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Antimicrobial use and antimicrobial resistance: standpoint and prescribing behaviour of Italian cattle and pig veterinarians

G. Pozza^a, A. Pinto^a, S. Crovato^a, G. Mascarello^a, L. Bano^a, M. Dacasto^b, A. Battisti^c, B. Bartoli^d, L. Ravarotto^a and S. Marangon^a

^aIstituto Zooprofilattico Sperimentale delle Venezie, Legnaro, Italy; ^bDipartimento Biomedicina Comparata e Alimentazione, Università di Padova, Legnaro, Italy; ^cIstituto Zooprofilattico Sperimentale del Lazio e della Toscana, Roma, Italy; ^dDemetra Opinioni.net, Venezia, Italy

ABSTRACT

The scientific community considers the improper use of antimicrobials in farm animals among the causes of the insurgent bacterial resistance contributing to the wider pool of resistance at the animal/human interface with serious public health implications. The present study aims to describe the current perceptions regarding antimicrobial use (AMU) and resistance (AMR) and the prescribing behaviour of two different target groups: cattle and pig veterinary practitioners working in Italy. A semi-structured questionnaire was designed and administered using the Computer-Assisted Web Interviewing method. Among the 789 participants who completed the questionnaire, 53.5% and 12.2% were cattle and pig veterinarians, respectively. Differences between the two groups emerged in their opinions concerning different topics. For example, 69.4% and 85.8% of cattle veterinarians claimed to 'somewhat or strongly agree' with the statements 'prescribing broad-spectrum antibiotics in rearing farms increases AMR' and 'the preventive use of antibiotics fosters the development of AMR', against the observed 59.4% and 69.8% of pig veterinarians ($p = .050$ and $p = .000$, respectively). Moreover, 26% of pig veterinarians claimed to 'somewhat or strongly agree' with the statement 'alternative methods currently available could be an efficient alternative to antimicrobial treatment', against 16.1% of cattle veterinarians ($p = .022$). At the same time, no differences between the two groups emerged regarding the danger inadequate AMU in animals poses on both animal and human health. From collected data, the need to provide appropriate training strategies with the aim of adopting a behaviour more consistent with the guidelines for prudent AMU in cattle and pig production systems has emerged.

HIGHLIGHTS

- 85.8% of cattle vs. 69.8% of pig veterinarians agreed with the statement 'the preventive use of antibiotics fosters the development of AMR'.
- 64.5% of cattle and 69.1% of pig veterinarians declared they suggest/prescribe alternative approaches to the use of antimicrobials.
- 'Hygiene-biosecurity-management' and 'nutritive principles' are the alternative strategies most suggested by cattle and pig veterinarians, respectively.

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Introduction


Antimicrobial usage and antimicrobial resistance in veterinary medicine

Current animal rearing systems often involve antimicrobial usage (AMU) for the prevention and treatment of infectious diseases resulting in healthier, more productive animals (Oliver et al. 2011). In modern farming systems, appropriate AMU has undoubted

advantages and contributes to answer the growing demand for animal proteins for human consumption worldwide (Van Boeckel et al. 2015).

Nevertheless, the wide AMU in the treatment and prevention of infectious diseases over the years has caused an evolutionary response by the microbial population to develop various forms of resistance against the applied antimicrobials (Michael et al. 2014).

CONTACT Dr A. Pinto  apinto@izsvenezie.it  Istituto Zooprofilattico Sperimentale delle Venezie, Legnaro 35020, Italy

 Supplemental data for this article can be accessed [here](#).

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Inappropriate AMU is partly responsible for the spread of resistant microbial strains in both humans and animals (Berge et al. 2006; Jensen et al. 2006). There are many connections among humans, animals, and the greater environment that allow the transfer not only of resistant bacteria but also of mobile genetic elements that permit horizontal transfer between different bacterial species (Woolhouse et al. 2015).

Excessive and/or improper AMU in farms can favour the growth of resistant bacterial strains, with the consequent potential spread to humans, representing a serious threat to public health (Page and Gautier 2012; World Health Organization 2014; Roca et al. 2015). Furthermore, the development of resistant bacteria can compromise the effective treatment of microbial diseases in animals, thus jeopardising the welfare of both food and companion animals (Lloyd 2007; Trevisi et al. 2014).

For these reasons, the request for more prudent AMU in farm animals is becoming increasingly urgent (McEwen 2006; Aarestrup et al. 2008; Prescott 2008).

