SCIENTIFIC STUDY ON PRESCRIPTION BEHAVIOUR, CONSUMPTION, USE AND WASTE MANAGEMENT OF ANTIBIOTICS/BIOCIDES IN BELGIUM AMONG VETERINARIANS FOR LIVESTOCK ANIMALS, INCLUDING A PILOT STUDY ON AN INTERVENTION TO OPTIMISE VETERINARIANS' PRESCRIPTION BEHAVIOUR

Report WP1 - Prescription behaviour, consumption, use and waste management of antibiotics/ biocides in Belgian livestock veterinarians.

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Title:

Prescription behaviour, consumption, use and waste management of antibiotics/biocides in Belgium in livestock veterinarians.

Research team:

Zoë De Mol, Ghent University

Dr. Dagje Boeykens, Antwerp University

Prof. dr. Sibyl Anthierens, Antwerp University

Prof. dr. Jeroen Dewulf, Ghent University

Prof. dr. Annelies Decloedt, Ghent University

Volksgezondheid
Veiligheid van de Voedselketen
Leefmilieu

FOD Volksgezondheid, Veiligheid van de Voedselketen en Leefmilieu

Directoraat-generaal Gezondheidszorg Galileelaan 5/2 – 1210 Brussel T.

+32 (0)2 524 97 97 (contact center)

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ABBREVIATIONS

AMR	Antimicrobial resistance
AMU	Antimicrobial usage
WHO	World Health Organization
OHA	One Health Approach
GP	General Practitioner
TDF	Theoretical Domain Framework
AMCRA	Antimicrobial Consumption and Resistance in Animals
FAVV	Federaal Agentschap voor de Veiligheid van de Voedselketen
FAGG	Federaal Agentschap voor Geneesmiddelen en Gezondheidsproducten
DGZ	Dierengezondheidszorg Vlaanderen
ARSIA	Association Régionale de Santé et d'Identification Animales
NSAID	Non-Steroidal Anti-Inflammatory drugs
BVD	Bovine Viral Diarrhea
PRRS	Porcine Reproductive and Respiratory Syndrome virus
PCR	Polymerase Chain Reaction
IM	Intramuscular
IV	Intravenous
SC	Subcutaneous
PO	Per os
CIA	Critically Important Antibiotic
NRT-tool	Nearly Real Time Tool

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SUMMARY

Background

Antimicrobial resistance poses a global threat to public health. Unfortunately, antibiotic usage and the use of broad-spectrum antibiotics in Belgium remains above the average in Europe. To shape future initiatives, there is a need for a better understanding of the barriers and facilitators that can lead to behavior change regarding antibiotic use and prescribing practices. To address these needs, 4 focus groups and 1 interview with 23 Belgian livestock veterinarians (pig, poultry and ruminants) were organized. The aim was to explore the determinants of antimicrobial prescription behaviour and the perceptions of Belgian veterinarians regarding antibiotic and biocidal use and waste disposal.

Results

Participants acknowledged that the established diagnosis significantly shapes the veterinarian's decision-making process when prescribing antibiotics. In addition to assessing clinical signs, participants indicated that diagnostic tools such as bacteriology and antibiograms play a pivotal role in the decision-making process. These tools aid in identifying the causative bacteria and determining the appropriate antibiotic. However, the delay in receiving test results was highlighted as a challenge. Despite these obstacles, participants generally recognized the advantages of employing diagnostic tools. A second factor in the decision-making process was the evaluation of available therapeutic options. This included the characteristics of available antibiotics, but also the available alternative therapies. Despite facing economic and time constraints, participants were increasingly inclined to adopt preventive measures, such as vaccination, and to explore alternatives to antibiotics, such as supplements and NSAIDs. This reflects the increasing emphasis on sustainable antimicrobial practices.

The inherent characteristics of the veterinarian were also identified to shape the decision-making process when prescribing antibiotics. Acknowledging the veterinarians' role in prescribing antibiotics and promoting responsible AMU was stressed. Participants' decision-making when prescribing antibiotics was primarily based on accumulated expertise, knowledge, and experience. Less experienced veterinarians often encountered challenges such as pressure to prescribe antibiotics. Collaboration among veterinarians was deemed essential for exchanging expertise and supporting younger colleagues. The veterinarian-farmer relationship was also found to exert a noteworthy influence. The importance of an effective communication style between veterinarians and farmers was highlighted, with a relationship-based approach showing promise. Economic considerations were stressed to play a prominent role for both veterinarians and farmers, given that sales of antibiotics and livestock represent sources of income. To address barriers faced by veterinarians, individual veterinary herd health management was identified as a solution to compensate for lost income. Additionally, a need for more resources was identified, including financial support and a larger number of practicing veterinarians, to focus on preventive veterinary medicine and promote responsible AMU. According to participants, administering antibiotics is often perceived by farmers as the most cost-effective and least labor-intensive solution. Farmers' awareness levels were believed to vary greatly and participants indicated that farmers often lack sufficient knowledge of antibiotics and antibiotic resistance.

Sensibilization and education were proposed as solutions to persuade livestock farmers to use antibiotics responsibly. Moreover, the participants emphasized the need for a unified "One Health" approach. Furthermore, there was a call for mandatory implementation of biosecurity and preventive measures.

Laws and legislation played a key role in participants' decision-making processes, with compliance or non-compliance influenced by increasing awareness among veterinarians and avoidance of consequences. However, there was a demand for more transparent communication from governments and the development of effective control strategies. Periodic AMU reports and antibiograms were also recognized as valuable tools to promote behavioral change and engage with farmers. Participants highlighted unclear waste management guidelines for antibiotics and biocides and noted that veterinarians do not distribute biocides but may offer advice or refer farmers to specialized companies.

In summary, the focus for future interventions could be on: 1) facilitating responsible use of antibiotics, 2) recognizing the role of the veterinarian in prescribing antibiotics and providing training, 3) countering economic factors, 4) launching targeted campaigns, 5) transparent communication on legislation, 6) highlighting the benefits of data collection and benchmarking, 7) developing guidelines on the use of biocides and waste management, and 8) promoting the use of antibiotic guidelines among veterinarians.

SAMENVATTING

Achtergrond

Antimicrobiële resistentie vormt een wereldwijde bedreiging voor de volksgezondheid. Het antibioticagebruik en gebruik van breedspectrumantibiotica blijft in België boven het gemiddelde in Europa. Om toekomstige initiatieven vorm te geven, is er nood aan een beter begrip van de barrières en hefbomen die kunnen leiden tot gedragsverandering met betrekking tot antibioticagebruik en voorschrijfgedrag in de diergeneeskunde. Om aan deze behoeften te voldoen, werden 4 focusgroepen en 1 interview met 23 Belgische dierenartsen (gespecialiseerd in varkens, pluimvee en herkauwers) georganiseerd. Het doel was om de determinanten van antibioticavoorschrijfgedrag te onderzoeken en de perceptie van Belgische dierenartsen met betrekking tot het gebruik van antibiotica, biociden en afvalverwijdering te exploreren.

Resultaten

Participanten erkenden dat de vastgestelde diagnose een belangrijke invloed heeft op het besluitvormingsproces van de dierenarts bij het voorschrijven van antibiotica. Naast het beoordelen van klinische symptomen, gaven de deelnemers aan dat diagnostische instrumenten zoals bacteriologie en het antibiogram een cruciale rol spelen in het besluitvormingsproces. Deze instrumenten helpen bij het identificeren van de oorzakelijke bacterie en het bepalen van het juiste antibioticum. Het wachten op de testresultaten werd echter als een uitdaging beschouwd. Desondanks erkenden de deelnemers de voordelen van het gebruik van diagnostische hulpmiddelen. Een tweede factor in het besluitvormingsproces was de evaluatie van beschikbare therapeutische opties. Dit omvatte de kenmerken van beschikbare antibiotica, maar ook de beschikbare alternatieve therapieën. Ondanks economische en tijdsbeperkingen waren de deelnemers steeds meer geneigd om preventieve maatregelen te implementeren, zoals vaccinatie, en om alternatieven voor antibiotica in te zetten, zoals supplementen en NSAID's. Dit reflecteert de toenemende nadruk op het verantwoord gebruik van antibiotica.

Ook dierenarts-specifieke kenmerken bepalen het besluitvormingsproces bij het voorschrijven van antibiotica. Het erkennen van de rol van de dierenarts bij het voorschrijven van antibiotica en het promoten van verantwoord antibioticumgebruik werd benadrukt. De besluitvorming van de deelnemers

bij het voorschrijven van antibiotica was voornamelijk gebaseerd op opgebouwde expertise, kennis en ervaring. De deelnemers gaven aan dat minder ervaren dierenartsen vaker geconfronteerd werden met uitdagingen zoals druk vanuit de veehouder om antibiotica voor te schrijven. Samenwerking tussen dierenartsen werd essentieel geacht voor het uitwisselen van expertise en het ondersteunen van jongere collega's. De relatie tussen dierenarts en veehouder bleek ook een belangrijke invloed te hebben. Er werd gewezen op het belang van een effectieve communicatiestijl tussen dierenartsen en veehouders, waarbij een op relaties gebaseerde aanpak veelbelovend bleek. Er werd benadrukt dat economische overwegingen een prominente rol spelen voor zowel dierenartsen als veehouders, aangezien de verkoop van antibiotica en de veestapel een bron van inkomsten zijn. Om de barrières waarmee dierenartsen worden geconfronteerd aan te pakken, werd individuele bedrijfsbegeleiding genoemd als een oplossing om verlies van inkomen te compenseren. Daarnaast werd vastgesteld dat er behoefte is aan meer middelen, waaronder financiële steun en een groter aantal praktiserende dierenartsen, om zich te richten op preventieve diergeneeskunde en verantwoord AMU te bevorderen. Volgens de deelnemers wordt het toedienen van antibiotica door veehouders vaak gezien als de goedkoopste en minst arbeidsintensieve oplossing. Men was van mening dat het bewustzijnsniveau van boeren sterk varieerde en de deelnemers gaven aan dat boeren vaak onvoldoende kennis hebben over antibiotica en antibioticaresistentie.

Sensibilisatie en educatie werden voorgesteld als oplossingen om veehouders te overtuigen om antibiotica verantwoord te gebruiken. Bovendien benadrukten de deelnemers de noodzaak van een "One Health"-aanpak. Verder werd er opgeroepen tot verplichte implementatie van bioveiligheid en preventiemaatregelen. Wetgeving speelde namelijk een belangrijke rol in het besluitvormingsproces van de deelnemers, waarbij het al dan niet naleven werd beïnvloed door een groter bewustzijn onder dierenartsen en het vermijden van consequenties. Er was echter vraag naar meer transparante communicatie vanuit overheidsinstanties en naar de implementatie van effectieve controlestrategieën. Periodieke antibioticumgebruik-rapporten en antibiogrammen werden ook gezien als waardevolle hulpmiddelen om gedragsverandering te bevorderen en het gesprek aan te gaan met de veehouder. Deelnemers benadrukten de onduidelijke richtlijnen voor afvalbeheer van antibiotica en biociden en merkten op dat dierenartsen geen biociden verdelen, maar wel advies kunnen geven of boeren kunnen doorverwijzen naar gespecialiseerde bedrijven.

