crossbreed	43 (38.7)
	Local	31 (28.0)

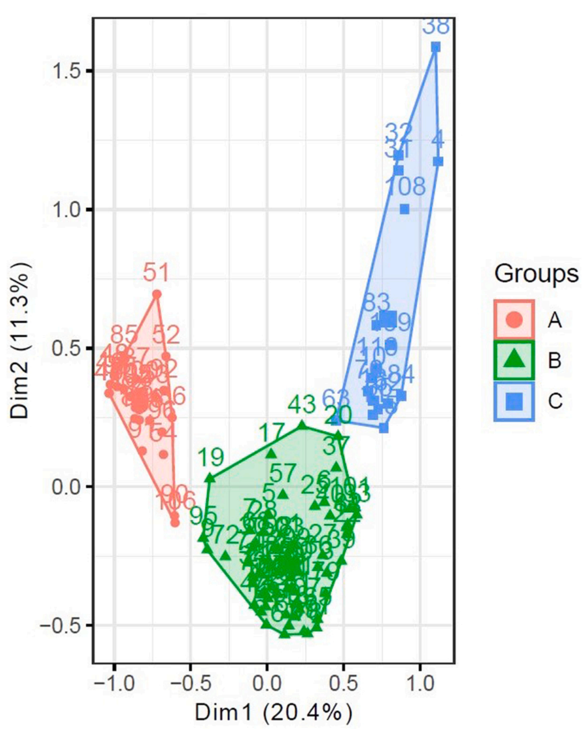

Fig. 4. Projection of the 111 Vietnamese chicken farms on the first two dimensions within the 3 groups identified through MCA and HCA performed on farming practices variables.

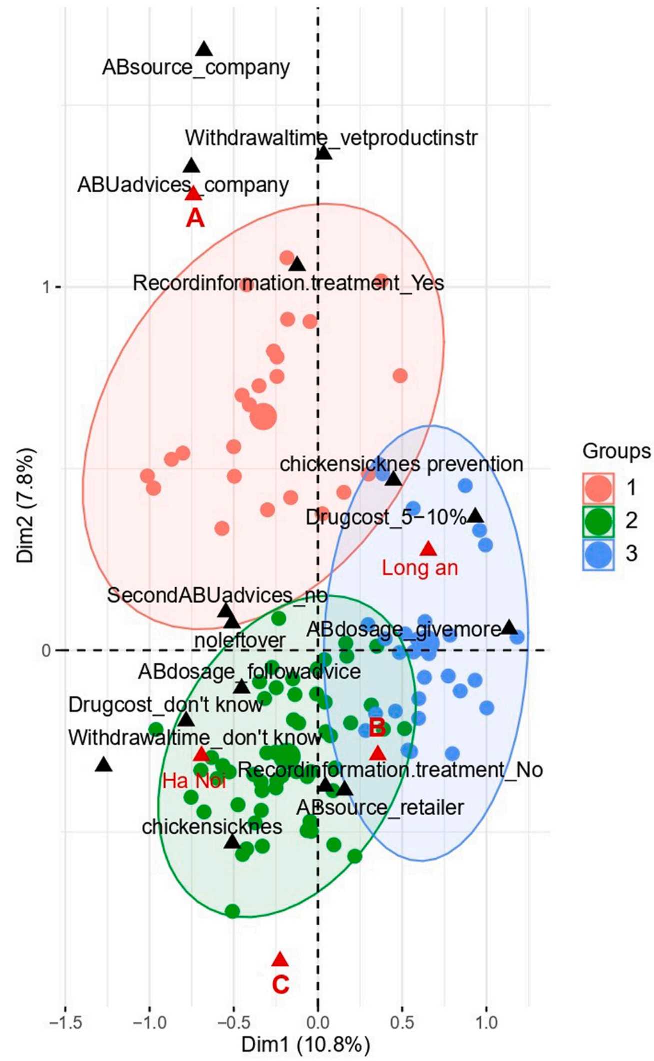

Fig. 5. Projection of the 111 Vietnamese chicken farms on the first two dimensions within the 3 groups identified through MCA and HCA performed on antibiotic usage patterns.
In black: categories of variables that most characterise the farms; in red: *ClusterTypo* and *FarmType* (supplementary variable).

were either compiled into a new one, correlated with other variables that were homogeneous in response, or not addressed by all respondents (Ornelas-Eusebio et al., 2020). The 3 groups were described from categories that were overexpressed (p-value less than 5%) in the group and they were transformed into a new variable called, *ClusterTypo*.

To create the typology on ABU, out of the 38 ABU variables, 15 were included in the second MCA/HCA. Then, *ClusterTypo* was introduced in the analysis as a supplementary to identify the association between farming practices and ABU (Fig. 2).

3. Results

3.1. Semi-structured interviews

Thirty-four interviews were conducted in Hanoi and Ho Chi Minh City from November 2019 to April 2020 with 18 experts from the public sector and 16 from the private sector. We identified 4 production systems characterised by their socio-demographic data, farm management, value chain, and antibiotic usage. Each farming system was defined according to its farm characteristics, place within the chicken value chain, health management, and antibiotic use (Fig. 3).

