Perception of poultry veterinarians on the use of antimicrobials and antimicrobial resistance in egg production

Mariana C. Torres [*,†] Tatiana R. Vieira [*] Marisa R. I. Cardoso,[*] Franciele M. Siqueira [†,‡,1] and Mauro R. Borba [*]

[*]*Department of Preventive Veterinary Medicine, Faculty of Veterinary Medicine, Federal University of Rio Grande do Sul, Rio Grande do Sul CEP: 91540-000, Brazil;* [†]*Postgraduate Program in Veterinary Science, Faculty of Veterinary Medicine, Federal University of Rio Grande do Sul, Rio Grande do Sul CEP: 91540-000, Brazil; and* [‡]*Department of Veterinary Clinical Pathology, Faculty of Veterinary Medicine, Federal University of Rio Grande do Sul, Rio Grande do Sul CEP: 91540-000, Brazil*

ABSTRACT This study aimed to describe the perception of veterinarians who work with commercial laying hens in the state of Rio Grande do Sul, Brazil, regarding the use of antibiotics and their possible impacts on animal, human, and environmental health. A descriptive epidemiological study was carried out through face-to-face or web conferencing interviews with the veterinarians that provide technical assistance at commercial laying hen operations. A standardized and structured questionnaire was developed based on the literature and expert opinion, which contained 1 opened and 40 closed questions. Conventional non-probabilistic sampling was used, based on an initial list of 15 veterinarians registered in the Poultry Production Association of Rio Grande do Sul, followed by the snowball technique. The acquisition of 26 contacts of veterinarians was accomplished, and 16 were interviewed. Through the answers obtained it was possible to verify that the interviewees' understanding regarding both the antibiotic resistance impact and the decision-making about the use of antibiotics seem to be linked to their practical experiences. Besides that, according to the veterinarians, farmers can acquire and administer the antimicrobials on their farms. Moreover, both farm storage and administration of lower doses of antibiotics than the recommended one could be contributing factors to resistant bacteria selection. Furthermore, controversially, the professionals believed that resistant bacteria can be transmitted to humans from eggs, but they said that there are no bacteria in eggs. Therefore, the veterinarians´ practices can be improved considering national and international guidelines on antimicrobial resistance to minimize the development of resistance. Finally, it is expected that the present results will contribute to a more complex discussion about antimicrobial resistance, helping to formulate public policies in the egg production industry.

Key words: laying hens, antibiotics, knowledge/awareness, One Health

2022 Poultry Science 101:101987
https://doi.org/10.1016/j.psj.2022.101987

INTRODUCTION

Infections with antimicrobial-resistant (**AMR**) bacteria cause numerous deaths in the human population each year (O'Neill, 2016; OECD, 2018; Cassini et al., 2019). The lack of new antimicrobials able to tackle resistant bacteria and the increasing prevalence of multidrug-resistant pathogens allow foreseeing that AMR may constitute a main threat to human health in the coming years (O'Neill, 2016).

In this scenario, the use of antimicrobials in food animals has gained a great deal of attention worldwide, particularly regarding the class of drugs that are medically important (Ma et al., 2021). Misuse and overuse of antimicrobials lead to increased selection pressure, which contributes to the emergence of resistant bacteria colonizing humans as well as to the transfer of resistance genes within the pathogenic and commensal microbiota (Ma et al., 2021).

Brazil is a well-recognized global player in poultry production, ranking as the third-largest poultry meat producer (ABPA, 2021). Although egg production plays a less important role in Brazilian exportations, the domestic consumption has been increasing in the last years, reaching 251 eggs per capita in 2020. To meet this demand, approximately 118.5 million laying hens were housed in the commercial production

Received March 8, 2022.
Accepted May 29, 2022.

[1]Corresponding author: franciele.siqueira@ufrgs.br

system in 2019 (ABPA, 2021). The southern and southwestern regions contribute with two-thirds of egg production in Brazil, predominantly from caged hens. However, the stock density of caged hens has implications on the production, welfare, and spread of diseases (Weimer et al., 2019). The latter factor in turn may be a driver for enhancing the prophylactic, metaphylactic, and therapeutic use of antimicrobials during the production cycle, which contributes to the selection pressure towards antimicrobial resistance. Several studies have reported antimicrobial resistance in commensal and pathogenic bacteria isolated from laying hens, demonstrating that selection pressure is present within the production systems (Kim et al., 2019; Moreno et al., 2019; Seo and Lee, 2019; Seo et al., 2020; Rivera-Gomis et al., 2021).

Veterinarians play a key role in antimicrobial prescription and use in animals (World Organization for Animal Health, 2015). A greater understanding of their beliefs and knowledge about antimicrobial use and AMR might provide insight into their prescribing behaviors and help to develop policies and strategies aiming at reducing antimicrobial use. Several studies carried out with veterinarians working in food animal production have resulted in highly variable outcomes; production type, professional experience, and country seem to influence these outcomes (Norris et al., 2019; Truong et al., 2019; Llanos-Soto et al., 2021; Padda et al., 2021). It is noteworthy that only few studies have targeted veterinarians working in poultry production, especially in egg production (Adam et al., 2019; Imam et al., 2020; Taylor et al., 2020). In Brazil, although antimicrobial resistance is recognized as an important matter, and a national program targeting antimicrobial use and AMR in food animal production has been launched (Brazil, 2018), there are still gaps in monitoring and knowledge that need to be addressed (Roth et al., 2019). To the best of our knowledge, so far, no study has been conducted on veterinarians' perceptions about antimicrobial use and AMR in Brazil.

In this context, the present study aimed to describe the perceptions and knowledge of veterinarians working in the commercial table egg layer industry about the use of antimicrobials and the impact of AMR on animal, human, and environmental health.

MATERIALS AND METHODS

Study Design, Target Population and Sampling Procedure

A descriptive epidemiological study with a conventional non-probabilistic sampling frame (Dohoo et al., 2014) was conducted between March 2020 and June 2021 in Rio Grande do Sul state, southern Brazil. According to Brazilian law, every commercial egg laying poultry farm must hire a veterinarian in charge of ensuring animal health and welfare and providing guidance on public health issues (Brazil, 1968). During the analyzed period, the state of Rio Grande do Sul had approximately 100 veterinarians registered in the State Department for Agriculture, Livestock, and Rural Development (**SEAPDR**) as health manager in commercial egg laying farms. Since personal information of these veterinarians could not be disclosed by SEAPDR, the e-mail addresses and phone numbers of the veterinarians were obtained among the members of the Poultry Production Association of Rio Grande do Sul (**ASGAV**). Thus, the source population was composed of 15 veterinarians currently working with commercial egg laying poultry and members of the ASGAV. Initial contact was made by e-mail, presenting the study and inviting them to participate. To increase the number of interviewees, the snowball technique was used (Naderifar et al., 2017), in which the veterinarians willing to participate in the study provided contact information of other veterinarians compatible with the study profile. Eventually, 26 invitations to participate in the study were sent by electronic mail. The study was approved by the Research Ethics Committee of the Federal University of Rio Grande do Sul (CAAE 41648620.4.0000.5347).

Questionnaire Design and Data Collection

A standardized and structured questionnaire (Supplementary Table 1) was developed based on the literature and opinions of experts (3 microbiologists and 1 epidemiologist). The questionnaire encompassed 1 open question and 40 closed ones; among these, 7 could be answered openly. The closed questions were composed of Likert scale answers (strongly disagree, disagree, neutral, agree, strongly agree), checklists, and multiple-choice answers, which are generally easier to be answered and coded in databases (Dohoo et al., 2014).