Samengevat zou de nadruk voor toekomstige interventies kunnen liggen op: 1) het faciliteren van verantwoord gebruik van antibiotica, 2) het erkennen van de rol van de dierenarts in het voorschrijven van antibiotica en voorzien van bijscholingen, 3) het counteren van economische factoren, 4) het opzetten van gerichte campagnes, 5) transparante communicatie over wetgeving, 6) het benadrukken van de voordelen van datacollectie en benchmarking, 7) het opstellen van richtlijnen voor het gebruik van biociden en afvalbeheer, en 8) het gebruik van antibiotica richtlijnen door dierenartsen bevorderen.

RÉSUMÉ

Contexte

La résistance aux antimicrobiens constitue une menace mondiale pour la santé publique. Malheureusement, l'utilisation d'antibiotiques et d'antibiotiques à large spectre en Belgique reste supérieure à la moyenne européenne. Afin d'orienter les initiatives futures, il est nécessaire de mieux comprendre les barrières et les facilitateurs qui peuvent conduire à un changement de comportement concernant l'utilisation des antibiotiques et les pratiques de prescription en médecine vétérinaire. Pour

répondre à ces besoins, quatre groupes de discussion et une interview ont été organisés avec 23 vétérinaires belges spécialisés dans le bétail (porcs, volailles et ruminants). L'objectif était d'explorer les déterminants du comportement en matière de prescription d'antimicrobiens et les perceptions des vétérinaires belges concernant l'utilisation d'antibiotiques et de biocides et l'élimination des déchets.

Résultats

Les participants ont reconnu que le diagnostic établi influence considérablement le processus décisionnel du vétérinaire lorsqu'il prescrit des antibiotiques. Outre l'évaluation des signes cliniques, les participants ont indiqué que les outils de diagnostic tels que la bactériologie et les antibiogrammes jouent un rôle essentiel dans le processus décisionnel. Ces outils permettent d'identifier la bactérie responsable et de déterminer l'antibiotique approprié. Cependant, le délai de réception des résultats des tests a été souligné comme un défi. Malgré ces obstacles, les participants ont généralement reconnu les avantages de l'utilisation d'outils de diagnostic. L'évaluation des options thérapeutiques disponibles constitue un deuxième facteur dans le processus de prise de décision. Il s'agit notamment des caractéristiques des antibiotiques disponibles, mais aussi des thérapies alternatives disponibles. Malgré les contraintes économiques et de temps, les participants étaient de plus en plus enclins à adopter des mesures préventives, telles que la vaccination, et à explorer des alternatives aux antibiotiques, telles que les suppléments et les AINS. Cela souligne l'importance croissante accordée aux pratiques antimicrobiennes durables.

Les caractéristiques inhérentes au vétérinaire ont également été identifiées comme influençant le processus de prise de décision lors de la prescription d'antibiotiques. L'accent a été mis sur la reconnaissance du rôle des vétérinaires dans la prescription d'antibiotiques et la promotion d'une utilisation des antibiotiques responsable. La prise de décision des participants lors de la prescription d'antibiotiques était principalement basée sur l'expertise, les connaissances et l'expérience accumulées. Les vétérinaires moins expérimentés ont souvent été confrontés à des difficultés telles que la pression exercée pour prescrire des antibiotiques. La collaboration entre vétérinaires a été jugée essentielle pour l'échange d'expertise et le soutien des jeunes collègues. La relation vétérinaire-agriculteur s'est également avérée exercer une influence significative. L'importance d'un style de communication efficace entre les vétérinaires et les agriculteurs a été soulignée, une approche basée sur les relations étant prometteuse car les caractéristiques des agriculteurs jouent un rôle dans l'utilisation responsable des antimicrobiens. Les considérations économiques ont été soulignées comme jouant un rôle prépondérant à la fois pour les vétérinaires et les agriculteurs, étant donné que les ventes d'antibiotiques et de bétail représentent des sources de revenus. Pour surmonter les obstacles rencontrés par les vétérinaires, la guidance vétérinaire individuelle a été identifiée comme une solution pour compenser la perte de revenus. En outre, les participants ont souligné la nécessité de disposer de plus de ressources, notamment d'un soutien financier et d'un plus grand nombre de vétérinaires praticiens, afin de se concentrer sur la médecine vétérinaire préventive et de promouvoir une utilisation des antibiotiques responsable. Selon les participants, l'administration d'antibiotiques est souvent perçue par les agriculteurs comme la solution la plus rentable et la moins exigeante en termes de main-d'œuvre. Les niveaux de sensibilisation des agriculteurs sont considérés comme très variables et les participants ont indiqué que les agriculteurs n'ont souvent pas une connaissance suffisante des antibiotiques et de la résistance aux antibiotiques.

La sensibilisation et l'éducation ont été proposées comme solutions pour persuader les éleveurs d'utiliser les antibiotiques de manière responsable. En outre, les participants ont souligné la nécessité d'une approche unifiée "One Health". En outre, un appel a été lancé en faveur de la mise en œuvre obligatoire de mesures de biosécurité et de prévention. Les lois et la législation ont joué un rôle important dans les processus de prise de décision des participants, le respect ou le non-respect de ces lois étant influencé par la sensibilisation accrue des vétérinaires et la prévention des conséquences. Toutefois, les participants ont demandé une communication plus transparente de la part des gouvernements et le développement de stratégies de contrôle efficaces. Les rapports périodiques d'utilisation des antibiotiques et les antibiogrammes ont également été reconnus comme des outils précieux pour promouvoir le changement de comportement et s'engager auprès des agriculteurs. Les participants ont souligné le manque de clarté des directives relatives à la gestion des déchets d'antibiotiques et de biocides et ont noté que les vétérinaires ne distribuent pas de biocides, mais qu'ils peuvent donner des conseils ou orienter les agriculteurs vers des entreprises spécialisées.

En résumé, les interventions futures pourraient se concentrer sur les points suivants : 1) faciliter l'utilisation responsable des antibiotiques, 2) reconnaître le rôle du vétérinaire dans la prescription d'antibiotiques et assurer formations, 3) lutter contre les facteurs économiques, 4) lancer des campagnes ciblées, 5) assurer une communication transparente sur la législation, 6) souligner les avantages de la collecte de données et benchmarking, 7) élaborer des lignes directrices sur l'utilisation des biocides et la gestion des déchets, et 8) promouvoir l'utilisation des lignes directrices sur les antibiotiques auprès des vétérinaires.

I. INTRODUCTION

INTRODUCTION

This scientific study elaborates on the project "Scientific study on prescription behaviour, consumption and use and waste management of antibiotics/biocides in Belgium among veterinarians, socio-economically disadvantaged populations & possible evaluations of impact public campaigns" by the University of Antwerp (March 2023 – March 2024). Based on this full-time 4-year PhD trajectory, we will be able to provide targeted advice needed to enable a One Health approach in Belgium, by extending the behavioural sciences research around antibiotic use in human medicine to the field of veterinary medicine. The project can thus be considered as an addendum that deepens and extends the knowledge obtained in the project "Scientific study on prescription behaviour, consumption and use and waste management of antibiotics/biocides in Belgium among veterinarians, socio-economically disadvantaged populations & possible evaluations of impact public campaigns".

The following work packages are part of the project by the University of Antwerp:

- WP1: Focus groups on antibiotic prescribing behaviour, antibiotic consumption, and biocide disposal among companion animal veterinarians.
- WP2: Interviews antibiotic prescribing behaviour, antibiotic consumption, and biocide waste disposal among healthcare providers working with socio-economically vulnerable groups.
- WP3: Scoping review: evaluation impact public campaigns.

In this complementary study, the following work packages are included:

- WP1: Focus groups antibiotic prescribing behaviour, antibiotic consumption, and biocide disposal among livestock veterinarians.
- WP2: Evaluation of autonomy-supportive coaching for reduced antibiotic use in livestock.
- WP3: Pilot study intervention for optimizing antibiotic prescribing behaviour by veterinarians: developing and evaluating the intervention.

This report will focus on the results of work package 1.

BACKGROUND

The introduction of antibiotics has allowed major improvements in morbidity and mortality by preventing and treating infections. Despite playing a pivotal role in modern medicine, antibiotics have given rise to the concerning issue of antimicrobial resistance (AMR) (1,2). The primary driver of AMR is the inappropriate and excessive antimicrobial usage (AMU) in human and veterinary medicine, as well as in agriculture. This has created a complex and dynamic landscape where commonplace infections become increasingly difficult to manage, and routine medical procedures like surgeries and chemotherapy carry higher risks (3). Consequently, AMR has emerged as a major threat to public health, jeopardizing the effectiveness of crucial medical interventions and the ability to combat infectious diseases (4).

The World Health Organization (WHO) and the World Organization for Animal Health (WOAH) have expressed significant concerns about AMR. They advocate for actions to reduce and optimize prescriptions and usage of antimicrobials/ antibiotics (5-7). Ideally, addressing AMR involves various components outlined in the One Health Approach (OHA) (7). OHA is characterized by a collaborative effort across different settings to provide solutions for human, animal, and environmental health. Especially AMR is intricately connected to all these dimensions within the OHA (8).

AMU in humans and animals has been reported in most EU countries for decades (9-10). Most antibiotics in the human and veterinary setting are prescribed in primary care, and Belgium remains the leader in Europe (11-12). In intensive animal farming, such as poultry and pig farming, large quantities of antibiotics are traditionally used because of the high stocking density and rapid spread of pathogens. As a result, large quantities of antimicrobials are traditionally used. From January 2022, the preventive use of antibiotics will no longer be allowed for groups of animals (European Legislation 2019/6). A qualitative evaluation of the impact of this measure on the prescribing behaviour of veterinarians within the livestock sector is imperative. In Belgium, several qualitative studies were already conducted that provided insights into the underlying determinants of GPs' prescribing behaviour, and how the context in which GPs work influences this (13-19). For Belgian veterinary medicine, there is still a gap in the science here. In the context of the growing importance of a "one health" approach, an exploratory study that identifies the prescribing context of Belgian veterinarians is needed.

Future interventions aimed at behaviour change should be implemented in the daily reality of prescribers. It is important that all prescribers receive the same key messages, which are adapted to their own context. Knowledge about the barriers and facilitators for behavioural change in all sectors are thus necessary. The research done in human medicine allows us to search for similarities, differences, or novel issues to consider in veterinary medicine.

In addition to the crucial role of antibiotics, responsible management of biocides is equally significant. Biocides, which are antimicrobial agents present in disinfectants and cleaning products, can also contribute to the emergence of AMR (20). The widespread use of biocides has notably surged, particularly since the onset of the COVID-19 pandemic. Therefore, it is essential to accord proper attention to biocides within the framework of a One Health approach.

