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Published in:
Zoonoses and Public Health

DOI:
10.1111/zph.12165

ORIGINAL ARTICLE

Antimicrobial Usage in Chicken Production in the Mekong Delta of Vietnam

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Impacts

- This paper reports high levels of antimicrobial usage in chicken farms in the Mekong delta of Vietnam (about 6 times higher than the levels of usage reported in some European countries); 84% of the administrations had prophylactic purposes (i.e. to prevent rather than treat disease).
- Household farms and meat chicken farms had increased levels of antimicrobial usage compared with small-to-medium farms and layer farms. Also farms run by females used less amounts of antimicrobials.
- Results from this study should help increase awareness and advocate for more rational use of antimicrobials in animal production in Vietnam and other developing countries.

Keywords:
Antimicrobial use; antimicrobial resistance; antibiotics; poultry; Vietnam

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Contents of this article were presented in an international expert meeting, 'Reducing antimicrobial usage in agriculture and aquaculture beyond regulatory Policy', held in Utrecht, The Netherlands, 1–3 July 2013. The Workshop was sponsored by the OECD Co-operative Research Programme on Biological Resource Management for Sustainable Agricultural Systems, the Netherlands Organization for Health Research and Development (ZonMW) and the Dutch Ministry of Economic Affairs. The opinions expressed and arguments employed in this publication are the sole responsibility of the authors and do not necessarily reflect those of the OECD or of the governments of its Member countries.

Received for publication October 12, 2013

doi: 10.1111/zph.12165

Summary

Antimicrobials are used extensively in chicken production in Vietnam, but to date no quantitative data are available. A 2012–2013 survey of 208 chicken farms in Tien Giang province, stratified by size (10–200 chickens; >200–2000), was carried out to describe and quantify the use of antibacterial antimicrobials (usage per week per chicken and usage per 1000 chickens produced) in the Mekong Delta and to investigate factors associated with usage. Twenty-eight types of antimicrobial belonging to 10 classes were reported. Sixty-three per cent of all commercial formulations contained at least two antimicrobials. On 84% occasions, antimicrobials were administered with a prophylactic purpose. The overall adjusted quantities of antimicrobials used/week/chicken and per 1000 chickens produced (g) were 26.36 mg (SE ± 3.54) and 690.4 g (SE ± 203.6), respectively. Polypeptides, tetracyclines, penicillins and aminoglycosides were the antimicrobials used by most farms (18.6% farms, 17.5%, 11.3% and 10.1% farms, respectively), whereas penicillins, lincosamides, quinolones, and sulphonamides/trimethoprim were quantitatively the most used compounds (8.27, 5.2, 3.16 and 2.78 mg per week per chicken, respectively). Factors statistically associated with higher levels of usage (per week per chicken) were meat farms (OR = 1.40) and farms run by a male farmer (OR = 2.0). All-in-all-out farming systems (correlated with medium farms) were associated with reduced levels of antimicrobial usage (OR = 0.68). Usage levels to produced meat chickens were considerably higher than those reported in European countries. This should trigger the implementation of surveillance programmes to monitor sales of antimicrobials that should contribute to the rational administration of antimicrobials in order to preserve the efficacy of existing antimicrobials in Vietnam.

Introduction

Antimicrobial resistance (AMR) is currently one of the most serious threats to global health, resulting in a decreasing repertoire of antimicrobials available to treat serious infections (WHO, 2000; Anon., 2013). Almost all classes of antibiotics available to humans have also been used in animal production (WHO, 2000; Anon., 2011b), and AMR has been increasingly identified in animal pathogens (Wissing et al., 2001; Pitkala et al., 2004; Katsuda et al., 2009). Over recent years there has been mounting evidence that the use of antimicrobials in agriculture is a major factor driving AMR globally (Silbergeld et al., 2008). Antimicrobials are extensively used in animal farming with the aim of treating and preventing animal diseases, as well as improving growth performance (Page and Gautier, 2012). Antimicrobial usage on farms selects for AMR bacteria and other genetic determinants that may spread to humans either through direct contact, consumption of meat or indirectly through environmental pathways (Aarestrup and Wegener, 1999; Silbergeld et al., 2008).

