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Antibiotic prescription patterns and non-clinical factors influencing antibiotic use by Ecuadorian veterinarians working on cattle and poultry farms: A cross-sectional study

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ABSTRACT

Understanding antibiotic prescription patterns and non-clinical factors influencing antibiotic use is essential for implementing strategies to promote appropriate antibiotic use. There is, however, limited research exploring these issues with Ecuadorian veterinarians. Therefore, a questionnaire was developed and applied cross-sectionally to veterinarians ($n = 173$) from two professional organizations to explore the antibiotic prescription patterns and non-clinical factors (e.g., attitudes and perceptions) influencing antibiotic use, and to identify strategies to reduce antibiotic use. The response rate was 78.4%. Responses were compared between veterinarians working mainly on cattle and poultry farms using Mann-Whitney U tests. The most important attitudes, beliefs and perceptions towards antimicrobial resistance (AMR) and antibiotic use were identified with the Relative Importance Index (RII). Veterinarians showed high awareness of AMR and its implications for public health, as well as the necessity of reducing antibiotic use. However, some veterinarians appear to underestimate the potential contribution of veterinary antibiotic use on AMR in humans. Veterinarians self-reported high prescription (> 20%) of antibiotics for cattle and poultry that are critically important for human medicine, such as 3rd and 4th generation cephalosporins, polymyxins and quinolones. Further, antibiotic therapy was not tailored to disease type. Cattle and poultry veterinarians perceived similar barriers to increasing antibiotic stewardship including: poor biosecurity measures, animal confinement, low feed quality, farmers' behaviors (such as stopping antibiotic treatment, storing antibiotics on farms, buying antibiotics in veterinary supply stores), and sales agents' roles as non-professional prescribers of antibiotics. Overall, veterinarians were broadly supportive (>90%) of most strategies to promote appropriate antibiotic use. They saw more merit in improving biosecurity of farms and implementing educational programs for farmers and veterinarians. This study provides insight into the complexity of antibiotic use on Ecuadorian farms and the need for holistic strategies in a One Health context, to achieve antibiotic stewardship.

1. Introduction

Antimicrobial resistance (AMR) is one of the top 10 global threats to public health and is thought to be partly driven by the widespread use of antibiotics in food-producing animals (WHO, 2021). Globally, a greater proportion of the tonnage of all antibiotics sold are for use in

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food-producing animal sectors compared to for use in humans (Van Boeckel et al., 2017). In 2017, an estimated 93 million kilograms of active ingredient were sold worldwide for use in food-producing animals, which is expected to rise by 11.5% by 2030, if no control measures are taken (Tiseo et al., 2020). In South America specifically, the estimated increase of antimicrobial use in tonnes is projected to be 15.4% from 2017 to 2030 (Tiseo et al., 2020).

It has been estimated that reduction of all antibiotic use in food-producing animals may decrease the prevalence of drug-resistant bacteria in animals by between 24% and 32% and by up to 24% in humans (Tang et al., 2017). This highlights the importance of a collaborative and transdisciplinary approach for combating AMR (Collignon and McEwen, 2019). In line with the One Health concept, the World Health Organization (WHO) published guidelines to reduce the use of medically important antimicrobials for humans in food-producing animals (Aidara-Kane et al., 2018). In parallel, the World Organization for Animal Health (WOAH) developed a list of restricted antibiotics for veterinary medicine (OIE, 2021) and the European Medicines Agency (EMA) updated the categorization of antibiotics used in animals to promote prudent use (EMA, 2020). All these guidelines seek to reduce AMR and to preserve the effectiveness of antibiotics for both humans and other animals.

Veterinarians play a role in reducing antibiotic use by ensuring appropriate prescribing, defined as prescribing a clinically effective drug at the right moment with the right dosage regimen (WHO, 1985). Growing evidence shows veterinarians are influenced by non-clinical factors when prescribing antibiotics. These factors include: socio-demographic characteristics (e.g., personal experience), attitudes (e.g., towards susceptibility testing), beliefs about farmers, and perceptions regarding AMR (McKernan et al., 2021; Servia-Dopazo et al., 2021). Additionally, antibiotic-related factors (e.g., withdrawal period, costs), farm management practices (e.g., biosecurity measures) and local and national polices can influence antibiotic prescribing practices by veterinarians (Speksnijder et al., 2015a, 2015b; Postma et al., 2016). Most of these studies were done in high-income countries in Europe and North America and demonstrated the variety of factors at play in these countries, indicating the complexity of prescribing behaviors among veterinarians.

Relatively little is known about how non-clinical factors influence veterinarians' antibiotic prescribing behavior in low- and middle-income countries, especially in Latin America, where veterinarian practices can differ from those in high-income countries. A qualitative study in Peru found that veterinarians perceived several barriers to appropriately prescribing antibiotics, such as the availability of antibiotics, professional competition, participation of non-veterinarian advisors, economic considerations and limited knowledge of farmers about AMR and antibiotic use (Redding et al., 2013). In Ecuador, a qualitative study focusing on smallholders showed that farmers generally do not use antibiotics to grow animals for household food supply (Waters et al., 2022). However, to the best of the authors' knowledge, there is no evidence available regarding prescribing beliefs and behaviors by Ecuadorian veterinarians. This information is crucial for identifying strategies for appropriate use of antibiotics. Our study used a cross-sectional survey to describe antibiotic prescription patterns by Ecuadorian veterinarians, and to explore their perceptions and attitudes towards antibiotic use and AMR, and finally, to explore possible strategies to promote appropriate antibiotic use and antibiotic stewardship in food-producing animals in Ecuador.

2. Methods

2.1. Study design and participants

A questionnaire was administered cross-sectionally to Ecuadorian veterinarians working on cattle and poultry farms. In Ecuador, the exact number of practicing veterinarians is unknown; however, some veterinarians working on cattle and poultry farms are registered with one of two professional organizations that focus on providing veterinary assistance on farms: 1) The Ecuadorian Association of Buiatrics (AEB), legally established in 2008, and 2) The Association of Veterinarians Specialized in Poultry Farming (AMEVEA), legally established since 1981. We therefore recruited participants via AEB and AMEVEA to enable access to practicing cattle (both dairy and beef) and poultry (both broilers and layers) veterinarians working in the two major livestock sectors in Ecuador.

The list of members was obtained through the Directory of AEB and AMEVEA organizations. These lists included telephone numbers and email addresses for 60 people from AEB and 176 people from AMEVEA. Because these lists had missing information and errors (for instance, names, telephone numbers or email addresses did not match), lists were updated by making phone calls to veterinarians and by attending routine meetings of the organizations. The final lists had in total 50 members from AEB and 103 members from AMEVEA who had at least 2 years of practical experience and worked at least 1–2 days per week.

2.2. Questionnaire development

A two-step approach was used to develop the questionnaire. The first step comprised face-to-face semi-structured interviews to identify themes to be included in the questionnaire. The interviews were conducted by the first author in March 2018 and were audio-recorded with consent from three interviewees who were veterinarians and professors at the Veterinary Medicine and Zootechnics Faculty of the Central University of Ecuador, each having more than 7 years of experience working with cattle or poultry farming. The interview guide consisted of a list of open questions based on relevant literature (Redding et al., 2013; Speksnijder et al., 2015a) designed to explore potential determinants influencing prescribing behavior, the perceived roles of farmers and non-veterinary advisors on antimicrobial usage (AMU), and the perceived importance of monitoring and regulating antibiotic use in food-producing animals. The interviews lasted on average 30 min. Answers were discussed to identify key themes. No formal analysis was done on these data.