It is imperative to initially understand the perspectives and experiences of livestock veterinarians concerning antibiotic prescribing and usage. Building on this understanding, recommendations can be developed to promote behavioural changes towards more proper antibiotic usage. To achieve this goal, the following research question for work package 1 was suggested: how do livestock veterinarians perceive their use of antibiotics/ biocides, the disposal of antibiotic and biocidal waste, and the consumption of antibiotics by farmers?

REPORT WORK PACKAGE 1

How do livestock veterinarians perceive (1) their use of antibiotics/ biocides, (2) the disposal of antibiotic and biocidal waste, and (3) the consumption of antibiotics by farmers?

AIM

The first work package aims to gain more insight into how livestock veterinarians perceive their use of antibiotics/ biocides, the disposal of antibiotic and biocidal waste, and the consumption of antibiotics by farmers.

DESIGN

In this work package, a qualitative design was employed, involving focus groups with pig, poultry, and ruminant veterinarians in Belgium. Qualitative design emphasizes the comprehension and interpretation of phenomena by collecting and analyzing non-numerical data. Focus groups allow for discussion and interaction among the participants capturing different perspectives into one overall understanding. This approach is particularly well-suited for delving into meanings and subjective experiences of individuals or groups within their natural contexts. The chosen qualitative approach proves ideal for this work package, enabling a nuanced exploration of veterinarians' experiences and detailed examination of behaviour-related determinants. This, in turn, facilitates the development of interventions targeted at reducing AMR.

SAMPLE

For the focus groups, veterinarians currently active as a practitioner possessing relevant experience with pigs, poultry or ruminants were recruited in different regions of Belgium (Flanders and Wallonia) were recruited. The recruitment approach involved purposive and convenience sampling. The recruitment process aimed to ensure diversity by considering variation in years of work experience, geographic location, and gender. Participants received a €25 gift voucher as a token of appreciation for their participation.

DATA COLLECTION

Veterinarians fitting the predefined study profile were selected from the researchers' network, by contacting them by mail or telephone using contact information available online and by recruiting participants during a fair for veterinary professionals. Additionally, a newsletter was distributed through several professional and scientific organizations. Non-responders received email reminders. A topic guide was developed based on the TDF and existing literature and discussed within the research team. The topics covered the veterinarian's experiences in prescribing antibiotics, the decision-making process, barriers and facilitators for a responsible antimicrobial usage, communication with farmers, (government) campaigns, the use of biocides, and the disposal of antibiotics and biocides. These focus groups were conducted digitally using Teams. To address the research question, 4 focus groups were convened in both the Dutch-speaking (Flanders) and French-speaking (Wallonia) regions of the country. A moderator, a member of the core research team (ZdM) led each Dutch-speaking focus group. A designated French-speaking PhD-researcher (SdW) led the French-speaking focus group. ZdM was trained in qualitative research methodologies during a 1-week Summer School organized by Antwerp University on Qualitative Research in Healthcare and introduced SdW with qualitative research principles during a 1h online meeting. An observer attended each session to record notes throughout and relay additional questions to the moderator. For the focus groups with pig and ruminant veterinarians, a post-doc researcher (EB) with relevant experience with pigs and ruminants observed the focus group. The poultry focus group was

observed by a PhD-researcher (MR) with relevant experience with poultry. The French focus ruminant focus group was observed by ZdM. After each focus group observer and moderator debriefed and discussed the tenor, flow, and general findings. The anticipated duration for each focus group was set at 90 minutes.

DATA ANALYSIS

The focus groups were audio-recorded and transcribed verbatim. The analysis of the focus groups unfolded in two distinct phases, namely an inductive and deductive phase (22). In the initial phase, an inductive analysis approach was employed, allowing for an open exploration of the data. The inductive analysis followed a thematic method, involving coding, formulation of sub-themes, and the development of overarching themes (23). Moreover, an Iterative process, whereby researchers move back and forth between data collection and data analysis, was performed. At different stages of the analysis process, researcher triangulation was performed, leading to an initial refinement of the analyses. Initially, the Dutch-language ruminant focus group was independently analyzed by ZdM (veterinarian) and DB (qualitative research expert), researchers within the project team. To enhance trustworthiness of the findings, ZdM and DB collaboratively reviewed their analyses, reaching consensus on formulated codes and subthemes. Following this, the remaining 3 focus groups and the individual interview underwent a similar analysis by ZdM. In the second phase, a deductive analysis was conducted to align the data from the focus groups with the fourteen domains of the Theoretical Domain Framework (TDF), which are illustrated in table 1, and explore on which determinants interventions should respond. The TDF was created and verified by behavioral scientists. Its purpose is to pinpoint obstacles and factors that facilitate the adoption of specific behaviors. It offers a thorough analysis of strategies aimed at tackling the core mechanisms that drive behavioral change. This framework aids to improve the use of antimicrobials and prescribing practices by understanding and addressing the factors influencing behavior in this context (21). The preliminary findings were shared and deliberated upon with the core research team, containing a veterinary epidemiologist, a qualitative research expert, and a veterinarian and senior lecturer in clinical and communication skills in veterinary medicine. This offered an integrated understanding of the behavioural components requiring attention to enhance responsible antimicrobial practices. Next, the outcomes of these analyses were presented to the members of the steering committee on March 20, 2024. The presentation and discussion of results aimed to offer an integrated understanding of the behavioral components requiring attention to enhance responsible antibiotic prescribing practices.

Table 1: Theoretical Domain Framework

Domain	Explanation
Knowledge	An awareness of the existence of something.
Skills	An ability or proficiency acquired through practice.
Social/ professional role and identity	A coherent set of behaviours and displayed personal qualities of an individual in a social or work setting.
Belief about capabilities	Acceptance of the truth, reality, or validity about an ability, talent, or facility that a person can put to constructive use.
Optimism	The confidence that things will happen for the best, or that desired goals will be attained.
Beliefs about consequences	Acceptance of the truth, reality, or validity about outcomes of a behaviour in a given situation.
Reinforcement	Increasing the probability of a response by arranging a dependent relationship, or contingency, between the response and a given stimulus.
Intentions	A conscious decision to perform a behaviour or a resolve to act in a certain way.
Goals	Mental representation of outcomes or end states that an individual wants to achieve
Memory, attention, and decision process	The ability to retain information, focus selectively on aspects of the environment, and choose between two or more alternatives.
Environmental context and resources	Any circumstances of a person's situation or environment that discourages or encourages the development of skills and abilities, independence, social competence, and adaptive behaviour.
Social influences	Those interpersonal processes that can cause an individual to change their thoughts, feelings, or behaviours.
Emotion	A complex reaction pattern, involving experiential, behavioural, and physiological elements, by which the individual attempts to deal with a personally significant matter or event.
Behavioural legislation	Anything aimed at managing or changing objectively observed or measured actions.

RESULTS

A total of twenty-three veterinarians participated in four focus groups and one individual interview. The four focus groups consisted of one focus group with seven poultry veterinarians, one focus group with five pig veterinarians, one focus group with seven Flemish ruminant veterinarians and, one focus group with three Walloon ruminant veterinarians. Additionally, an in-depth individual interview was performed with one Walloon ruminant veterinarian to confirm data saturation. An overview of the participants is given in Table 2. A distinction in participants was made between gender, age, experience, region, main species treated, and setting. The focus groups lasted between 70 and 90 minutes.

Table 2: Participants' characteristics

	Poultry veterinarians		**Pig veterinarians**		**Ruminant veterinarians**	
	N= 7		N= 5		N= 11	
Gender	Women	2	Women	1	Men	11
	Men	5	Men	4		
Age (years)	20-30	2	41-50	2	31-40	1
	31-40	2	51-60	1	41-50	6
	41-50	2	>61	2	51-60	2
	51-60	1			>61	2
Experience	0-2	2	10-20	1	10-20	5
(years)	5-10	1	>20	4	>20	6
	10-20	3				
	>20	1				
Region	Wallonia	1	Belgium	1	Liège	3
	Walloon-Brabant	1	Flanders	1	Hainaut	1
	Liège	1	West-Flanders	2	West-Flanders	2
	Antwerp	4	Antwerp	1	East-Flanders	3
	Limburg	2			Antwerp	2
					Limburg	2
					Flemish-Brabant	1
Main species	Broilers	7	Pigs	5	Dairy	11
	Laying hens	3			Cattle	5
	Parent stock birds	1			Calves	1

Setting	Group practice	7	Group practice n/a	4 1	Group practice	11

1. Inductive analysis

1.1. Antimicrobial prescription behaviour and decision-making process

Thematic analysis of the transcripts revealed five themes, providing deeper insights into veterinarians' antimicrobial prescription behaviour and decision-making process. Table 3 offers a comprehensive overview of the identified themes and subthemes.

Table 3: *Overview of the identified themes and subthemes regarding antimicrobial prescription behaviour and decision-making process*

I. **Theme 1: The established diagnosis significantly shapes the veterinarian's decision-making process when prescribing antibiotics.**
   - Subtheme 1.1: The clinical examination and evaluation of clinical signs are essential in determining the need for an antibiotic treatment.
   - Subtheme 1.2: The characteristics of the diseased animals influence the decision-making process.
   - Subtheme 1.3: Diagnostic tools assist the veterinarian in determining the need for an antibiotic treatment and prescribing the appropriate antibiotic.

II. **Theme 2: The evaluation of available therapeutic options contributes to the veterinarian's decision-making process when prescribing antibiotics.**
   - Subtheme 2.1: The characteristics of available antibiotics.
   - Subtheme 2.2: The available alternative therapies and preventive measures.

III. **Theme 3: The inherent characteristics of the veterinarian contribute to shaping the decision-making process when prescribing antibiotics.**
   - Subtheme 3.1: The veterinarian's attitude towards antibiotic treatment.
   - Subtheme 3.2: The veterinarian's expertise.
   - Subtheme 3.3: The veterinarian's awareness on responsible antimicrobial prescription and antimicrobial resistance.
   - Subtheme 3.4: The veterinarian's economic and financial interests.
   - Subtheme 3.5: Veterinarian-client communication

IV. **Theme 4: The veterinarian considers the characteristics of farmer and farm in the decision-making process when prescribing antibiotics.**
   - Subtheme 4.1: Farmer's knowledge and awareness on the importance of responsible antimicrobial usage and antimicrobial resistance.
   - Subtheme 4.2: The farmer's economic and financial interests.
   - Subtheme 4.3: The farm-specific factors.

V. **Theme 5: Government initiatives promoting responsible antimicrobial usage influence the decision-making process when prescribing antibiotics.**
   - Subtheme 5.1: Legislation on antimicrobial usage and prescription in veterinary medicine.
   - Subtheme 5.2: Antimicrobial usage data collection and benchmarking.
   - Subtheme 5.3: Guidelines on antimicrobial usage in veterinary medicine.
   - Subtheme 5.4: Campaigns to promote the importance of a responsible antimicrobial usage and the danger of antimicrobial resistance.

I. Theme 1: The established diagnosis significantly shapes the veterinarian's decision-making process when prescribing antibiotics.

