2025, Scienceline Publication
World's Veterinary Journal
World Vet J, 15(2): 375-388.
ISSN 2322-4568

DOI: https://dx.doi.org/10.54203/scil.2025.wvj38
PII: S232245682500038-15

A Nationwide Survey on the Administration of Antibiotics in Companion Animals by Veterinary Practitioners in Nigeria

Mary Idowu Olasoju[1]*, Pius Soladoye Olagunju[1], Aderonke Oluwakemi Alamu[2], Hezekiah Kehinde Adesokan[3], Taiwo Israel Olasoju[4], Olufunke Omowunmi Adebayo[5], Afeez Jimoh[1], Adenike Iyabo Adeleye[5], and Oluwawemimo Oluseun Adebowale[1]

1Department of Veterinary Public Health and Preventive Medicine, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Abeokuta, Ogun State, Nigeria
2Department of Veterinary Medicine, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Abeokuta, Ogun State, Nigeria
3Department of Veterinary Public Health and Preventive Medicine, Faculty of Veterinary Medicine, University of Ibadan, Ibadan, Oyo State, Nigeria
4Department of Veterinary and Pest Control Services, Federal Ministry of Agriculture and Food Security, Abuja, Federal Capital Territory, Nigeria
5Veterinary Teaching Hospital, College of Veterinary Medicine, Federal University of Agriculture, Abeokuta, Ogun State, Nigeria

*Corresponding author's Email: maryvet2006@yahoo.com

ORIGINAL ARTICLE
Received: March 16, 2025
Revised: April 17, 2025
Accepted: May 19, 2025
Published: June 25, 2025

ABSTRACT

Antimicrobial use (AMU) in companion animals in Nigeria is underreported, raising public health concerns due to antimicrobial resistance (AMR). The present study aimed to establish baseline data on antimicrobial stewardship (AMS) among veterinarians treating small animals and, with a focus on prescription patterns and adherence to the World Health Organization (WHO) guidelines on the Highest Priority Critically Important Antimicrobials (HP-CIAS). A nationwide web-based cross-sectional survey was conducted between August and November 2022, utilizing an online self-administered questionnaire among 96 companion animal veterinarians (CAVs) in Nigeria. Data collected included veterinarians' demographics, diseases treated, prescribed antimicrobial agents, utilization of laboratory diagnostic tests, and veterinarians' knowledge of AMS and MAR. The survey was conducted using KoBo Toolbox (Cambridge, MA, USA), and the variables were analyzed with Epi Info version 7.1.3.10. Among the 96 respondents, 62.5% were male. The most frequently reported conditions were infectious and parasitic diseases (80.6%), followed by abscesses, injuries, and bite wounds (68.8%), and digestive system diseases (65.6%). The most commonly prescribed first-line antibiotics were oxytetracycline (81.4%) and metronidazole (56.9%), while ciprofloxacin (39.8%) and gentamicin (33.7%) were often prescribed as second-line antibiotics for companion animals. Approximately 38.3% of respondents reported 100% efficacy of the first antibiotic prescribed, while 90.3% were aware of laboratory test results before using antimicrobial agents. The data collected provides essential baseline insights into AMU patterns among CAVs in Nigeria, which are critical for guiding AMR interventions focused on responsible antimicrobial use, including the development of AMS initiatives and educational programs for veterinary practices nationwide.

Keywords: Prescription patterns, Antimicrobial resistance, Antimicrobial stewardship, Companion animals, Veterinary practice

INTRODUCTION

Antimicrobials play a critical role in preventing and treating diseases in veterinary practice. However, the inappropriate use of these agents has led to the emergence of resistant microbial genes in both animals and humans (Boerlin and White 2013; Rodríguez-Rojas et al., 2013; Caneshi et al., 2023). Once a resistant strain emerges, restoring susceptibility to antimicrobial therapy is challenging, often requiring considerable time (Papich, 2020). Antimicrobial resistance poses a significant risk to companion animals and represents a serious threat to public health. Humans can be exposed to antimicrobial agents and resistance from animals through direct or indirect contact with companion animals (Bronzwaer et al., 2002; Pomba et al., 2017). Recent studies have highlighted the role of companion animals as significant reservoirs of resistant and multi-resistant microbes that pose a risk to human health. Their proximity to humans in shared environments facilitates exposure to various infections, thereby increasing the likelihood of transmission of resistant pathogens (Joosten et al., 2020; Li et al., 2021; Schwarz, 2021; Smoglica et al., 2022). Antimicrobial stewardship (AMS) is an essential strategy advocated by the World Organization for Animal Health (WOAH) and the World Health Organization (WHO). A substantial body of research has examined the various factors that affect the prescribing practices of healthcare professionals regarding antimicrobial agents in human medicine (Livorsi et al., 2015; Chem et al., 2018; Lum et al., 2018). However, research focusing on veterinary medicine is limited. Some researchers have proposed that veterinarians' prescribing practices for antimicrobial agents are determined by their perceptions of drug efficacy, ease of administration, and personal preferences and experiences (Mateus et al., 2011; Hughes et al., 2012; Jacob et al., 2015; Fowler et al., 2016), These findings highlight a significant divergence from established guidelines set forth by the

To cite this paper: Olasoju MI, OlagunjuPS, Alamu AO, Adesokan HK, Olasoju TI, Adebayo OO, Jimoh A, Adeleye AI, and Adebowale OO (2025). A Nationwide Survey on the Administration of Antibiotics in Companion Animals by Veterinary Practitioners in Nigeria. *World Vet. J.,* 15(2): 375-388. DOI: https://dx.doi.org/10.54203/scil.2025.wvj38

World Organization for Animal Health (WOAH), which emphasize the importance of evidence-based practices in prescribing antimicrobials to mitigate the risk of resistance development (WOAH, 2024).