Antibiotics are routinely used in rearing farms in three alternative ways. 'Therapeutic use' is the treatment of a sick animal or a group of sick animals following diagnosis of a disease or an infection. 'Prophylactic use' means the preventive use of antibiotics in healthy animals to prevent the onset of a disease or infection (World Health Organization 2017). The term 'metaphylaxis' is defined as the administration of antibiotics to a group of animals for a short period, in the case of infectious diseases, to prevent dissemination of illness despite the exhibition of clinical symptoms in a few animals (Economou and Gousia 2015). In rearing farms, it is often more practical to administer antimicrobials to the whole group through food or water, as implemented, for example, in poultry farming. Therefore, in metaphylactic treatment, antimicrobials are used for therapeutic purposes on sick animals and for prophylactic purposes on the remaining healthy animals of the group (McEwen and Fedorka-Cray 2002).

The current European legislation (Directive 2004/28/EC amending the Directive 2001/82/EC on the Community code relating to veterinary medicinal products) establishes that AMU is the responsibility of a veterinarian.

In Italy, veterinarians of the National Service are responsible for pharmacovigilance and pharmacosurveillance; normally, these veterinarians do not prescribe veterinary drugs, with particular exceptions (for example, when they are authorised to carry out clinical activities); while drug prescription is normally in

charge of self-employed veterinarians or veterinarians employed in the feed industry.

In this scenario, it is essential to increase the veterinarians' awareness of antimicrobial resistance (AMR) and prudent AMU in livestock farms, as the prescription of drugs falls within their responsibilities (World Health Organization 2014; European Centre for Disease Prevention and Control 2015; World Organisation for Animal Health 2016). The veterinarian therefore has a double task: to prescribe antimicrobials in a coherent way, and to render farmers aware of the correct use of antimicrobials.

To define the most appropriate training and refresher paths, it is necessary to identify knowledge gaps and information needs of veterinarians using appropriate needs assessment methods (Moore et al. 2002; Dale et al. 2008).

Currently, only a few published studies have aimed to investigate these issues in an Italian context and to assess veterinarians' awareness of AMR problems (Busani et al. 2004). To update this knowledge and outline the opinions, habits and prescribing behaviour of this target population, an Italian national survey was carried out.

In the present study, only some of the results obtained through the survey are described. In particular, our attention is focussed on the different approaches, perceptions and prescribing habits of two specific target groups: cattle and pig veterinarians. This choice is justified by the fact that cattle and pig farming represents an important sector of the Italian national livestock production (Istituto Nazionale di Statistica 2016).

The present study has three aims:

- Identify knowledge gaps and causes of possible misuse of antimicrobial drugs of cattle and pig veterinarians.
- Analyse the potential differences in points of view and prescribing behaviour of the two different target groups.
- Explore the attitude of the two target groups towards the application of alternative strategies or therapies to prevent and control livestock diseases.

Materials and methods

Sampling and data collection

Data were collected between September 27th and November 20th, 2017, using the Computer-Assisted Web Interviewing method.

The frame population was extracted from veterinarians who were registered to National Federation of Italian Veterinary Orders (FNOVI) in 2017; therefore, it represents veterinarians working in 2017.

A list of 13,794 contacts was created by consulting the FNOVI database and including only those who had an email address. An email explaining the project aims and containing the link for completing the questionnaire was sent to all contacts.

To increase the response rate and reduce the non-response bias, a reminder was sent one week after the first email contact. No economic incentives were given to promote the completion of the questionnaire.

The survey was carried out as a census field (Callegaro et al. 2015), leading therefore to a representative sampling frame of the population.

To comply with the privacy policy, there was a privacy agreement request with a checkbox at the beginning of the questionnaire.

The questionnaire

A semi-structured questionnaire was designed based on the existing literature (Busani et al. 2004; García et al. 2011; Visschers et al. 2015) and the research team's experience. The questionnaire consisted of the following sections: socio-demographic characteristics; opinions towards AMU and AMR in livestock farms; and prescribing behaviour.

The questionnaire was designed and structured to minimise the error during sampling (Callegaro et al. 2015); in particular two screening questions were introduced to avoid interviewing veterinarians outside the target population (e.g. retired, not dealing with livestock). Moreover, consistency checks (to assess data quality and coherence between questions) were applied to avoid measurement errors.

Before administration, the questionnaire was pre-tested on four veterinarians to identify and eliminate any unclear or dubious questions.

Of the 20 introduced questions, 14 were included in the present study (please see the [Supplemental Material, Table SM1](#)). The other 6 questions were considered irrelevant to the aim of this study.

Collected data were treated according to the General Data Protection Regulation (EU) 2016/679.