Subtheme 1.1: The clinical examination and evaluation of clinical signs are essential in determining the need for an antibiotic treatment.

Participants emphasized the importance of conducting a clinical examination and evaluating the animal's clinical signs. This is the first consideration in the decision-making process to determine whether a bacterial disease is suspected.

"Our clinical examination, of course, is the basis." (FG1, P3)

Participants noted that antibiotics are considered when clinical signs, like fever or dyspnea, suggest a disease with a primary bacterial etiology, such as mastitis or pneumonia. Mastitis was stated to be the primary indication in dairy cows for AMU. The severity of these clinical signs contributes to the decision-making process, more severe symptoms result in a lower antibiotic prescription threshold, stressing the importance of early disease detection. Moreover, participants added that antibiotics may be considered for multifactorial conditions, like Bovine Respiratory Disease (BRD) and Porcine Reproductive and Respiratory Syndrome (PRRS), when bacterial co-infections are suspected.

"Anything that is infectious, like think of fever [...]. Anyway with a mastitis you already start thinking towards antibiotics, with a metritis you start thinking towards antibiotics, with a pneumonia you start thinking about antibiotics, because that is where you classically expect bacteria as causative agents. (FG1, P3)"

Participants declared that ruminant veterinarians conduct a thorough clinical examination on each individual animal, selectively treating only those displaying clinical signs (curative treatment). Participants added that veterinarians may administer antibiotics to both infected and non-infected animals in a group when necessary, though this is believed to occur less frequently. These group treatments are administered to safeguard the non-infected animals from falling ill (metaphylactic treatment). Practical constraints, time limitations, and highly infectious bacterial agents make this approach necessary according to participants.

"We often work on an individual basis. Even when we have another sick calf, we try to target it individually. When it's not too big a batch and when it's technically feasible because, […], you also have to realize the reality of the situation in the field, there are times when it's almost impossible to treat […] specifically one of the calves compared to the other and we still sometimes treat batches, don't we? You cannot deny it, it still happens." (I1)

Participants stated that pig and poultry veterinarians evaluate the collective clinical symptoms present in the group when determining the need for antibiotic prescription. This evaluation considers the morbidity, mortality, and severity of clinical signs within the group. Participants added that the decision between individual and group treatments is also based on these factors.

"Yes, the clinical symptoms especially, the percentage of animals that are sick in the stall and how many animals are falling sick" (FG3, P3)

Subtheme 1.2: The characteristics of the diseased animals influence the decision-making process.

Participants highlighted that veterinarians consider the animal's immunity in their decision-making process, considering certain low-immunity risk periods, such as the peri-calving or neonatal period. As a result, younger animals often receive antibiotics due to their perceived higher susceptibility to infectious diseases. Moreover, some participants advocated for immediate group treatment for group-housed calves, believing that issues resolve more efficiently through immediate group treatment. Additionally, participants noted that cattle veterinarians consider other immunity related factors like biochemical profiles, colostrum quality, and udder health.

"For example, it depends on the age of course. Calves in group housing, you can be almost sure that it just spreads, right? From one to another. And then you might be better off injecting the whole box." (FG1, P2)

Participants discussed how the breed of affected animals affects veterinarians' decision-making. Belgian White Blue cattle, which undergo more frequent cesarean sections, exhibit higher AMU compared to Limousin cattle. It was mentioned that antibiotics like penicillin are still commonly used during cesarean sections. Additionally, participants noted a shortage of available antibiotics for sheep and goats due to insufficient registered antibiotics for these species. Participants added that organic poultry and slow growers face stringent antibiotic legislation, with most farms situated in Wallonia. These restrictions prompt poultry veterinarians to explore alternative options and preventive measures. In conventionally raised chickens, antibiotic use was perceived to be similar in Flanders and Wallonia.

"But when it comes to meat, let us just say Limousin. […] When it is a caesarean section or in case of claw disorders, but otherwise we don't have any antibiotics in Limousin cattle. Sometimes a small calf may get [antibiotics] occasionally, one that hasn't had colostrum or that is sick, but that's very limited." (FG4, P1)

Participants stated that veterinarians consider the history of affected animals, relying on supplied animal quality, and prior exposure to antibiotics. In poultry, issues in parent animals and hatcheries can affect chicks' health. In pigs, factors like farm origin and disease status are considered. These uncontrollable factors potentially lead to disease outbreak, prompting farmers and veterinarians to install an antimicrobial treatment according to participants.

Subtheme 1.3: Diagnostic tools assist the veterinarian in determining the need for an antibiotic treatment and prescribing the appropriate antibiotic.

Participants highlighted the use of diagnostic tools to aid veterinarians in assessing the need for antibiotic treatment and selecting appropriate antibiotics. Sampling for bacteriology and antimicrobial susceptibility testing is the primary diagnostic tool for ruminants, pigs, and poultry, used for confirming and identifying bacterial etiology and assessing antimicrobial efficacy and resistance.

Participants claimed that poultry veterinarians prescribe antibiotics based mainly on bacteriology and antimicrobial susceptibility testing. Due to the short lifespan of broiler chickens (42 days), samples are proactively taken from diseased chickens, allowing for informed decisions during future outbreaks. Participants stated that ruminant veterinarians collect samples in cases of mastitis, pneumonia, and diarrhea.

"In the end when you do bacteriology and you have an antibiogram, you must count on 2, 3 days and you only have 42 days for a broiler age. It is sometimes difficult then to wait until the antibiogram, […], to finally start treatment, so that is why a sample is often taken preventively from a number of diseased chickens." (FG3, P1)

Participants emphasized that antibiotic treatment may be initiated before the test results are available to ensure timely intervention and prevent further disease escalation, with treatment adjustments made upon receiving test results. This is due to the prolonged waiting time for results from bacteriology and antimicrobial susceptibility testing in a laboratory. However, time-constraints were also noted to result in omitting sampling in urgent cases. Participants noted that in-house bacteriology often provides faster results, allowing veterinarians to delay antibiotic prescription initially, opting for NSAIDs instead, and initiate treatment upon receiving test results. Despite challenges with extended waiting times for results, participants appreciate the quality and efficiency of tests performed by laboratories such as DGZ or ARSIA. Participants emphasized that while sampling initially costs the farmer, it enables more targeted treatment, speeding up recovery and reducing mortality, ultimately saving money. Consequently, participants stated that most farmers prefer sampling, highlighting the importance of bacteriology and antimicrobial susceptibility testing in promoting responsible antimicrobial practices.

"I don't see an antibiogram as an obstacle, I see it as a tool." (FG3, P1)

Besides bacteriology and antimicrobial susceptibility testing, participants mentioned other diagnostic tools that assist in the decision-making process. These tools include thoracic ultrasound to assess pneumonia severity in calves, somatic cell counts to inform antibiotic decisions for mastitis, autopsies, and advanced diagnostics like PCR tests. In conclusion, technological advancements enable faster and accurate diagnosis, empowering veterinarians to administer more targeted treatment.

"We're examining calves now. We have not used it much yet, but we are starting to get ultrasound scans that we can use to help diagnose the severity of pneumonia, so there you go. That is all there is to it, so we are trying to refine the diagnosis." (I1)

II. Theme 2: The evaluation of available therapeutic options contributes to the veterinarian's decision-making process when prescribing antibiotics.

<u>Subtheme 2.1: The characteristics of available antibiotics.</u>

Participants noted that veterinarians conduct a thorough evaluation of the characteristics of available antibiotics to choose the appropriate treatment. Participants mentioned the antibiotic's withdrawal time for milk, meat, or eggs having a major influence, especially in dairy cattle to ensure antibiotic residue-free milk. In beef cattle, administering antibiotics may affect the cow's eligibility for slaughter depending on the withdrawal period, thereby impacting the animal's economic value for the farmer. In poultry, participants highlighted that only a few antibiotics without a withdrawal time for eggs are registered for laying hens, which limits options in case of disease. Participants observed that guidelines specify withdrawal time should not be the primary determinant as broilers approach the slaughter date, when a lengthy withdrawal time is undesirable. Veterinarians are advised to opt for less critical antibiotics. However, selecting a less critical antibiotic with a longer withdrawal time over a critical one with a shorter withdrawal time presents a challenge for poultry veterinarians at the end of the broiler production cycle, considering their short lifespan. As a result, antibiotics are more commonly administered earlier in the

cycle, when there are no restrictions regarding withdrawal time. However, participants noted that significant outbreaks near the end of the cycle may prompt farmers to administer antibiotics to prevent further escalation.

"Whereas with dairy cows, yes, that [withdrawal time] does come up quite often, doesn't it? If you want to start treating something. I'm just saying, a cow with an infection somewhere on a joint or pneumonia. Then we begin to talk very quickly about the withdrawal time, of course, isn't it?" (FG1, P4)

Participants recognized that veterinarians also consider pharmacokinetic properties. Specific antibiotics are chosen based on their distribution or ability to penetrate infection sites effectively, ensuring targeted treatment. According to participants, the route of administration (IM, IV, SC, PO) and the antibiotic's duration of action (long-acting or short-acting) are additional factors. Participants stated that farmers often opt for group treatments through medicated feed.

Subtheme 2.2: The available alternative therapies and preventive measures.

Participants stated that veterinarians' antimicrobial prescription behaviour depends on the availability of preventive measures and alternative therapies. Veterinarians prioritize preventive advice over systematic antimicrobial prescription and usage, this being the preferred tactic to promote long-term responsible antimicrobial practices. However, time constraints are believed to hinder in-depth discussions with farmers on preventive measures. Participants summarized financial aspects, farmer skepticism about effectiveness, and lack of motivation to change behaviour pose obstacles for adopting preventive measures, this will be further discussed in theme IV.

Participants emphasized that veterinarians perceive vaccination as one of the most important preventive measures, for example to prevent pneumonia and diarrhea in calves. Participants mentioned that when viral diseases lack vaccines or existing vaccines do not offer adequate protection, antibiotics are administered during outbreaks to prevent secondary bacterial infections.

"But our advice that we give is often inadequate, vaccination does not catch on and then we have to resort to antibiotics again anyway." (FG2, P1)

Participants noted that both veterinarians and farmers should prioritize the management of dry and pregnant cows, focusing on aspects such as high-quality colostrum, vaccination, and hygiene. This is important to prevent neonatal infectious diseases and reduce the need for antibiotics. Participants added that mastitis prevention in dairy cows involves vaccination and selective dry cow therapy. Participants highlighted that modifications in feed or water can significantly impact disease prevention in pigs, addressing concerns like weaning diarrhea in piglets and tail biting in fattening pigs and sows.

"And we are also emphasizing prevention strategies, everything to do with neonatal diseases. We work a lot on colostrum, so we put a lot of emphasis on prevention with colostrum and good colostrum management." (FG4, P3)

Participants stated that antimicrobial practices have evolved, with a shift from systematic antibiotic use to providing supportive symptomatic treatment initially and initiating antibiotics only if symptoms worsen. In cases of mild clinical signs of pneumonia or mastitis in cattle, these initial treatments may include NSAIDs, fluid therapy, or bolus administration; for pigs, aspirin is considered. Participants

emphasized that it is crucial for farmer and veterinarian to closely monitor animals when antibiotics are withheld, ensuring timely antimicrobial administration if needed (safety netting).