To effectively combat antimicrobial resistance (AMR) in companion animals, several key strategies should be implemented. Veterinarians must minimize unnecessary antibiotic prescriptions and ensure that pet owners complete the full course of treatment (WHO, 2015). Good hygiene practices, including regular cleaning of living areas and proper handwashing, are essential for reducing the spread of resistant bacteria (Maillard et al., 2020). Additionally, increasing vaccination programs for pets against bacterial diseases is vital, as it helps prevent infections and decreases reliance on antibiotics (Hoelzer et al., 2018). Finally, continuous monitoring of antimicrobial use and resistance patterns is crucial for informing treatment guidelines (Morel et al., 2021).

In Nigeria, veterinarians often prescribe critically important antimicrobials as first-line treatments, frequently without verifying the existence of bacterial infections (Briyne et al., 2014; Buckland et al., 2016; Van Cleven et al., 2018). A significant number of animals treated in veterinary hospitals receive antimicrobial agents unnecessarily. Studies indicate that the most frequently used antibiotics in Nigeria include tetracyclines (94.2%), followed by beta-lactams/aminoglycosides (74%), aminoglycosides (72%), and fluoroquinolones (69%) (Mateus et al., 2011; Hughes et al., 2012; Jacob et al., 2015; Fowler et al., 2016). Additionally, oxytetracycline, tylosin, and gentamicin are frequently recommended by veterinarians, with oxytetracycline cited by 82.6% of respondents in recent surveys (Jolaoso et al., 2024). This pattern of antibiotic use raises serious concerns about the potential development of antimicrobial resistance due to inappropriate administration (Wayne et al., 2011). The misuse of antimicrobials—through underdosing, off-label use, and misdiagnosis—has been identified as a primary contributor to the emergence of resistant bacterial strains (Pokharel et al., 2020; Allerton and Russell, 2023). These concerns underscore the urgent need for a comprehensive survey on antimicrobial usage in companion animals across veterinary practices. Such a survey is crucial for developing strategies for responsible antimicrobial stewardship, improving diagnostics, and addressing the public health threat of antimicrobial resistance (AMR). To this end, this study evaluates the awareness of antimicrobial stewardship and resistance among companion animal practitioners in Nigeria, examines prescription patterns, and assesses adherence to WHO guidelines concerning high-priority critically important antimicrobial agents (HP-CIAS). The WHO identifies certain antimicrobials, such as third-generation cephalosporins and macrolides, as critical due to their importance in human medicine and the risk of resistance transfer from animals (WHO, 2023a). Despite the global threat of AMR, information on antimicrobial use in Nigerian companion animal practice remains scarce. The present study aims to address this gap by thoroughly assessing awareness, prescription habits, and adherence to WHO guidelines among practitioners in Nigeria.

MATERIALS AND METHODS

Ethical considerations

This research did not involve any regulated animals, nor were any scientific procedures of any kind conducted on animals. Ethical approval for the present study was obtained from the College of Veterinary Medicine Research Ethics Committee (CREC), Federal University of Agriculture, Abeokuta, Abeokuta, Nigeria, on January 17, 2022, with the approval reference number FUNAAB/COLVET/CREC/2022/01/02**.** Informed consent was obtained from all participants at the beginning of the questionnaire, and those unwilling to participate were immediately taken to the submission panel of the software application. Participation was voluntary based on the individuals' availability and willingness to participate in the study. All participants were notified of their right to discontinue at any stage of the survey.

Study design and study location

A web-based cross-sectional survey was carried out among companion animal veterinary practitioners in Nigeria using a twenty-one-item self-administered questionnaire. Nigeria is a West African country located in the Northern and Eastern Hemispheres of the Earth with coordinates of 9°04'39.90" N 8°40'38.84" E. In addition, the country comprises 36 states and a Federal Capital Territory (FCT). Companion Animal Veterinarians (CAVs) from 23 states and the FCT participated in the survey (Figure 1). The states represented in the survey included Abia, Akwa Ibom, Anambra, Bauchi, Bayelsa, Benue, Cross River, Delta, Edo, Enugu, FCT Abuja, Ekiti, Gombe, Katsina, Kwara, Lagos, Nasarawa, Ogun, Ondo, Osun, Oyo, Plateau, River, and Sokoto States (Figure 1).