For some questions, the results were merged together, modifying the response options reported in the questionnaire, before the analysis. In particular, the results of the question 'how long have you been working as a veterinarian?' were classified into the categories: '< 10 years', '10–20 years', and '> 20 years'.

Referring to the variable 'position', the response options 'private practitioners' and 'veterinarians employed in private companies' were aggregated in the 'private veterinarians' category, while the option 'veterinarians employed in public institutions' (public veterinarians) remained the same.

Finally, the response scale of the question 'indicate your degree of agreement with the following statements' was changed to: 'not at all or slightly agree', and 'somewhat or strongly agree'.

Statistical analysis

Both quantitative and qualitative analyses were performed based on the research objectives and the nature of the variables.

Regarding quantitative analyses, univariate summary statistics were used to summarise the two groups of respondents. Bivariate analyses (contingency table and chi-square test) were then performed to investigate the dependent relationships between categorical variables. The Mann-Whitney U-test was used to determine differences in the distributions of ordinal variables expressed on a 1–10 Likert scale (Freund and Wilson 2001).

Qualitative analyses were performed to study the responses to the open-ended questions 'do you suggest/prescribe alternative strategies/therapies to antibiotics? If yes, specify which strategies' and 'in your opinion, which strategy could be effective in the AMU reduction in rearing farms?'. Lexicometric analysis was applied to explore the interviewees' responses. In particular, explorative textual techniques for automatic text categorisations (Bolasco 2013) were applied to the four textual corpora created, starting from cattle and pig veterinarians' responses to the two questions, respectively. The corpora were pre-processed by means of normalisation; the textual segments with higher occurrences (cut-off equal to 3) were then identified according to Morrone's statistical relative IS index (Morrone 1993) and included in the analysis as textual units. Due to the low number of responses to the first question and the presence of technical terms, the textual units of the two corresponding corpora were manually categorised by two experts of the research team in two different time points. The results were then discussed and merged together in the creation of the categories. Finally, two-word clouds were generated to overview the textual units of the two corpora created from the responses of the second open-ended question.

The word clouds were created in the Italian language to preserve the correct meanings of the lexical units.

The level of statistical significance was set at 5% ($\alpha = 0.05$). The quantitative analysis was performed using Statistical Package for Social Science (SPSS) software (version 21.0.0.0) for Windows (SPSS Inc., Chicago, Illinois), and the qualitative analysis was executed using TalTaC2 software (version 2.10.2) (Bolasco et al. 2000) and Iramuteq software (version 0.7 alpha 2) (Ratinaud 2009).

Results

Socio-demographic characteristics

Out of 13,794 contacts, 9,390 declined to participate (this number includes those who were eligible for the survey but did not finish the questionnaire compiling process, those who did not click the survey link, and those who stated that they were not interested in participating), 3,615 were not eligible on account of being retired or not dealing with livestock animals, and 789 completed the questionnaire (response rate equal to 7.75%). Among them, 53.5% specified that they mainly specialise in cattle, 12.2% in pigs, 10.3% in small ruminants, 8.2% in poultry species, 8.2% in equines, 2.4% in fish species, 2.2% in rabbits, and 3% in other species.

Data referring to the two larger groups, cattle ($n_{\text{cattle vets}} = 422$) and pig practitioners ($n_{\text{pig vets}} = 96$), were analysed in this study.

In both groups, the majority of respondents were male between 45 and 60 years old. They worked only on livestock animals; they had been working as veterinarians for more than 20 years and mostly worked in the private sector (Table 1).

Opinions towards AMU and AMR in rearing farms

It should be noted that veterinarians, by profession, often deal with more than one animal species. For this reason, respondents were invited to refer to the animal species selected in the question 'which supply chain do you mainly deal with?' in the compiled questionnaire.

Referring to the interviewees' opinions towards AMU in the livestock sector or farms on which they work, it emerged that the majority of both cattle and pig veterinarians considered that AMU is not always in line with the National and European guidelines (Table 2).

Table 1. Socio-demographic characteristics of the two target groups ($n_{\text{cattle vets}} = 422$, $n_{\text{pig vets}} = 96$).

Characteristics	Cattle veterinarians (%)	Pig veterinarians (%)
Gender		
Male	85.8	79.2
Female	14.2	20.8
Age		
< 45	36.3	34.4
45–60	52.1	46.9
> 60	11.6	18.7
You deal with ...		
Livestock animals	64.2	79.2
Both pets and livestock animals	35.8	20.8
How long have you been working as veterinarian?		
< 10 years	23.7	16.7
10–20 years	20.1	29.2
> 20 years	56.2	54.1
Position		
Private veterinarian	68.5	72.9
Public veterinarian	31.5	27.1

Moreover, the veterinarians' opinions towards AMU and AMR in rearing farms were investigated by requesting their degree of agreement with respect to the set of statements listed in Table 3.