"Antibiotics for mastitis, for example. It used to be systematic and even the farmers have changed too, because they do not call us for all mastitis. Their first instinct is to use anti-inflammatories." (I1)

Participants explained that poultry veterinarians often rely on supplements as an alternative because of limited available antibiotics in laying hens. This trend is more pronounced in organic poultry and slow-growing broilers, due to strict antimicrobial guidelines. However, supplements are most effective when used as a long-term preventive measure and are therefore not beneficial for acute outbreaks. Participants advocated for more accessible and effective alternatives and antibiotics in both layers and broilers.

"Yes, maybe the alternatives and the supplements, I think we do our best to go to something like that, also in broilers and layers. If possible, to use supplements first, and most poultry farmers also go along with that, right?" (FG3, P6)

III. Theme 3: The inherent characteristics of the veterinarian contribute to shaping their decision-making process when prescribing antibiotics.

Subtheme 3.1: The veterinarian's attitude towards antibiotic treatment.

Participants highlighted that most veterinarians consider antibiotics as the safest option, aiming to prevent further escalation of disease outbreaks and mitigate financial losses. Consequently, veterinarians hesitate to deviate from established antibiotic practices, considering the omission of antibiotics only if supported by scientific evidence. Participants emphasized that prescribing antibiotics to animals should remain the veterinarian's responsibility, stressing the importance of therapeutic freedom combined with self-critical reflection on their antimicrobial prescription patterns to ensure responsible AMU. Furthermore, they emphasized the importance of antibiotics in veterinary medicine to ensure animal health and welfare.

"As mentioned by [P4], the responsibility lies with the veterinarian. We still have the discretion to select the antibiotic we intend to use or administer, considering several factors, right?" (FG1, P2)

Subtheme 3.2: The veterinarian's expertise.

Participants emphasized that veterinarians make deliberate antibiotic prescription decisions and formulate preventive advice based on their expertise. This expertise originates from a combination of knowledge and experience. Participants noted that that the veterinary curriculum includes education on responsible antimicrobial usage and prescription, AMCRA guidelines, alternative therapies, and the repercussions of AMU on animal and human health. In addition, participants added that veterinarians engage in continuous education to enhance their knowledge. This was deemed crucial for staying current with rapidly evolving guidelines. The importance of attending courses at diverse institutions, featuring different lecturers, and covering diverse topics was stressed. Participants believed some veterinarians are more motivated to attend courses, particularly those in group practices who are perceived to have less time constraints. Consequently, there is a growing need for courses that target both motivated and non-motivated veterinarians, some participants even opted for mandatory training. Participants added that

pharmaceutical company representatives can serve as an information source, especially for veterinarians working independently and infrequently attending refresher courses.

> *"Well, I work there, I work in the faculty, but someone who has just graduated, my classmates who graduated like me 16 years ago, their knowledge of veterinary medicine may be 16 years old, and in 16 years, things have changed dramatically. They do a lot of continuous education." (FG4, P1)*

Participants emphasized the significant impact of experience on veterinarians' decision-making process. Experience with prescribing antibiotics, alternative therapeutic options, preventive measures, and previous disease outbreaks shapes the decision-making process over time through trial and error. More experienced veterinarians often have established relationships with farmers and knowledge of farm disease history. Limited experience can lead to uncertainty in decision-making. While participants stated that young veterinarians are more aware of responsible AMU, they may lack experience. This may make them hesitant to challenge farmer demands, leading to quickly prescribing antibiotics to avoid conflicts. Participants noted that antibiotic choices are often influenced by fellow veterinarians, highlighting the importance of support from experienced colleagues. Participants highlighted that in group practices, knowledge exchange among veterinarians of different ages promotes responsible antimicrobial practices, with young veterinarians contributing formal up-to-date training knowledge and experienced colleagues offering guidance and support.

"Working as part of a team, that's essential for me, it's being part of a group […] we benefit from what the younger people have learnt at school and the younger people benefit from my experience. And then we all swap ideas, the one who has been on a training course, well he is not going to keep it to himself. Well, we are going to get together and we are going to discuss it. So, information passes much more quickly when there is more than one of us." (I1).

Subtheme 3.3: The veterinarian's awareness on responsible antimicrobial prescription and antimicrobial resistance.

Participants observed a shift in veterinarians' awareness towards responsible antibiotic use and prescription. This was driven by avoidance of consequences and a genuine conviction of the necessity for such practices, particularly since legislation restricted the use of critically important antibiotics (CIA). They emphasized the importance of reaching all veterinarians with sensibilization campaigns, as not all are aware of the need of responsible AMU or the danger of AMR. AMCRA's efforts in sensitizing veterinarians were acknowledged but deemed insufficient without continuous education initiatives.

"These people who are here (focus group) I think are not going to be the problem I think, you must be motivated to be here. Those people want to do something about it, they are aware of the problem, the people who are here." (FG1, P2)

Subtheme 3.4: The veterinarian's economic and financial interests.

Participants noted that veterinarians often face challenges in urging farmers to reduce AMU due to commercial reasons. Participants expressed concern that failing to meet farmer demands may result in losing business to a competing veterinarian. However, some participants stated that competition among peers is diminishing as more practitioners adhere to legislations and become more aware of responsible antibiotic use. In addition, the sale and prescription of antibiotics constitutes a significant income source

for veterinarians and participants expressed that the reduction of antibiotic use leads to financial losses. Participants added that this income decline can potentially be compensated by the implementation of individual herd health management, focusing on personalized diagnosis, preventive measures, and sampling.

"At the end of the day for a lot of vets, medication does generate income." (FG1, P1)

Participants added that the nature of veterinary practice plays a role in influencing antimicrobial practices and antibiotic selling prices. In large group practices, there is flexibility in offering discounts, a luxury not always available in smaller practices. Furthermore, participants stated that veterinarians historically faced pressure from employers or pharmaceutical companies to promote antibiotic sales.

According to the participants, the primary obstacle for livestock veterinarians to engage in responsible antimicrobial practices is insufficient time and human resources. Antibiotics often represent the more convenient solution in terms of labor and time. Limited time prevents veterinarians from engaging in preventive measures, individual farm guidance, and clinical examinations. Participants stated that the veterinary profession faces a shortage of practitioners due to unattractive working conditions and retirements. Increased workload, administration demands, and overall pressure are believed to be particularly pronounced for solo practice veterinarians. Veterinarians in group practices, benefiting from more time and staff, are perceived to be better positioned for prevention and follow-up activities.

"I think it's really a question of time here, because I think they're all overworked. In addition to the animals that are examined, we have been given a huge number of administrative tasks and I think that this also puts the brakes on some people's desire to go further […] and some people's desire to try and change their practice a little and go more into the area of prevention." (FG4, P3)

Consequently, participants called for the government to allocate increased financial resources. These resources are crucial to attract more veterinarians to veterinary practice, optimize veterinary farm health management, promote preventive veterinary medicine, reduce AMU in livestock, perform data collection, and compensate veterinarians' revenue losses.

Subtheme 3.5: Veterinarian-client communication.

Participants stressed the veterinarian's pivotal role in fostering a strong relationship with the farmer and communicating on AMU, including suggesting optimal treatment and addressing irresponsible use. Participants reported two distinct communication styles to achieve this goal. On the one hand, the traditional role of veterinarians in decision-making was described as a veterinarian-centered approach, with an authoritarian and directive communication style. On the other hand, participants stressed the importance of effective communication in addressing challenges like farmer unawareness, unwillingness to change, non-compliance, and pressure for antimicrobial prescribing. Participants highlighted the role of educating farmers and discussing treatment options. They emphasized the relevance of trust and a one-to-one relationship with the farmer, considering the farmer's perspective in the decision-making process to enhance therapy adherence and provide a tailored approach. This relationship-centered approach was perceived as more time-consuming, but beneficial for promoting responsible AMU and behavioural change in the long run.

"So I think that we do have a great strength there, that we can determine very strongly there what will actually be treated with antibiotics or not." (FG1, P4)

"If you want to go for treatment, you have to do it right. Yes, at least suggest the best possible treatment. If that farmer then has other considerations […] for another treatment he prefers, then you go along with that, but you can still […] surely you should always suggest the best possible treatment? (FG1, P3)"

Participants mentioned diverse communication strategies to promote responsible AMU and clarify their decision-making process. Veterinarians explain clinical signs and examinations to rationalize withholding antibiotics when unnecessary. They employ safety netting, monitoring disease progression and instructing farmers to report changes or emphasize the link between AMR in human medicine to persuade farmers to change practices. They utilize AMU reports and antibiograms to start conversations and motivate change. While some participants welcomed antibiotic coaching, others received this skeptically, fearing external intervention. Participants emphasized that consistent messaging within group practices fosters farmer compliance, supported by standardized protocols ensuring uniform advice across veterinarians.

"Yes that [pressure from farmer to prescribe antibiotics] we are going to try to counter that, right? If we see that it is certainly not bad enough, that we say, look, there is no need to start treatment now. We will re-visit within two days and re-check how that evolves, but then also give some tasks to the farmer to follow it up properly that it is not just like, I'm just going to let it take its course without intervening." (FG3, P2)

Participants emphasized the importance of transparent communication among all stakeholders on livestock farms to promote responsible AMU. This includes communication between veterinarians, farms of origin, feed companies, and hatcheries. Transparency allows access to antibiograms, facilitating faster problem anticipation during rearing and mitigating pressure from feed companies or hatcheries to prescribe antibiotics.

"Yes, when you then talk about representatives or other people that. We then often start the conversation, make a phone call with them as well, hear what they have to say. That already helps sometimes, just communicating well with all the people who visit the farm." (FG3, P6)

IV. Theme 4: The veterinarian considers the characteristics of farmer and farm in the decision-making process when prescribing antibiotics.

Subtheme 4.1: Farmer's knowledge and awareness on the importance of responsible antimicrobial usage and antimicrobial resistance.

Participants stated that farmers' knowledge and awareness of the importance of responsible AMU and AMR varies. Although participants stressed that most farmers are aware, like veterinarians, they often consider antibiotics to be the safest option. According to participants, changing farmers' antimicrobial behaviour is a gradual process, necessitating a mindset shift over time. They added that farmers are also influenced by their peers, which inspires behavioural change.

"You have farmers who are far along and have been using less antibiotics for some time. Or who really wants less antibiotics too. And then you have other farmers who do not give it as much thought? Or who are now obliged to, with the [AMU] reports. But you do have conscious farmers too, don't you? Who have long wanted us to use less antibiotics." (FG2, P4)

Participants highlighted that insufficient awareness and knowledge on AMU legislation leads to challenges in persuading farmers to adopt responsible antimicrobial practices. In general, younger farmers were believed to be more aware. However, they were still perceived as a minority. Participants added that dairy farmers generally have higher awareness due to pressure from dairies, driven by the demand for antimicrobial residue-free milk. However, this pressure is less evident from abattoirs or cattle dealers, leading to higher AMU in beef cattle. Belgian Blue beef farmers were perceived to have a limited awareness and less urge toward preventive measures or responsible AMU, often relying on routine AMU.