In the questionnaire, five major groups of questions were asked, namely sociodemographic characteristics, knowledge about antibiotics use in the production of eggs, knowledge about possible routes for the dissemination of resistant bacteria, identification of factors that influence antibiotics use in animals, and the existence of alternative methods to the use of antibiotics.

The questionnaire was prepared in the target-population native language (Portuguese), applied by a single and trained researcher (M.C.T.), and submitted to pre-test with 3 veterinarians working in the commercial egg laying industry. Through the pre-test, it was possible to identify and eliminate inconsistencies to achieve better data quality.

The questionnaire was applied through interviews over video conference or face-to-face. At the beginning of the interview, the respondents were informed about the research objectives and were asked to express their consent to participate in the study by signing the informed consent form. In this consenting form, they were informed about their voluntary participation, confidentiality of responses, and the possibility of withdrawing from the study at any time.

Data Management and Analysis

The participants' responses were initially summarized in Microsoft Excel 7 (Microsoft Corporation, Redmond, WA) spreadsheets. The open questions and the questions with the possibility of complementation were transcribed into a Microsoft Word 7 (Microsoft Corporation) file. Analyses of the distribution of responses on the Likert scale were performed using Microsoft Excel 7 (Microsoft Corporation), and the narratives were evaluated by searching for the most cited terms of the respondents through Nvivo 12 (QRS International, Melbourne, Australia). The QGis Desktop 3.8.3 software was used to build the map depicting the location of the egg farms under the supervision of the interviewed veterinarians.

RESULTS

Sociodemographic Data

Sixteen veterinarians (61.5% of the invited) working in commercial egg farms agreed to participate in the interviews and answer the questionnaire. The interviewed veterinarians provided technical assistance to 167 egg farms, in which approximately 16,940,000 laying hens were housed. The farms were located in the Northwest, Northeast, and Mideast regions of Rio Grande do Sul and in the metropolitan region of its capital Porto Alegre (Figure 1). The typical interviewee as a male veterinarian, between 30 and 50 years old, practicing for 10 or more years, and in charge for up to 20 egg farms (Table 1).

Table 1. Demographics information of veterinarians interviewed.

Demographic		Veterinarians (n[1])
Sex	Male	12
	Female	4
Age	Median (range)	49.5 (28−73) yrs
	<30 yrs	1
	30−40 yrs	4
	41−50 yrs	4
	>50 yrs	7
Total years working in the egg production	< 1yr	1
	1−5 yrs	3
	6−10 yrs	3
	>10 yrs	9
Number of farms under the veterinarian technical supervision	Median (range)	5.5 (1−60)
	<5 farms	7
	5−20 farms	6
	20−40 farms	2
	>40 farms	1

[1]Number of respondents, from a total of 16 veterinarians.

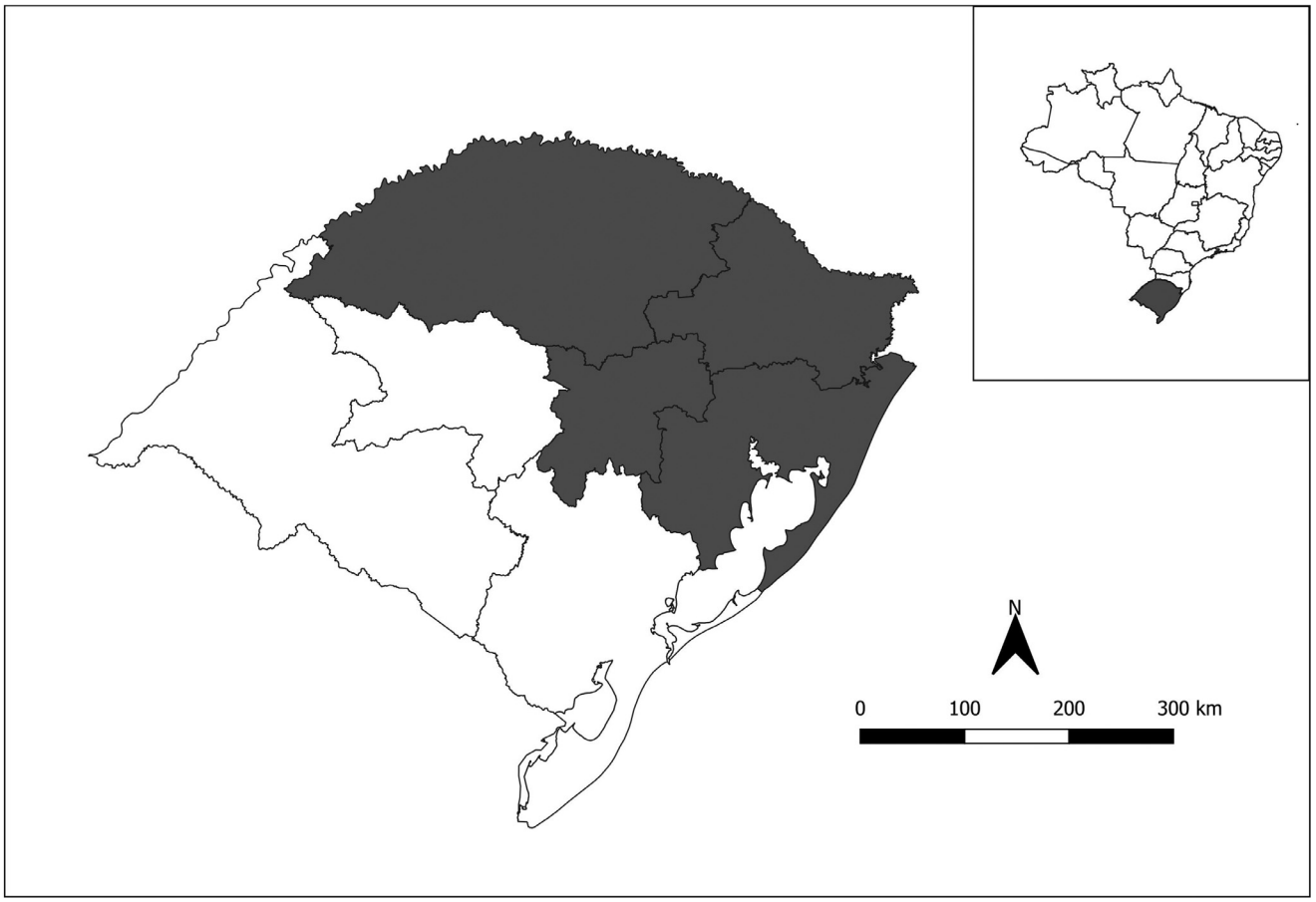

Figure 1. Geographical illustration of the regions covered by the study. In the upper right corner is represented Brazil, and in gray the state of Rio Grande do Sul. The image in the center is the Rio Grande do Sul and in gray the regions covered by the study.

Factors Influencing Antibiotic use

This issue was targeted by 4 Likert scale questions and one open question. When asked about the choice of the antibiotic to be used (Figure 2), the majority of the respondents agreed or strongly agreed that the presence of clinical signs (14 of 16) and the veterinarian experience (13 of 16) are key factors for the decision. The cost of the antibiotic was not a consistent factor pointed out in the answers; while half of the respondents agreed with this criterion, the other half disagreed or strongly disagreed with it. Noteworthy was the answer about the need of performing antimicrobial resistance testing (antibiogram) prior to the antibiotic choice, since the great majority agreed (9 of 16) and even strongly agreed (3 of 16) that the antibiotic choice decision is made without the result of antimicrobial resistance testing. These perceptions are also displayed in the open question ("*Which factors are key factors for the administration of antibiotics*?"). All respondents mentioned one or more of the following factors: mortality of animals, clinical signs, drop in egg production, and salmonellosis. Increased antimicrobial use was referred to occur from d 1 to approximately 18 wk of life. A veterinarian working for more than 10 yr in egg production stated: "*After the appearance of symptoms in the animals, sometimes only antibiotic administration is capable of controlling the problem*". Another veterinary with a similar experience in the field added: "*If the use of antibiotics is required, mortality and delayed growth are already causing economic losses. Therefore, the focus should be the prevention of diseases*".