Among cattle veterinarians, the highest degree of agreement emerged with the statement 'inadequate AMU in animals is dangerous for human health'; however, among pig veterinarians, the highest degree of agreement emerged with the statement 'inadequate AMU in animals is dangerous for their health'.

A statistically significant dependence between the respondents' level of agreement and the animal species they specialised in (either cattle or pigs) arose with respect to the following statements: 'prescribing broad-spectrum antibiotics in rearing farms increases AMR', 'the preventive use of antibiotics fosters the development of AMR', and 'alternative methods currently available (homeopathy, phytotherapy, etc.) could be an efficient alternative to antimicrobial treatment'.

Prescribing behaviour

The prescribing behaviour of the respondents was investigated on two different levels, including the veterinarians' habit of prescribing antibiotics and their attitude towards suggesting/prescribing alternative strategies/therapies.

Respondents' habits of prescribing antibiotics

Out of 422 cattle veterinarians and 96 pig veterinarians, 72% ($n_{\text{cattle vets}} = 304$) and 70.8% ($n_{\text{pig vets}} = 68$), respectively, stated that they prescribe antibiotics. A dependent relationship emerged between the age

Table 2. Opinions on AMU and antimicrobial prescribing habits of survey respondents ($n_{\text{cattle vets}} = 422$, $n_{\text{pig vets}} = 96$).

Statements	Cattle veterinarians (%)	Pig veterinarians (%)	Chi-square	p-value
<i>Do you think that AMU in the rearing farms in which you work is ...</i>				
Adequate, in line with the National and European guide lines	40.3	46.9	1.752	.416
Not always in line with the National and European guide lines	53.3	48.9		
I don't know	6.4	4.2		
<i>(For those who stated that they prescribe antibiotics) How frequently do you prescribe antibiotics for prophylactic purposes?^a</i>				
Often (every day)	6.9	10.3	3.989	.263
Sometimes (1–2 times a week)	24.7	33.8		
Rarely (2–3 times a month)	45.4	38.2		
Never	23.0	17.7		
<i>(For those who stated that they prescribe antibiotics) How frequently do you prescribe antibiotics for therapeutic purposes?^a</i>				
Often (every day)	37.2	30.9	3.514	.319
Sometimes (1–2 times a week)	43.1	54.4		
Rarely (2–3 times a month)	18.4	14.7		
Never	1.3	0.0		
<i>(For those who stated that they prescribe antibiotics) Do you suggest or prescribe alternative strategies/ therapies to antimicrobials^a</i>				
Yes, often	8.5	13.2	3.647	.302
Yes, sometimes	31.3	38.2		
Yes, rarely	24.7	17.7		
No, never	35.5	30.9		

^a $n_{\text{cattle vets}} = 304$, $n_{\text{pig vets}} = 68$.
AMU: Antimicrobial usage.

Table 3. Respondents' agreement with some statements on AMU and AMR ($n_{\text{cattle vets}} = 422$, $n_{\text{pig vets}} = 96$).

Statements	Cattle veterinarians (%)	Pig veterinarians (%)	Chi-square	p-value
<i>Inadequate AMU in animals is dangerous for their health</i>				
Not at all or slightly agree	14.0	16.7	0.456	.500
Somewhat or strongly agree	86.0	83.3		
<i>Inadequate AMU in animals is dangerous for human health</i>				
Not at all or slightly agree	13.3	19.8	2.686	.101
Somewhat or strongly agree	86.7	80.2		
<i>Antimicrobials are over-used in Italian rearing farms</i>				
Not at all or slightly agree	23.5	25.0	0.102	.749
Somewhat or strongly agree	76.5	75.0		
<i>AMR is a relevant problem in Italy</i>				
Not at all or slightly agree	23.2	28.1	1.027	.311
Somewhat or strongly agree	76.8	71.9		
<i>Prescribing broad-spectrum antibiotics in rearing farms increases the antimicrobial resistance</i>				
Not at all or slightly agree	30.6	40.6	3.609	.050
Somewhat or strongly agree	69.4	59.4		
<i>The preventive use of antibiotics fosters the development of AMR</i>				
Not at all or slightly agree	14.2	30.2	14.05	.000
Somewhat or strongly agree	85.8	69.8		
<i>Alternative methods currently available (homeopathy, phytotherapy, etc.) could be an efficient alternative to antimicrobial treatment</i>				
Not at all or slightly agree	83.9	74.0	5.233	.022
Somewhat or strongly agree	16.1	26.0		