"So, in dairy, everyone is aware. In dairy we're on the right track, we're heading in the right direction. Meat, it's a different matter." (FG4, P1)

Participants noted that while most poultry farmers understand the importance of reduced and responsible AMU, some lack sufficient knowledge about antimicrobial use and resistance. Many poultry farmers prioritize animal health but may not fully grasp the connection between AMR in animals and humans. However, awareness was perceived to be higher among organic and slow-growing poultry farmers.

"The farmer is not concerned with antibiotic resistance in humans, he is only concerned with the antibiotic resistance he sees in his antibiogram, and in his chickens eventually. But that link to human medicine, that is still far away with many poultry farmers. " (FG3, P1)

Participants differed in views on their role in raising awareness among farmers, with some considering their past efforts ineffective and not seeing sensibilization as their responsibility. Nonetheless, they expressed readiness to engage in this role, given adequate governmental support, and advocated for targeted farmer re-education campaigns. Some participants mentioned organizing training sessions for their farmers on antimicrobial practices themselves. However, they also emphasized the need for government-led initiatives or increased support from farmer organizations to enhance awareness. Pig veterinarians doubted the effectiveness of awareness campaigns but recognized that most pig farmers are aware of the need to alter their antimicrobial practices, despite having limited knowledge of antibiotics and antimicrobial resistance (AMR). Participants suggested that awareness efforts should focus on explaining the reasons behind the need for responsible AMU, as this knowledge could drive farmers' behavioural change. They also noted that firsthand experiences with AMR can further heighten farmers' awareness.

Subtheme 4.2: The farmer's economic and financial interests

The livestock sector operates as an economic entity. Veterinarians bear the responsibility of healing animals and optimizing their health in the most cost-effective and timely manner. Given that livestock animals serve as an income, participants noted that the primary motivation for farmers to use antibiotics is to prevent financial losses. Consequently, veterinarians consistently experience pressure from farmers to ensure successful treatment.

Prescribing antibiotics was perceived by most participants as the cheapest and easiest solution, with preventive measures requiring more initial investment and labor. Despite the higher upfront costs, preventive measures were deemed more advantageous eventually. Participants noted that the financial

capabilities of the farmer influence the decision between antibiotics and preventive measures, with those having more resources being able to invest in preventive measures.

"It is often the cheapest solution, giving antibiotics." (FG1, P3)

Participants highlighted the influence of antibiotic pricing, suggesting that higher prices might lead to more thoughtful consideration before prescribing. The increased cost of long-acting antibiotics, group administrations, and medicated feed contribute to the veterinarian's decision-making process. Financial constraints can make farmers and veterinarians more cautious about antibiotic use and prescription due to associated expenses. However, participants prioritized disease control over the initial costs of antibiotics, recognizing the potential for greater losses from uncontrolled outbreaks when antibiotics are not utilized.

The prices farmers receive for meat, milk, and eggs are also noted to be of importance. Poultry farmers may pressure veterinarians to prescribe antibiotics, believing it enhances growth and consequently boosts the price farmers obtain, especially during periods of high chicken meat prices. Participants added that consumer preferences and retail dynamics significantly impact these prices. Market demands influence the popularity of conventional poultry versus organic or slow-growing broilers, with stricter legislation on AMU for the latter. However, consumers tend to prefer conventional poultry over organic and slow-growing broilers, because of the lower prices. Farmers receiving lower prices for chickens treated with antibiotics may be advantageous to enable behaviour change, while some participants suggested higher prices for chickens that did not receive antibiotics may stimulate farmers to reduce AMU.

Subtheme 4.3: The farm-specific factors

Participants highlighted that the need for AMU is influenced by farm-specific factors, notably biosecurity measures, including elements like the all-in, all-out system, ventilation, animal origins, cleaning and disinfection procedures, stocking density, and overall infrastructure. Participants added that farmers may face challenges in making significant infrastructure improvements to bolster biosecurity, either due to financial limitations or a lack of motivation to follow the veterinarian's suggestions. In addition to biosecurity measures, participants noted that effective farm management plays a crucial role in influencing antibiotic use, with well-managed practices associated with lower AMU. Participants summarized that the multifactorial nature of farm and management factors highlights the need to advocate for more research into the determinants of low AMU. Additionally, participants stressed the importance of considering the farm's history, including past disease outbreaks and antibiograms, to make informed decisions when prescribing antibiotics.

"If you look at farms that are already switching to a different system, for example, so that they wean later or a system where they have much lower stocking rates. Then you do see that on those farms, this has a serious effect on the structural use of antibiotics, because I think we should look at it that way." (FG2, P2)

V. Theme 5: Government initiatives promoting responsible antimicrobial usage influence the decision-making process when prescribing antibiotics.

Subtheme 5.1: Legislation on antimicrobial usage and prescription in veterinary medicine

When prescribing antibiotics or giving advice, participants noted that veterinarians take the relevant legislation regarding AMU and prescription in veterinary medicine into consideration. Participants stated that medication leaflets guide veterinarians in their antimicrobial prescribing behaviour by considering registered indications, animal species, and administration routes. However, participants highlighted that the restrictive conditions in leaflets lead veterinarians to depend on off-label use of antibiotics.

Participants stated that royal decree 21/07/2016 on the conditions for the use of medicines by veterinarians and those responsible for animals aids veterinarians and farmers to restrict the use and prescription of critically important antibiotics (CIA) in livestock. It mandates a comprehensive process, including clinical examination, bacteriology, and laboratory-performed antimicrobial susceptibility tests, for bacterial diagnosis and appropriate antibiotic prescription. Participants noted they have shifted their mindset in compliance with this legislation. Participants perceived the rule to be clear for both veterinarians and farmers, leading to minimal discussion with farmers. Participants added that initially, some veterinarians did not comply when the legislation was introduced but there is an observed trend of increasing compliance.

"That [restricted use of CIA] is a clear guideline, for farmers also very clear and then there is also little discussion about that. And then that is a good evolution absolutely." (FG1, P4)

Participants mentioned that the fear of penalties drives this behavioural change, with older or solo-practice veterinarians perceived to be initially more reluctant but now increasingly aligning with the regulation. Participants mentioned that farmers adjust their AMU to avoid consequences like an antibiotic coach or quality label exclusion. Participants recommended rewarding those reducing antibiotic use instead of imposing consequences, and suggested benchmarking low AMU may be more motivational.

"They want of course, not to get into trouble, because they are in the red or have a red report. This can be because they are getting an antibiotic coach or they are flying off the label, for example." (FG2, P3)

Participants discussed royal decree 10/04/2000 on veterinary herd health management, which mandates a diagnosis before antibiotic treatment by the responsible herd veterinarian, and royal decree 21/07/2016, which describes the legislation regarding on-farm stock. Participants regarded on-farm stock as the most cost-effective option for farmers. Some participants suggested that restricting on-farm stock might discourage farmers from administering antibiotics and encourage both farmers and veterinarians to alter their antimicrobial usage and prescription. These participants emphasized the need for farmer education on early disease detection, alternatives such as NSAIDs, and timely consultation with veterinarians for appropriate treatment if on-farm antibiotic stock were restricted, to ensure animal health. Furthermore, challenges exist to time-constraints, without on-farm stock, veterinarians would need to visit farms for each problem requiring antibiotics, which was perceived to be challenging. Other participants stressed the benefits of individual guidance by the herd veterinarian, who is responsible for the veterinary herd health management. This ensures an established farmer-veterinarian relationship and promotes responsible AMU. Additionally, some participants proposed restricting the provision of

antibiotics for on-farm stock by third parties, such as locum veterinarians, as potentially advantageous. They suggested that the herd veterinarian should be the primary supplier and prescriber of antibiotics for on-farm stock, with locum veterinarians only providing antibiotics in the absence of the herd veterinarian. Open communication between farmers, herd veterinarian, and locum veterinarians were deemed necessary. Moreover, participants advocated for more clarity on these legislations and effective control strategies to promote adherence. In summary, participants emphasized the necessity for interim measures and governmental assistance, including the allocation of financial resources, to attract more veterinarians to work in veterinary practice and establish individual veterinary herd health management.

Participants emphasized that farmers often turn to medicated feeds, leading to increased AMU. They advocated for making the use of medicated feed regulated. Furthermore, they prioritized regulated disease control to reduce AMU in the future. Additionally, participants noted that without legal requirements for prevention and biosecurity measures, antibiotics remain the easiest short-term solution for livestock farmers. Participants emphasized the need for more clarity regarding the legislation on herd health management and on-farm stock.

Participants noted significant variations in AMU policies between Belgium and neighboring countries, with Scandinavian nations enforcing stricter legislations. Achieving uniformity across Europe regarding legislation, withdrawal times and antibiotic pricing was seen as crucial.

They stressed the need for timely and comprehensive communication of regulatory changes to veterinarians and farmers, advocating for transparent communication from government agencies such as FAGG and FAVV. Participants highlighted the importance of explaining the government's position on responsible AMU to farmers and instilling confidence in veterinarians' abilities through open and respectful communication.

Subtheme 5.2: Antimicrobial usage data collection and benchmarking

Veterinarians are required to register prescriptions of antibiotics in laying and broiler chickens, pigs, and veal calves. This results in AMU reports that give an overview of qualitative and quantitative data for each individual farm, including benchmarking AMU with other farms. In case of long-term high AMU in pigs and poultry, the farmer receives a red report and is prompted to define an action plan or consult an antibiotic coach. Participants stated that despite performing efforts for this data collection, veterinarians do not receive financial compensation from the government for the invested time and effort. However, with consequences now attached to long-term high AMU, participants highlighted that veterinarians are now able to better motivate farmers to change. Previously unaware farmers are now compelled to adjust their antimicrobial practices. The substantial impact on the antibiotic registry of long-acting antibiotics, group administrations, and medicated feed are key factors. Consequently, participants stated that the antibiotic register, antibiotic report, and the Nearly Real Time Tool (NRT-tool) serve as tools for veterinarians. However, participants nuanced that some veterinarians lack knowledge of the AMU reports and register, hindering their ability to guide farmers effectively. Antibiotic registration for pigs is divided into four animal-categories, leading some to intentionally register antibiotics in other categories to avoid red AMU reports, a temporary solution to save time according to participants. Moreover, participants advocated for a more user-friendly, uniform, and error-free data collection system. Additionally, participants

emphasized the delicate balance between animal welfare and intensive production amid consistently decreasing AMU. They advocated for ensuring constant availability of antibiotics in veterinary medicine to prevent adverse effects on animal welfare.