Perceptions About the way Antibiotics are Used in Commercial Laying Chickens

The use of antibiotics was targeted in single and multiple-choice questions and Likert scale questions, with the possibility of adding comments. The answers to the single and multiple-choice questions showed that the veterinarian was the one in charge to treat sick animals (Table 2). Again, the criterion of antibiotic use when clinical signs are detected was mentioned by most respondents; in addition, most respondents stated that in these occasions, antibiotics are given to all animals housed in the barn, despite their health status. Moreover, most interviewees reported that the veterinarian carries out antibiotic prescription and dosage setting in accordance with the recommendations of the manufacturer (Table 2).

Regarding the protocol of antimicrobial use (Figure 2), most respondents agreed or strongly agreed that the antibiotic withdrawal period should be respected before the commercialization of eggs. In addition, most (10 of 16) disagreed or strongly disagreed that antibiotics administration should be discontinued as soon as the animals' health improves. Following the manufacturer's recommendations was mentioned as an adequate practice by several interviewees. Only one respondent declared that "*the remission of clinical signs should*

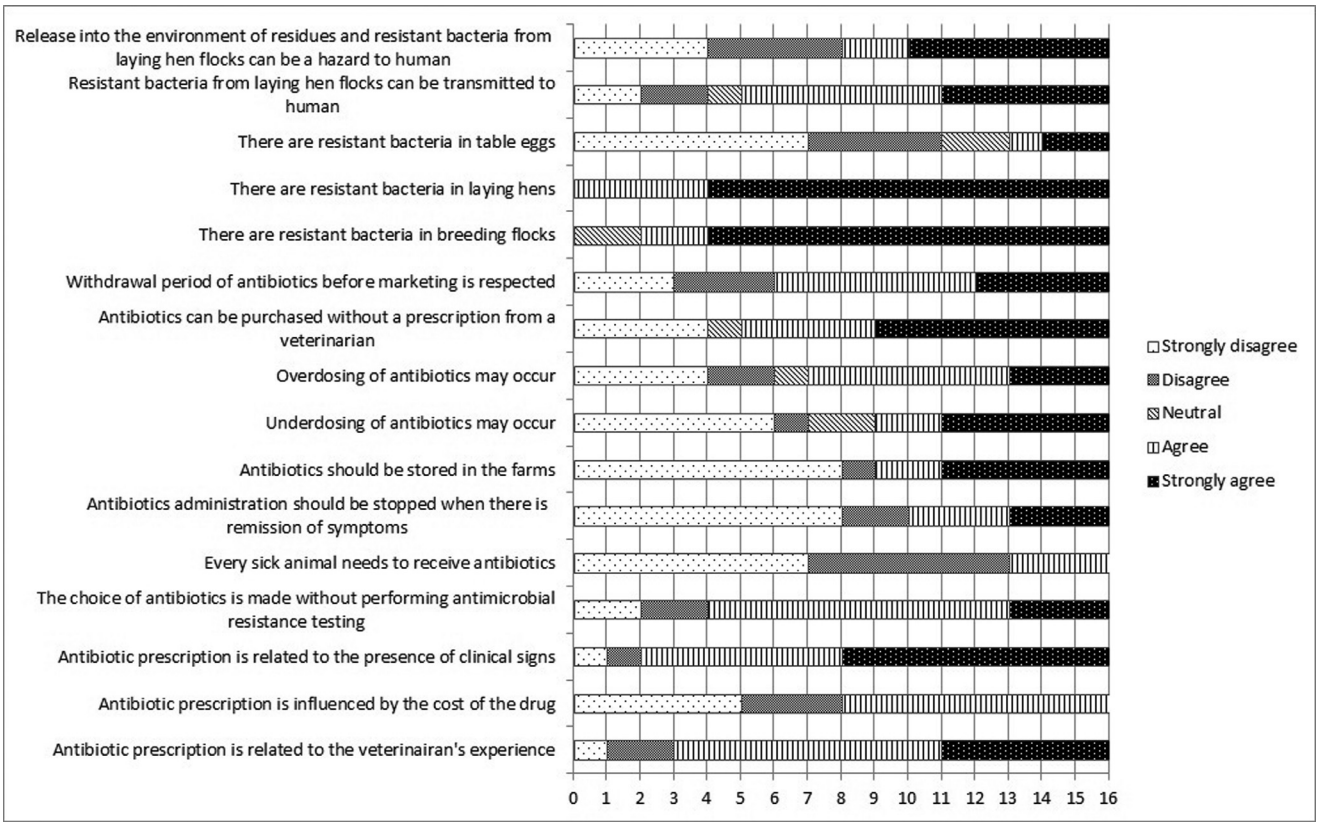

Figure 2. Questions and answers related to factors that influence and the use of antibiotics in the egg production in Rio Grande do Sul state. Presentation of the questions and the respective number of answers (total of 16) referring to each level of the Likert scale (strongly disagree, disagree, neutral, agree, strongly agree).

Table 2. Multiple choice questions and answers about use of antibiotics in egg production in Rio Grande do Sul state, Brazil.

Question	Veterinarians' answers (n[1])
Main responsible for attending sick animals	
• Private practice veterinarian	7
• Veterinarian working for pharmaceutical companies	1
• Poultry veterinarian	12
• Farmer	3
• Inspection veterinarians	0
• Animal technician	3
Antibiotics are used	
• Always or frequently in feed to keep animals healthy and prevent disease	0
• For all chickens in a barn when some are sick	11
• Only in sick animals	4
• I don't know	0
The use of antibiotics in sick animals occurs	
• Following the antibiotic manufacturer's instructions	9
• Following the veterinarian's instructions	12
• One single dose	0
• Single daily dose until recovery	3
Objective of antibiotic use in the production of table eggs	
• Treatment of infections	14
• Infection prevention	1
• Growth promotion	1
Antibiotics are purchased from	
• Veterinary pharmacies	8
• Human pharmacies	0
• Pharmaceutical distributors	13
• Private veterinarian	3
• Provided by other farmers	1
• Provided by the poultry veterinarian	4
Antibiotics are usually administered to laying hens by	
• Veterinarians	3
• Farm employee	8
• Farmer	11
The dose of antibiotic administered to the animals is determined by	
• Manufacturer's guidelines	10
• Private veterinarian	6
• Veterinarian from pharmaceutical supplier	8
• Poultry veterinarian	13
• Arbitrarily	0
• I don't know	0
Antibiotics are mostly administered	
• In water	15
• In feed	12
• Intramuscularly	6
• On the skin	0

[1]Number of respondents, from a total of 16 veterinarians.

result in stopping antibiotic administration, since this procedure will diminish drug residues".

Although the presence of clinical signs was considered an important criterion for antimicrobial use, the great majority of the respondents (13 of 16) disagreed or strongly disagreed that any sick animal should receive antibiotics. They pointed out that viruses or molds cause some diseases, which do not respond to antibiotics. The adoption of other measures, such as disinfection, organic acids, and probiotics, were mentioned as more efficient in some cases. One respondent working for more than 10 yr on egg farms stated that "*antimicrobial use has turned to be more prudent in the last years, and the evaluation of the disease severity has been playing a role in the decision*".