The second step was the development of the questionnaire based on the key themes identified in the first step and from relevant literature (Speksnijder et al., 2015b; Postma et al., 2016; McDougall et al., 2017). The questionnaire consisted of 5 main parts: 1) Demographic information, 2) Perceptions and attitudes regarding AMU and AMR, 3) Veterinarian's self-reported antibiotic prescription pattern, 4) Perceptions of farmers' role on AMU, and 5) Strategies to reduce AMU in food-producing animals. Parts 1 and 3 had multiple-choice and open questions, while parts 2, 4 and 5 had 5-point Likert scale statements (1 = completely disagree, 2 = somewhat disagree, 3 = neutral, 4 = somewhat agree, 5 = completely agree). In addition, at the end of the questionnaire an open question was included to suggest other potential participants. The questionnaire was originally developed in English and later translated into Spanish by the first author. The Spanish version of the questionnaire was tested with five professors at the Veterinary Medicine and Zootechnics Faculty, who were not involved in the study. The questionnaire was edited accordingly (Text. S1).

2.3. Data collection

Between September 2018 and February 2019, potential participants were contacted by phone to explain the general goals of this study and to determine their willingness to participate. Those that agreed to participate were asked for their preference for filling in the questionnaire, either receiving a PDF version by email or receiving a hyperlink survey (https://encuesta.com). We decided to provide these two options to increase the response rate considering the work dynamic and reachability of veterinarians. Weekly reminders were sent out to non-responders via email, for up to 2 months. Responses were collected anonymously unless participants chose to leave contact details.

This study was exempt from ethical approval according to the regulations from the Central University of Ecuador's Ethics Committee because this study was considered of minor risk given the application of the questionnaire was anonymous, no confidential or identifiable information was collected, and no patients were involved. Verbal informed consent was obtained from all participants, and all those that agreed to participate received a confidentiality agreement outlining the anonymous use of the collected data.

2.4. Data analysis

Data were analyzed using R version 4.1.2. For descriptive analyses we categorized participants into two groups, cattle and poultry veterinarians, depending on the professional associations they were recruited through. Participants were also classified as generalists and specialists considering their percentage of working time in either cattle or poultry farms (Speksnijder et al., 2015b). Veterinarians were considered specialists when working more than 60% of their time in cattle farming (summing up the working time with dairy and beef cattle) or poultry farming (summing up the working time with broilers and hens).

To describe antibiotic prescription patterns by veterinarians, antibiotic classes were categorized into four categories: avoid, restrict, caution and prudence antibiotics based on EMA categorization of important antibiotics for human medicine (EMA, 2020); these categories are shown in Table 2. To assess these prescribing patterns, participants were asked: *"Thinking about your own prescribing, please indicate what percentage of your prescriptions are accounted for by the following classes of antibiotics. Please also indicate the cases you typically use each class for (you may list more than one)."* These percentages were used to calculate the mean, median and percentiles (75% and 90%) of antibiotics prescribed by each antibiotic class. Comparisons between cattle and poultry groups, and also between generalists and specialists within each group, were performed using Mann-Whitney U tests. Comparisons between antibiotic categories within cattle and poultry groups were performed using Kruskal-Wallis tests. Multivariable logistic regression models were used to explore whether demographic factors were associated with antibiotic prescription patterns. In these models, the prescription of a particular antibiotic class (e.g., yes/no prescription of penicillins) was the binary response variable, while veterinary group (cattle/poultry), years of experience, practice situation (assessor, owner, other) and postgraduate studies after getting an undergraduate veterinary degree (yes/no) were the predictor variables. In addition, respondents were asked to indicate the type of disease(s) they most commonly prescribed each antibiotic class for. Based on these responses (some of which were specific; some were more general), diseases were classified as gastrointestinal system, respiratory system, urinary system, musculoskeletal system, eyes problems, udder health, and skin. It should be noted that most responses were global in nature, for example "respiratory disease" or "changes in urinary tract" and not necessarily only for the main species.

Likert-scale statements were analyzed by comparing the mean score responses between cattle and poultry groups using Mann Whitney-U test. Statements that assessed similar concepts (e.g., awareness of own responsibility on antibiotic use) were grouped to facilitate interpretation and were visually presented in diverging stacked bars. The Relative Importance Index (RII) method was applied to summarize the importance of each statement based on participants' responses and ranked accordingly (Abdulrahim and Mabrouk, 2020; Kassem et al., 2020). RII was calculated using the following formula:

$$RII = \frac{\sum Rn_i}{A \times N} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5 \times N},$$

where R is the respondent's rating scale value ranging from 1 to 5, n_i is the number of respondents answering to each Likert scale (e.g., $n_5=$ number of respondents for completely agree), A is the highest value on the scale (i.e., 5 in this study), and N is the total number of respondents. RII ranged from 0 to 1, with 1 representing the most important statement.

3. Results

In total, 120/153 questionnaires were returned (45/50, 90.0%, from the cattle group; 75/103, 72.8%, from the poultry group) with an overall response rate of 78.4%. Only 45% (54/120) of questionnaires were complete (28/45, 62.2%, from the cattle group; 26/75, 34.7%, from the poultry group); data from incomplete questionnaires were still used in the analyses. Based on veterinarian preferences, all 50 AEB members received a PDF version by email, of which 16 sent it back by email and 29 filled out a hard copy that was collected at the AEB office. All 103 members from AMEVEA received a hyperlink survey and responses were downloaded.

Table 2
Percentage of self-reported prescriptions accounted for by each antibiotic class by Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming. Antibiotics classes are categorized based on the European Medicines Agency categorization.

Antibiotic classes	Cattle (n = 35)				Poultry (n = 41)				Test statistic	p- value
	Mean	Median	P75	P90	Mean	Median	P75	P90		
Category A: Avoid	**0.0**	**0**	**0**	**0**	**1.1**	**0.0**	**0.0**	**25**	682.5	**0.19**
Other (Fosfomycin)	0	0	0	0	1.1	0	0	0	682.5	0.19
Category B: Restrict	**21.0**	**21**	**29**	**38**	**36.1**	**30**	**50**	**60**	449.5	**0.01**
Cephalosporins 3rd/4th gen.	13.7	10	25	30	0.7	0	0	1	1194.5	< 0.001
Polymyxins	0.6	0	0	0	2.9	0	2	10	551.5	0.01
Quinolones	6.7	5	10	20	32.5	30	50	60	265.0	< 0.001
Category C: Caution	**19.6[a]**	**20**	**25**	**46**	**20.7[b]**	**20**	**30**	**46**	701.5	**0.87**
Aminoglycosides	7.6	5	10	20	2.7	0	0	10	957.5	0.003
Amphenicols	0.3	0	0	0	4.0	0	10	10	488.5	0.001
Cephalosporins 1st/2nd gen.	6.6	0	10	20	1.0	0	0	5	898.0	0.02
Pleuromutillins	0.0	0	0	0	1.1	0	0	0	647.5	0.06
Macrolides	5.1	0	10	13	11.9	5	20	30	501.5	0.02
Category D: Prudence	**59.4[a]**	**60**	**70**	**90**	**42.2[b]**	**40**	**50**	**100**	1021.5	**0.002**
Aminopenicillins	3.8	0	4.5	10	2.0	0	0	5	816.0	0.15
Penicillins	29.3	25	40	56	1.5	0	0	5	1366.0	< 0.001
Nitrofurans	0.0	0	0	0	0.6	0	0	0	665.0	0.11
Trimethoprim/Sulfonamides	11.8	10	20	25	14.8	10	20	30	699.5	0.85
Tetracyclines	14.5	15	20	25	23.3	10	30	75	699.5	0.85

Test statistics and p-values are based on a Mann-Whitney U test comparing the percentage of self-reported antibiotic prescriptions between cattle and poultry groups. Superscripts show significant differences between antibiotic categories within cattle and poultry groups. [a], Kruskal-Wallis test within cattle group, $\chi^2 = 72.42$, $p < 0.001$. [b], Kruskal-Wallis test within poultry group, $\chi^2 = 49.17$, $p < 0.001$.