Table 2
Frequency of ABU variables categories according to the 3 groups on ABU patterns identified from the MCA/HCA performed on the 111 Vietnamese chicken farms surveyed in 2020. Categories that are over-represented within each group figure in bold and under-represented in italics, * : $p < 0.05$, **: $p < 0.01$, *** : $p < 0.001$.

Variables	AB farms (n = 111)	Group 1 (n = 25)		Group 2 (n = 57)		Group 3 (n = 29)	
KNOWLEDGE							
AB definition							
Correct	6 (5.4%)	1 (4.0%)		4 (7.0%)		1 (3.4%)	
Partially correct	66 (59.5%)	14 (56.0%)		28 (49.1%)	*	**24 (82.8%)**	**
Incorrect	39 (35.1%)	10 (40.0%)		25 (43.9%)		*4 (13.8%)*	**
Source of training							
Public	10 (9.0%)	0 (0.0%)		*1 (1.8%)*	**	**9 (31.0%)**	***
Private	38 (34.2%)	10 (40.0%)		*22 (38.6%)*	*	6 (20.7%)	
Both	10 (9.0%)	4 (16.0%)		5 (8.8%)		1 (3.4%)	
No training	53 (47.8%)	11 (44.0%)		29 (50.9%)		13 (44.8%)	
Record information on treatment							
Yes	29 (26.1%)	**18 (72.0%)**	***	*2 (3.5%)*	***	9 (31.0%)	
No	82 (73.9%)	*7 (28.0%)*	***	**55 (96.5%)**	***	20 (69.0%)	
USAGE							
Reason							
Treatment	52 (46.9%)	*7 (28.0%)*	*	**40 (70.2%)**	***	*5 (17.2%)*	***
Treatment and prevention	59 (53.1%)	**18 (72.0%)**	*	*17 (29.8%)*	***	**24 (82.8%)**	***
Growth promotion	0 (0.0%)	0 (0.0%)		0 (0.0%)		0 (0.0%)	
AB in the feed							
Yes	12 (10.8%)	2 (8.0%)		3 (5.3%)		**7 (24.1%)**	*
No	99 (89.2%)	**23 (92.0%)**		54 (95.7%)		*22 (75.9%)*	*
ADVICE							
First source of advice							
Company	27 (24.3%)	**23 (92.0%)**	***	*3 (5.3%)*	***	*1 (3.4%)*	**
Drugstore	34 (30.6%)	*1 (4.0%)*	***	**28 (49.1%)**	***	5 (17.2%)	
Local veterinarian	15 (13.5%)	*0 (0.0%)*	*	**14 (24.6%)**	***	1 (3.4%)	
Own experience	35 (31.5%)	1 (4.0%)	***	12 (21.1%)	*	**22 (75.9%)**	***
Second source of advice							
Company	14 (12.6%)	*6 (24.0%)*	*	5 (8.8%)		3 (10.3%)	
Drugstore	16 (14.4%)	1 (4.0%)		*2 (3.5%)*	***	**13 (44.8%)**	***
Local veterinarian	7 (6.3%)	1 (4.0%)		14 (24.6%)		2 (6.9%)	
Other farmers	9 (8.1%)	0 (0.0%)		5 (8.8%)		4 (13.8%)	
Own experience	11 (9.9%)	0 (0.0%)		12 (21.1%)		5 (17.2%)	
No	54 (48.6%)	**No**	*	**35 (61.4%)**	**	*2 (6.9%)*	***
PRACTICES							
Source of AB							
Company	21 (18.9%)	**20 (80.0%)**	***	*0 (0.0%)*	***	*1 (3.4%)*	**
Retailers	90 (81.1%)	*5 (20.0%)*	***	**57 (100.0%)**	***	**28 (96.5%)**	**
Drug cost							
< 3%	15 (13.5%)	2 (8.0%)		**12 (21.1%)**	*	1 (3.4%)	
3–5%	11 (9.9%)	1 (4.0%)		8 (14.0%)		2 (6.9%)	
5–10%	30 (27.0%)	7 (28.0%)		*4 (7.0%)*	***	**19 (65.5%)**	***
> 10%	18 (16.2%)	5 (20.0%)		8 (14.0%)		5 (17.2%)	
Don't know	37 (33.3%)	10 (40.0%)		**25 (43.9%)**	*	*2 (6.9%)*	***
Dosage							
More	27 (24.3%)	2 (8.0%)		*5 (8.8%)*	***	**20 (69.0%)**	***
Follow advice	79 (70.3%)	20 (80.0%)		**51 (89.5%)**	***	*7 (24.1%)*	***
Less	6 (5.4%)	3 (12.0%)		1 (1.8%)		2 (6.9%)	
Duration							
More	9 (8.1%)	0 (0.0%)		3 (5.3%)		**6 (20.7%)**	*
Follow advice	83 (74.8%)	21 (84.0%)		**48 (84.2%)**	*	*14 (48.3%)*	***
Less	5 (4.5%)	0 (0.0%)		*0 (0.0%)*	*	**5 (17.2%)**	***
Until recover	14 (12.6%)	4 (16.0%)		6 (10.5%)		4 (13.8%)	
Administer all chickens							
Yes	89 (80.2%)	19 (76.0%)		43 (75.4%)		**27 (93.1%)**	*
No	22 (19.8%)	6 (24.0%)		14 (24.6%)		*2 (6.9%)*	*
Measure not cured							
Ask for advice	21 (18.9%)	4 (16.0%)		7 (12.3%)		**10 (34.5%)**	*
Cull	5 (4,5%)	1 (4.0%)		2 (3.5%)		2 (6.9%)	
Change AB	79 (71.2%)	19 (76.0%)		43 (75.4%)		17 (58.6%)	
Don't have the case	6 (5.4%)	1 (4.0%)		5 (8.8%)		0 (0.0%)	
Withdrawal time							
Veterinarian or product instruction	15 (13.5%)	**10 (40.0%)**	***	*2 (3.5%)*	*	3 (10.3%)	
Own experience	81 (73.0%)	*11 (44.0%)*	***	45 (79.0%)		25 (86.2%)	
Don't know	15 (13.5%)	4 (16.0%)		10 (17.5%)		1 (3.4%)	
Leftover							
Keep	38 (34.2%)	*4 (16.0%)*	*	16 (28.1%)		**18 (62.1%)**	***
Throw away	13 (11.7%)	2 (8.0%)		5 (8.8%)		6 (20.7%)	
No leftover	60 (54.0%)	*19 (76.0%)*	*	36 (63.2%)		*5 (17.2%)*	***
SUPPLEMENTARY VARIABLES							
Farm type							
Backyard	22 (19.8%)	0 (0.0%)	**	**18 (31.6%)**	* *	4 (13.8%)	