AMU: antimicrobial usage; AMR: antimicrobial resistance.

groups and prescribing behaviour of cattle veterinarians (Chi-square = 17.958, $p = .000$), while no dependent relationship emerged with regard to pig veterinarians (Chi-square = 1.213, $p = .545$). In particular, out of 304 cattle veterinarians who stated that they prescribe antibiotics, 42.4% was lower than 45 years old, 47.0% was between 45 and 60 years old, 10.5% was over than 60 years old. On the contrast, out

of 118 cattle veterinarians who stated that they do not prescribe antibiotics, 20.3% was lower than 45 years old, 65.3% was between 45 and 60 years old, 14.4% was over than 60 years old.

Only veterinarians who stated that they prescribe antibiotics were asked how frequently they prescribe antibiotics with prophylactic purposes and with therapeutic purposes. It emerged that the number of those

Table 4. Factors influencing the choice of antibiotics to be prescribed. Median values (Likert scale from 1 minimum to 10 maximum, $n_{\text{total sample}} = 372$, $n_{\text{cattle vets}} = 304$, $n_{\text{pig vets}} = 68$).

Factors	Total sample	Cattle veterinarians	Pig veterinarians	Standardized test	<i>p</i> -value
Efficacy	10	9 ^a	10 ^a	2.964	.003
Field experience	9	9	9	1.687	.092
Training/scientific knowledge	9	8	9	0.754	.451
Current legislation	8	8 ^b	9 ^b	2.723	.006
Duration of the withdrawal period	9	9	8	-1.264	.206
AMR risk	8	8	8	-0.871	.384
Laboratory diagnosis including drug susceptibility testing	8	8	8	1.600	.110
Ease of administration	8	8	7.5	0.457	.647
Guidelines or national/international protocols on the rational use of drugs	7	7	7	0.394	.693
Price	7	7 ^c	6 ^c	-2.894	.004
Avoiding CIAs (critically important antimicrobials)	6	6	5	-0.967	.333
Easy access in the market	6	6	6	-1.092	.275
Opinion of a colleague	6	6	6	1.341	.180
Habit	5	6 ^d	4 ^d	-3.550	.000
Fear of penalties	5	5	6	0.702	.482
Opinion of the farmer	3	3	3	1.006	.314
Pharmaceutical representatives	3	3	3	-1.692	.091
Advertisement	2	2	2	-1.608	.108
Opinion of the pharmacist	1	1	1	-0.253	.801

^aCattle: (first quartile; third quartile) = (9; 10) | Pig: (first quartile; third quartile) = (9; 10).

^bCattle: (first quartile; third quartile) = (6; 10) | Pig: (first quartile; third quartile) = (7; 10).

^cCattle: (first quartile; third quartile) = (5; 8) | Pig: (first quartile; third quartile) = (3.25; 7.75).

^dCattle: (first quartile; third quartile) = (3; 7) | Pig: (first quartile; third quartile) = (2; 6).

who prescribe antibiotics for prophylactic purposes was higher among pig veterinarians (Table 2). Additionally, concerning pig veterinarians, 44.1% stated that they do it often (every day) or sometimes (1–2 times a week), compared to 31.6% of cattle veterinarians.

In both subgroups, more than 80% of the respondents prescribed antibiotics for therapeutic purposes often (every day), or sometimes (1–2 times a week), and in particular, the corresponding proportion of pig veterinarians exceeded 85% (Table 2).

Finally, practitioners who prescribed antibiotics were asked to what extent the factors listed in Table 4 affected the choice of the antibiotic to be prescribed. In general, it occurred that the main factors were 'efficacy', 'training/scientific knowledge', 'field experience', and 'duration of the withdrawal period'. In contrast, the factors that less affected the choice of the antibiotic were 'opinion of the farmer', 'pharmaceutical representatives', 'advertisement', and 'opinion of the pharmacist'.

According to the Mann-Whitney test, differences between the distributions of the two groups emerged with respect to the factors: 'efficacy', 'current legislation', 'habit', and 'price'.

Respondents' attitude to suggesting/prescribing alternative strategies or therapies

The attitude regarding suggesting/prescribing alternative strategies/therapies was investigated in those who stated that they prescribe antibiotics. In particular, they were asked how frequently they suggested or

prescribed alternative strategies or therapies. As shown in Table 2, 64.5% of cattle veterinarians and 69.1% of pig veterinarians declared that they suggest/prescribe alternative approaches to the use of antimicrobials.