In Vietnam, high levels of resistance against a number of antimicrobials have been reported in foodborne pathogens such as non-typhoid *Salmonella* serovars and *Campylobacter* spp. in poultry, livestock and meat (Garin et al., 2012; Thai and Yamaguchi, 2012; Thai et al., 2012a,b,c; Carrique-Mas et al., 2014). Compared with isolated from pigs and fish, *E. coli* from Vietnamese chickens have higher levels of AMR (Van et al., 2008). In Vietnam, antimicrobials are available to farmers over the counter without prescription. Some reports have suggested high levels of usage of a range of antimicrobials in pig and poultry farming, although the quantities used are unknown (GARP, 2010; Dang et al., 2011).

The aims of this study were: (i) to describe and quantify levels of antimicrobial usage, both in terms of usage per unit time as well as per chicken produced, in farms in the Mekong Delta; and (ii) to identify factors associated with usage. Results from this study will serve to increase awareness and identify required efforts to reduce usage of antimicrobials in animal production in the region.

Materials and Methods

Survey design and data collection

Data on antimicrobial usage on chicken farms were obtained from a survey carried out on 208 chicken farms sampled from three districts containing 40% poultry population in Tien Giang province, Mekong Delta, Vietnam. The survey was carried out between March 2012 and April 2013. For logistic reasons, sampling was stratified by size (10–200, 'household farms'; 201–2000 chickens, 'small-to-medium farms') and district (My Tho, Cho Gao and Chau Thanh) (total 6 strata), with ~34 farms sampled per stratum. Within each stratum, farms were randomly selected from the census by staff from Tien Giang sub-Department of Animal Health. The sample size per stratum (34) was determined based on requirements for determining the prevalence in each district of *E. coli* resistance against a number of antimicrobials. Questionnaires with both open and closed questions were used to obtain data on antimicrobial usage. Farm owners were asked about details on administration of any bacterial antimicrobial formulations over a period of time, including: (i) Method of administration (water, feed, injection, spray); (ii) Type of use (prophylactic/therapeutic/both); (iii) Timing of application: (a) continuously; (b) on arrival; (c) in response to disease; (c) periodic (i.e. change of season, changing feed, before selling). Quantitative data on each formulation administered over a set period of time were gathered, including the commercial name of the product, presentation and number of containers used. From these data, the total amount of active antimicrobial compound was calculated. Questionnaires enquired about usage 'from restocking until the visit date' for small-to-medium farms. A fixed period of observation (90 days) was determined for household farms, as household farms did not practice all-in-all-out production. In addition, farmers were asked about the source of advice for using the antimicrobial (veterinary pharmacist; district veterinarian; chief animal health worker; drug company sales person; friend/neighbour; and 'other').

Calculation of antimicrobial usage

Two outcomes were of interest: (i) usage per chicken per time unit (or 'intensity' of usage); and (ii) usage related to production output (usage per 1000 chickens produced).

Usage per week per chicken ($U_{\text{wc } milligrams}$) was calculated by dividing in each farm the amount of each antimicrobial used ($U_{\text{r } milligrams}$) by the length of the reporting period for that farm ($t_{\ weeks}$), and then by the number of chickens present in the farm ($N_{\ chickens}$) on the visit date. The 'amount of each antimicrobial used to produce 1000 chickens' (in grams) ($U_{\text{1000c } grams}$) is dependent on the length of production cycle in each farm. Therefore chicken output and antimicrobial usage were estimated in each study farm over 1 year.

Estimated annual antimicrobial usage ($U_{\text{y } grams}$) was calculated for each antimicrobial:

$$U_{y\ grams} = U_{r\ milligrams} * 0.001_{grams/milligram} * (52_{weeks} - [0.1 * 52_{weeks}])/t_{weeks}$$

From the above formula, $U_{1000c\ grams}$ was derived:

$$U_{1000c\ grams} = U_{y\ grams} * 1000_{chickens}/(C * N_{chickens}).$$

C (number of cycles of production per year) was obtained from:

$$C = 1/(a_{years} + [0.1 * a_{years}])$$

where a is the expected age of depopulation of chickens. These calculations assume a fixed downtime of 10% (i.e. time when the farm is not productive and therefore neither chickens are produced nor antimicrobials are used). Estimates of usage (farm prevalence of usage by farm and quantitative estimates) were calculated after adjusting for the stratified study design by assigning a stratum-specific sampling weight to each observation unit (farm). Standard errors were corrected to take into account the potential similarities of usage between farms in each stratum (Dohoo et al., 2003).