(*continued on next page*)

Table 2 (*continued*)

Variables	AB farms (n = 111)	Group 1 (n = 25)		Group 2 (n = 57)		Group 3 (n = 29)	
Semi-intensive	28 (25.2%)	2 (8.0%)	*	17 (29.8%)		9 (31.0%)	
Intensive family	37 (33.3%)	*3 (12.0%)*	**	19 (33.3%)		**15 (51.7%)**	*
Contract	24 (21.6%)	**20 (80.0%)**	***	*3 (5.3%)*	***	*1 (3.4%)*	**
ClusterTypo							
A	26 (23.4%)	**22 (88.0%)**	***	*3 (5.3%)*	***	*1 (3.4%)*	**
B	68 (61.3%)	*3 (12.0%)*	***	40 (70.2%)		**25 (86.2%)**	**
C	17 (15.3%)	*0 (0.0%)*	**	**14 (24.6%)**	**	3 (10.3%)	

3.2. Description of the study population

Out of the 125 selected farms, 7 were initially removed from the dataset, and 7 did not use any antibiotics (Supplementary materials). The MCA/HCA analysis was performed on 111 farms 54 in Hanoi province and 57 in Long An province. In total, we surveyed 22 (19.8%) backyard, 28 (25.2%) semi-intensive, 37 (33.3%) intensive and 24 (21.6%) contract farms. Socio-demographic data are presented in Table 1.

3.3. Typology of farming practices

We selected the first six components of the MCA that explained 50% of the total variance to perform the HCA (supplementary materials). We then selected three groups based on the total loss of inertia and the ability to describe them (Husson et al., 2017). We called these A, B, and C (Fig. 4). The active variables that best characterised the partitioning into three groups were: the main outlet of the farm's products, the source of supply of Day-Old Chicks (DOCs) or pullets, duration of the downtime period, whether fed with cereals, and the presence of a biosecurity protocol (supplementary materials).

Group A included 27 farms, which mainly raised exotic breed chickens in a closed, equipped building with biosecurity measures. This system was characterised by the full integration of the farm through a contract with a chicken company (from DOC to final product) for most of the farms. Farmers were young (under the age of 30), had less than 5 years of experience, and graduated from college or further higher education.

Group B included 67 farms, mainly raising crossbreed chickens (mix between a local and an exotic breed) raised in a semi-confined system without automatic facilities and biosecurity. DOCs and/or pullets were usually supplied by a local hatchery or hatchery companies and the farm products were sold mostly through middlemen. The respondents were experienced farmers (more than 15 years) and graduated from secondary school. They combined poultry production with other agriculture-related activities and worked alone or with their family.

Group C included 17 farms, raising local breed chickens in semi-confined or in a free-range system in contact with other poultry. DOCs and pullets were produced on-farm and chickens were raised mainly for their own consumption or sold directly. Poultry production was not their main activity and represented less than 25% of their income. The 3 groups are fully described in the supplementary materials.

From these groups a new variable, called *ClusterTypo* was created with the 3 groups as categories.

3.4. Typology of antibiotic usage

We selected the first six components of the MCA, explaining 50% of the total variance, to perform the HCA (supplementary material). From the HCA, we selected three groups (named 1, 2 and 3, Fig. 5) based on the total loss of inertia and the ability to describe them.

The active variables that best characterised the partitioning into three groups were: the primary source of advice (*ABUadvice*), the source of AB supply (*source*), recording information on the treatment (*Record information. treatment*), the dosage of antibiotics (*ABdosage*), and the secondary source of advice (*SecondABUadvice*).