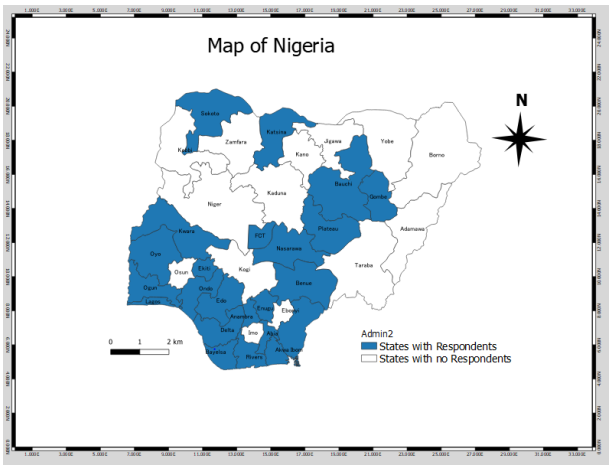

Figure 1. The map of states in the study area

Inclusion and exclusion criteria

The participants in this study were veterinarians specializing in companion animals who are affiliated with the Small Animal Veterinary Association of Nigeria (SAVAN). This group primarily focuses on the care of dogs and cats, which are the most frequently seen companion animals in veterinary clinics across Nigeria. Veterinarians who focused solely on companion animals other than dogs and cats were excluded from the study.

Sample size determination, questionnaire, and data collection

The sample size was determined using the formula described by Thrushfield (2005), at a 95% confidence level and a precision of 10% with the formula. $n = \frac{Za^2(1-P)}{d^2}$ (Formula 1)

Where n is the minimum sample size, Zα is the standard deviation at a 95% confidence interval equal to 1.96, *p* is the proportion of outcome of interest from previous studies or reports, q is 1-p, and d is the absolute error or level of precision. Assuming a total population of 106 registered SAVAN members, Epi Info software was used to calculate the sample size using an expected frequency of 50% and a confidence level of 95%. The sample size for questionnaire administration was calculated to be 83. Taking into account the anticipated nonresponse rate, the final sample size was adjusted to 92 respondents using the attrition rate formula.

$\frac{n}{1-f}$ (Formula 2)

Where f is the attrition rate (10%) and n is the calculated sample size

The survey instrument was adopted from two previous studies comprising questions on antimicrobial usage and prescription patterns in companion animals and then modified to meet the objectives of the present survey (Galarce 2021; Odoi 2021).

The semi-structured online questionnaire was developed in English using KoBo Toolbox software (KoBo, Inc., Cambridge, MA 02138). It comprised three sections aimed at collecting data on the participants' sociodemographic details, the use of antimicrobials in companion animals, and their awareness of antimicrobial stewardship (AMS) and resistance. Section A consisted of seven questions that assessed the sociodemographic profiles of the respondents, such as location of practice, age in years, sex, highest level of education, marital status, type of practice, and number of years of companion animal practice (CAP). Section B included ten questions on antimicrobial usage in companion animals. The last section (C) consisted of four questions on awareness of AMR and AMS. These three sections contained only closed-ended questions consisting of yes/no and occasionally multiple-choice options.

The questionnaire underwent initial validation by specialists in veterinary public health from the Federal University of Agriculture's College of Veterinary Medicine, Nigeria, aimed at identifying any unclear or misleading questions. A pretest was subsequently conducted with a small group of clinicians from the Veterinary Teaching Hospital (VTH) located at both the Alabata and Kemta Annex branches of the Federal University of Agriculture, Abeokuta, Nigeria. This approach helped to identify all important issues concerning the timing of the questionnaire response and other confusing and difficult-to-understand questions. The questionnaire was refined based on their feedback. The results of the pretest were not included in the final results.

Questionnaire administration

Prior to the deployment of the survey instrument, the Chairperson of the Small Animal Association of Nigeria (SAVAN) was contacted to obtain his consent on behalf of the association, and upon his approval, the survey questionnaire was uploaded to the WhatsApp platform of SAVAN, who are members of the Nigerian Veterinary Medical Association (NVMA) and were registered with the Veterinary Council of Nigeria (VCN). Patients were requested to participate anonymously in the survey. To enhance the response rate during the survey, three reminder messages were sent through the platform, encouraging members to complete the questionnaire and expressing gratitude to those who had already participated. The online survey was conducted from August 20, 2022, to November 24, 2022. Informed consent was obtained from participants at the start of the questionnaire, and individuals who chose not to participate were promptly directed to the submission panel of the software application. Participation was entirely voluntary, depending on each individual's availability and willingness to engage in the study. All participants were informed of their right to withdraw at any point during the survey (WMADH, 2013).

Data analysis

The data collected were exported from the Kobo Toolbox application (Cambridge, MA, USA) into a Microsoft Excel® 2016 spreadsheet (Microsoft Corporation, Redmond, WA, USA), and the variables were analyzed using Epi Info version 7.1.3.10. Descriptive statistics including frequencies, proportions, and percentages were calculated at 95% confidence intervals (CIs). The results are presented in the figures.