Risk factor analyses

Risk factor analyses for usage were carried out by fitting proportional odds model (ordinal logistic model) (McCullagh, 1980) for the two outcomes describing total antimicrobial usage (i.e. usage in relation to time, usage in relation to production), after adjusting for the stratified survey design. Data on usage were categorized into three levels: no use; low level usage; and high level usage. Low and high level usage categories were determined from dividing the farms that had consumed antimicrobials into two categories, based on the median quantity used. The following explanatory variables were investigated: (i) farmer's gender; (ii) farmer's age (years) (log); (iii) farmer's highest educational attainment (four levels: 'no formal education', 'primary school', 'secondary school' and 'higher'); (iv) farmer's experience in chicken farming (years) (log); (v) number of chickens (log); (vi) type of production (three levels: meat; layer; and dual purpose); (vii) density of chickens (chickens/sq. metre) in houses; (viii) all-in-all-out production; (ix) chickens lost to disease over the previous 90 days; (x) presence of species other than chickens (pigs, cattle/buffalo or ducks) in the farm; and (xi) district (Cho Gao, Chau Thanh and My Tho). Candidate variables were those significant in the univariable models for any of the two outcomes ($P < 0.05$). Variables were ranked by their degree of significance and were included in the model starting with the most significant ones using a step-wise forward approach (Hosmer and Lemeshow 1989). In the final multivariable model, variables were retained if their P-value was <0.05 for any of the two outcome variables. All interactions between all significant variables in the model were assessed. The suitability of each new variable included in the model was assessed using the AIC information criterion (Thrusfield, 2007). All interactions between final significant variables were tested. All statistical analyses were performed using R (packages 'epicalc', 'epiR' and 'survey') (http://www.r-project.org).

Results

Antimicrobial usage in study farms

A total of 123 farms (59.1%) reported administration of at least one antimicrobial formulation. A total of 168 administrations of an antimicrobial formulation were reported. A higher percentage of owners of medium farms reported administering antimicrobials in their farms, compared with owners of small farms (71.2% versus 47.1%, respectively) ($\chi^2 = 11.5$, $P < 0.001$). Owners of small-to-medium farms reported usage over a median of 140 days [56–224] (i.e. the median age of flocks visited), whereas owners of household farms reported usage over a fixed period of 90 days (Table 1). For 157 of 168 (95.7%) administrations, the active ingredients (antimicrobial compounds) could be accurately described, either by direct observation of the container, or by farmer's recollection. A total of 28 different antimicrobial compounds belonging to 10 classes were identified (Table 2). A total of 100 of 157 administrations (63.7%) consisted of formulations containing at least two antimicrobial classes (Table 3). After adjusting for the sampling frame, polypeptides, tetracyclines, penicillins and aminoglycosides were the antimicrobials used by most farms.

The most common antimicrobial formulations combining multiple antimicrobial classes included penicillins and polypeptides (21% of all formulations) followed by macrolides plus tetracyclines (15.9%). A total of 28 of 157 (17.8%) of products reported included a combination of an antimicrobial considered to be bacteriostatic with another antimicrobial considered bactericidal (Table 3). Formulations including bacteriostatic/bactericidal combinations included: aminoglycosides combined with tetracyclines (i.e. gentamycin/doxcycyline, neomycin/tetracycline) or polypeptides combined either with tetracyclines (i.e. colistin/oxytetracyclin); sulphonamides (colistin/sulphadimethoxine); or macrolides (colistin/tylosin)

Antimicrobial formulations were administered in water on 137 (81.5%) occasions, followed by both in feed and water (9.5%) and in feed only (4.2%). In 4.2% cases, antimicrobial formulations were injected. In 141 (84%) cases, farmers reported that the antimicrobial formulation was administered for prevention of disease (prophylaxis), and in 21 (12%) cases, they were used exclusively for

Table 1. Number of antimicrobial formulations used by chicken farmers, stratified by farm size (Tien Giang province, Vietnam)