Group 1 (n = 25) included farmers who sought advice on ABU from companies (chicken, drug, or feed company) from which they also purchased antibiotics. Antibiotics were used for prevention and treatment, according to the recommendations provided by the company. Group 2 (n = 57) included farmers who used AB according to the advice provided by the local drugstore or veterinarian. They purchased antibiotics from retailers (local veterinarians or drugstores). Antibiotics were only used for treatment and according to retailer instructions. Finally, group 3 (n = 29) did not seek professional advice and used AB based on their own experience. Antibiotics were used for treatment and prevention at a higher dosage and duration than indicated by the veterinarian or indicated on the product (the details are shown in Table 2).

3.5. Association between farming practices typology and antibiotic usage patterns

The results showed that group A was associated with group 1 (88% of farms in group A are in group 1), group B with group 3 (86.2%), and group C with group 3 (24.6%) (Fig. 5).

We then tested the association between the pattern of ABU and the farming practice variables including socio-demographic variables. The Long An province was statistically associated with group 3 and Hanoi province was associated with group 2 (Table 3).

4. Discussion

In this study, we identified three chicken production systems associated with three different ABU patterns. This exploratory approach allowed us to anticipate an ABU pattern based on the production system adopted by the farms in northern and southern Vietnam. The relationship between the production system and ABU in Vietnam has been explored before (Kim et al., 2013; Luu et al., 2021). But to our knowledge, this is the first study to explore the association between farming practices (as a group or by individual variables) and patterns (which group several variables associated with each other) of ABU in northern and southern Vietnam.

From the multivariate analysis, we identified three contrasting chicken production systems. Group A represents a very distinct group of contract farms comprising of a vertical integration by foreign multinationals (Duc and Long, 2008). The company provides all supplies to the integrated farm including AB and sells the meat and eggs to supermarkets or catering facilities. Group B consists of family commercial farms that have developed a market-oriented production of hundreds to thousands of hybrid chickens, sold on the local market, raised in a semi-confined system and fed with commercial feed. Group C is made of backyard farms characterised by a few dozen local breed chickens raised in an extensive system for the household's own consumption. Our results are in line with those found in the literature (Burgos et al., 2007; Delabouglise, 2015; Desvaux et al., 2008; Duc and Long, 2008). It is noteworthy that the respondents from the semi-structured interviews divided group B into two production systems: intensive and

Table 3
Association between categories of farming practice variables and the three ABU patterns that are statistically ($p < 0.05$) significant.

Group 1	Category of farming practices variable	p.value	Group 2	Category of farming practices variable	p.value	Group 3	Category of farming practices variable	p.value
	DOC/pullet supplier_chicken company	1.1×10^{-12}		Technical record_No	4.6×10^{-8}		Province_Long An	5.2×10^{-8}
	Technical Record_Yes	3.2×10^{-12}		Automatic water_No	1.4×10^{-6}		Main outlet_middle men	2.9×10^{-6}
	Employees_Yes	1.9×10^{-10}		Province_Hanoi	3.2×10^{-6}		Feed cost_65–80%	3.3×10^{-4}
	Protocol of biosecurity_Yes	6.0×10^{-10}		Protocol of biosecurity_No	3.9×10^{-5}		Breed_local	1.6×10^{-3}
	Breed_foreign	3.4×10^{-9}		Income from poultry activity_< 25%	2.1×10^{-4}		Employee_No	1.7×10^{-3}
	Automatic water_Yes	1.8×10^{-8}		Pest control_No	4.5×10^{-4}		Scavenging feed_Yes	1.2×10^{-2}
	Entering in the farm_ vet and staff only	6.1×10^{-7}		Employees_No	6.7×10^{-4}		Alternative product in feed_probiotic Vitamin electrolyte detox	1.4×10^{-2}
	Investment source_company	2.4×1^{-6}		Hire land_No	7.2×10^{-4}		Anticoccidial drugs_Yes	2.1×10^{-2}
	Housing_inside	5.6×10^{-6}		Education_secondaryschool	8.1×10^{-4}		Housing_in and out	3.6×10^{-2}
	Deworming_No	6.3×10^{-5}		Cereals_Yes	1.1×10^{-3}			
	Hire land_Yes	1.7×10^{-4}		Productive crop_Yes	2.0×10^{-3}			
	Age_< 30	1.7×10^{-4}		Main activity_agriculture	4.9×10^{-3}			
	Main activity_poultry	2.6×10^{-4}		Entering in the farm_different visitors	5.4×10^{-3}			
	Scavenging feed_No	4.7×10^{-4}		Main outlet_own consumption	7.8×10^{-3}			
	Cereals feed_No	6.6×10^{-4}		Chicken breed_cross breed	2.3×10^{-2}			
	Anticoccidial drugs_No	8.0×10^{-4}		Fallowing tim_< 2 weeks	2.7×10^{-2}			
	Income from poultry activity_don't know	3.2×10^{-3}		Family worker_Yes	3.1×10^{-2}			
	Start working on the farm_< 5	4.3×10^{-3}		Investment source_own money	3.3×10^{-2}			
	Education_College/higher	5.6×10^{-3}		Deworming_Yes	3.9×10^{-2}			
	Productive crop_No	7.7×10^{-3}		Main outlet_direct selling	4.0×10^{-2}			
	Pest control_Yes	9.9×10^{-3}		DOC/pullet supplier_trader/market	4.0×10^{-2}			
	Fallowing period_2 weeks	1.0×10^{-2}		Investment source_own money and bank	4.5×10^{-2}			
	Borrow money_No	2.0×10^{-2}						
	Feed cost_51–65%	2.1×10^{-2}						
	Experience of farming_< 5	2.2×10^{-2}						
	Income from poultry activity_76–100%	2.9×10^{-2}						
	Other animals_Yes	4×10^{-2}						
	Give an alternative to sick animals_vitamins electrolytes or probiotics	5.0×10^{-2}						