Veterinarians from cattle and poultry groups had all practiced, on average, for more than 13 years and at more than 13 client farms (Table 1). More than 70% of veterinarians from both groups worked as assessors of farms (e.g., giving management advice to farmers, taking care of animals). Approximately two-thirds of veterinarians worked more than 60% of their time in either cattle or poultry farming, and therefore were considered specialists. Veterinarians distributed the rest of their working time across various animal species, but mainly with pigs and companion animals (Tables 1 and S2). The percentage of veterinarians having done postgraduate studies was significantly higher in cattle (51.1%) than in poultry (28.8%) ($\chi^2 = 5.11$, $p = 0.03$) (Table 1).

3.1. Description of antibiotic prescription patterns

Only 63.3% (76/120) of participants answered the question regarding antibiotic prescription. Based on these answers, the mean percentages of antibiotic prescriptions were significantly different between cattle and poultry groups for the majority of antibiotic classes (Table 2). In the cattle group, on average, the most prescribed antibiotic classes were penicillins (29.3%, a prudence category antibiotic) and 3rd/4th generation cephalosporins (13.7%, a restrict category antibiotic). In the poultry group, on average, the most prescribed antibiotic classes were quinolones (32.5%, restrict category) and tetracyclines (23.3%, a prudence category antibiotic). Although veterinarians from both groups prescribed on average mostly antibiotic classes from the prudence category (59.4% for cattle and 42.2% for poultry), 25.0% of total prescriptions by the cattle group and 36.1% by the poultry group were from the restrict category. On average, the most prescribed antibiotic classes of the caution category were aminoglycosides (7.6%) and 1st/2nd generation cephalosporins (6.6%) in the cattle group, while in the poultry group these were amphenicols (4.0%) and macrolides (11.9%). Only two participants from the poultry group reported the prescription of fosfomycin (1.1%), an antibiotic from the avoid category (Table 2).

When comparing the mean percentage of antibiotic prescription between generalist and specialist veterinarians within cattle and poultry groups, there were no significant differences between veterinarian category except for 3rd/4th generation cephalosporins (cattle: generalist = 7.7%, specialist = 17.3%, Mann-Whitney $W = 73$, $p = 0.02$; poultry: generalist = 2.5%, specialist = 0.3%, Mann-Whitney $W = 174.5$, $p = 0.02$) (Table S3). In addition, results from the logistic regression analyses showed that demographic factors (e.g., years of experience, practice situation and postgraduate studies) other than veterinarian group were generally not associated with the prescription of a particular antibiotic class (Table S4).

Table 1
Characteristics of participating Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming.

Variables	Cattle	Poultry	Test statistic[a]	p-value
Years of experience	**n = 45**	**n = 66**		
Mean (95%CI)	13.4 (11.0–15.8)	16.8 (14.3–19.4)	1220	0.11
Number of farms	**n = 41**	**n = 60**		
Mean (95%CI)	16.0 (7.8–24.3)	13.7 (8.1–19.4)	1323	0.52
Percentage of working time, mean (95%CI)	**n = 45**	**n = 68**		
Laying hens	0.7 (0.0–1.4)	21.8 (15.9–27.8)	550	< 0.001
Broiler	2.1 (0.6–4.1)	54.2 (46.8–61.7)	185	< 0.001
Pigs	9.8 (5.8–13.7)	9.2 (5.9–12.5)	1625.5	0.54
Dairy cattle	61.7 (53.2–70.2)	5.0 (2.6–7.5)	2985	< 0.001
Beef cattle	8.3 (4.0–12.6)	1.6 (1.0–2.6)	1981.5	< 0.001
Small ruminants	4.4 (1.2–7.5)	1.2 (0.0–2.6)	1865.5	0.003
Horses	3.7 (1.4–6.0)	0.8 (0.0–1.7)	1948	< 0.001
Companion animals	7.6 (2.9–12.3)	2.4 (1.0–3.8)	1831.5	0.03
Other (e.g., fish, guinea pigs, turkey)	1.8 (0.0–4.2)	3.8 (0.5–7.2)	1344.5	0.07
Practice situation, n (% within sector)	**n = 45**	**n = 68**		
Assessor	32 (71.1)	54 (79.4)	5.11	0.09
Owner	12 (26.7)	11 (16.2)		
Other (e.g., lab technicians, sales agents)	1 (2.2)	3 (4.4)		
Postgraduate studies, n (% within sector)	**n = 45**	**n = 66**		
Yes	23 (51.1)	19 (28.8)	4.75	0.03
No	22 (48.9)	47 (71.2)		
Veterinarian category, n (% within sector)	**n = 45**	**n = 75**		
Generalist	18 (40.0)	26 (34.7)	0.15	0.69
Specialist	27 (60.0)	49 (65.3)		

Differences in numbers (n) due to incomplete questionnaires.
[a] Test statistic comparing responses between cattle and poultry groups. The Mann-Whitney U test was used for numeric variables and the chi-squared test was used for categorical variables.

3.2. Prescription of antibiotics according to disease

Generally, veterinarians reported prescribing different antibiotic classes to treat the same type of disease (Fig. 1, Table S5). The most frequent diseases that antibiotics were prescribed for were respiratory (cattle = 23.9%, poultry = 35.3%) and gastrointestinal (cattle = 19.6%, poultry = 20.6%). Approximately 30% of veterinarians from cattle and poultry groups prescribed antibiotic classes from the restrict category to treat respiratory and gastrointestinal diseases, especially quinolones and polymyxins. Similarly, antibiotic classes from the caution category were mostly prescribed to treat respiratory and gastrointestinal diseases, but also for reproductive diseases, udder diseases, and other type of disease including skin and eye problems. In the poultry group, fosfomycin was reported to be used for respiratory disease (Fig. 1).

3.3. Attitudes and perceptions of veterinarians towards AMR and antibiotic use

Generally, veterinarians showed a high concern about AMR and its implications for public health (mean scores > 4.5 for all statements). Interestingly, veterinarians from the poultry group were more likely to report neutral beliefs about the notion that AMR in animals will only be a problem for veterinary medicine, while veterinarians from the cattle group were more likely to disagree or strongly disagree with this statement (Mann-Whitney $W = 119.5$, $p = 0.003$) (Tables 3 and S6). Moreover, most veterinarians strongly agreed with their own responsibility as prescribers and showed high awareness towards the need for reduction of antibiotic use (mean scores > 4.0 for all statements) (Tables 4 and S7). Most veterinarians strongly agreed that pharmaceutical companies play an important role in antibiotic use, and agreed that other non-veterinary advisors (e.g., zootechnicians, sales agents), also play an important role. Furthermore, veterinarians strongly agreed that the most important barriers for appropriate antibiotic use were poor biosecurity measures on farms, animal confinement, and poor-quality feed (Table 4).