		Household farms			Small-to-medium farms		
	All farms (*N* = 208)	All (*N* = 104)	Meat (*N* = 79)	Mixed (*N* = 25)	All (*N* = 104)	Meat (*N* = 40)	Eggs (*N* = 63)
Number of antimicrobial formulations used	168	68	52	16	100	39	59
Number of farms that used antimicrobial formulations (%)	123 (59.1%)	49 (47.1%)	40 (50.6%)	9 (36%)	74 (71.2%)	30 (76.9%)	43 (68.2%)
Number of different antimicrobial formulations used per farm							
0	85	55	39	16	30	10	20
1	85	32	29	3	53	22	31
2	32	15	10	5	17	7	9
3	5	2	1	1	3	1	2
4	1		0	0	1		1
Median observation time per farm(days) [IQR]	90 [90–140]	90 [90–90]	90 [90–90]	90 [90–90]	140 [56–224]	49 [28–70]	196 [157–280]

Table 2. Types of antimicrobials administered in 123 chicken farms, Tien Giang, Vietnam (2012–2013)

Class of antimicrobial	Name of antimicrobial	Number. (%) formulations administered containing the antimicrobial (N=157) (%)	Number (%) farms using antimicrobial (N=208) (%)	Adjusted % farms using antimicrobial (95% CI)
Tetracyclines	Docycycline, oxytetracycline, tetracycline	57 (36.3)	52 (25.0)	17.5 (16.9–18.1)
Polypeptides	Colistin	48 (30.6)	39 (18.8)	18.6 (9.9–27.3)
Macrolides	Tylosin, tilmicosin, erythromycin, spiramycin	40 (25.5)	40 (19.2)	9.7 (8.2–11.3)
Penicillins	Ampicillin, amoxicillin	41 (26.1)	33 (15.9)	11.3 (10.4–12.1)
Quinolones	Flumequine, oxolinic acid, norfloxacin, enrofloxacin	22 (14.0)	19 (9.1)	6.0 (0.1–12.1)
Aminoglycosides	Spectinomycin, neomycin, gentamicin, apramycin, streptomycin	19 (12.1)	19 (9.1)	10.1 (8.0–12.1)
Phenicols	Florfenicol, thiamphenicol	14 (8.9)	13 (6.3)	0.90 (0–2.5)
Sulphonamides/ trimethoprim	Sulfamethoxazole, sulphadimidine, sulphadimetoxine, sulphadimerazine, trimethoprim	12 (7.6)	12 (5.8)	6.1 (4.7–7.5)
Lincosamides	Lincomycin	4 (2.5)	4 (1.9)	4.3 (1.9–6.8)
Pleuromutilins	Tiamulin	1 (0.6)	1 (0.5)	0.03 (0.01–0.05)

CI, Confidence interval.

therapeutic reasons (i.e. to treat disease). On 6 (3.8%) occasions, farmers reported using the antimicrobial formulation with a double purpose (both to prevent and treat). The most commonly reported timing of use was on arrival (34.4%), followed by periodic (28.7%) and continuously (18.5%). The most common sources of advice with regard to antimicrobial formulations used were: the drug seller (56%), the district veterinarian (18%), a friend/neighbour (12%), a salesperson (12%) and 'other' (2%).

Quantitative estimates of antimicrobial usage

Household farms used 24.9 mg (SE $\pm$ 7.91) of antimicrobial per chicken per week, compared with 5.21 mg

Table 3. Detailed description of classes of antimicrobial contained in 157 antimicrobial formulations administered by 123 chicken farmers, Tien Giang, Vietnam.

	Penicillin	Polypeptide	Macrolides	Tetracyclines	Quinolones	Phenicols	Aminoglycosides	Sulphonamides	Lincosamides	Pleuromutilins	No. applications with each class of antimicrobial
Penicillin	6	33		1				1			41
Polypeptides		2	2	5	1		1	3			48
Macrolides			3	25*			5	4		1	40
Tetracyclines				13		6	7				57
Quinolones					20		1				22
Phenicols						8					14
Aminoglycosides							1	1	3		19
Sulphonamides/ trimethoprim								3			12
Lincosamides									1		4
Pleuromutilin											1

*One formulation included a macrolide/tetracycline/polypeptide combination. Shaded cells indicate a combination of a bactericidal and a bacteriostatic compound.