When asked if there was a possibility that the administered antibiotic doses may be higher or lower than those recommended in the label, the interviewees provided different answers, demonstrating that there is no consensus about this matter. However, the majority declared that these are rare events or happen only on few occasions (Figure 3).

About the common practice of obtaining and storing antibiotics, most (13 of 16) respondents declared that antibiotics are purchased from pharma industry suppliers, and the administration doses are set according to the manufacturer recommendation and by the veterinarians; however, the administration itself is done by the farmers. The antibiotics are usually administered in feed or water (Table 2). However, most respondents (11 of 16) agreed or strongly agreed that the scenario in which antibiotics are purchased without a veterinarian prescription occurs. The storage of antibiotics in the farms resulted in different opinions; half of the respondents agreed while the other half disagreed with this practice. The respondents that agreed with the practice justify their opinion by the necessity of a rapid start of treatment to avoid greater losses; those that disagreed pointed out the hazard of inadequate or unnecessary administration performed single-handedly by the farmer.

Nine respondents reported disease problems in the last production cycle in farms under their supervision. Among them, five reported the use of antibiotics such as gentamicin, amoxicillin, bacitracin, and quinolone. Based on the respondents' answers, the top 5 antibiotics administered to laying hens were tiamulin, β-lactams (penicillins), bacitracin, fluoroquinolones, and macrolides (Figure 4).

Knowledge About the Dissemination of Resistant Bacteria

The knowledge about resistance was targeted by 1 opened question and 14 closed questions. Among them, 8 used Likert scale answers, 5 were multiple choice, and one was single choice (yes/no). The first questions were related to the respondents' knowledge about the existence of resistant bacteria. In this regard, all agreed that there are resistant bacteria colonizing the laying hens, while most (11 of 16) disagreed that they are present in eggs (Figure 2). The respondents were consistent in pointing out that resistant bacteria in laying hens are a cause of treatment failure, longer periods of illness, and higher economic losses. They also stated that the infection by resistant bacteria in humans may result in the same consequences listed for laying hens in terms of treatment failure and costs (Table 3). The majority (11 of 16) agreed or strongly agreed that resistant bacteria present in commercial egg production can be transmitted to humans, but four respondents declared that they

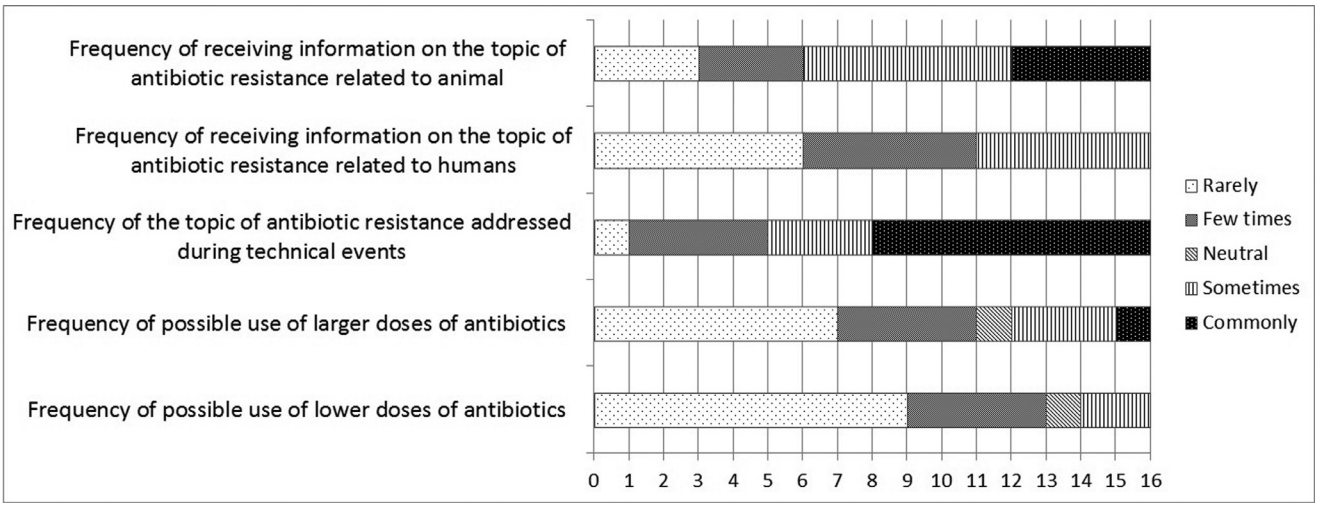

Figure 3. Frequency of the interviewees access to information of antibiotic resistance and interviewees practices of antibiotic dosage. Presentation of the questions and the respective number of answers (total of 16) referring to each level of the Likert scale (rarely, few times, neutral, sometimes, commonly).

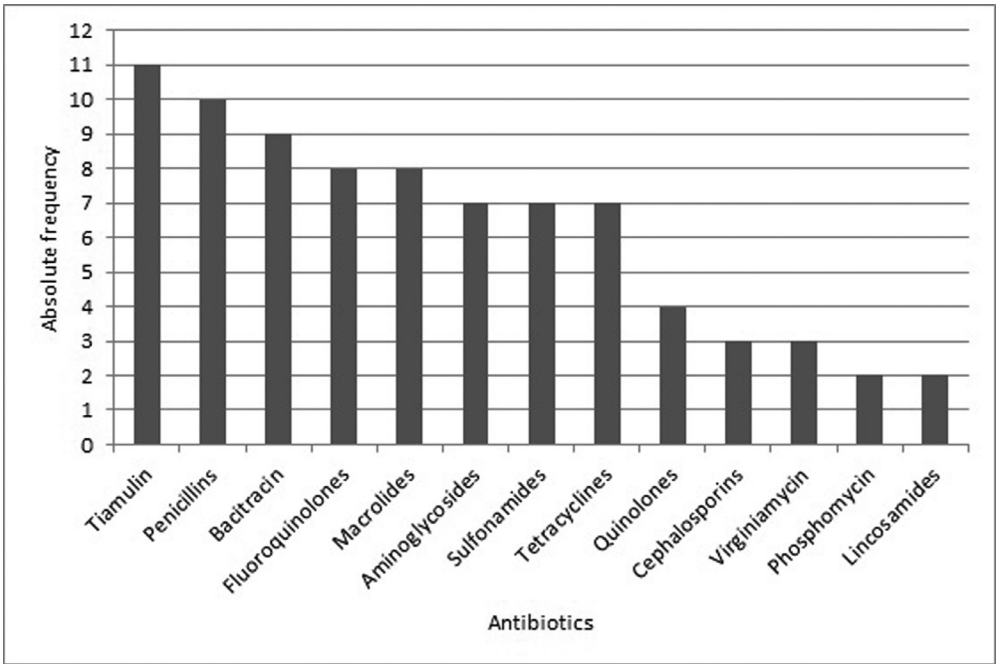

Figure 4. Antibiotics used in egg production in Rio Grande do Sul state, Brazil.

are not transmitted. The mentioned ways of transmission were through meat and egg consumption and to workers in contact with the poultry (Table 3). On the contrary, the importance to human health of releasing resistant bacteria in the environment was not a consensus. Half agreed or strongly agreed that this event is relevant, and the other half disagreed or strongly disagreed. The majority (10 of 16) of the respondents declared that they had been informed about the topic of antimicrobial resistance in animal production but rarely or only on a few occasions about resistance in human medicine. Antimicrobial resistance is a topic commonly addressed in scientific and technical events, according to half of the respondents (Figure 3). However, they frequently expressed their doubts regarding the current legislation and the information material produced by the Ministry for Agriculture, Livestock, and Food Supply (Table 3). On the last 2 questions of this session, the respondents were asked if they were aware of which antimicrobials are classified as critically important to human health and about their opinions on their use in animal production. Only 9 respondents declared to know the meaning of this classification. Considering the opinions of all respondents, 8 assumed that critically important antimicrobials should not be used in animal production or be used with utmost care and as a last resort. However, different opinions were also found; an interviewee with less than 1 yr experience in the egg industry stated that "*withdrawing antimicrobials from animal production had no effect on the resistance profile of bacteria. The restriction on use should encompass human medicine as well*". In addition, another

Table 3. Multiple choice questions and answers about pathways for dissemination of resistant bacteria in Rio Grande do Sul state, Brazil.