semi-intensive family commercial farms. The combination of these two groups into a single group suggested that they shared similar characteristics and that intensification is not necessarily synonymous with industrialisation (Robinson and FAO, 2011).

The use of antibiotics for preventive purposes in livestock production is common in Vietnam (Carrique-Mas et al., 2015; Luu et al., 2021; Truong et al., 2019) and was, in the present study, found to be associated with contract and commercial farms (group A and B). The AB misuses (improper dosage, no professional advice) of group 3 were found to be associated with the family and commercially oriented production system (group B) that use more antibiotics than backyard farms (group C). Our findings are concordant with previous results that have shown that intensive farms use higher levels of antibiotics than backyard (Luu et al., 2021). Farmers who consume their own products tend to use fewer antibiotics for prevention (Kim et al., 2013) than commercially oriented systems.

In our study, no farmers reported the use of antibiotics as growth promoters, which was also found in other studies conducted after the implementation of the law (Luu et al., 2021; Pham-Duc et al., 2019) compared to previous studies (Kim et al., 2013). As using AB for growth promotion and prevention may be difficult to distinguish and may be under reported by farmers (Coyne et al., 2020), these results should be taken with caution. From semi-structured interviews, the addition of AB for growth promotions is still reported by respondents and more than half of the farmers (53,1%) reported using AB for both treatment and prevention. Eleven farms reported mixing AB into the feed and 10 used it after the 21 days allowed by the government (The Government of the Socialist Republic of Vietnam, 2020). These practices are associated with the group B. With a total ban of AB in feed for prophylaxis purposes planned for 2025, there is an urgent need to raise awareness among farmers and specifically target commercial family farmers.

Group C was associated with a pattern of ABU where farmers comply with the dosage instructions provided by retailers and better ABU (group 2), while group B was associated with a pattern where farmers do not follow the recommended dosage and use higher amounts of antibiotics (group 3). Another study reported that semi-industrial farms (that shared common characteristics with group B) have higher compliance with dosage than backyard (related to group C) (Luu et al., 2021). Our findings can be explained because group B is a large group that might include some farms that lie at the limit between backyard and family commercial farms. Increasing the biosecurity protocol of commercial farm could be a way to reduce the usage of antibiotic in commercial farm. In group A, the antimicrobial-decision-making system is driven by the company's orientation. When facing to a disease, farmers must call the veterinarian or the technician of the company, that will decide to give AB or not. Farmers also have a precise husbandry protocol with the vaccination and AB (in prevention) schedule. Targeting these companies is therefore an approach that can help to reduce ABU in integrated farms. We identified an association between the ABU pattern of group 2 with Long An province and of group 3 with Hanoi province. This difference between provinces can be explained by the fact that data collection was conducted by two different teams using different tools (paper version and tablet). However, no differences were identified between provinces regarding the typology of farming practices. We can hypothesise that the higher dosages of antibiotic observed in Long An province can be explained by a lower quality of the drug, as it has been found in the Mekong delta in south Vietnam (Yen et al., 2019). There is also a greater weather variation in the north which was associated with seasonal variation of outbreaks of highly pathogenic avian influenza while it was not the case in the south (Delabouglise et al., 2017). It has also been shown that the higher proportion of large-scale farms in the south was associated with the presence of more drugstores (Delabouglise, 2015). However, those differences don't correspond to our findings. It suggests that other factors could have an impact on the antibiotic usage such as political factors in relation with the organisation of the Vietnamese government.

The high proportion of farmers using antibiotics on the basis of their own experience has been widely documented in Vietnam (Kim et al., 2013; Pham-Duc et al., 2019; Truong et al., 2019). This practise is facilitated by the availability of cheap drugs (Carriques-Mas et al., 2019) over the counter (Carrique-Mas et al., 2015) as in other countries in Southeast Asia (Lekagul et al., 2020; Om and McLaws, 2016) and in the human health sector (McKinn et al., 2021). Drugstores have already been shown to be the main source of advice and supply for small-scale farms (Phu et al., 2019). But advice must progress towards more prudent ABU to efficiently reduce its usage. Drugstores must also to be included in the process of reducing antibiotic usage in Vietnam by improving their awareness and knowledge. Indeed, a three-year intervention study has demonstrated that providing professional advice to farmers on small-scale farms leads to a reduction in ABU (Phu et al., 2021). Currently, there is no surveillance system for ABU and ABR in Vietnam, developing it, is one of the objectives of the NAP. As experienced in a recent study, AB monitoring at drugstores level is a way to develop ABU surveillance in Vietnam (Ha et al., 2021). The new circular on prevention may also be a way of surveillance but further studies on the level of compliance of drug sellers in issuing prescriptions should be conducted.