Mostly, cattle and poultry veterinarians were either neutral or disagreed with statements related to that antibiotic prescription is a quick and easy solution, meaning not having many perceived obstacles for antibiotic prescription (mean scores between 1.0 and 3.0) (Tables 5 and S8). The majority of veterinarians agreed or strongly agreed with statements regarding the need for appropriate antibiotic use (mean score between 3.6 and 4.7). However, poultry veterinarians less commonly agreed with banning antibiotics as growth promoters compared to cattle

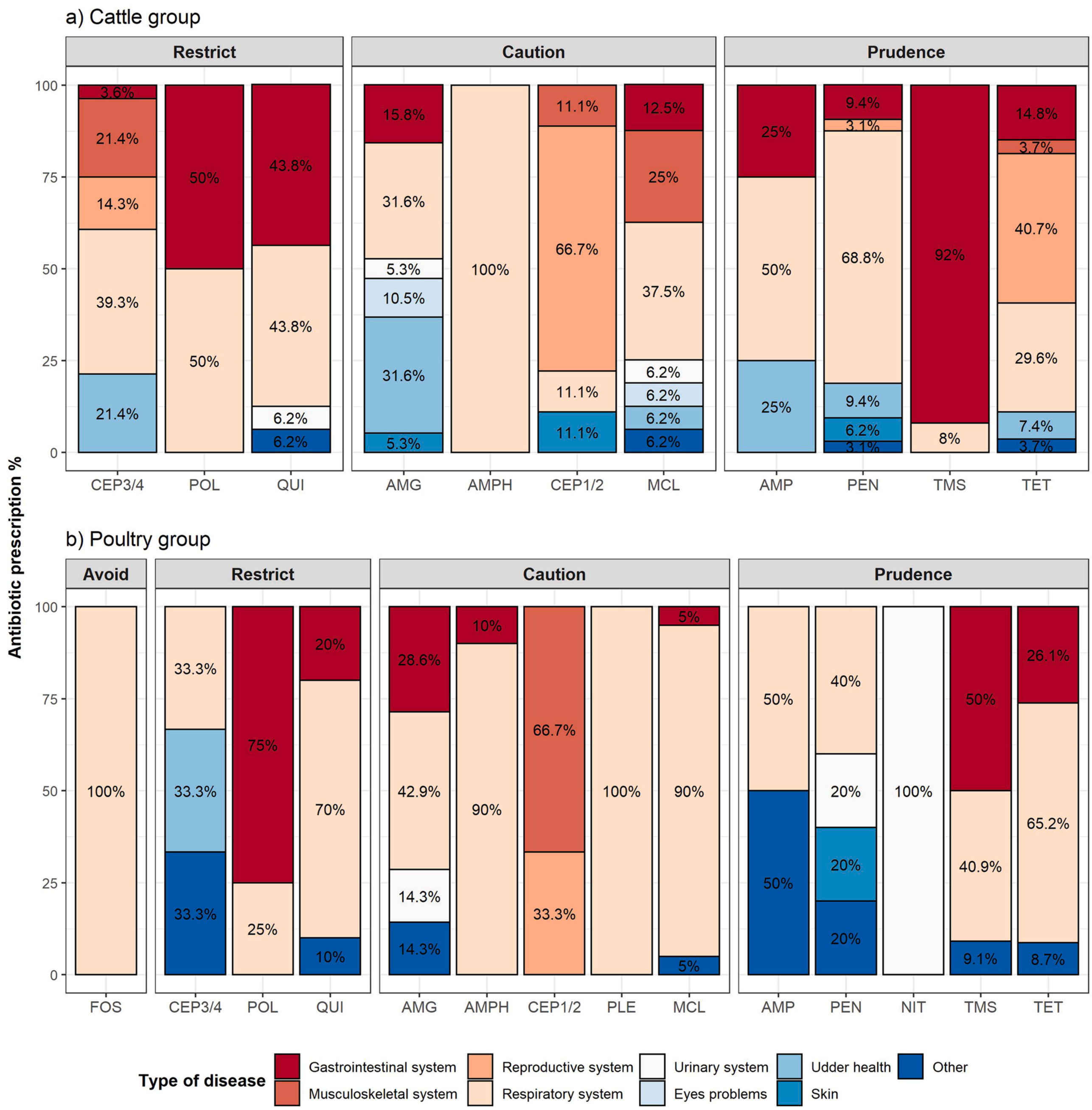

Fig. 1. Percentage of antibiotic prescriptions according to the type of disease and antibiotic category by Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming (please note that as some veterinarians were generalists, not all prescriptions relate directly to treatment for cattle or poultry). FOS, Fosfomycin; CEP3/4, Cephalosporins 3rd/4th generation; POL, Polymyxins; QUI, Quinolones; AMG, Aminoglycosides; AMPH, Amphenicols; CEP1/2, Cephalosporins 1st/2nd generation; PLE, Pleuromutilins; MCL, Macrolides; AMP, Aminopenicillins; PEN, Penicillins; NIT, Nitrofurans; TMS, Trimethoprim/Sulfonamides; TET, Tetracyclines. The category "other" includes diseases such as omphalitis, haemoparasites diseases (piroplasmosis, anaplasmosis) and general septicemia.

veterinarians (poultry: mean = 3.76, SD = 1.39; cattle: mean = 4.44, SD = 1.14; Mann-Whitney $W = 2103.5$, $p = 0.001$), while cattle veterinarians less commonly agreed with susceptibility testing compared to poultry veterinarians (cattle: mean = 3.67, SD = 1.24; poultry: mean = 4.26, SD = 0.97; Mann-Whitney $W = 1135.0$, $p = 0.01$) (Table 5).

In addition, the most important considerations for both cattle and poultry veterinarians when choosing which antibiotic to prescribe were: type of disease, results of susceptibility testing, and withdrawal period (mean scores > 4.5 for all statements). Fig. 2 shows pooled results of cattle and poultry veterinarians since there were no significant differences between groups (results for each group are in the supplementary materials).

3.4. *Beliefs regarding farmers' role in antibiotic use*

The most important beliefs for both cattle and poultry veterinarians regarding the role of farmers in antibiotic use were: farmers do not call a veterinarian due to economic reasons; farmers tend to buy antibiotics themselves and store them on their farms, and farmers stop an antibiotic treatment shortly after clinical signs disappear (mean scores > 4.2 for all statements). Fig. 3 shows pooled results of cattle and poultry veterinarians (with results by group in the supplementary materials). Most

Table 3
Relative importance Index (RII) and mean score of 5-point Likert scale statements regarding awareness towards antimicrobial resistance (AMR) and its implications for public health by Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming.

Statements	Cattle n	Cattle Mean (SD)	Cattle RII[a]	Poultry n	Poultry Mean (SD)	Poultry RII	Test statistic[b]	P value
– Veterinarians have a crucial role in protecting public health.	45	4.98 (0.15)	1.00	74	4.45 (1.18)	0.89	2038.0	0.001
– The possible contribution of veterinary AMU to the development of AMR in humans is worrisome.	45	4.58 (0.97)	0.92	73	4.11 (1.12)	0.82	2108.0	0.004
– Antibiotic treatment failures are often experienced in daily practice.	45	3.78 (1.38)	0.76	74	3.84 (1.17)	0.77	1848.0	0.05
– Authorities overstate the risk of AMR.	45	2.49 (1.58)	0.50	74	2.77 (1.50)	0.55	1511.0	0.38
– AMR in animals will only be a problem for veterinary medicine.	45	1.64 (1.25)	0.33	74	2.53 (1.62)	0.51	1179.5	0.003

Differences in numbers (n) due to incomplete questionnaires; RII value, the closer to 1 the more important; Test statistic corresponded to a Mann-Whitney U test comparing the distribution of the scores between cattle and poultry groups.

Table 4
Relative importance Index (RII) and mean score of 5-point Likert scale statements regarding perceptions towards antibiotic use in food-producing animals by Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming.