Only veterinarians who stated that they suggest/prescribe alternative strategies ($n_{\text{cattle vets}} = 196$, $n_{\text{pig vets}} = 47$) were asked to specify which strategies. The responses grouped in categories are reported in Table 5.

The alternative strategies most frequently mentioned by cattle veterinarians were categorised in 'hygiene/biosecurity/management', 'phytotherapy' and 'homeopathy/homotoxicology', while those most frequently mentioned by pig veterinarians were categorised in 'nutritive principles', 'pre-/probiotics' and 'hygiene/biosecurity/management'.

The word clouds created, starting from the cattle and pig veterinarians' responses to the free open-ended question 'in your opinion, which strategy could be effective in the AMU reduction in rearing farms?' are reported in Figures 1 and 2.

A translation of the main words is provided in Supplemental Material (Table SM2).

In the cattle veterinarians' opinion, effective strategies for AMU reduction should be applied on different fronts, including the management practices of livestock farms, farmers, animals, veterinarians, biosecurity measures, etc.

From the pig veterinarians' responses, the importance of biosecurity measures emerged, followed by vaccines and the management of livestock farms.

Table 5. Main alternative strategies suggested by the cattle veterinarians and the pig veterinarians (total occurrences and percentages, $n_{\text{cattle vets}} = 196$, $n_{\text{pig vets}} = 47$).

Main alternative strategies to antimicrobials	Cattle veterinarians			Pig veterinarians		
	Occurrences	%	Rank	Occurrences	%	Rank
Hygiene/Biosecurity/Management	48	15.7	1	11	13.1	3
Phytotherapy	46	15.1	2	9	10.7	4
Homeopathy/Homotoxicology	42	13.8	3	1	1.2	8
Anti-inflammatory	41	13.4	4	5	5.9	6
Vaccines	34	11.1	5	7	8.3	5
Nutritive principles	23	7.5	6	14	16.7	1
Immunostimulants	16	5.3	7	3	3.6	7
Pre-/Probiotics	10	3.3	8	12	14.3	2
Disinfectants/Antiseptics	8	2.6	9	1	1.2	8
Essential oil	3	1.0	10	5	5.9	6
Acidifying substances	1	0.3	11	9	10.7	4
Other	33	10.8	–	7	8.3	–



Figure 1. Word cloud of the strategies proposed by the cattle veterinarians. ^aWords with a greater number of occurrences included 'Rearing farm', 'Animal', 'Farmer', 'Biosecurity', 'Veterinarian', 'Antibiotic', 'Animal welfare', and 'Welfare'.

Discussion

AMR and AMU issues have been largely debated in the recent decades. In the European context, several studies investigated the opinions, knowledge and perceptions regarding AMR in different populations, from junior doctors (Pulcini et al. 2011), to dairy cow farmers (Higham et al. 2018), farmers (Visschers et al. 2015, 2016; Di Martino et al. 2019), and the general public (André et al. 2010). Additionally, the veterinarians'

points of view and prescribing behaviour were investigated in the European context (Speksnijder et al. 2015; McDougall et al. 2017; Van Cleven et al. 2018). However, only a few studies have aimed to investigate these issues specifically in the Italian context. Busani (Busani et al. 2004), for example, performed a telephone survey on Italian beef and dairy cattle veterinarians. The aim of the investigation was to deepen the understanding of several aspects of AMR, including veterinarian backgrounds, training activities,

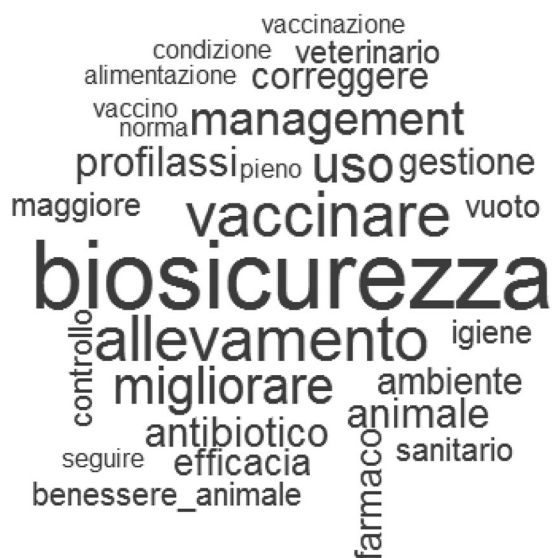


Figure 2. Word cloud of the strategies proposed by the pig veterinarians. ^aWords with a greater number of occurrences included 'Biosecurity', 'Rearing farm', 'Vaccinate', and 'Improve'.

diagnostics, treatments, prophylactic practices for specific diseases, and the participants' perception of the threat posed by AMR. Starting from the survey conducted by Busani, we aimed to outline the opinions, habits, and prescribing behaviour of Italian veterinarians, by means of an online survey.