RESULTS

General characteristics of the respondents

A total of 96 respondents from 23 states across Nigeria participated in the survey, resulting in a response rate of 97.0%, with respondents from Lagos State accounting for 11.46% of the total, followed by Oyo State at 9.38%. Osun, Ogun, and Nasarawa States each with an equal representation of 6.25% (see Table 1). The states with the fewest respondents were Enugu, Ekiti, and Katsina, each contributing 1.04%. Demographically, the majority of respondents were male (62.50%), over the age of 30 (59.38%), and married (55.21%). In terms of educational qualifications, most held a Doctor of Veterinary Medicine (DVM) degree (70.83%), while others had a master's degree (19.79%), a Ph.D. (7.29%), or were Fellows of the College of Veterinary Surgeons Nigeria (2.08%). Regarding professional involvement, respondents worked in various practice types: companion animal practices (25%), first opinion practices (general veterinary practices serving as the initial contact for pet owners) (6.25%), mixed practices (66.67%), and referral practices (specialist hospitals) (2.08%). Additionally, a significant majority had been practicing for ten years or less (68.75%) (Table 1).

Table 1. Sociodemographic characteristics of the companion animal veterinarians in Nigeria, August-November 2022

Variables	Frequency	Percentage (%)	95% confidence interval
Gender			
Female	36	37.5	27.83 – 47.97
Male	60	62.5	52.03 – 72.18
Age group			
≤ 30	39	40.6	30.71 – 51.13
> 30	57	59.4	48.87 – 69.29
Marital status			
Married	53	55.2	41.71 – 65.37
Single	43	44.8	34.63 – 55.29
Educational level			
D.V.M	68	70.8	60.67 – 79.67
Master's degree	19	19.8	12.36 – 29.17
Ph.D.	7	7.3	2.98 – 14.45
F.C.V.S.N	2	2.1	0.25 – 7.32
Years of companion animal practice			
>10	30	31.3	22.18 – 41.52
≤ 10	66	68.8	57.42 – 82.57
Type of practice			
Mixed practice *	64	66.7	55.26 – 80.69
Companion animal practice	24	25.0	16.72 – 34.88
First opinion practice	6	6.3	2.33 – 13.11
Referral practice	2	2.1	0.25 – 7.32

D.V.M: Doctor of Veterinary Medicine; F.C.V.S.N: Fellow of the College of Veterinary Surgeons, Nigeria; Ph. D.: Doctor of Philosophy *Deals with dogs and cats, and other companion animals.

Antimicrobial agent usage in companion animals

Respondents reported using antimicrobials in companion animals with the following frequencies: always (26.0%), frequently (39.6%), infrequently (1.0%), and only when necessary (33.3%). A significant majority of respondents (88.42%) were involved in treating infectious diseases in the two months leading up to the survey. In terms of the number of animals treated, approximately 11.5% of participants treated fewer than five dogs, while 39.6% treated fewer than five cats. Additionally, 29.2% treated between five and ten dogs, and 15.6% treated between five and ten cats. Furthermore, 26.04% treated between eleven and fifteen dogs, while 5.2% treated between eleven and fifteen cats. Finally, 31.25% of respondents treated more than twenty dogs, and 1.04% treated more than twenty cats in the two months prior to the survey (Table 2; Figure 2). The diseases most frequently reported by respondents included infectious and parasitic diseases (80.65%), abscesses, injuries, and bite wounds (68.82%), as well as digestive system disorders (65.59%). In terms of diagnostic testing, only 36.96% of respondents requested a full blood count (FBC) for infectious or parasitic diseases, while 34.78% requested an antibiotic sensitivity test (AST) for digestive tract disorders (Table 2; Figure 2).

Approximately 38.4% of respondents reported experiencing 100% efficacy from the first-line antibiotics prescribed (Table 3), while 55.8% indicated that the antibiotics were effective sometimes (see Figure 3). The most frequently prescribed first-line antibiotics were oxytetracycline (81.40%) and metronidazole (56.98%). In contrast, ciprofloxacin (39.76%) and gentamicin (33.73%) were the most commonly used second-line antibiotics for treating companion animals (see Figure 4). The most frequently prescribed classes of antibiotics included tetracyclines (88.9%), penicillins (76.7%), and aminoglycosides (48.89%). In comparison, lincosamides (3.3%), polypeptides (1.1%), and mupirocins (0.0%) were the least frequently prescribed antimicrobial agents (Figure 5).

Table 2. Antimicrobial usage in companion animals in Nigeria, August-November 2022

Variables	Frequency	Percentage	95% confidence interval
Frequency of antimicrobial usage			
Often	38	39.6	29.8-50.1
Always	25	26.0	17.6-36.0
Rarely	1	1.0	0.03-5.7
When needed	32	33.3	22.0-43.7
Have you treated an infectious disease in the last two months?			
Yes	84	88.4	88.2-94.1
No	11	11.6	5.9-19.8
How many dogs did you treat in the past two months?			
Below 5	11	11.5	5.9-19.6
Between 5 and 10	28	29.2	20.3-39.3
Between 11 and 15	25	26.0	17.6-36.0
Above 20	30	31.3	22.2-41.5
None	2	2.1	0.3-7.3
How many cats did you treat in the past two months?			
Below 5	38	39.6	29.3-50.1
Between 5 and 10	15	15.6	9.0-24.5
Between 11 and 15	5	5.2	1.7-11.7
Above 20	1	1.0	0.0-5.7
None	37	38.3	28.8-49.0