Question	Veterinarians' answers (n[1])
Effects of antibiotic-resistant bacteria in commercial laying hens	
• Non-response to treatment	16
• Extra costs for treatment	11
• Longer duration of illness and treatment	11
• None	0
• I don't know	0
Antibiotic residues present in laying poultry can be transmitted to humans through	
• Consumption of contaminated meat	7
• Consumption of contaminated eggs	10
• Contact of farmers/employees with animals	2
• Contact with contaminated environment/instruments	2
• There is no transmission	4
• I don't know	2
Antibiotic-resistant bacteria present in laying poultry can be transmitted to humans through	
• Consumption of contaminated meat	6
• Consumption of contaminated eggs	10
• Contact of farmers/employees with animals	6
• Contact with contaminated environment/instruments	6
• There is no transmission	4
• I don't know	0
Possible effects of the presence of resistant bacteria on humans	
• Non-response to treatment	15
• Extra costs for treatment	10
• Longer duration of illness and treatment	12
• None	1
• I don't know	0
Sources of information on antibiotic resistance that you have consulted	
• Current legislation	12
• National Action Plan for Prevention and Control of Antibiotic Resistance in Brazil (PanBR)	6
• National Program for the Prevention and Control of Antibiotic Resistance in Agriculture (AgroPrevine)	2
• Technical publications of the Ministry of Agriculture, Livestock and Supply (MAPA)	13
• None	0
• Other	11

[1]Number of respondents, from a total of 16 veterinarians.

interviewee with more than 10 yr of experience in the field declared "*if the antibiotic is approved by the Brazilian authorities, it can be used*".

Knowledge About Alternative Methods to Using Antibiotics

When asked whether the use of alternative methods to the use of antibiotics is economically viable for egg production, 4 respondents agreed and 10 strongly agreed. Subsequently, the respondents were asked to describe which method or practice would contribute to reducing the use of antibiotics in the production of eggs for human consumption. The most cited methods or practices were improvement of management and biosecurity (n = 6), disinfection (n = 7), vaccination (n = 7), and the use of alternative products such as prebiotics, probiotics, essential oils, and organic acids (n = 12).

DISCUSSION

The present study shows that veterinarians have a direct influence on the way antimicrobials are used in the egg production in Rio Grande do Sul, Southern Brazil. In this scenario, veterinarians need to be part of building the understanding of AMR and in the search for solutions (World Health Organization, 2015; Aenishaenslin et al., 2019; Bordier et al., 2020). In this regard, successful initiatives to reduce the use of antimicrobials in livestock production have been linked to the awareness of the factors that lead to the prescription of antimicrobials and the perceptions of veterinarians about the drivers toward resistance (Zhuo et al., 2018; Norris et al., 2019; Truong et al., 2019; Taylor et al., 2020; Padda et al., 2021).

In this study, 2 aspects were highlighted as drivers for antimicrobial use: the need for a quick decision in view of the clinical symptoms detected in the flock and the veterinariańs experience as the parameter for antimicrobial prescription associated with the manufacturer's guidelines. Among the reasons considered as requiring a quick decision, the occurrence of mortality in the flock was the most frequently cited one, followed by the presence of clinical signs with potential to cause mortality or a drop in egg production. The presence of clinical signs and increased mortality stand out as the main factors for the use of antibiotics in previous studies related to poultry production (Adam et al., 2019, 2020; Imam et al., 2020) and other livestock species (Norris et al., 2019; Imam et al., 2020), indicating that the worry about economic losses is an important driver for the use of antimicrobials. Among the diseases that lead to the use of antimicrobials, those related to the respiratory and gastrointestinal tracts were the most frequently mentioned ones in the above studies, as well as those listed by the interviewees in our study. In other words, infectious diseases with high transmissibility in intensively farmed flocks, which lead to prompt economic losses without rapid intervention, seem to be important drivers for antimicrobial use. This factor justifies the respondents' concern to make a quick decision regarding treatment, which leads to basing the choice of antimicrobials on the veterinarian's experience.

The prioritization of the professional's experience instead of a decision based on investigation of both the disease causes and the results of antimicrobial resistance testing has also appeared in other studies. In this sense, the costs of such procedures and, mainly, the lack of accessibility to microbiological diagnostic services were mentioned as major bottlenecks (Norris et al., 2019; Adam et al., 2020; Padda et al., 2021). For instance, Bourély et al. (2018) pointed out that the lack of proximity between farms and diagnostic laboratories

represents a delay factor in obtaining results and a reason for not performing antimicrobial resistance testing. To avoid this problem, actions such as keeping recent records of diseases that have affected the herd or flock, the antibiotics used in previous production cycles, and the resistance profiles of bacteria promoting previous outbreaks were mentioned as practices that can help in quick decision-making based on experience, albeit within a concept of the prudent use of antibiotics (Adam et al., 2020; World Organization for Animal Health, 2020).

The need for a prompt decision on the implementation of antimicrobial therapy to mitigate economic losses may have also contributed to the opinion of half of the interviewees about the importance of keeping a stock of antibiotics at the farm, as well as to the perception that farmers sometimes acquire antimicrobials "over the counter". Both cases can lead to the inappropriate and excessive use of antimicrobials since it is highly possible that farmers choose the antimicrobials or use them without any scientific criteria or even for fear of onset of infectious diseases, as reported in other studies (Rees et al., 2019; Truong et al., 2019; Imam et al., 2020). Notably, the selling of antibiotics in veterinarian stores, without a veterinarian's prescription, is a practice that ought to be banned in Brazil, as it has occurred in other countries (European Surveillance of Veterinary Antimicrobial Consumption). In Brazil, since 2011, antimicrobials used for human treatment outside the hospital setting have been only purchased with medical prescriptions, which are retained at the pharmacy (Brazil, 2011). This practice has resulted in reductions in the use of antibiotics and in their more prudent use in human medicine (Sampaio et al., 2018; Lima et al., 2019). Thus, the adoption of similar policies in livestock, poultry, and companion animals may contribute to tackle the problem of overuse and misuse of antimicrobials.

The concern of uncontrolled antibiotics use takes on even greater importance when it is verified that, according to the practice of the interviewees, among the top 5 antimicrobials used in laying hens were fluoroquinolones and macrolides, which are on the list of antimicrobials considered critically important in human medicine (World Health Organization, 2018). Moreover, although veterinarians declared that they used antibiotics following the dosage and treatment length recommended by the manufacturer's guidelines, they admitted that underdosing may occur. Even though not mentioned by the interviewees, underdosing may be associated with failures in the administration of antimicrobials, which is routinely done by the farmers, according to the interviewees' responses. To circumvent this problem, training farmers in good antimicrobial use practices should be considered since underdosing is one important driver for the emergence of resistant bacterial strains (Li et al., 2017). In summary, farmers and veterinarians must be aware that one of the most important factors in preventing the development of bacterial resistance is the prudent use of antimicrobials, which encompasses the use of the right drug, at the recommended dose, at the right time, and for the needed duration (Mittal et al., 2020).