Socio-demographic characteristics

Most veterinarians who replied to the questionnaire worked with cattle and pigs, and this result reflects the importance of these two animals in the Italian livestock sector. Most veterinarians specialising in cattle and pigs were male and had more than 20 years of work experience. In Italy, the overall ratio between male and female veterinarians is more balanced (57.6% and 42.4%, respectively) compared to the results of the present survey (Nomisma 2014).

The veterinary profession has changed substantially over the years in terms of the male/female ratio; the number of female professionals has gradually increased, and now, in certain countries, they are a majority in the profession (Allen 2016). Nevertheless, most veterinarians who choose jobs on animal farms are male (Shepherd and Pikel 2011). The greater propensity of male veterinarians, compared to females, for specialising in farm animals can explain the relatively high age of respondents and allows a better interpretation of some opinions and habits, considering the temporal distance from academic training and the role of age-linked professional experience. However, the sample cannot be considered representative of the population of Italian farm animal

veterinarians for any socio-demographic characteristics. All the available contacts were invited by email but the participation in the study was voluntary and conditioned only by the two initial screening questions.

Opinions on AMU and AMR

The protocols and rules to be applied for a prudent AMU are widely described in various national and international documents and guidelines (Ministero della Salute 2012, 2017; World Health Organization 2014; European Centre for Disease Prevention and Control 2015; World Organisation for Animal Health 2018), which are available to all veterinarians.

Most of cattle and pig veterinarians believe that AMU on the livestock farms in which they operate is not always in line with national and European guidelines. This result is not easy to explain because drug use in Italy is a direct responsibility of veterinarians and therefore of the people who completed the questionnaire. Thus, the interpretation of this outcome has been further explored by investigating the opinions of veterinarians on AMU and AMR.

As shown in Table 3, some responses given by cattle veterinarians compared to pig veterinarians (prescription of broad-spectrum antibiotics, preventive use of antibiotics and use of alternative strategies to antimicrobials) probably reflect the different approaches of practitioners operating on two different types of livestock production. In the case of cattle, the veterinarian has a clinical approach to both individual animals and group clinics, while in pig farming the veterinarian's activity is almost exclusively aimed at the health management of the animal groups. This different approach necessarily involves a different AMU and can generate a different perception of the problems related to AMR. In general, both cattle and pig veterinarians agreed with the fact that inadequate AMU in livestock has clear animal and human health implications. The percentage of professionals who disagreed with the above statements is still high and probably reveals a gap in knowledge and awareness on the AMR issue.

Taking into account the good level of awareness (> 80%) of veterinarians about the clear implications for both humans and animals regarding antimicrobial misuse in the livestock sector, it is even more perplexing that only in a limited number of farms are antimicrobials used according to national and European guidelines (Table 2). As suggested by De Briyne et al., it is probable that external factors (owner influence, ease of drug administration, price or other economic

elements) affecting AMU in the farm are involved (De Briyne et al. 2013).

Approximately one-quarter of cattle and pig veterinarians do not completely believe that antimicrobials are over-used and that AMR is a major problem. On the one hand, more than 80% of veterinarians recognise that inadequate AMU can generate problems for human and animal health; on the other hand, more than a quarter of veterinarians do not consider AMR a relevant problem in Italy. Nevertheless, official documents state that 'In Italy, AMR remains among the highest in Europe, almost always above the average' (Ministero della Salute 2017). This outcome also indicates a major gap in knowledge on the topic.

Finally, there is a lack of awareness regarding the impact of the use of broad-spectrum antibiotics on AMR; about 30% of cattle veterinarians and 40% of pig veterinarians are little or not at all in agreement with the fact that the use of broad-spectrum antibiotics in livestock production may facilitate an increase in AMR (Karam et al. 2016).

Antimicrobial prescribing habits

A dependent relationship emerged between age groups and prescribing behaviour of cattle veterinarians. In particular, those who prescribe antibiotics tend to be younger than those who do not prescribe them. This result suggests that age could play a role in prescribing habits. However, the same result does not emerge for pig veterinarians. In light of this discrepancy, the role of age in prescribing behaviour should be studied more in depth.