Our study presents some limitations. As antibiotic usage can be a sensitive subject, especially when farmers do not comply with recommendations or regulations, answers related to the misuse or overuse of antibiotics may be biased. Moreover, a misunderstanding of the definition of antibiotics can also lead to erroneous answers. We limited this bias by adding farm observations and an explanation of the definition of antibiotics.

5. Conclusions

This study showed different ABU across various chicken production systems in Vietnam, suggesting that the ABU pattern can be associated with socio-economic and technical factors. Considering the urgency to reduce and improve ABU in Vietnam, the findings from this study may contribute to developing targeted communication strategies. In the context of policy changes, this study can also provide evidence of antibiotic usage practices that are necessary to develop targeted interventions to increase the compliance of farmers in reducing their antibiotic use. Family commercial farms should be targeted to emphasise the need to seek professional advice, which is associated with better ABU. The other target population could be drugstores, private veterinary practitioners or corporate veterinarians that provide direct advice to farmers and could act as information relays and provide leverage to foster better ABU on chicken farms in Vietnam.

Data statement

Dataset and script used to produced the analysis and figures of this publications are available at: https://github.com/loire/AMU_ChloeBatie2022.

Conflict of interest

Declarations of interest: none.

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Appendix A. Supporting information

Supplementary data associated with this article can be found in the online version at doi:10.1016/j.prevetmed.2022.105731.

References

Alvarez, S., Timler, C.J., Michalscheck, M., Paas, W., Descheemaeker, K., Tittonell, P., Andersson, J.A., Groot, J.C.J., 2018. Capturing farm diversity with hypothesis-based typologies: an innovative methodological framework for farming system typology development. PLoS One 13. https://doi.org/10.1371/journal.pone.0194757.

Bordier, M., Binot, A., Pauchard, Q., Nguyen, D.T., Trung, T.N., Fortané, N., Goutard, F. L., 2018. Antibiotic resistance in Vietnam: moving towards a One Health surveillance system. BMC Public Health 18, 1136. https://doi.org/10.1186/s12889-018-6022-4.

Burgos, S., Hong Hanh, T., Roland-Holst, P., Burgos, S A., D., 2007. Characterization of poultry production systems in Vietnam. Int. J. Poult. Sci. 6, 709–712. https://doi.org/10.3923/ijps.2007.709.712.

Carrique-Mas, J.J., Trung, N.V., Hoa, N.T., Mai, H.H., Thanh, T.H., Campbell, J.I., Wagenaar, J.A., Hardon, A., Hieu, T.Q., Schultsz, C., 2015. Antimicrobial usage in chicken production in the mekong delta of Vietnam. Zoonoses Public Health 62, 70–78. https://doi.org/10.1111/zph.12165.

Carrique-Mas, J.J., Choisy, M., Van Cuong, N., Thwaites, G., Baker, S., 2020. An estimation of total antimicrobial usage in humans and animals in Vietnam. Antimicrob. Resist. Infect. Control 9, 16. https://doi.org/10.1186/s13756-019-0671-7.

Carriques-Mas, J., Van, N.T.B., Cuong, N.V., Truong, B.D., Kiet, B.T., Thanh, P.T.H., Lon, N.N., Giao, V.T.Q., Hien, V.B., Padungtod, P., Choisy, M., Setyawan, E., Rushton, J., Thwaites, G., 2019. Mortality, disease and associated antimicrobial use in commercial small-scale chicken flocks in the Mekong Delta of Vietnam. Preventive Veterinary Medicine 165, 15–22. https://doi.org/10.1016/j.prevetmed.2019.02.005.

Castel, J.M., Madry, W., Gozdowski, D., Roszkowska-Madra, B., Dabrowski, M., Lupa, W., Mena, Y., 2010. Family dairy farms in the Podlasie province, Poland: farm typology according to farming system. Span. J. Agric. Res. 8, 946. https://doi.org/10.5424/sjar/2010084-1390.

Catley, A., Alders, R.G., Wood, J.L.N., 2012. Participatory epidemiology: Approaches, methods, experiences. The Veterinay Journal 191 (2), 151–160. https://doi.org/10.1016/j.tvjl.2011.03.010.

Cesaro, J.D., Duteurtre, G., Nguyen Mai Huong, 2019. Atlas de la transition de l'élevage au Vietnam (1986–2016). IPSARD-CIRAD.

Choisy, M., Van Cuong, N., Bao, T.D., Kiet, B.T., Hien, B.V., Thu, H.V., Chansiripornchai, N., Setyawan, E., Thwaites, G., Rushton, J., Carrique-Mas, J., 2019. Assessing antimicrobial misuse in small-scale chicken farms in Vietnam from an observational study. BMC Vet. Res. 15, 206. https://doi.org/10.1186/s12917-019-1947-0.

Coyne, L., Benigno, C., Giang, V.N., Huong, L.Q., Kalprividh, W., Padungtod, P., Patrick, I., Ngoc, P.T., Rushton, J., 2020. Exploring the socioeconomic importance of antimicrobial use in the small-scale pig sector in Vietnam. Antibiotics 9, 299. https://doi.org/10.3390/antibiotics9060299.