Statements	Cattle			Poultry			Test statistic	P value
	n	mean (SD)	RII	n	mean (SD)	RII		
Awareness of own responsibility on antibiotic use								
– Antibiotic prescriptions for animals should be solely done by veterinarians.	44	4.91 (0.60)	0.98	74	4.80 (0.60)	0.96	1848.0	0.05
– Veterinarians should improve their communication skills with farmers to promote prudent antibiotic use.	44	4.84 (0.43)	0.97	54	4.83 (0.54)	0.97	1161.5	0.74
Awareness towards reduction of antibiotic use								
– It is important to reduce antibiotic use for public health and food safety.	44	4.75 (0.72)	0.95	56	4.82 (0.43)	0.96	1228.0	0.97
– Veterinary antibiotic use should be reduced because of increasing resistance.	44	4.36 (1.06)	0.87	57	4.28 (1.11)	0.86	1310.0	0.66
– The current consumption level of antibiotics in food-producing animals is too high.	45	4.24 (1.00)	0.85	73	4.04 (1.16)	0.81	1775.5	0.43
– Veterinary antibiotic use has been reduced compared to past years.	45	2.69 (1.49)	0.54	74	3.22 (1.36)	0.64	1333.5	0.06
Non-veterinarians' role on antibiotic use								
– Controlling veterinary antibiotic sales at pharmacies would reduce inappropriate antibiotic use.	44	4.61 (0.97)	0.92	57	4.60 (0.68)	0.92	1379.0	0.27
– Pharmaceutical companies have influence on the high veterinary antibiotic use.	45	4.47 (0.84)	0.89	74	4.09 (1.23)	0.82	1894.5	0.16
– Pharmaceutical companies have an important role in promoting prudent antibiotic use.	44	4.36 (1.06)	0.87	56	4.50 (0.85)	0.90	1170.0	0.61
– Non-veterinary advisors frequently provide information about antibiotic therapy to farmers.	45	3.56 (1.71)	0.71	74	3.65 (1.60)	0.73	1637.5	0.87
– Better quality requirements for animal-feed companies have contributed to reduce antibiotic use.	45	3.33 (1.33)	0.67	74	4.04 (0.88)	0.81	1173.5	0.004
– Small holders are more responsible for inappropriate use of antibiotics than commercial farmers.	45	3.29 (1.41)	0.66	73	3.32 (1.50)	0.66	1606.5	0.84
Barriers to appropriate antibiotics use								
– Poor biosecurity measures on the farm leads to infectious diseases spreading.	44	4.98 (0.15)	0.99	57	4.88 (0.38)	0.97	1358.0	0.11
– Farm animal confinement increases stress in animals leading to increased risk of infectious diseases.	44	4.64 (0.81)	0.93	57	4.53 (0.78)	0.90	1382.5	0.27
– Poor quality feed in animals leads to immunity problems making them susceptible for infectious diseases.	44	4.34 (0.91)	0.86	57	4.61 (0.75)	0.92	1045.5	0.09
– Aiming for maximum growth or production makes animals more susceptible to infections.	44	4.50 (0.98)	0.90	57	4.16 (1.15)	0.83	1501.5	0.05
– Antibiotic therapies are often economically beneficial for treating low to moderate clinical symptoms.	43	3.28 (1.22)	0.65	57	3.84 (1.21)	0.92	864.5	0.01
– Reducing veterinary antibiotic use will be at the cost of animal health and welfare.	44	3.55 (1.41)	0.71	57	3.53 (1.50)	0.71	1241.0	0.93
– The prescription of antibiotics represents financial benefits for veterinarians.	44	2.09 (1.27)	0.42	57	2.56 (1.40)	0.51	1017.5	0.09
– The addition of antibiotics in animal feed is necessary to achieve high production levels.	44	2.16 (1.33)	0.43	57	2.67 (1.34)	0.53	983.0	0.05

Differences in numbers (n) due to incomplete questionnaires; RII value, the closer to 1 the more important; Test statistic corresponded to a Mann-Whitney U test comparing the distribution of the scores between cattle and poultry groups.

Table 5
Relative importance Index (RII) and mean score of 5-point Likert scale statements regarding attitudes towards antibiotic prescription by Ecuadorian veterinarians from two professional organizations focused on cattle or poultry farming.

Statements	Cattle			Poultry			Test statistic	P value
	n	Mean (SD)	RII	n	Mean (SD)	RII		
Antibiotic prescription can be a quick and easy solution								
– My principal indicator to prescribe antibiotics in a sick animal is presence or absence of fever.	45	2.98 (1.44)	0.60	70	2.63 (1.48)	0.53	1798.5	0.19
– When confronted with diseased animals, I immediately apply antibiotics to prevent spread of the disease.	45	2.69 (1.40)	0.54	70	2.87 (1.41)	0.57	1464.5	0.51
– Occasionally I feel pressure from farmers to prescribe antibiotics.	45	2.36 (1.55)	0.47	70	3.14 (1.40)	0.63	1138.5	0.01
– I sometimes use antibiotics, even when the diagnosis is unclear.	44	2.02 (1.19)	0.40	70	2.90 (1.35)	0.58	996.0	0.001
– When I experience antibiotic treatment failure, I tend to increase the dose and days of treatment.	45	1.76 (1.11)	0.35	70	2.04 (1.30)	0.41	1424.5	0.34
– I am in favor of using antibiotics in healthy animals to prevent animal diseases.	45	1.09 (0.36)	0.22	70	1.53 (1.13)	0.31	1329.0	0.03
Willingness for appropriate antibiotic use								
– I consider it an obligation to provide information regarding appropriate antibiotic use to farmers.	45	4.69 (0.85)	0.94	70	4.69 (0.84)	0.94	1577.5	0.99
– It is my goal to reduce antibiotic use as much as possible.	45	4.64 (1.05)	0.93	70	4.43 (1.03)	0.89	1857.0	0.03
– I would support a ban of using antibiotics as growth promoters.	45	4.44 (1.14)	0.89	70	3.76 (1.39)	0.75	2103.5	0.001
– It is important to try treatments other than antibiotics to treat animals with clinical symptoms.	45	4.16 (1.17)	0.83	68	4.19 (0.93)	0.84	1599.5	0.66
– When I experience antibiotic treatment failure, I tend to change the class of antibiotic used.	45	4.00 (1.22)	0.80	70	3.63 (1.31)	0.73	1856.5	0.09
– I do all the antibiotic prescription and farmers do the administration under my instructions.	44	3.93 (1.23)	0.79	68	4.06 (1.01)	0.81	1472.0	0.88
– I always take a sample for susceptibility testing to choose the correct antibiotic treatment.	45	3.67 (1.24)	0.73	70	4.26 (0.97)	0.85	1135.0	0.01

Differences in numbers (n) due to incomplete questionnaires; RII value, the closer to 1 the more important; Test statistic corresponded to a Mann-Whitney U test comparing the distribution of the scores between cattle and poultry groups.

veterinarians disagreed with the statement that farmers know about the risk of AMR (mean = 2.45, SD = 1.41). There were significant differences between cattle and poultry groups mean responses to two statements: farmers tend to buy the cheapest antibiotic (cattle: mean = 4.41, SD = 0.97; poultry: mean = 3.91, SD = 1.19; Mann-Whitney $W = 174.5$, $p = 0.01$) and farmers used antibiotics as a preventive measure (cattle: mean = 3.46, SD = 1.41; poultry: mean = 4.18, SD = 0.87; Mann-Whitney $W = 909.5$, $p = 0.01$) (Table S10).

3.5. Strategies to promote appropriate antibiotic use in food-producing animals

Fig. 4 shows pooled results between cattle cand poultry veterinarians because there were no significant differences between the two groups (results by group reported in the supplementary materials). Over 80% of veterinarians agreed that all possible strategies presented in the questionnaire would promote appropriate antibiotic use and there were no significant differences between cattle and poultry groups (Table S11). The most important strategies according to veterinarians were: improving biosecurity measures, implementing education programs for veterinarians about prudent antibiotic use, and education programs for farmers about prevention of infectious diseases (mean scores > 4.8 for all statements). Strategies that were rated by veterinarians as less important were: restricting the addition of antibiotics in animal feed, developing general guidelines for antibiotic prescription, and restricting the use of antibiotics as a preventive measure (Fig. 4).

4. Discussion

In this cross-sectional study we explored antibiotic prescription patterns and non-clinical factors influencing antibiotic use by Ecuadorian veterinarians who work mainly on cattle and poultry farms and were members of a professional association. Findings indicate that on average, approximately 20% of estimated (self-reported) prescriptions by cattle and poultry veterinarians in Ecuador are classified as the restrict category by EMA (EMA, 2020), and that antibiotic therapy was not always tailored to disease. Cattle and poultry veterinarians share similar attitudes and perceptions regarding AMR and antibiotic use. They also share similar beliefs about the role of farmers as users of antibiotics. In general, veterinarians were broadly supportive of most strategies to promote appropriate antibiotic use and antibiotic stewardship in food-producing animals.