Regarding the respondents' perception of AMR, several discrepant responses were identified. On the one hand, most respondents had the perception that there are resistant bacteria colonizing laying hens and that they can reach humans through the consumption of eggs. On the other hand, the respondents pointed out that they do not believe that resistant bacteria are present in eggs. Furthermore, half of the respondents did not recognize that the environmental release of resistant bacteria and antibiotic residues from laying hen farms could be important to the AMR issue. Due to the complexity of AMR, there is consensus that a One Health approach is necessary to tackle the AMR problem (World Health Organization, 2015). In this sense, it is recognized that human, animal, and environmental health are so intertwined that the response to AMR will need to result from collaborative efforts of stakeholders, scientists, and professionals from different sectors (White and Hughes, 2019).

It appears, from the perceptions of the interviewees, that there is a lack of knowledge of the One Health approach in relation to AMR. They reported to have both little knowledge or access to information about AMR in humans and considered that environmental health plays a minor role in AMR. However, it is known that the environment can act as a reservoir of resistant bacteria, contributing to their maintenance and circulation among strata over time (Lucia et al., 2021). For example, the application of manure from commercial laying hens can significantly increase the abundance of bacterial resistance genes in soil and in the endosphere of lettuces fertilized with this residue (Huang et al., 2021).

Interestingly, the insights gathered in the present study were in accordance with previous reports, in which, while medical professionals understand that animal production is an important driver for AMR in humans, veterinarians generally do not (Jones et al., 2015; Zhuo et al., 2018; McKernan et al., 2021; Padda et al., 2021). The difficulty of demonstrating the relationship between the use of antibiotics and the presence of resistant bacteria in the environment, in addition to their subsequent impact on human health (Chang et al., 2014), makes it even more difficult to understand AMR from a One Health perspective. Furthermore, "blaming" or "transferring responsibility to others" are important barriers to behavior change and must be considered and managed when public health policies are developed (Rüegg et al., 2017). In this case, it is possible to assume that both human medicine professionals and veterinarians find it difficult to define their actual role in increasing and mitigating AMR.

Most respondents mentioned that they had already been in contact with the topic of AMR in animals, addressed in conferences and technical lectures, but that information on AMR in humans was rarely included in events. Likewise, not all respondents knew the World Health Organization classification of antimicrobials according to their importance to humans. At this point, the discrepancy between perception and practice is

evident; while half of the respondents said that critically important antibiotics for humans should not be routinely used in animals, fluoroquinolones and macrolides were among the top 5 antibiotics administered by them to laying hens. These results indicate the need to expand the information on the interaction of animal, human, and environmental health (One Health approach) in relation to AMR.

When the respondents were asked how they sought to clarify doubts on antimicrobial use and AMR, the legislation and information provided by the Ministry of Agriculture were considered important sources. In Brazil, there are specific laws on antimicrobial use concerning the presence of antibiotic residues in foods (Brazil, 2019; 2020a), withdrawing the use of specific antibiotics as growth promoters (Brazil, 2003, 2004, 2005, 2009, 2012, 2016, 2020b), and the actions proposed in the National Plan for the Prevention and Control of Antimicrobial resistance in livestock (PAN-BR Agro; Brazil, 2018).

The existence of a legislation may have reflected the concern of all interviewees with both the time taken to withdraw antibiotics before the eggs were put at the market and the fact that only the therapeutic and metaphylactic uses were mentioned in the responses. It is possible that the resistance monitoring actions in animal production that are being implemented within the PAN-BR Agro will contribute to increasing attention on AMR among Brazilian veterinarians in the future.

Regarding the use of alternative methods to antibiotic therapy, most of the interviewees believe that it is economically viable to adopt some of alternatives, ranging from improved management, the use of vaccines, and the application of additives such as organic acids and probiotics. In this sense, studies on alternative methods to antibiotic therapy and the impacts on antimicrobial use and AMR should be encouraged to provide future scientific basis for safer adoption in egg production. Likewise, studies that estimate the cost of decreasing antimicrobial use and the implementation of alternative measures need to be prioritized, as the fear that abandoning the use of antimicrobials (including prophylactically) could lead to economic losses is widespread among farmers and veterinarians (Truong et al., 2019; Imam et al., 2020; McKernan et al., 2021).

In addition, knowledge about AMR and the use of antimicrobials should be prioritized in veterinarian schools. As in Australia, where students increase their knowledge about antimicrobial resistance throughout the course (Hardefeldt et al., 2018), there is a need to strengthen school curricula for the proper use of antibiotics in both companion and production animals. Gaps between theoretical concepts and clinical applications must be identified and corrected so that new professionals can adequately use antimicrobials (Smith et al., 2019).

Although this study provides important and new information about the perception of veterinarians regarding antimicrobial use and AMR in egg production in Southern Brazil, it has some limitations. First, the number of veterinarians accessed, among the professionals registered in SEAPDR, was limited. Still, there was good adherence to the invitations sent (16/26), which may indicate the interest and willingness to discuss the matter among veterinarians. Second, the conduction of the study during the COVID-19 pandemic also limited the number of face-to-face interviews, and the questionnaires needed to be carried out remotely, which may also have contributed to the nonadherence of some professionals. On the other hand, the population of respondents was made up of veterinarians with extensive experience in the area and who had been serving a significant number on farms, qualifying the information and insights obtained. Third, the limitation of the geographic scope of the study also leads to the results being interpreted and applied considering veterinarians who work in egg production in the state of Rio Grande do Sul (Southern Brazil). Although perceptions may be shared by veterinarians from other regions, generalizations must be made with caution. Even so, the information obtained in the present study will be useful for the design of future studies and for guiding continuing education initiatives for the target group of the study.

In conclusion, the results of the interviews indicate that some points should be prioritized in the future. Specifically, the improvement of the diagnosis and performance of antimicrobial resistance testing associated with keeping records on a flock basis will contribute to building a prudent antimicrobial use strategy, along with the ban of antimicrobial purchasing without a veterinarian prescription. Regarding the improvement of awareness among veterinarians working in table egg production, the need of a One Health approach to address the AMR issue should be stressed in continuing education and technical meetings. Specifically, the gap in the knowledge about the role of environmental health should be addressed.

ACKNOWLEDGMENTS

The authors are grateful to the Coordination for the Improvement of Higher Education Personnel (CAPES) Finance code 001, the Fund for the Development and Defense of Animal Health of Rio Grande do Sul State (FUNDESA), and the Poultry Production Association of Rio Grande do Sul State (ASGAV).

DISCLOSURES

No conflict of interest exits in the submission of this manuscript, and it was approved by all authors for publication.

SUPPLEMENTARY MATERIALS

Supplementary material associated with this article can be found in the online version at doi:10.1016/j.psj.2022.101987.

REFERENCES

ABPA. 2021. Brazilian Animal Protein Association. Annual report. São Paulo: ABPA, 2021. 75 p. Accessed Dec. 2021. http://abpa-br.org/relatorios/.

Adam, C. J. M., N. Fortané, A. Coviglio, L. Delesalle, C. Ducrot, and M. C. Paul. 2019. Epidemiological assessment of the factors associated with antimicrobial use in French free-range broilers. BMC Vet. Res. 15:1–11.

Adam, C. J. M., N. Fortané, C. Ducrot, and M. C. Paul. 2020. Transition pathways toward the prudent use of antimicrobials: the case of free-range broiler farmers in France. Front. Vet. Sci. 7:1–12.

Aenishaenslin, C., B. Häsler, A. Ravel, J. Parmley, K. Stärk, and D. Buckeridge. 2019. Evidence needed for antimicrobial resistance surveillance systems. Bull. World Health Organ. 97:283–289.