Delabouglise, A., 2015. Les enjeux territoriaux de la surveillance de la santé animale: le cas de l'influenza aviaire hautement pathogène au Viet Nam et en Thaïlande.

Delabouglise, A., Choisy, M., Phan, T.D., Antoine-Moussiaux, N., Peyre, M., Vu, T.D., Pfeiffer, D.U., Fournié, G., 2017. Economic factors influencing zoonotic disease dynamics: demand for poultry meat and seasonal transmission of avian influenza in Vietnam. Sci. Rep. 7, 5905. https://doi.org/10.1038/s41598-017-06244-6.
Delpont, M., Blondel, V., Robertet, L., Duret, H., Guerin, J., Vaillancourt, J.-P., Paul, M. C., 2018. Biosecurity practices on foie gras duck farms, Southwest France. Prev. Vet. Med 11. https://doi.org/10.1016/j.prevetmed.2018.07.012.
Desvaux, S., Vu Dinh, T., Phan Dang, T., Pham Thi Thanh, H., 2008. Research consortium on risks associated with livestock intensification. Agricultural Publishing House, Hanoi.
Duc, N.V., Long, T., 2008. Poultry production system in Vietnam (No. GCP/RAS/228/GER Working Paper No. 4). FAO, Rome.
GSOV, 2020a. Livestock production Vietnam. Specialized information on livestock announcements (In Vietnamese). [WWW Document]. URL ⟨http://channuoivietnam.com/thong-ke-chan-nuoi/tk-chan-nuoi/⟩ (accessed 7.6.22).
GSOV, 2020b. Statistical Yearbook of Vietnam. Statistical publishing house, Hanoi.
GSOV, 2016. Results of the rural, agricultural and fishery census. Statistical Publishing House, Hanoi, p. 2016.
Ha, L.T.T., Rueanghiran, C., Giang, N.T.H., Thuy, D.P., Phu, D.H., Tuan Kiet, B., Hien, V. B., Hue, L.T., Padungtod, P., Truong, B.D., Carrique-Mas, J.J., 2021. Antimicrobial usage surveillance through sales at veterinary drug shops intended for livestock in Vietnam. Front. Sustain. Food Syst. 5, 784500 https://doi.org/10.3389/fsufs.2021.784500.
Hanh, P.T.H., Burgos, S., Roland-Holst, D., 2007. The Poultry Sector in Viet Nam: Prospects for Smallholder Producers in the Aftermath of the HPAI Crisis (No. RR Nr. 07–10). Pro-Poor Livestock Policy Initiative A Living from Livestock Research Report.
Holmes, A.H., Moore, L.S.P., Sundsfjord, A., Steinbakk, M., Regmi, S., Karkey, A., Guerin, P.J., Piddock, L.J.V., 2016. Understanding the mechanisms and drivers of antimicrobial resistance. Lancet 387, 176–187. https://doi.org/10.1016/S0140-6736(15)00473-0.
Husson, F., Le, S., Pagès, J., 2017. Exploratory Multivariate Analysis by Example Using R, Second ed. Chapman & Hall/CRC, New York.
Husson, F., Josse, J., Le, S., Mazet, J., 2020. FactoMineR: Multivariate Exploratory Data Analysis and Data Mining.
Kassambara, A., Mundt, F., 2020. factoextra: Extract and Visualize the Results of Multivariate Data Analyses.
Kim, D.P., Saegerman, C., Douny, C., Ton, V., Xuan, B.H., Dang Vu, B., 2013. First survey on the use of antibiotics in pig and poultry production in the Red River Delta region of Vietnam. Food Public Health 3 (5), 247–256. https://doi.org/10.5923/j.fph.20130305.03.
Lekagul, A., Tangcharoensathien, V., Mills, A., Rushton, J., Yeung, S., 2020. How antibiotics are used in pig farming: a mixed-methods study of pig farmers, feed mills and veterinarians in Thailand. BMJ Global Health 5 (2). https://doi.org/10.1136/bmjgh-2019-001918.
Luu, Q.H., Nguyen, T.L.A., Pham, T.N., Vo, N.G., Padungtod, P., 2021. Antimicrobial use in household, semi-industrialized, and industrialized pig and poultry farms in Viet Nam. Prev. Vet. Med. 189, 105292 https://doi.org/10.1016/j.prevetmed.2021.105292.
MARD, 2017. The National Action Plan for Management of Antibiotic Use and Control of Antibiotic Resistance in Livestock Production and Aquaculture during the period of 2017–2020.
MARD, 2020. Circular on management of veterinary drugs containing narcotic substances and precursors and veterinary prescription. 2/2020/TT-BNNPTNT [WWW Document]. URL ⟨https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Circular-12–2020-TT-BNNPTNT-management-of-veterinary-drugs-containing-narcotic-substances-and-precursors-459279.aspx⟩ (accessed 6.25.22).
MARD, 2021. The National Action Plan on Preventing and Combating Antibiotic resistance in the Agricultural Sector for the period 2021–2025 (In Vietnamese)., Decision 3609/QĐ-BNN-TY.