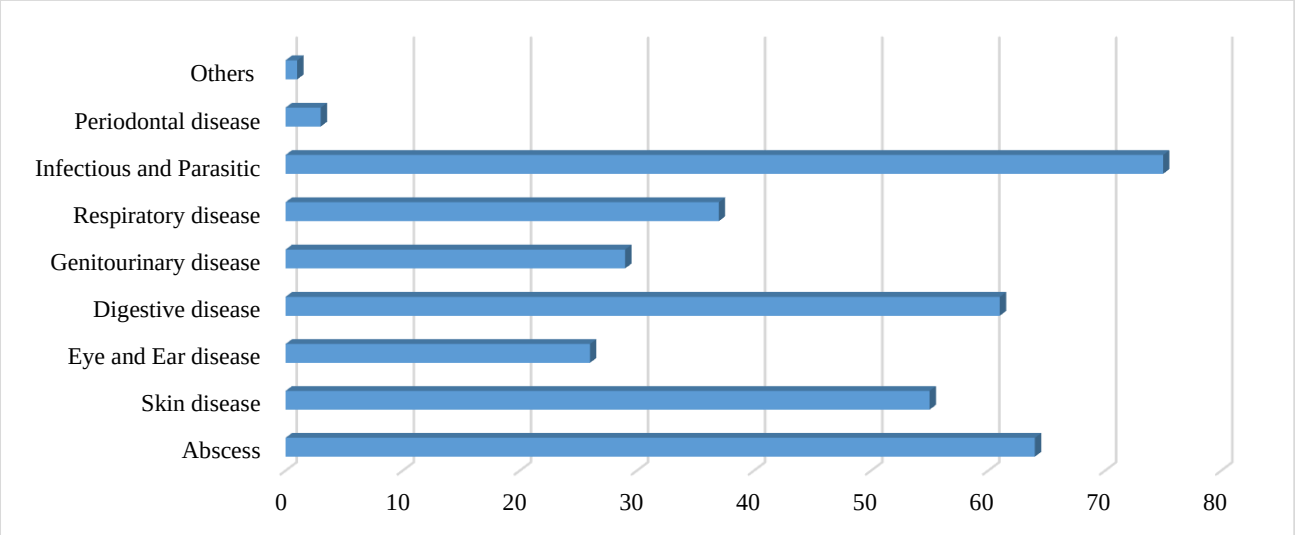

Figure 2. Commonly encountered diseases/conditions by companion animal practitioners in Nigeria, August-November, 2022

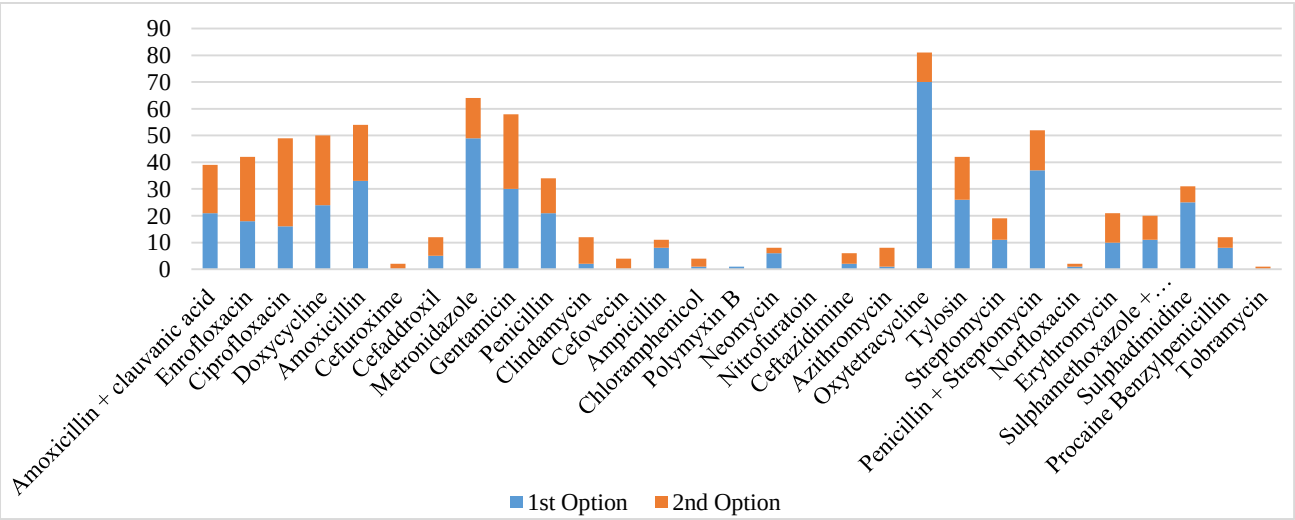

Figure 3. Antibiotics prescribed as first and second treatment options by companion animal practitioners in Nigeria, August-November 2022