Bordier, M., T. Uea-Anuwong, A. Binot, P. Hendrikx, and F. L. Goutard. 2020. Characteristics of One Health surveillance systems: a systematic literature review. Prev. Vet. Med. 181:1–13.

Bourély, C., N. Fortané, D. Calavas, A. Leblond, and E. Gay. 2018. Why do veterinarians ask for antimicrobial susceptibility testing? A qualitative study exploring determinants and evaluating the impact of antibiotic reduction policy. Prev. Vet. Med. 159:123–134.

Brazil. 1968. Law n° 5.517 of October 23, 1968. Accessed Feb. 2022. http://www.planalto.gov.br/ccivil_03/leis/l5517.htm.

Brazil. 2003. Ministry of agriculture, livestock and supply. Normative instruction n° 9, of June 27, 2003. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/alimentacao-animal/arquivos-alimentacao-animal/legislacao/instrucao-normativa-no-9-de-27-de-junho-de-2003.pdf/view.

Brazil. 2004. Ministry of agriculture, livestock and supply. Normative instruction n° 11, of November 24, 2004. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/alimentacao-animal/arquivos-alimentacao-animal/legislacao/instrucao-normativa-no-11-de-24-de-novembro-de-2004.pdf.

Brazil. 2005. Ministry of agriculture, livestock and supply. Normative instruction n° 35, of November 14, 2005. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/alimentacao-animal/arquivos-alimentacao-animal/legislacao/instrucao-normativa-no-35-de-14-de-novembro-de-2005.pdf.

Brazil. 2009. Ministry of agriculture, livestock and supply. Normative instruction n° 26, of July 9, 2009. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/alimentacao-animal/arquivos-alimentacao-animal/legislacao/instrucao-normativa-no-26-de-9-de-julho-de-2009.pdf.

Brazil. 2011. Ministry of health. RDC n° 20, of May 5, 2011. Accessed Feb. 2022. https://bvsms.saude.gov.br/bvs/saudelegis/anvisa/2011/rdc0020_05_05_2011.html.

Brazil. 2012. Ministry of agriculture, livestock and supply. Normative instruction n° 14, of May 17, 2012. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/alimentacao-animal/arquivos-alimentacao-animal/legislacao/instrucao-normativa-no-14-de-17-de-maio-de-2012.pdf/view.

Brazil. 2016. Ministry of agriculture, livestock and supply. Normative instruction n° 45, of November 22, 2016. Accessed Feb. 2022. https://www.in.gov.br/materia/-/asset_publisher/Kujrw0TZC2Mb/content/id/22078290/do1-2016-11-30-instrucao-normativa-n-45-de-22-de-novembro-de-2016-22078259.

Brazil. 2018. National action plan for prevention and control of resistance to antimicrobials, in the framework of agriculture (PAN-BR Agro). Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/insumos-agropecuarios/insumos-pecuarios/resistencia-aos-antimicrobianos/pan-br-agro.

Brazil. 2019. Ministry of agriculture, livestock and supply. Normative instruction n° 5, April 23, 2019. Accessed Feb. 2022. https://www.gov.br/agricultura/pt-br/assuntos/inspecao/produtos-animal/plano-de-nacional-de-controle-de-residuos-e-contaminantes/InstruoNormativaN05.2019PNCRC2019.pdf.

Brazil. 2020a. Ministry of agriculture, livestock and supply. Decree n° 10.468, August 18, 2020. Accessed Feb. 2022. https://www.in.gov.br/en/web/dou/-/decreto-n-10.468-de-18-de-agosto-de-2020-272981604.

Brazil. 2020b. Ministry of agriculture, livestock and supply. Normative instruction n° 1, January 13, 2020. Accessed Feb. 2022. https://www.in.gov.br/en/web/dou/-/instrucao-normativa-n-1-de-13-de-janeiro-de-2020-239402385.

Cassini, A., L. D. Högberg, D. Plachouras, A. Quattrocchi, A. Hoxha, and G. S. Simonsen. 2019. Attributable deaths and disability-adjusted life-years caused by infections with antibiotic-resistant bacteria in the EU and the European Economic Area in 2015: a population-level modelling analysis. Lancet Infect. Dis. 19:56–66.

Chang, Q., W. Wang, G. Regev-Yochay, M. Lipsitch, and W. P. Hanage. 2014. Antibiotics in agriculture and the risk to human health: how worried should we be? Evol. Appl. 8:240–247.

Dohoo, I., W. Martin, and H. Stryhn. 2014. Questionnaire design. Pages 57−71 in Veterinary Epidemiologic Research. I. Dohoo, W. Martin and H. Stryhn, eds. VER, Chalottetown, Prince Edward Island, Canada.

Hardefeldt, L., T. Nielsen, H. Crabb, J. Gilkerson, R. Squires, J. Heller, C. Sharp, R. Cobbold, J. Norris, and G. Browning. 2018. Veterinary students' knowledge and perceptions about antimicrobial stewardship and biosecurity − a national survey. Antibiotics 7:1–15.

Huang, J., J. Mi, Q. Yan, X. Wen, S. Zhou, Y. Wang, B. Ma, Y. Zou, X. Liao, and Y. Wu. 2021. Animal manures application increases the abundances of antibiotic resistance genes in soil-lettuce system associated with shared bacterial distributions. Sci. Total Environ. 787:1–12.

Imam, T., J. S. Gibson, M. Foysal, S. B. Das, S. D. Gupta, G. Fournié, Md. A. Hoque, and J. Henning. 2020. A cross-sectional study of antimicrobial usage on commercial broiler and layer chicken farms in Bangladesh. Front. Vet. Sci. 7:1–11.

Jones, P. J., E. A. Marier, R. B. Tranter, G. Wu, E. Watson, and C. J. Teale. 2015. Factors affecting dairy farmers' attitudes towards antimicrobial medicine usage in cattle in England and Wales. Prev. Vet. Med. 121:30–40.

Kim, Y. B., K. W. Seo, J. B. Shim, S. H. Son, E. B. Noh, and Y. J. Lee. 2019. Molecular characterization of antimicrobial-resistant Enterococcus faecalis and Enterococcus faecium isolated from layer parent stock. Poult. Sci. 98:5892–5899.

Li, J., S. Xie, S. Ahmed, F. Wang, Y. Gu, C. Zhang, X. Chai, Y. Wu, J. Cai, and G. Cheng. 2017. Antimicrobial activity and resistance: influence factors. Front. Pharmacol. 8:1–11.

Lima, A. L.de, C. R. B. Rodrigues, E. G. da Silva, E. da R. Lemes, R. M. C. Pinto, and V. Kusano. 2019. Analysis of beta-lactam antibiotics dispense after RDC No. 20/2011 in a pharmacy chain in the city of Ponta Grossa, Paraná, Brazil. Visão Acad. 20:68–82.

Llanos-Soto, S. G., N. Vezeau, M. Wemette, E. Bulut, A. G. Safi, P. Moroni, M. A. Shapiro, and R. Ivanek. 2021. Survey of perceptions and attitudes of an international group of veterinarians regarding antibiotic use and resistance on dairy cattle farms. Prev. Vet. Med. 188:1–13.

Lucia, A.de., R. M. Card, N. Duggett, R. P. Smith, R. Davies, S. A. Cawthraw, M. F. Anjum, M. Rambaldi, F. Ostanello, and F. Martelli. 2021. Reduction in antimicrobial resistance prevalence in Escherichia coli from a pig farm following withdrawal of group antimicrobial treatment. Vet. Microbiol. 258:3–8.

Ma, F., S. Xu, Z. Tang, Z. Li, and L. Zhang. 2021. Use of antimicrobials in food animals and impact of transmission of antimicrobial resistance on humans. Bio. Health. 3:32–38.