"I think that with these red codes that they have now, you can make the farmer more aware that he has to work on it. If I compare that to before, there weren't really any consequences and I remember I had a client who said: yes red, that doesn't hurt. But now it can hurt and then you can point that out to them […] you can motivate them much more to think about it and be more conscious about it. I do think that's a big difference from before." (FG2, P2)

Subtheme 5.3: Guidelines on antimicrobial usage in veterinary medicine

Participants noted that AMCRA guidelines offer practical antibiotic prescribing guidance, shaping habits and serving as a reference for young veterinarians. However, while familiar with guidelines, participants stressed that their decision-making relies more on expertise, valuing therapeutic freedom. Participants added that regular training is needed to keep veterinarians updated on evolving guidelines.

"Yes, the formularies of AMCRA are good, they are well thought out, the involvement of the veterinarians has been asked about that, yes, they are realistic, they are really okay." (FG1, P3)

Furthermore, the color classification of antibiotics formulated in the guidelines and the indication of their significance in human medicine aids the initial decision-process. Participants mentioned that the preference is initially for non-critical, first-choice antibiotics. If these prove ineffective, a shift is made to more critical second or third-choice antibiotics, often based on bacteriology and antimicrobial susceptibility testing.

"Quite often we limit ourselves basic antibiotics in terms of therapeutic range, so a lot of penicillin, a little amoxicillin. And then, in some cases, we go a bit higher." (FG4, P3)

Standardized protocols within a veterinary practice or for on-farm antibiotic administration by farmers ensure consistency and provide farmers with uniform information. Some participants stated that they formulate these protocols based on AMCRA guidelines, scientific knowledge, and experience.

Subtheme 5.4: Campaigns to promote the importance of a responsible antimicrobial usage and the danger of antimicrobial resistance.

Some participants stated that raising awareness among consumers about responsible antibiotic use is needed, but they emphasized that it must be done thoughtfully due to the complexity of the issue. Explaining AMR and responsible AMU in a clear and understandable manner is time-consuming. Campaigns should also avoid creating a negative perception of the agricultural sector, which could reduce consumer consumption of animal products. However, societal pressure for responsible antibiotic use was perceived to be a motivator for farmers and veterinarians to aim for responsible antimicrobial practices.

"I find that [campaigns targeting consumers] a difficult one actually. Because […] those technical files, they take time to explain. Just what that means, right? And with campaigns, there's no time to explain that. Those are slogans and I think that's a difficult one. If you see how difficult it is for our farmers when we explain what it [AMR

and responsible AMU] is and how it has to be dealt with, then I hold my breath on how that will come across to the consumer." (FG1, P3)

Participants expressed feelings of isolation in the fight against AMR and urged for greater efforts from human medicine to reduce antimicrobial prescriptions. They emphasized the need for alignment between human and veterinary medicine to enhance credibility and foster support among farmers. Participants called for increased awareness efforts from human medicine and emphasized the importance of improved communication among all stakeholders to address AMR effectively through a unified "One Health" approach.

"I think vets get tired of fighting because they feel a bit lonely in the medical profession and they don't feel that in human medicine they worry about antibiotic resistance and at some point they say to themselves why am I going to bother doing this when human medicine doesn't give a damn and I understand them completely." (FG4, P3)

1.2. The use of biocides and disposal of biocides and antibiotics

Thematic analysis of the transcripts revealed three themes providing deeper insights into how veterinarians perceive the use of biocides and disposal of antibiotic and biocidal waste. Table 4 offers a comprehensive overview of the identified themes:

Table 4: Overview of the identified themes and regarding the use of biocides and the disposal of antibiotic and biocidal waste

I. Theme 1: the distribution and use of biocides.
II. Theme 2: the advice given regarding the responsible use of biocides.
III. Theme 3: the disposal of biocidal and antibiotic waste.

I. Theme 1: the distribution and use of biocides.

Participants noted that veterinarians typically do not directly manage the distribution of biocides; instead, this responsibility falls on specialized companies that sell biocides to livestock farmers. Selling these products can be challenging for veterinarians due to practical-constraints and may not be financially viable. However, veterinarians will often refer farmers to these companies or contact them themselves if there are issues with cleaning or disinfection on the farm. Participants indicated that ruminant veterinarians use biocides during surgeries for surgical-site disinfection, such as alcohol, povidone-iodine, and chlorhexidine.

"We once tried it with dips and products for the footbath. But pricewise you can't keep up with the good services of [these specialized companies]." (FG1, P6)

II. Theme 2: The advice given regarding the responsible use of biocides.

Participants mentioned that specialized companies often provide advice on biocide usage. Additionally, some participants noted that, drawing from their experience with biocides and knowledge gained during veterinary training, veterinarians offer guidance and stress the importance of cleaning and disinfection, for example to prevent cryptosporidiosis in calves.

"Yep, you do give a direction. Products that you've had good experiences with you're going to say use that or that product right?" (FG2, P4)

Participants highlighted that veterinary students receive theoretical education on biocide properties, hazards, and usage, along with biosafety practices and cleaning and disinfection protocols. This education includes guidance on disinfecting surgical and medical equipment, housing, and other facilities. Furthermore, students learn about the appropriate use of biocides and hygiene measures for dealing with multi-resistant bacteria, equipping them to offer tailored advice to clients in their future practice.

III. Theme 3: the disposal of biocidal and antibiotic waste

Some participants noted that veterinarians generally do not handle the disposal of biocides or antibiotics, considering it outside their responsibilities. However, some indicated that veterinarians may accept empty containers at their practices and manage their own antibiotic waste by disposing it in designated medical waste containers, despite associated costs and hygienic concerns. Participants added that veterinary students are currently educated on responsible biocidal and antibiotic waste disposal practices.

Participants mentioned providing advice on proper disposal methods and highlighting mistakes made by farmers. However, they expressed uncertainty about the correct advice to offer livestock farmers regarding the disposal of biocidal and antibiotic waste. Livestock farmers typically dispose of antibiotic waste either with household waste, in glass containers, or in designated medical waste containers. Compliance is monitored through quality labels and environmental inspections, with environmentally conscious farmers more likely to adhere to proper disposal methods. Some municipalities and farmer organizations offer waste collection services and distribute designated containers for disposal.

"They ask that question, what should I do with my medicines? [thought] I'm going to have to tell them to take them back, don't I? And I had pretty much pushed that question away and eventually they came themselves with the solution of, we are allowed to hand that into our municipality. I wouldn't like to take them back […] Just for hygiene alone, and for sanitary conditions." (FG1, P3)

2. Deductive analysis

In the second phase, the results were deductively compared with the domains of the Theoretical Domain Framework.

2.1. Knowledge

The participants showed awareness of the existence of diagnostic tools, antibiotics' characteristics, alternatives for antibiotics, preventive measures, legislation on AMU, guidelines, continuous training, AMR, and the influence of farmer-specific factors. There is a notable gap in their knowledge concerning the management of antibiotic and biocidal waste. Participants emphasized the importance of attending continuous training to keep their knowledge up to date and stressed the benefits of working in a group practice, where knowledge exchange between colleagues is facilitated.

2.2. Skills

The participants showed proficiency in diagnosing a bacterial disease, performing a clinical examination, using diagnostic tools, considering economical factors, guiding the farmer towards preventive measures, and giving recommendations regarding responsible antimicrobial practices. Some participants showed skills in shared decision making and used several communication methods to enhance compliance and promote responsible AMU.

2.3. Social/ professional role and identity

The participants emphasized the significance of the expertise they acquired during their veterinary training and professional experience. As such, they highlighted the value of their judgement, stressing the importance of therapeutic freedom. Besides that, they highlighted that prescribing antibiotics should be the responsibility of the veterinarian, remaining self-critical, being an example for farmers regarding responsible antimicrobial practices and educating the farmer to increase their awareness. However, some participants stated that the sensibilization of farmers is not the veterinarians' responsibility. Participants pointed out that they are not responsible for the distribution of biocides, with some also mentioning that the disposal of biocidal and antibiotic waste is not within their scope.

2.4. Beliefs about capabilities

The participants strongly believed in their own capabilities as a veterinarian, being skilled in performing a clinical examination, evaluating the clinical signs, and using diagnostic tools to diagnose a disease and making an informed decision regarding antibiotics. Moreover, they stressed their belief in the veterinarians' knowledge, skills, and expertise regarding promoting responsible AMU. They emphasized that governmental agencies should also believe in their capabilities when implementing legislations. They also stressed the importance of effective communication skills. Most participants indicated that it is not just about treating animals but also educating and involving farmers in the process, enabling compliance, and improving the farmer's willingness to change.

2.5. Optimism

Most participants are optimistic that AMU in veterinary medicine can be optimized by evolving towards individual farm guidance, establishing a one-to-one relationship, focusing on preventive herd medicine, and banning on-farm antimicrobial stock. Furthermore, they emphasized that there are already several tools helping them towards responsible antimicrobial prescription behaviour, such as diagnostic tools, legislation, data collection, farmer awareness and communication methods.

2.6. Beliefs about consequences

The participants believed that aiming towards a reduction in AMU will lead to a reduction in their income. Farmers are also believed to be initially reluctant because of the financial costs of implementing preventive measures. However, other participants stated that evolving towards a more individual and preventive veterinary medicine will generate more income and will be beneficial for animal health in the long-run, compensating for these initial losses. Next, participants worried that this evolution is more time-consuming, while veterinarians and farmers are often faced with time-constraints and the veterinary profession is confronted with insufficient practitioners. Furthermore, participants believed that farmers will initially react reluctantly to change but will alter their mindset once they realize this change is mandatory.

2.7. Reinforcement

Participants noted that farmers and veterinarians change their behaviour regarding AMU because they fear consequences when they do not comply. The participants emphasized that the focus should also be

on rewarding responsible AMU, instead of punishing. They stressed that reinforcement, such as financial support, and attracting more veterinarians to work in veterinary practice may aid the veterinarian in aiming for responsible AMU.

2.8. Intentions

The participants articulate their intention to achieve a balance encompassing expertise, diagnostic tools, legislation, guidelines, and farmer considerations to ensure informed decisions. Furthermore, there is a specific intention to aim for preventive veterinary medicine, use more diagnostic tools to confirm the diagnosis, and reduce the usage of critically important antibiotics.

2.9. Goals

The participants mentioned that the primary goal of an antimicrobial treatment is to optimize animal health and prevent financial losses. Participants emphasized that their secondary goal is aiming towards a responsible AMU, with respect for animal welfare, taking into consideration economical factors, and legislation. Less attention has been given to the overall aim to reduce AMR.

2.10. Memory, attention, and decision process

The participants recognized the vital role of diagnostic tools in veterinary decision-making, advanced technologies are leveraged for diagnoses. Next, they underscored the importance of evaluating the alternatives for antibiotics during the decision-making process and considering animal characteristics, clinical examination, farmer and farm characteristics, legislation, guidelines, and economical factors. They prioritized clear communication with farmers, aiming to establish trust and collaboration. This approach ensures farmers are well-informed and actively contribute to responsible AMU.