(SE ± 0. 91) used by small-to-medium farms (Kruskal–Wallis test; $P = 0.014$). Likewise, household farms used greater amounts to produce 1000 chickens, compared with small-to-medium farms (543.4 g, SE ± 223.4 versus 172.8 g, SE ± 25.2) (Kruskal–Wallis test; $P = 0.360$). After adjusting for the sampling frame, estimates of usage increased, as household farms in the district of Chao Gao reported by far the highest levels of usage, and household farms in this district had the greatest sampling weight (as they contained 46% of chickens of the study area according to the census) (Table 4). The adjusted levels of usage of antimicrobial per week per chicken and per 1000 chickens (U_{wc} and U_{1000c}) produced were, respectively, 26.36 mg (SE ± 3.54) and 690.4 g (SE ± 203.6). The model derived estimates of antimicrobial consumed per 1000 meat, and layer chickens produced were 470.4 g (SE ± 184.1) and 870.1 g (SE ± 263.9), respectively (model derived $P = 0.325$). Penicillins, lincosamides, quinolones and sulphonamides/trimethoprim were the four most commonly used antimicrobials, with average U_{wc} values of 8.27, 5.20, 3.16 and 2.78 mg/week/chicken, and average U_{1000c} values of 142.4, 38.7, 35.6 and 38.0 g per 1000 chickens produced (Fig. 1).

Risk factors for antimicrobial usage

Results indicated a significantly higher prevalence of usage per unit time (U_{wc}) for farms located in Cho Gao (OR = 1.49) and Chau Thanh (OR = 1.53) compared with My Tho (baseline). Male farmers used more antimicrobials per unit time (OR = 2.02). Meat farms used higher amounts of antimicrobial per unit time, compared with layer and dual purpose production (OR = 1.40). All-in-all-out systems (highly correlated with small-to-medium farms) had reduced levels of usage per unit time compared with farms with continuous production (correlated with household farms) (OR = 0.68). No interactions were significant.

Discussion

To our knowledge, this is the first study quantifying antimicrobial usage in chicken farms in Vietnam. The key findings are: (i) An extensive range of antimicrobials compounds (n = 28) belonging to ten antimicrobial classes were used, including macrolides, quinolones and polypeptides; (ii) A majority of antimicrobials (84%) were used to prevent, rather than to treat clinical diseases of chickens; (iii) Higher levels of usage (per unit time) were associated with meat and household production systems.

We estimated usage of antimicrobials for chicken production in the Mekong delta region from a detailed survey of 208 farms in Tien Giang province. Although we believe

Table 4. Sampling weights and sampling fraction and administration of antimicrobials by in poultry farms belonging to each survey stratum, Tien Giang, Vietnam

Stratum	Number of farms sampled	Number of chickens sampled	Number of chickens (census)	Fraction sampled (%)	Sampling weight	Milligrams of active compound used per week per chicken (±SE)	Grams of active compound per 1000 chickens produced
CG, hh	34	2890	409 850	0.007	141.8	30.4 (±15.6)	901.2 (±622.8)
CG, sm	34	47 970	128 250	0.374	2.7	5.3 (±1.5)	167.5 (±63.9)
CT, hh	36	4505	268 295	0.017	59.5	5.6 (±1.4)	327.8 (±122.4)
CT, sm	36	50 230	56 700	0.886	1.1	18.6 (±7.2)	193.1 (±57.3)
MT, hh	34	2290	58 310	0.039	25.5	26.4 (±17.2)	413.8 (±256.4)
MT, sm	34	52 500	73 300	0.716	1.4	4.7 (±1.9)	156.6 (±63.7)
All	208	160 385	994 705	0.161		15.1 (±4.0)	358.1 (±113.5)

CG, Cho Chao; CT, Chau Thanh; MT, My Tho; hh, household farms; sm, small-to-medium farms.