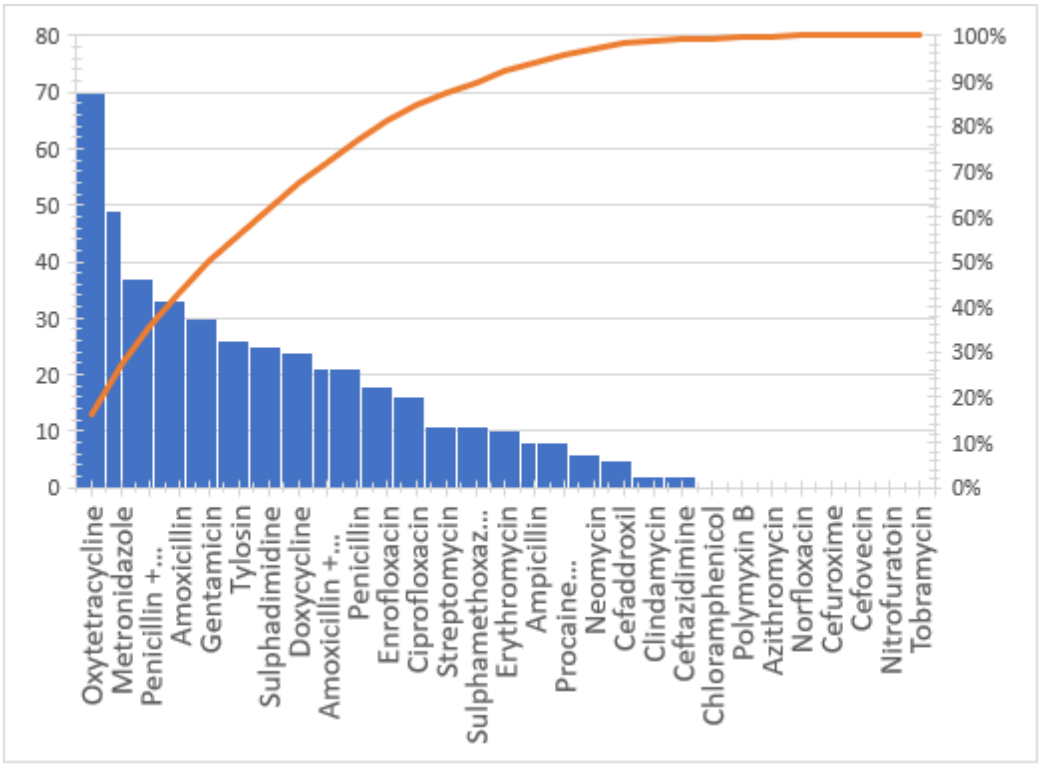

Figure 4. Commonly prescribed antibiotics by companion animal practitioners in Nigeria, August-November 2022

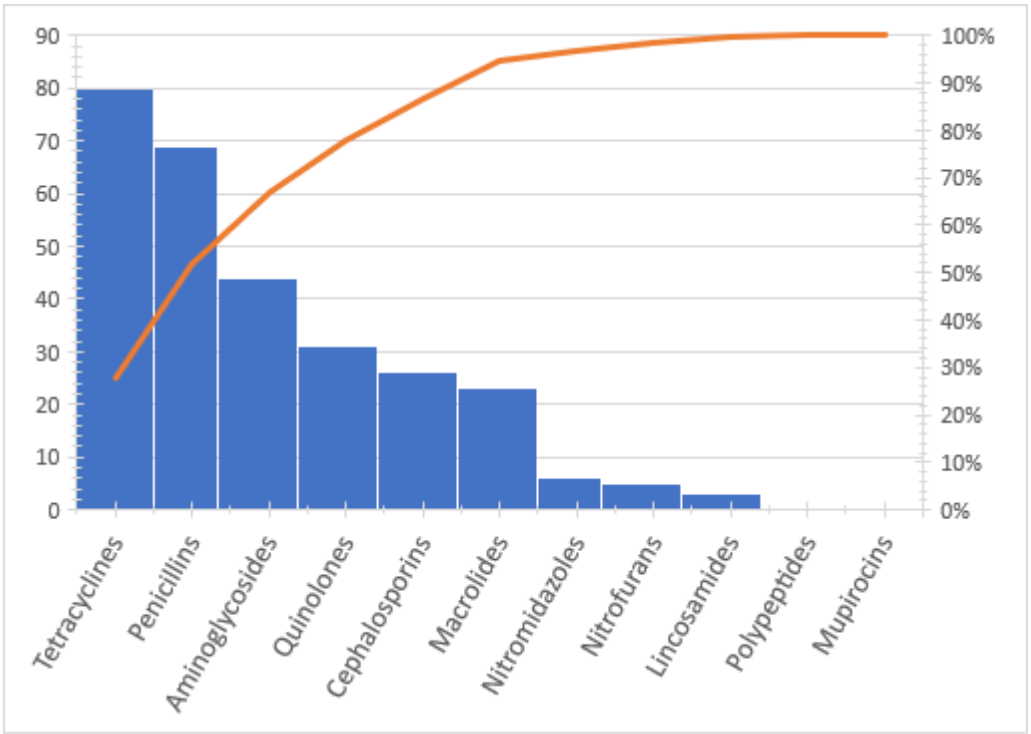

Figure 5. Commonly prescribed classes of antibiotics by companion animal practitioners in Nigeria, August-November 2022

Table 3. Methods of antimicrobial administration in companion animals by companion animal practitioners in Nigeria, August-November 2022