2.11. Environmental context and resources

Participants stated that veterinarians in a group practice are often perceived to have more time to invest in preventive veterinary medicine and attend continuous education, enabling them to promote a responsible AMU. Participants emphasized that veterinarians often lack the time and human resources to invest in individual guidance and preventive veterinary medicine. The farm infrastructure, biosecurity measures in place and farmer's financial situation influence the ability of the farmer to change their behaviour regarding antimicrobial practices.

2.12. Social influences

In group practices, collaboration within the team may promote responsible antibiotic prescribing practices. This collaborative dynamic emphasizes the impact of peer interactions on fostering responsible behaviour, with an active exchange of expertise and knowledge regarding responsible antimicrobial practices among colleagues. The participants also noted that farmers' awareness is influenced by their environment's and peers' awareness. Moreover, they stated that general societal pressure towards responsible AMU has an influence on farmers' awareness.

2.13. Emotion

The participants stressed that they feel undervalued for the efforts the veterinary sector has already made to reduce antimicrobial usage and prescription. Participants expressed frustration regarding making unsuccessful attempts to change farmers' behaviour regarding AMU.

2.14. Behavioural legislation

Participants highlighted the impact of legislation on veterinarians' and farmers' behaviour change towards a reduced and responsible AMU. Next, pressure from dairies or quality labels are also effective to enable behaviour change, this is because farmer fear consequences if they do not comply.

DISCUSSION

This study explored how Belgian livestock veterinarians perceive their use of antibiotics and biocides, the disposal of antibiotic and biocidal waste, and the consumption of antibiotics by farmers using qualitative research methods.

Using diagnostic tools was highlighted as an aid to confirm diagnosis and select appropriate antibiotics. Previous studies on AMU in livestock in Flanders and the Netherlands also highlighted the importance of diagnostic tools such as bacteriology and antimicrobial susceptibility testing (24). However, the waiting time for test results posed a significant barrier, this was also found to be an important barrier for veterinarians in the UK, the Netherlands, Denmark, and Switzerland (26,28,29). While some studies with Dutch veterinarians identified the cost of diagnostic tools as a barrier (28), most participants did not view this as a barrier. They reasoned that performing further testing enables a more targeted approach, leading to long-term financial benefits. Implementing targeted awareness campaigns, guidance, and educational programs for veterinarians emphasizing the potential return on investment from improved treatment outcomes and reduced AMU may be essential.

The withdrawal time was noted to be a very important factor, especially in poultry and dairy cows. This was also found in previous research with Flemish and Dutch veterinarians (24). Notably, participants showed a trend towards using preventive measures and alternatives for antibiotics, despite challenges like economic factors, time-constraints, and farmer skepticism. Overcoming these barriers is crucial for promoting responsible AMU. A comprehensive approach that integrates understanding antibiotic characteristics with proactive preventive measures and accessible alternatives could mitigate AMU. Moreover, collaborative efforts, government support, and advancements in preventive strategies are essential for achieving responsible and sustainable AMU in animal health.

The crucial role of the veterinarian was emphasized. Veterinarians' knowledge and experience are pivotal in fostering strong relationships with farmers and promoting behavioural change towards responsible AMU. Young veterinarians were seen as more knowledgeable on responsible AMU, but often lack practical experience and sometimes succumb to pressure to prescribe. Previous research with Dutch livestock veterinarians showed that an increase in experience was associated with a decrease in frequence of felt pressure to prescribe (28). Collaboration among colleagues was seen as vital by participants, this enables

an exchange in knowledge and experience. Moreover, working in a group-practice was believed to be beneficial by participants, while other qualitative studies on antimicrobial prescribing behaviour among cattle veterinarians in Ireland and the Netherlands did not mention this to be an asset (30,32). While pressure from more experienced colleagues to prescribe was stated to be historical in this study, other previous studies with UK pig and cattle veterinarians stated the opposite (31,34). Introducing ongoing education initiatives centered on responsible AMU, fostering collaboration among veterinarians to share knowledge and experiences, and establishing support structures for young veterinarians to manage prescribing pressures may be necessary.

Two veterinarian-client communication styles were described: the veterinarian-centered and the relationship-centered approach, the latter may be beneficial for promoting long-term responsible practices. A relationship-centered approach has been demonstrated to improve the accuracy of information gathering, client satisfaction, and adherence to advice through an improved veterinarian-client relationship (36,37). Going forward, interventions could enhance veterinarian's effective communication skills and stimulate responsible antimicrobial practices. Utilizing resources like the Calgary Cambridge Communication Guide (38), which provides a structured framework for communication skills, can support veterinarians in fostering productive relationships and promoting responsible antimicrobial practices.

Interestingly, economic considerations were found to be important for both veterinarian and farmer. Focusing on veterinary herd health management may address veterinarians' barriers, allowing an individual approach by means of advisory farm visits by the herd veterinarian. This can result in potential revenue-loss compensation. Furthermore, challenges of time-constraints, workload, and financial pressures faced by veterinarians underscored the need for increased support from government and industry stakeholders. Moreover, the animals serve as a source of income for farmers. Consequently, economic factors significantly influence farmers. Raising knowledge and awareness on long-term cost-effectiveness of preventive measures may be beneficial to persuade farmers to change their behaviour. However, future research should also explore how AMU can be reduced with minimal economic risk (35).

A shift was noted towards responsible antimicrobial practices among participants, motivated by increased awareness and concerns about consequences. Increasing awareness among the whole veterinary population was highlighted as essential for widespread adoption of responsible practices. Moreover, a variation in farmers' knowledge and awareness on responsible AMU and AMR was found. A growing recognition of the importance of responsible AMU among farmers was noted, driven by consumer demands and regulatory pressures. However, some farmers were believed to lack knowledge on AMU and AMR. While farmers' pressure to prescribe antibiotics appears to be decreasing, challenges persist in changing entrenched habits and raising awareness. The opinions on roles of veterinarians in raising awareness varied among participants, some advocated for targeted re-education campaigns led by government or farming organizations, while others emphasized the veterinarians' responsibility in this regard. Addressing these complexities could be vital in fostering more informed and responsible antimicrobial practices in livestock.

Interestingly, participants underscored the impact of farm-specific factors like biosecurity, infrastructure, and management on AMU. However, participants noted challenges in addressing these factors due to farmers' financial constraints or lack of motivation and awareness. Measures such as financial support, awareness-raising, and mandatory implementation of preventive and biosecurity measures may help tackle these challenges. The multifactorial nature of farm factors underscored the need for more research to increase the knowledge on drivers of AMU.

Notably, legislation on AMU and medication leaflets were found to guide veterinarians in their decision-making process. An increased compliance over time was found, due to fear of consequences and increased awareness. Interestingly, the royal decree of legislation 21/07/2016, which restricts the use of CIA in livestock, was seen as a clear and helpful tool for veterinarians and farmers. Other studies with Dutch and UK livestock veterinarians have also shown that restrictions on antibiotic administration contribute to reduced AMU (32,33). Furthermore, restricted on-farm stock was suggested to discourage AMU by farmers. Negative consequences such as increased workload for veterinarians or farmers delaying veterinary intervention were mentioned. Educating farmers on early-disease recognition and the use of NSAID may be beneficial if on-farm stock would be restricted. Moreover, more clarity on legislations, transparent communication on regulatory changes, and effective control strategies may aid livestock veterinarians. AMU and benchmarking reports were found to assist veterinarians in decision-making and motivating behavior change in farmers while in 2016, Flemish veterinarians showed little belief in the positive effects of benchmarking (24). However, participants emphasized the need for a user-friendly data collection system and a balance between animal welfare, intensive production, and restricted AMU. Enhancing understanding of AMU reports' effectiveness in prompting behavior change and providing financial support for data collection may be necessary, as previous studies have also noted the lack of incentives in this regard (25).

Not unexpectedly, guidelines on AMU were found to be informative but not the primary consideration in the decision-making process, with professionals relying more on their expertise. Increasing the use guidelines by livestock veterinarians could be beneficial to promote responsible AMU and establish uniform messaging towards farmers. Regular training on up-to-date guidelines and increased awareness regarding the benefits of using guidelines may improve antimicrobial prescription behaviour.

The importance of raising consumer awareness was mentioned. Notably, participants emphasized that campaigns should avoid negative perceptions of agriculture. However, they nuanced that societal pressure for responsible AMU can motivate both farmers and veterinarians. Moreover, participants emphasized the collective responsibility of all stakeholders in the medical community, including both human and veterinary sectors, to address AMR and promote responsible antimicrobial usage through a unified "One Health" approach. Pinpointing the responsibility of other professional groups as being the main cause of spread of AMR was also described in previous qualitative studies on antimicrobial prescription behaviour in UK and Dutch livestock veterinarians (26,27,28,31).

Some participants engaged in advising on biocide use in livestock farming, while others did not. Veterinarians may offer guidance on proper usage of biocides or refer farmers to specialized companies,

but they do not directly distribute these products. Training on biocides in the veterinary curriculum and continuing education can ensure comprehensive education for all veterinarians. Developing guidelines and awareness campaigns can promote responsible biocide use, but challenges persist, especially regarding waste disposal methods. Addressing the lack of awareness or unclear guidelines on waste disposal requires comprehensive solutions: awareness campaigns, clear guidelines, and technical support.

A critical reflection on the purposeful sample is crucial in order to judge the transferability of the findings. Notably, the majority of participants were male (n=20), and all worked in group practices or veterinary clinics, limiting representation from female veterinarians and those working independently. Additionally, the participating pig and ruminant veterinarians had extensive experience (n=15: 10-20 years, n=10: >20 years), potentially overlooking insights from recent graduates in these fields. However, two recent-graduate poultry veterinarians contributed, offering perspectives on young professionals in their field. Furthermore, experienced participants shared insights into the antimicrobial prescription behavior of young veterinarians, drawing from their own experiences or those of their colleagues. Difficulties occurred in recruiting Walloon veterinarians in Wallonia, often caused by participants' time-constraints, although the four Walloon ruminant veterinarians provided valuable insights. It's worth noting that the pig and poultry sector in Belgium is predominantly located in Flanders, explaining the absence of Walloon pig and poultry veterinarians in our study. Finally, the researcher (ZdM) has a background as a small animal veterinarian, which may have influenced the interpretation of the data. The researcher strived to maintain objectivity and recognized any potential biases that could arise from prior knowledge in the field.

There are several potential strengths to consider in this study, including the achieved data saturation and the replication of findings across diverse participants. The breadth of topics discussed, and the identification of numerous overlapping themes suggest that results may be applicable to the utilization of antibiotics and biocides in Belgian livestock practices. Moreover, the study facilitated a thorough comparison across various sectors, including those of pigs, poultry, cattle, and dairy cows. To our knowledge, this is the first qualitative study to explore the determinants of the antimicrobial prescription behaviour among Belgian ruminant, pig, and poultry veterinarians.

In conclusion,
the identified themes provide a framework for understanding the dynamics of antimicrobial prescription behaviour, biocidal use, and disposal of antibiotic/biocidal waste in livestock veterinary medicine, revealing both barriers and facilitators for responsible antimicrobial, biocidal and waste management practices. These insights suggest potential areas for targeted interventions.

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