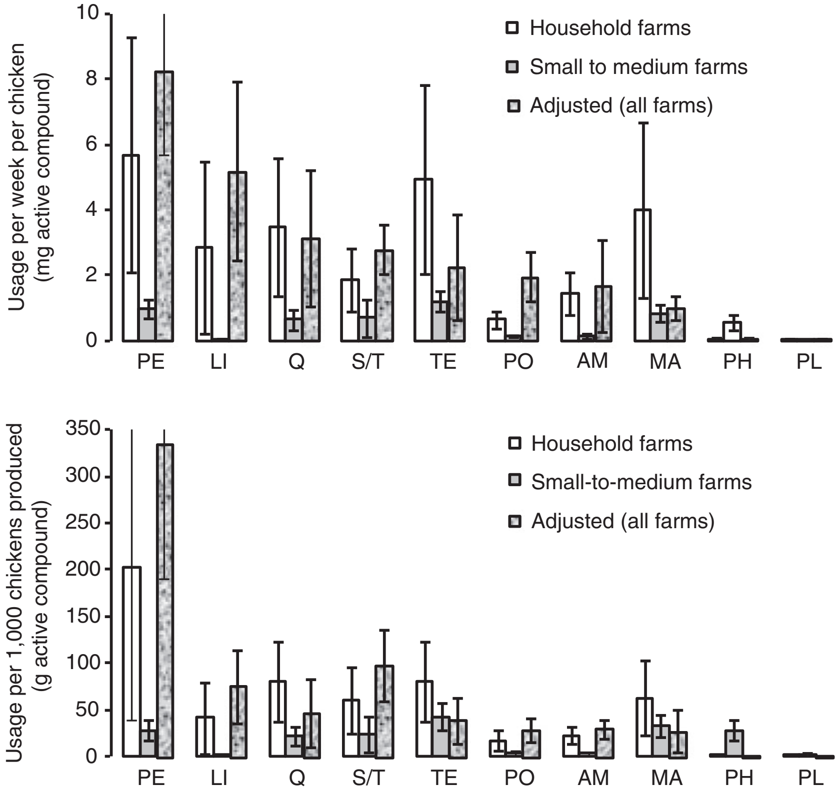

Fig. 1. Top: Antimicrobial usage per week per chicken (milligrams of active compound) (both unadjusted and adjusted by the survey design). Bottom: Antimicrobial usage per 1000 chickens produced (grams of active compound) (unadjusted and adjusted by survey design), 208 chicken farms, Tien Giang, Vietnam. Key: PE, Penicillins; LI, Lincosamides; Q, Quinolones; S/T, Sulphonamides/trimethoprim; TE, Tetracyclines; PO, Polypeptides; AM, Aminoglycosides; MA, Macrolides; PH, Phenicols; PL, Pleuromutilins.

that chicken production systems are quite homogeneous across the Mekong delta, results must be interpreted with caution given the limited geographical scope of our sample (i.e. three districts) and the limited sample size. Even small recall errors on behalf of the farmers may have skewed the results in unforeseen directions. In particular, the reported higher usage (in quantitative terms) in smaller farms may well reflect a recall bias of usage over an arbitrary period of 90 days. For medium farms, recall biases are likely to be less important, as the questionnaire gathered information about 'any antimicrobials used since restocking', which is generally easier to remember. Results reported here are likely to underestimate total antimicrobial usage, as commercial feed commonly includes subtherapeutic amounts of chlortetracycline and bacitracin, among other antimicrobials. Unfortunately, data on feed consumption were not systematically collected.

Our results suggest that a total of 470.4 mg of antimicrobials was used to produce one 'meat' chicken in the Mekong delta. These results contrast with data from other

Table 5. Results showing final multivariable proportional odds model (ordinal logistic model) investigating the outcomes: (i) antimicrobial usage per week per chicken (U_{wc}); and (ii) antimicrobial usage per 1000 chickens produced (U_{1000c}). Only variables remaining significant in either model are kept. 208 chicken farms, Tien Giang, Vietnam

	Usage per chicken per week (U_{wc})			Usage per 1000 chickens produced (U_{100c})		
	OR	95% CI	*P*-value	OR	95% CI	*P*-value
District (baseline=My Tho)	1.0			1.0	1.0	
Cho Gao	1.49	1.42–1.55	<0.001	1.01	0.50–2.01	0.998
Chau Thanh	1.53	1.47–1.59	<0.001	1.22	0.61–2.45	0.575
Male farmer (baseline=Female)	2.02	1.53–2.61	<0.001	2.18	1.12–3.98	0.019
Meat production (baseline layer and 'dual purpose')	1.40	1.01–1.89	0.040	0.65	0.43–1.38	0.374
All-in-all-out	0.68	0.56–0.81	<0.001	0.76	0.39–1.23	0.211

OR, Odds ratio; CI, Confidence interval.

European countries (2009), where sales ranged from 14 mg/chicken produced (Norway) to 165 mg (Netherlands), with an overall country average of 77.0 mg (SD = 53.4) (Anon., 2011b). However, it is important to highlight that the average production cycles of meat chickens are longer in the Mekong Delta (20.2 weeks SE ± 0.62 in our data set) compared with most developed countries (7–8 weeks). In addition, a considerable proportion (24%) of farms in our data set were 'dual purpose' systems, which (per unit time) used less amount of antimicrobials compared with 'specialized' meat chicken farms.