Variables	Frequency	Percentage	95% Confidence Interval
Did you experience 100% efficacy for the first therapeutic option?			
Yes	33	38.4	28.08 – 49.49
Sometimes	48	55.8	44.70 – 66.52
No	5	5.8	1.91 – 13.05
What were the frequently used routes of administration in the companion animal practice?			
1. Topical	24	26.7	17.89 – 37.03
2. Intravenous	43	47.8	37.13 – 58.57
3. Intramuscular	89	98.9	93.96 – 99.97

Awareness of antimicrobial stewardship and resistance by companion animal practitioners in Nigeria, August-November 2022

The majority of respondents reported obtaining current information on antimicrobial agents and their usage primarily from textbooks and drug handbooks (50.54%) and continuing professional development courses (54.8%). Additionally, 55.4% of respondents indicated that they had a standardized protocol for antimicrobial prescriptions in their companion animal practices. A substantial majority (96.6%) acknowledged the necessity of laboratory tests prior to prescribing antibiotics, while 63.4% were familiar with the World Health Organization (WHO) and World Organization for Animal Health (OIE) classifications of critically important antimicrobials (CIAs) for both veterinary and human medicine. Furthermore, 87.2% recognized that companion animals could transfer resistance genes to their owners, although only 45.9% had participated in training specifically focused on antimicrobial usage in companion animals (Table 4).

Table 4. Awareness of antimicrobial stewardship and resistance by companion animal practitioners in Nigeria, August-November 2022

Variables	Frequency	Percentage (%)	95% Confidence Interval
What were the primary sources from which you received information on antimicrobials and their usage?			
Practice policies	31	33.3	23.89 – 43.87
Pharmaceutical companies	22	23.7	15.46 – 33.60
Veterinary medicine directorates	37	39.8	29.78 – 50.46
Peer-reviewed scientific literature	36	38.7	28.78 – 49.38
Textbook/drug handbooks	47	50.5	39.97 – 61.07
Continuing professional development courses	51	54.8	44.17 – 65.19
Others	15	16.1	9.32 – 25.20
Did your companion animal practice have a standardized protocol regarding antimicrobial prescriptions?			
Yes	41	55.4	44.70 – 65.81
No	84	44.6	34.19 – 55.30
Were you aware of the usage of laboratory tests prior to the prescription of antimicrobials?			
Yes	6	90.3	90.25 – 99.28
No	3	6.5	0.72 – 9.75
Were you aware of the WHO-OIE groups of critically important antimicrobials (CIAs) in veterinary and human medicine?			
Yes	59	63.4	52.81 – 73.19
No	34	36.6	26.81 – 47.19
Were you aware that companion animals could transfer bacterial resistance genes to their owners?			
Yes	75	87.2	8.27 – 93.44
No	11	12.8	6.56 – 21.72
Have you ever attended any training sessions on antimicrobial usage in companion animals?			
Yes	40	45.9	35.23 – 57.00
No	47	54.0	43.00 – 64.77

DISCUSSION

Antimicrobial resistance (AMR) is an emerging issue in companion animals due to the prevalence of difficult-to-treat infections, the demand for antimicrobial agents that are critical in human medicine, and the risk of zoonotic transmission. The scope and significance of AMR in companion animals are underreported in Nigeria. This study evaluated antimicrobial usage among companion animal veterinarians in Nigeria.

Most of the companion animal veterinarians who participated in the present survey were from Lagos, Oyo, Osun, and Ogun States in the southwestern zone of Nigeria, with Lagos State having the highest percentage. Lagos State is a hub of small animal practice, probably due to the Muritala International Airport being situated in Lagos, which facilitates the importation of veterinary supplies and medications. This accessibility enhances the capacity of veterinarians to provide comprehensive care and services to companion animals, contributing to the higher percentage of veterinarians in the region. The concentration of veterinary clinics and hospitals in Lagos further supports this trend, allowing for better resources and specialized care for pets. This finding aligns with the report by Hambolu et al. (2014), which also noted a high dog-to-human ratio in Lagos. This variation may be attributed to the growing human population and the demand for dogs for security needs amid rising security challenges. Additionally, the majority of respondents were male, with ages ranging from 25 to 61 years. These findings show that more males than females are active in the field of companion animal practice.

In the current study, the observation that a greater proportion of companion animal veterinarians treated more dogs than cats suggests a demographic trend in pet ownership within the study area. This trend may indicate a preference for dogs as companion animals among pet owners, influenced by cultural, social, and economic factors. Dogs are often valued for their companionship, security, and loyalty, which may align more closely with the local population's lifestyle and needs. Additionally, the higher treatment rates for dogs could reflect a greater availability of resources and veterinary services focused on canine care compared to feline care. This disparity also underscores the necessity for targeted educational outreach and veterinary services for cat owners to ensure that feline health care is adequately addressed. This finding aligns with previous research indicating that dogs are generally more prevalent than cats in Nigeria, as noted by various authors (Fasasi et al., 2022; Adebowale et al., 2023). The predominance of dogs over cats in veterinary treatments could reflect several factors, including cultural preferences. In many regions, including Nigeria, cultural attitudes often favor dogs as companions due to their roles in protection, herding, and companionship. Moreover, the specialization of veterinary practice may influence this trend; companion animal veterinarians might customize their services to address the needs of dog owners, who are likely to seek veterinary care more frequently than cat owners. The findings are further supported by Joosten et al. (2020), who explored antimicrobial usage and resistance in companion animals in three European countries (Belgium, Italy, and the Netherlands). Their research highlights the significant role of dogs in veterinary practices and raises awareness about the implications of pet ownership trends on veterinary medicine and public health. Also, studies from other countries further reinforce these observations. For example, a nationwide survey in Portugal assessed dog and cat owners' knowledge, attitudes, and perceptions regarding antibiotic use, revealing that 21% expected their pets to need antibiotics prior to consultation (Dias et al., 2024). In the United States, a comprehensive analysis of antimicrobial susceptibility patterns in companion animals indicated common resistance issues that could affect both animal health and public safety (Sobkowich et al., 2023). Collectively, these studies underscore the critical role of dogs in veterinary practices worldwide while highlighting interconnectedness between pet ownership trends and public health. The close relationship between humans and companion animals creates opportunities for the transmission of antimicrobial resistance, which poses significant risks to both animal and human health. Addressing these challenges through responsible antimicrobial stewardship is essential for safeguarding public health in the context of increasing pet ownership.