McKernan, C., T. Benson, S. Farrell, and M. Dean. 2021. Antimicrobial use in agriculture: critical review of the factors influencing behavior. JAC Antimicrob. Resist. 3:1–15.

Mittal, A. K., R. Bhardwaj, P. Mishra, and S. K. Rajput. 2020. Antimicrobials misuse/overuse: adverse effect, mechanism, challenges and strategies to combat resistance. Open Biotech. 14:107–112.

Moreno, M. A., S. García-Soto, M. Hernández, C. Bárcena, D. Rodríguez-Lázaro, M. Ugarte-Ruíz, and L. Domínguez. 2019. Day-old chicks are a source of antimicrobial resistant bacteria for laying hen farms. Vet. Microbiol. 230:221–227.

Naderifar, M., H. Goli, and F. Ghaljaie. 2017. Snowball sampling: a purposeful method of sampling in qualitative research. Strides. Dev. Med. Educ. 14:1–6.

Norris, J. M., A. Zhuo, M. Govendir, S. J. Rowbotham, M. Labbate, C. Degeling, G. L. Gilbert, D. Dominey-Howes, and M. P. Ward. 2019. Factors influencing the behaviour and perceptions of Australian veterinarians towards antibiotic use and antimicrobial resistance. PLoS One. 14:1–19.

OECD. 2018. Stemming the superbug tide: just a few dollarsmore. OECD Health Policy Studies. OECDPublishing, Paris, France.

O'Neill, J. 2016. Tackling Drug-Resistant Infections Globally: Final Report and Recommendations: The Review on Antimicrobial Resistance. Wellcome Trust, HM Government, London. Accessed Jun. 2021 https://amr-review.org/sites/default/files/160518_Final%20paper_with%20cover.pdf.

Padda, H., M. Wemette, A. G. Safi, W. Beauvais, M. A. Shapiro, P. Moroni, and R. Ivanek. 2021. New York State dairy veterinarians' perceptions of antibiotic use and resistance: a qualitative interview study. Prev. Vet. Med. 194:1–10.

Rees, G. M., D. C. Barrett, H. Buller, H. L. Mills, and K. K. Reyher. 2019. Storage of prescription veterinary medicines on UK dairy farms: a crosssectional study. Vet. Rec. 184:1–8.

Rivera-Gomis, J., P. Marín, J. Otal, J. S. Galecio, C. Martínez-Conesa, and M. J. Cubero. 2021. Resistance patterns to C and D antibiotic categories for veterinary use of Campylobacter spp., Escherichia coli and Enterococcus spp. comensal isolates from laying hen farms in Spain during 2018. Prev. Vet. Med. 186:1–8.

Roth, N., A. Kasbohrer, S. Mayrhofer, U. Zitz, C. Hofacre, and K. J. Domig. 2019. The application of antibiotics in broiler production and the resulting antibiotic resistance in Escherichia coli: a global overview. Poult. Sci. 98:1791–1804.

Rüegg, S. R., B. J. McMahon, B. Häsler, R. Esposito, L. R. Nielsen, C. I. Speranza, T. Ehlinger, M. Peyre, M. Aragrande, J. Zinsstag, P. Davies, A. D. Mihalca, S. C. Buttigieg, J. Rushton, L. P. Carmo, D. de Meneghi, M. Canali, M. E. Filippitzi, F. L. Goutard, V. Ilieski, D. Milicevic, H. O'Shea, M. Radeski, R. Kock, A. Staines, and A. Lindberg. 2017. A blueprint to evaluate One Health. Front. Public Health. 5:1–16.

Sampaio, P.da S., L. G. Sancho, and R. F. do Lago. 2018. Implementation of new regulations for prescribing and dispensing of antibiotics: challenges and possibilities. Cad. Saúde Colet. 26:15–22.

Seo, K. W., and Y. J. Lee. 2019. Detection of plasmid-mediated quinolone resistance genes in β-lactamase-producing Escherichia coli isolates from layer hens. Poult. Sci. 98:1480–1487.

Seo, K. W., J. B. Shim, Y. B. Kim, S. H. Son, E. B. Noh, S. Yoon, S.-K. Lim, and Y. J. Lee. 2020. Impacts and characteristics of antimicrobial resistance of Escherichia coli isolates by administration of third-generation cephalosporins in layer hatcheries. Vet. Microbiol. 243:1–7.

Smith, P. W., M. Agbaje, L. LeRoux-Pullen, D. van Dyk, L. K. Debusho, A. Shittu, M. M. Sirdar, O. G. Fasanmi, O. Adebowale, and F. O. Fasina. 2019. Implication of the knowledge and perceptions of veterinary students of antimicrobial resistance for future prescription of antimicrobials in animal health, South Africa. J. S. Afr. Vet. Assoc. 90:1–8.

Taylor, D. D., J. N. Martin, P. S. Morley, K. E. Belk, A. E. White, and E. J. S. Walter. 2020. Survey of production animal veterinarians' prescription practices, factors influencing antimicrobial drug use, and perceptions of and attitudes toward antimicrobial resistance. J. Am. Vet. Med. Assoc. 257:87–96.

Truong, D. B., H. P. Doan, V. K. D. Tran, V. C. Nguyen, T. K. Bach, C. Rueanghiran, A. Binot, F. L. Goutard, G. Thwaites, J. Carrique-Mas, and J. Rushton. 2019. Assessment of drivers of antimicrobial usage in poultry farms in the mekong delta of Vietnam: a combined participatory epidemiology and q-sorting approach. Front. Vet. Sci. 84:1–11.

Weimer, S. L., C. I. Robison, R. J. Tempelman, D. R. Jones, and D. M. Karcher. 2019. Laying hen production and welfare in enriched colony cages at different stocking densities. Poult. Sci. 98:3578–3586.

White, A., and J. M. Hughes. 2019. Critical Importance of a One Health approach to antimicrobial resistance. Ecohealth. 16:404–409.

World Health Organization. 2015. Global Action Plan on Antimicrobial Resistance. WHO, Geneva. Accessed Jan. 2022 https://www.who.int/publications/i/item/9789241509763.

World Health Organization. 2018. Critically important antimicrobials for human medicine. Accessed Jun. 2021. https://www.who.int/foodsafety/publications/WHO-CIA-list-6flyer-EN.pdf?ua=1.

World Organisation for Animal Health − OIE. 2015. OIE standards, guidelines and resolution on antimicrobial resistance and the use of antimicrobial agents. Accessed Jun. 2021. https://web.oie.int/delegateweb/eng/ebook/AF-book-AMRANG_FULL.pdf?WAHISPHPSESSID=03152ead00d06990fa9066b7b71fcabc.

World Organisation for Animal Health. 2020. Responsible and prudent use of antimicrobial agents in veterinary medicine. In: OIE Standards, Guidelines and Resolutions on Antimicrobial Resistance and the Use of Antimicrobial Agents. Accessed Jan. 2022. https://www.oie.int/app/uploads/2021/03/book-amr-ang-fnl-lr.pdf.

Zhuo, A., M. Labbate, J. M. Norris, G. L. Gilbert, M. P. Ward, B. V. Bajorek, C. Degeling, S. J. Rowbotham, A. Dawson, K. Nguyen, G. A. Hill-Cawthorne, T. C. Sorrell, M. Govendir, A. M. Kesson, J. R. Iredell, and D. Dominey-Howes. 2018. Opportunities and challenges to improving antibiotic prescribing practices through a One Health approach: results of a comparative survey of doctors, dentists and veterinarians in Australia. BMJ Open 8:1–12.