Since we did not collect data regarding the circumstances and details of each prescription, we acknowledge that some specific instances of prescribing within the following patterns we discuss may well reflect appropriate antibiotic use (e.g., only available treatment option, lack of access to diagnostic testing). Nevertheless, the overall patterns of prescription for some classes of antibiotics reported by our participants can still be considered deleterious from the perspective of human and animal health, preserving effective antibiotics for future generations, and the goal of reduction of AMR. Veterinarians in our study reported prescribing a wide range of antibiotics to treat common diseases and often prescribed antibiotics from the restrict category (3rd/4th generation cephalosporins, polymyxins, quinolones) and from the avoid category (fosfomycin). Self-reported prescribing of restrict and avoid antibiotics tended to be higher among poultry veterinarians than cattle veterinarians. The use of these antibiotics in food-producing animals should be limited due to increasing rates of AMR in animals, and due to the potential risk of AMR transmission to humans via the food-chain (Chang et al., 2015; Aidara-Kane et al., 2018; EMA, 2020). In fact, in Ecuador, high resistance levels to these antibiotics (ranging from 50% to 90%) were found in *Salmonella*, *Campylobacter* and *Escherichia coli* isolates from retail poultry meat (Vinueza-Burgos et al., 2016, 2017; Ortega-Paredes et al., 2020), and *E. coli* isolates carried genes that confer resistance to colistin (a polymyxin antibiotic) and broad spectrum β-lactam antibiotics (i.e., penicillins and cephalosporins antibiotics)

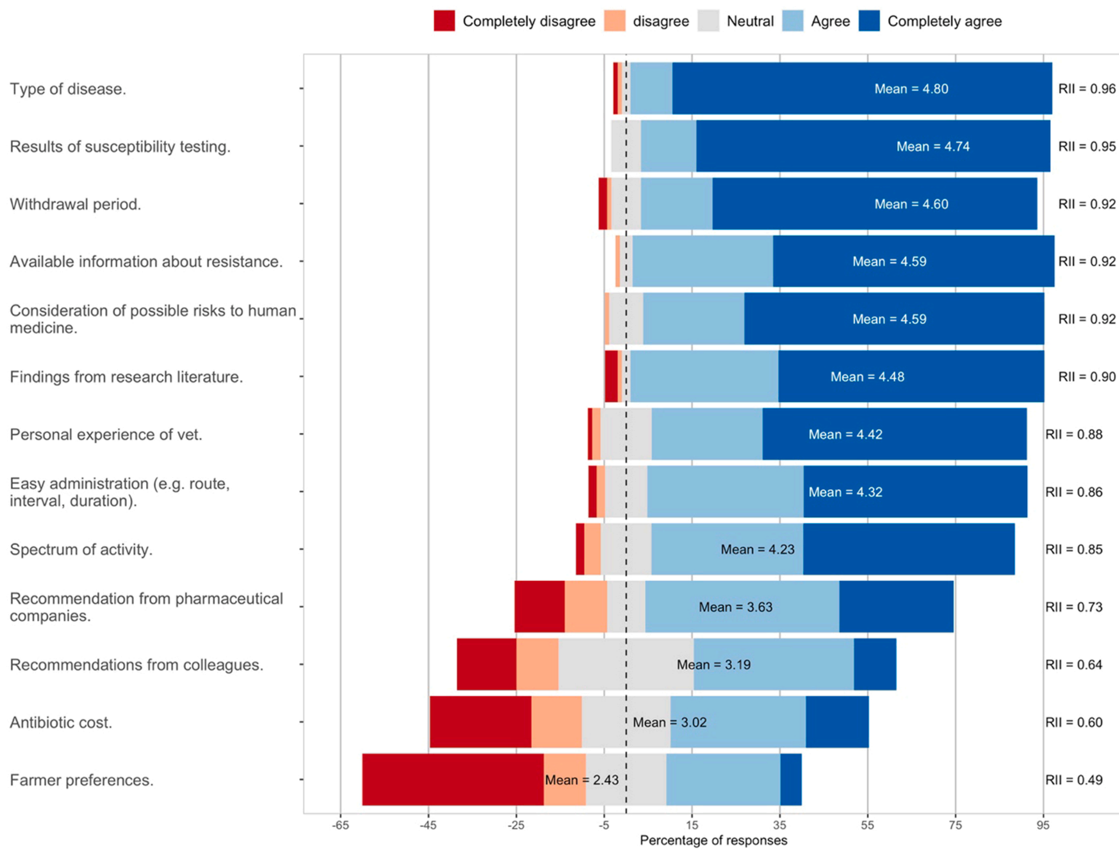

Fig. 2. Considerations of Ecuadorian veterinarians working mostly on cattle and poultry farms when choosing which antibiotic to prescribe. Statements are ranked from most to least important based on the Relative Importance Index (RII) values, the closer to 1 being the more important. Mean values inside bars represent the mean score of each 5-point Likert scale statement.

(Vinueza-Burgos et al., 2019). Considering the available evidence, the use of antibiotics in Ecuadorian farms warrants attention, particularly in the poultry sector.

The self-reported prescribing patterns by veterinarians in our study could partially result from the lack of sector-specific antibiotic therapy guidelines and the lack of restrictive policies in Ecuador. Antibiotic therapy guidelines are considered important tools for antibiotic stewardship by human clinicians and veterinarians alike (Maina et al., 2021; Roger et al., 2022). In our sample, 86.5% of veterinarians agreed with the development of therapy guidelines; therefore, this seems a viable and acceptable strategy to support more appropriate antibiotic use in Ecuador. Available evidence from other countries shows that restrictive policies influence prescribing behavior by veterinarians (McKernan et al., 2021; Servia-Dopazo et al., 2021). In Ecuador, a few governmental regulations have been taken, such as the banning of the use of nitrofurantoin (a nitrofuran), chloramphenicol (an amphenicol) and colistin (a polymyxin) in food-producing animals (AGROCALIDAD, 2016, 2019). Our study was conducted before the ban of colistin in 2019, and indeed this antibiotic was still commonly prescribed by our sample, especially among poultry veterinarians (29.3% compared to 5.7% of cattle veterinarians), but the prescription of nitrofurantoin, for instance, was limited given its ban since 2016. It is notable that even though only two poultry veterinarians reported prescribing fosfomycin, this antibiotic is used prophylactically on poultry farms in Ecuador (Vinueza-Burgos et al., 2019), as are quinolones, which are antibiotics not currently restricted by regulations in Ecuador. Hence, our findings suggest the need for better policies for antibiotic stewardship on Ecuadorian farms.

The majority of veterinarians in our study were aware of AMR and its implications for public health, as well as the need for appropriate antibiotic use. However, some veterinarians appear to underestimate the potential contribution of veterinary antibiotic use on AMR in humans. This finding was in line with previous studies (Speksnijder et al., 2015b; Hardefeldt et al., 2018; Norris et al., 2019) and may be partially explained by the presence of optimism bias (i.e., a cognitive expectation of people to underestimate the likelihood of a negative event) among veterinarians (Sharot, 2011). Optimism bias was associated with suboptimal antibiotic use by clinicians working in human medicine (Langford et al., 2020). Future research could explore whether optimism bias is also important in influencing beliefs about AMR and prescribing behaviors among veterinarians.