Furthermore, after statistical adjustment, quantitative estimates were much higher due to the higher weight of observations from household farms in the district of Cho Gao. Household farms (<200 chickens) represented 74% of the chicken census in our study population, a similar figure for the whole of Vietnam (79% of chicken production). The observed higher levels of usage among household farms may reflect either lack of technical ability to administer antimicrobials correctly, or a higher perception of risk of disease by household farm owners. This suggests that training of household farmers on the correct administration of antimicrobials would be an effective strategy aiming at reducing overall antimicrobial usage on poultry farms.

Results from the study have highlighted important discrepancies between qualitative and quantitative estimates of usage. For example, polypeptides, tetracyclines, penicillins and aminoglycosides were the most commonly used antimicrobials in terms of reported usage by farms; however, penicillins, lincosamides, quinolones and sulphonamides/trimethoprim were used more in quantitative terms. Differences in the doses and concentration of active principles of the different antimicrobials used may explain these differences. There were also some differences in the quantitative assessment of antimicrobial usage, depending on the chosen estimate. For example, lincosamides ranked second to penicillins in terms of 'usage per unit time' (U_{wc}) (19.7% of total usage), but third in terms of usage per chicken produced (U_{1000c}) (11.1% of total usage). The reason for these discrepancies lies in the variable levels of usage of antimicrobials in different production systems. Antimicrobials used with similar intensity (per unit time) in layer and meat flocks will result in overall higher estimates of usage per 1000 chickens, compared with antimicrobials used more commonly in meat flocks, as layer flocks have a longer lifespan. In particular, lincosamides were administered to relatively few layer flocks (data not shown).

Most of the reported antimicrobial usage was 'prophylactic', that is in the absence of clinical disease to prevent infection. This explains why the variable 'chickens lost to disease in the last three months' was not associated with higher usage in our risk analyses. Our results contrast with studies in chicken farms in Europe and Africa where usage was largely explained by history of disease in the flocks a response to disease (Mitema et al., 2001; Hughes et al., 2008).

Quinolones and macrolides, both listed by the World Health Organization as antimicrobials 'critically important for human medicine' (Anon., 2011a), represented 15.8% (per unit time) and 11.0% (per chicken produced) of overall antimicrobial usage. Neither the use of glycopeptides nor cephalosporins were reported in our study, although avoparcin (a glycopeptide) is sometimes used in feed, and ceftiofur and cefquinome (third/fourth generation cephalosporins) are currently licenced for animal production in Vietnam (Anon., 2013). Polypeptides (colistin) were the second most commonly used antimicrobials, and represented 4–7% of all usage in quantitative terms in our study, compared with 1.6% reported from nine European countries (Anon., 2011b). This is a concern since colistin is a very valuable to treat serious nosocomial infections caused by multidrug-resistant gram-negative bacteria such as *Pseudomonas aeruginosa* and *Acinetobacter baumannii* in humans (Kadar et al., 2013).

The finding that female farmers used less antimicrobials merits further investigation and suggests that cultural factors may also explain behaviour related to antimicrobial usage on farms. In our study, females accounted for 35% of all farmers.

In Vietnam, chicken production represents only a small fraction of total animal production, fish and pork being more common animal protein sources (Anon., 2004a). Usage of antimicrobials in Vietnamese aquaculture has been reported to be high compared with most other countries (700 g per tonne of production, compared to 1–200 g per tonne in three European countries, Canada and Chile) (Smith, 2008). In order to provide an accurate estimate of the selective pressure for antimicrobial resistance in each species, it would be important to determine the comparative levels of usage in all relevant types of animal production, as well as in humans, as has been recommended internationally (Anon., 2004b, 2007). Quantitative data on antimicrobial usage on farms should ideally be complemented with surveillance of antimicrobial resistance of selected bacterial species in farmed animals, food and humans. This should allow accurate monitoring of potential reductions in use and resistance in animal production as well as in humans.

Acknowledgements

We would like to thank staff at the Sub-Department of Animal Health of Tien Giang and the District Veterinary Station of the participating districts for their support. We are indebted to Dr Marcel Wolbers (OUCRU) for statistical advice. Work was funded by ZonMw/WOTRO (The Netherlands) (VIBRE Project, No. 205100012).

Conflict of Interest

The authors have no conflicts of interest to declare.

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