National Assembly of the Socialist Republic of Vietnam, 2018. Law on Animal Husbandry. 32/2018/QH14 [WWW Document]. URL ⟨https://www.economica.vn/Content/files/LAW%20%26%20REG/Law%20on%20Animal%20Husbandry%202018.pdf⟩ (accessed 6.25.22).
McKinn, S., Trinh, D.H., Drabarek, D., Trieu, T.T., Nguyen, P.T.L., Cao, T.H., Dang, A.D., Nguyen, T.A., Fox, G.J., Bernays, S., 2021. Drivers of antibiotic use in Vietnam: implications for designing community interventions. BMJ Global Health 6 (7). https://doi.org/10.1136/bmjgh-2021-005875.
Om, C., McLaws, M.-L., 2016. Antibiotics: practice and opinions of Cambodian commercial farmers, animal feed retailers and veterinarians. Antimicrobial Resistance and Infection Control 5, 42. https://doi.org/10.1186/s13756-016-0147-y.
Ornelas-Eusebio, E., García-Espinosa, G., Laroucau, K., Zanella, G., 2020. Characterization of commercial poultry farms in Mexico: towards a better understanding of biosecurity practices and antibiotic usage patterns. PLoS One 15, e0242354. https://doi.org/10.1371/journal.pone.0242354.
Pham, P., Vinck, P., 2020. KoBoToolbox. ⟨https://www.kobotoolbox.org/⟩.
Phu, D.H., Giao, V.T.Q., Truong, D.B., Cuong, N.V., Kiet, B.T., Hien, V.B., Thwaites, G., Rushton, J., Carrique-Mas, J., 2019. Veterinary drug shops as main sources of supply and advice on antimicrobials for animal use in the Mekong Delta of Vietnam. Antibiotics 8, 195. https://doi.org/10.3390/antibiotics8040195.
Pham-Duc, P., Cook, M.A., Cong-Hong, H., Padungtod, P., Nguyen-Thi, H., Dang-Xuan, S., 2019. Knowledge, attitudes and practices of livestock and aquaculture producers regarding antimicrobial use and resistance in Vietnam. PLOS ONE 14(9), 10.1371/ journal.pone.0223115.
Phu, D.H., Cuong, N.V., Truong, D.B., Kiet, B.T., Hien, V.B., Thu, H.T.V., Yen, L.K., Minh, N.T.T., Padungtod, P., Setyawan, E., Thwaites, G., Rushton, J., Carrique-Mas, J., 2021. Reducing antimicrobial usage in small-scale chicken farms in Vietnam: a 3-year intervention study. Front. Vet. Sci. 7, 1244. https://doi.org/10.3389/fvets.2020.612993.
Prime Minister, 2021. Decision approving the Master plan agricultural restructure in the 2021–2025 period, 255/QD-TTg [WWW Document]. URL ⟨https://thuvienphapluat.vn/van-ban/Linh-vuc-khac/Quyet-dinh-255-QD-TTg-2021-Ke-hoach-co-cau-lai-nganh-nong-nghiep-giai-doan-2021–2025-465941.aspx⟩ (accessed 11.25.21).
Robinson, T.P., FAO (Eds.), 2011. Global livestock production systems. Food and Agriculture Organization of the United Nations, Rome.
Robinson, T.P., Bu, D.P., Carrique-Mas, J., Fèvre, E.M., Gilbert, M., Grace, D., Hay, S.I., Jiwakanon, J., Kakkar, M., Kariuki, S., Laxminarayan, R., Lubroth, J., Magnusson, U., Thi Ngoc, P., Van Boeckel, T.P., Woolhouse, M.E.J., 2017. Antibiotic resistance: mitigation opportunities in livestock sector development. Animal 11, 1–3. https://doi.org/10.1017/S1751731116001828.
The Government of the Socialist Republic of Vietnam, 2020. Elaboration the Law on Animal Husbandry. Decree 13/2020/NDCP [WWW Document]. URL ⟨https://english.luatvietnam.vn/decree-no-13–2020-nd-cp-dated-january-21–2020-of-the-government-on-detailing-a-number-of-articles-of-the-law-on-animal-husbandry-180147-Doc1.html⟩ (accessed 6.25.22).
Vaissie, P., Monge, A., Husson, F., 2021. Factoshiny: Perform Factorial Analysis from "FactoMineR" with a Shiny Application.
Truong, D.B., Doan, H.P., Doan Tran, V.K., Nguyen, V.C., Bach, T.K., Rueanghiran, C., Binot, A., Goutard, F.L., Thwaites, G., Thwaites, J., Rushton, J., 2019. Assessment of Drivers of Antimicrobial Usage in Poultry Farms in the Mekong Delta of Vietnam: A Combined Participatory Epidemiology and Q-Sorting Approach. Frontiers in Veterinary Science 6, 84. https://doi.org/10.3389/fvets.2019.00084.
Yen, N.T.P., Phu, D.H., Van Cuong, N., Kiet, B.T., Hien, B.V., Padungtod, P., Truong, D.B., Thwaites, G.E., Carrique-Mas, J.J., 2019. Labelling and quality of antimicrobial products used in chicken flocks in the Mekong Delta of Vietnam. Vet. Med. Sci. 5, 512–516. https://doi.org/10.1002/vms3.189.