In our study, more than 90% of veterinarians showed high awareness of their own responsibility as prescribers and agreed with statements concerning appropriate antibiotic use (e.g., reduce antibiotic use, enhance communication with farmers). Nevertheless, some veterinarians disagreed with a number of statements aligned with practices necessary for reducing overall antibiotic use and increasing antibiotic stewardship, such as the banning of antibiotics as growth promoters (AGPs) (Laxminarayan et al., 2013; Dyar et al., 2017). Specifically, 20% of poultry veterinarians disagreed with banning of AGPs, compared with 6.7% of cattle veterinarians. This finding may be related to norms within the poultry industry, where the use of AGPs is socially acceptable (McKernan et al., 2021), and widely practiced in Ecuador, whereas AGPs are less widely used in the cattle industry in Ecuador. These norms may result in perceived pressure upon poultry veterinarians to use AGPs to achieve the demands and expectations from clients; indeed, 48.5% of poultry veterinarians from our study reported feeling pressure from farmers to prescribe antibiotics. The feeling of pressure to prescribe antibiotics was also reported by veterinarians from other countries (McKernan et al., 2021; Servia-Dopazo et al., 2021). Improving

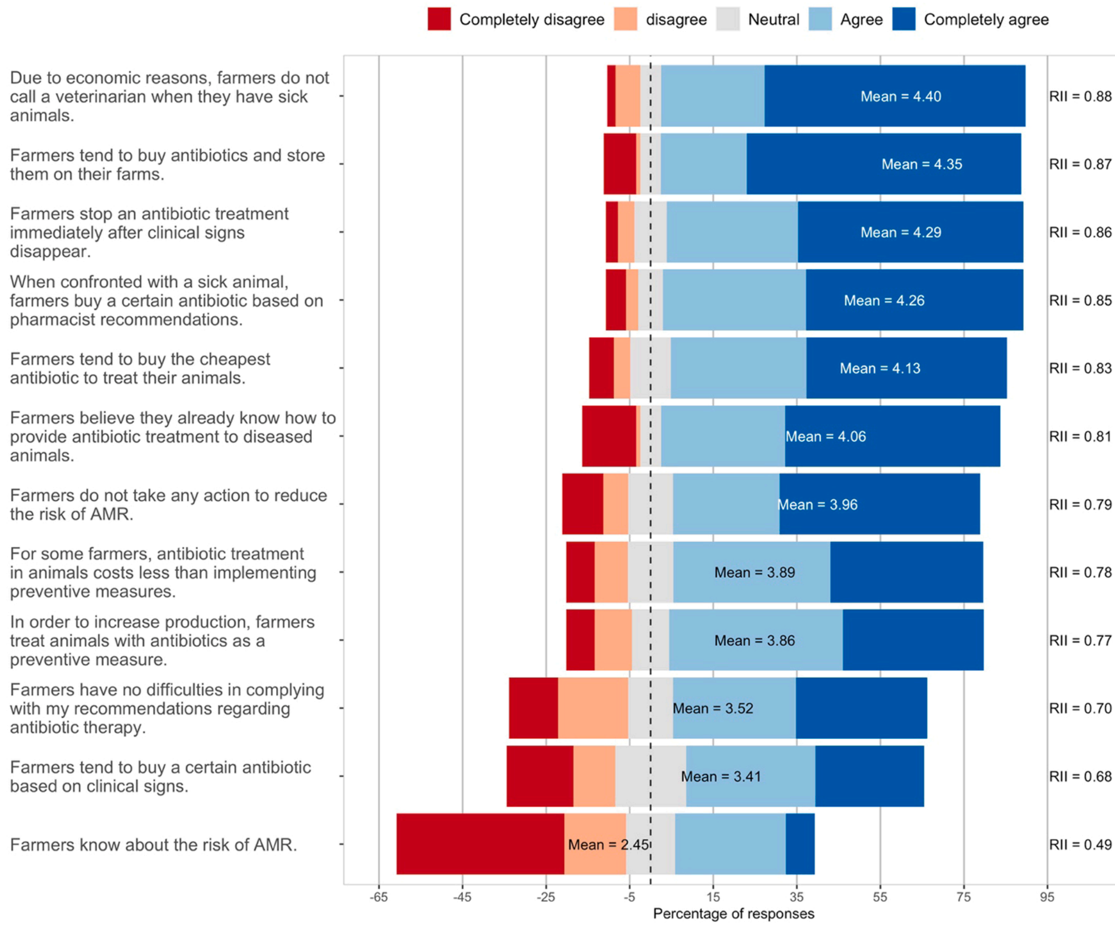

Fig. 3. Beliefs of Ecuadorian veterinarians working mostly on cattle and poultry farms regarding the role of farmers as user of antibiotics. Statements are ranked from most to least important based on the Relative Importance Index (RII) values, the closer to 1 being the more important. Mean values inside bars represent the mean score of each 5-point Likert scale statement.

veterinarian-client relationships may attenuate this pressure and support veterinarians in challenging farmers' expectations for antibiotic prescriptions (Speksnijder et al., 2015a; Visschers et al., 2016; Higgins et al., 2017). Potentially, a social identity approach could be used to improve the relationship between veterinarians, farmers, and company representatives to encourage all actors to work together towards the common goal of reducing antibiotic use (Golding et al., 2019).

Several barriers for the reduction of antibiotic use and improved stewardship in Ecuador were identified in our study. In line with previous studies (Servia-Dopazo et al., 2021), cattle and poultry veterinarians perceived structural-management factors (e.g., poor biosecurity measures, animal confinement and poor quality of animal feed) as important barriers. The importance of biosecurity as a strategy to reduce antibiotic use in farms has previously been described (Stygar et al., 2020), and this strategy was accepted by 97.1% of veterinarians in our study. However, the decision by farmers to adopt biosecurity measures is complex, as it is likely influenced by various factors including personal experience, perceived responsibility for public health, and cost-benefit considerations (Ritter et al., 2017). Veterinarians also recognize the complexity of implementing biosecurity measures on farms (Shortall et al., 2016). By understanding the role of these factors, communication strategies focused on evidence-based benefits may help improve the adoption of biosecurity measures and further reduce antibiotic use (Renault et al., 2021). Future studies focused on factors influencing biosecurity adoption by Ecuadorian farmers will be necessary to find effective communication strategies to help promote veterinary antibiotic stewardship in the Ecuadorian context.

Other barriers for improved antibiotic stewardship may be veterinarians' beliefs and perceptions regarding farmers' attitudes as users of antibiotics (e.g., do not call a veterinarian due to economic reasons, stopping a treatment after clinical signs disappear, buying antibiotics and storing them on their farms), and the role of non-veterinary advisors (e.g., sales agents) as potential "prescribers of antibiotics". For instance, more than 90% of veterinarians in our study believe that antibiotic use could be reduced by controlling antibiotic sales in stores. Indeed, a simulated client study in veterinary supply stores from Ecuador showed that 68% of sales agents recommended AGP and 48% recommended the wrong antibiotic class for disease treatment (Butzin-Dozier et al., 2021). The role of the pharmaceutical industry and sales agents was also found to be inappropriate in other developing countries, since they routinely sell antibiotics without a veterinary prescription (McKernan et al., 2021). By working closely with farmers, behaviors such as purchasing antibiotics based on sales agents' advice could be reduced. It would also be necessary, however, to explore in future studies, farmers' beliefs and values that underpin their attitudes and behaviors, to effectively influence behavior change as users of antibiotics (Redding et al., 2020). Nevertheless, by focusing on supply stores and farmers, veterinarians are potentially shifting responsibility for AMR to other actors. Other-blaming and this shifting of responsibility has been reported in other studies of veterinarians, farmers, and human clinicians and patients (Schneider et al., 2018; Smith et al., 2018; Golding et al., 2019, 2021). Similar findings have also been found among veterinary and medical students (Dyar et al., 2018; Odetokun et al., 2019; Golding et al., 2022). Working to reduce this other-blaming is a potential area for intervention by motivating behavioral changes among all actors involved in prescribing and using antibiotics.