Another interesting aspect concerns the prophylactic use of antibiotics, with many veterinarians declaring to prescribe antibiotics for preventive use. This may be explained by the fact that it is sometimes difficult to distinguish between the metaphylactic and prophylactic use of antibiotics. In daily practice, respondents may consider as prophylaxis the metaphylactic drug use in a group of animals after the clinical diagnosis of a disease in a few individuals.

Antibiotics can be used in livestock for therapeutic or preventive purposes, and the veterinarian must prescribe their application after having identified the aetiological agents involved and their antimicrobial sensitivity (European Centre for Disease Prevention and Control 2015).

The answers provided by both cattle and pig veterinarians on the prophylactic use of drugs show a certain discrepancy between what is recommended in all guidelines (strict limitation of prophylactic use of

antibiotics) and what happens in daily practice. It is necessary to underline, however, some peculiarities that concern the different types of animal rearing. In some types of animal rearing, for example, in pigs, the use of 'per os' antimicrobials is commonly carried out (Burow et al. 2014) through medicated feeds in particularly stressful phases of the production cycle (Li 2017). Therefore, medicated feed can be applied for both therapeutic and prophylactic purposes.

Another important factor to be taken into account for the interpretation of the data concerns the type of cattle rearing; the study did not discriminate between dairy cow, fed lot cattle and veal calf production. Each type of animal rearing has specific characteristics regarding the administration of drugs for prophylactic use; as an example, we should consider the possible extensive use of dry cow therapy in dairy cattle (Witteck et al. 2018).

Regarding the frequency of drug prescription for therapeutic use, we observed a difference between veterinarians of cattle and pigs (Table 2) that reflects, again, the different approach to health problems in these two types of rearing systems. A greater frequency (daily) of drug prescription for therapeutic use can be connected to a greater demand for clinical interventions on single animals, as probably happens in cattle operations; however, in pigs daily drug prescription for prophylactic use is more relevant, assisting to the overall health management (and treatment) of animal groups (Table 2).

Finally, potential factors influencing the choice of the antibiotic by the veterinarian were evaluated (Table 4). The 'efficacy' of the antibiotic and veterinary 'field experience' were the two common factors between cattle and pig rearing and were considered the most important for identifying the antibiotic to be used. For cattle veterinarians, it was essential to evaluate, among other factors, the 'duration of the withdrawal period', i.e. the waiting period since the last treatment, before using the animal products for human consumption (e.g. milk). In dairy cows, the length of the withdrawal period was an important parameter to estimate the economic losses due to antimicrobial treatment, which mainly resulted from failure to collect and sell the milk produced from treated lactating cows (Shim et al. 2004). Training and scientific knowledge as well as regulatory aspects were important for pig veterinarians. External elements, such as advertising, the opinion of pharmacists, representatives from pharmaceutical companies or the opinion of farmers, did not seem to influence veterinarians' choice of antibiotics.

Alternative strategies to antimicrobials

As shown in Table 3, only a minor percentage of veterinarians believed that alternative methods could be effectively used instead of antimicrobials. However, in everyday practice, alternative measures were recommended with interestingly high frequency (Table 2). This discrepancy can be explained by evaluating the answers provided by veterinarians for the open-ended question regarding this topic, as grouped in Table 5 and represented graphically in a word cloud (Figures 1 and 2).

In addition to 'alternative therapies', such as prebiotics, probiotics, essential oils, and homeopathy, which are currently much debated (Keller and Sundrum 2018), there are 'alternative strategies' of recognised effectiveness (hygiene, biosecurity, health management schemes, vaccines) that are recommended to the farmer as an alternative to AMU.

The answers to the relevant open-ended question allowed for a better understanding of the differences in sensitivity and perspectives of veterinarians, and highlighted the need to apply other measures or tools to limit AMU in livestock.

Conclusions

This survey highlighted veterinarians' knowledge gaps and information needs about AMR and prudent AMU. Several discrepancies emerged between the veterinarians' opinions, perceptions and self-reported behaviour. Moreover, the behaviour declared (for example, the use of broad-spectrum antibiotics, and prophylactic use of antibiotics) does not seem in line with prudent AMU in the considered types of livestock production systems in Italy.

Hence, the need to provide appropriate training strategies with the aim of adopting a behaviour more consistent with the guidelines for prudent AMU in cattle and pig production systems has emerged.

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Ethical approval

The study design meets the requirements established by the Ethics Committee of the Istituto Zooprofilattico Sperimentale delle Venezie.

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