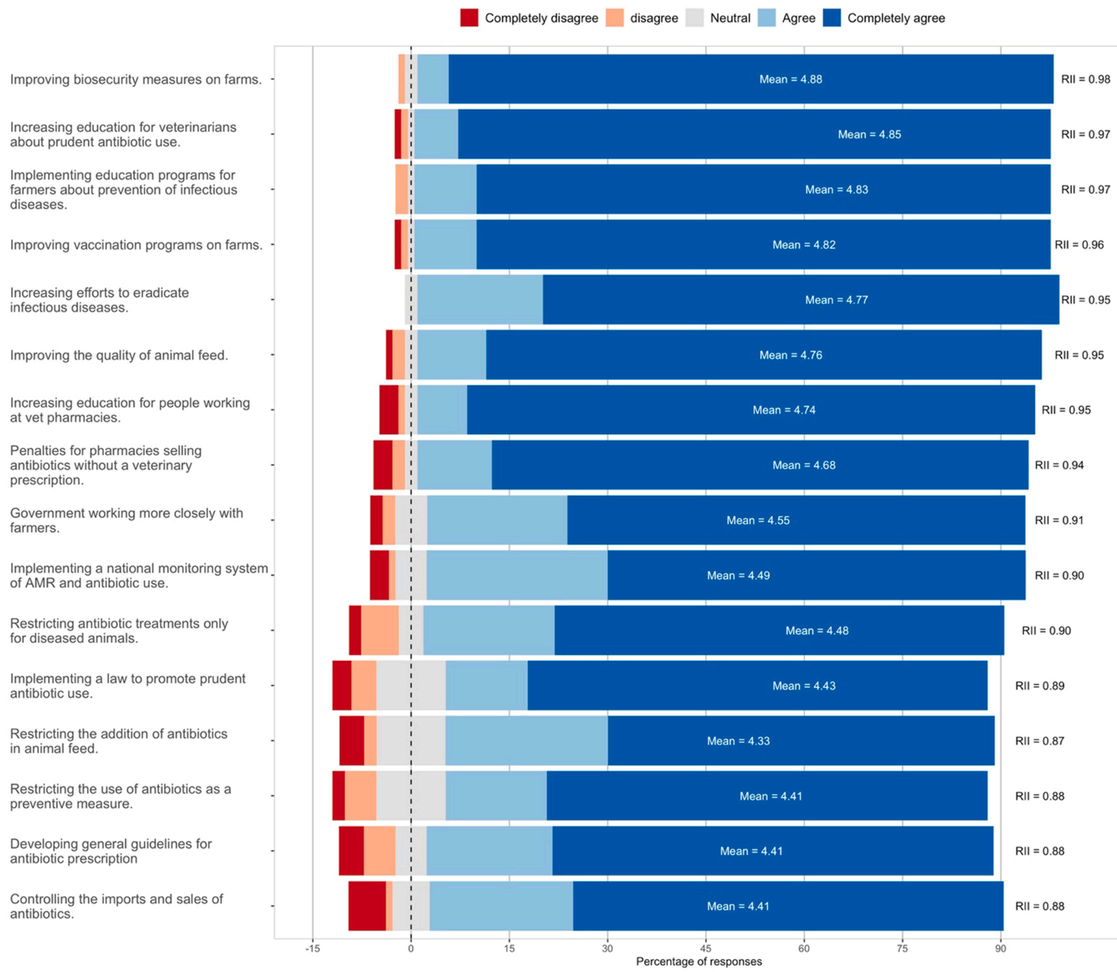

Fig. 4. Perceived most important strategies to promote appropriate antibiotic use by Ecuadorian veterinarians working mostly on cattle and poultry farms. Statements are ranked from most to least important based on the Relative Importance Index (RII) values, the closer to 1 being the more important. Mean values inside bars represent the mean score of each 5-point Likert scale statement.

Dyar et al. (2017) argue that antimicrobial stewardship involves multiple actors engaging in a coherent set of actions that promote appropriate and responsible use, and overall, the cattle and poultry veterinarians in our study were broadly supportive of the proposed strategies for increasing antibiotic stewardship. Multiple strategies will likely be required, however, led by active participation of the Government in implementing national policies to increase antibiotic stewardship in food-producing animals in Ecuador. Such policies should focus on controlling antibiotic sales in veterinary supply stores, developing national antibiotic guidelines that will serve as a basis for sector-specific guidelines, restricting the use of antibiotics for preventive and AGP uses, and implementing a national antibiotic usage surveillance program in Ecuador. Although context and challenges for each country are different, a combination of such strategies in Denmark and the Netherlands has led to a 50–70% reduction in AMU with no observed decrease in animal health (Hammerum et al., 2007; Mevius and Heederik, 2014; Santman-Berends et al., 2021). Further, strategies aimed at direct interaction with all antibiotic use actors across all food-producing animals' sectors (veterinarians, non-veterinary advisors and farmers) will be necessary to achieve antibiotic stewardship. For instance, specific educational programs designed for each sector will be an important strategy, and this was considered acceptable by more than 95% of the veterinarians in our sample. Ultimately, veterinary antibiotic stewardship in Ecuador will require a combination of interdisciplinary strategies under the concept of One Health, requiring collaboration across all sectors and industries to positively change antibiotic prescribing and usage behaviors by all actors (Powell et al., 2017; Flowers, 2018).

5. Limitations

One limitation of our study may be the sampling of veterinarians, which was based on two professional organizations that mostly focus on cattle and poultry farming. Therefore, our results may not represent the beliefs and opinions held by veterinarians not registered with these organizations or those practicing in other areas of veterinary medicine in Ecuador. However, this study provides insight into antibiotic use in these sectors, as our participants did have more than two years' experience of working on farms, and thus, able to clearly express their professional opinions. Another possible limitation is that validation of scales was not performed as this study was designed as first attempt to explore non-clinical factors influencing antibiotic use by veterinarians in Ecuador. Furthermore, we cannot rule out the potential difference between what veterinarians answered and what they would likely do in the real world. Social desirability bias can occur in self-reporting surveys and may well be present in our study. For example, some of our Likert scale questions about mitigation strategies might be considered leading and it is possible that participants gave socially desirable responses, as the veterinarians who took part might well be aware that all of these mitigation strategies have merit in tackling AMR. We took some actions to reduce this bias such as anonymous collection of the data in an online survey (Larson, 2019). However, our findings should be interpreted with caution, especially given the high levels of agreement with some statements in the survey, and should be used as a baseline for future studies to explore the non-clinical factors underlying antibiotic prescribing behavior in cattle and poultry sectors in Ecuador. One final limitation of this study is that we collected self-reported, rather than objective, data regarding antibiotic use, and thus our study provides only an indication of actual AMU in Ecuador. However, the primary goal of this study was to explore the opinions and experiences of the veterinarians and not to quantify the amount of AMU. Of course, collecting objective AMU data could be a suitable follow-up to this study.

6. Conclusion

Professional cattle and poultry veterinarians from Ecuador were highly aware of AMR and its implications for public health, as well as the necessity for antibiotic stewardship in food-producing animals. However, in practice, veterinarians' self-reported antibiotic prescription patterns suggested prescribing behavior deleterious to the goals of reducing AMU and AMR (perhaps more so among poultry veterinarians), because they frequently prescribe antibiotics for cattle and poultry that are critically important for human medicine and antibiotic therapy was poorly tailored to disease type. Veterinarians perceived several barriers to increasing antibiotic stewardship that include structural-management factors on farms, farmers' attitudes as users of antibiotics and the participation of non-veterinary advisors as prescribers. Veterinarians were supportive of a range of strategies to increase appropriate antibiotic use and antibiotic stewardship, including improved biosecurity and education programs for both veterinarians and farmers. Antibiotic stewardship in food-producing animals in Ecuador will require collaborative efforts between all actors to implement effective strategies under the concept of One Health.

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.2023.105858.

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