The commonly prescribed AMs in companion animals, as well as the first option AMs prescribed by CAVs, were oxytetracycline, followed by metronidazole, penicillin combined with streptomycin, amoxicillin, and gentamycin, which indicates a preference for broad-spectrum antibiotics that are effective against a variety of bacterial infections. The present study documented tetracycline (TC) as the most frequently prescribed class of antimicrobial agents (AMs). Oxytetracycline, a broad-spectrum antibiotic effective against both gram-positive and gram-negative bacterial organisms, is commonly used. This prevalence may be linked to the high incidence of infectious and parasitic diseases identified by CAVs in the current survey. In contrast, amoxicillin-based medications were predominantly prescribed for dogs and cats in Australia (De Briyne et al., 2014; Hardefeldt et al., 2018; Hur et al., 2020).

According to the present study, metronidazole was the second most commonly prescribed antimicrobial agent for companion animals in Nigeria. As a member of the nitroimidazole class, metronidazole is frequently utilized to treat gastrointestinal infections, as well as parasitic diseases such as trichomoniasis, giardiasis, and amebiasis. This antibiotic has been in use for several decades and is distinguished by its dual action as both an antibiotic and an antiparasitic agent,

enabling it to address a wide range of infections. It is available in various forms, including capsules, tablets, topical applications, and suppositories. Schnepf et al. (2021) reported that metronidazole ranked as the second most frequently documented antimicrobial used in veterinary practice, suggesting that it may be prescribed not only for bacterial infections but also for parasitic conditions. Recent data from Nigeria indicates that metronidazole is the antimicrobial with the highest volume administered among companion animals (Adebowale et al., 2023). This finding is not surprising considering that dogs are frequently infused with metronidazole 500 mg/100 mL twice daily (b.i.d.), most notably for the treatment of parvoviral enteritis, which is endemic in Nigeria, resulting in higher volumes of metronidazole administered to dogs compared to other medications.

The present study observed a significant prevalence of broad-spectrum antimicrobial agents used in both dogs and cats across all companion animal practices. This finding aligns with results from earlier studies conducted in Australia, Finland, and Italy (Watson and Maddison 2001; Thomson et al., 2009; Escher et al., 2011). The primary systemic antimicrobial agents administered to dogs and cats were potentiated amoxicillin and amoxicillin, both of which are broad-spectrum β-lactams. In contrast, the current study identified oxytetracycline and metronidazole as the most commonly used systemic antimicrobials in practice, even though they are also classified as broad-spectrum antibiotics. The frequent use of broad-spectrum antimicrobials may indicate challenges in accurately diagnosing clinical conditions (Mateus et al. 2011). Data from Nordic countries indicated variations in the use of systemic antibiotics, with some regions showing a preference for non-β-lactam antibiotics like macrolides and lincosamides for specific indications (Skajaa et al. 2022).

The necessity to select a second antimicrobial option following the failure of the first choice highlights a critical aspect of antibiotic stewardship in clinical practice. In the present study, ciprofloxacin emerged as the preferred second-line treatment, closely followed by gentamicin. This choice reflects a strategic approach to managing treatment failures, particularly in contexts where initial therapies do not yield the desired clinical outcomes. Antibiotic treatment failure can occur for various reasons, which complicates the decision-making process regarding subsequent therapies. Common causes include incorrect initial antibiotic selection, inadequate dosing, and the presence of resistant bacterial strains (Habboush and Guzman, 2024). Additionally, factors such as delayed administration of antibiotics or failure to address underlying issues like source control in cases of abscesses or infected wounds can contribute to perceived treatment failures. The findings of this study resonate with those reported by Galarce et al. (2021), who observed that clinicians frequently rely on critically important antibiotics right after the initial treatment fails, often without thoroughly investigating the reasons for that failure. This practice raises concerns about the potential for increased resistance development and highlights the need for a more thoughtful approach to antibiotic prescribing. Ciprofloxacin, a fluoroquinolone antibiotic, is often chosen for its broad-spectrum activity against gram-negative bacteria (Sharma et al., 2017), making it a suitable option when first-line treatments fail. Its effectiveness against common pathogens in various infections underscores its role in empirical therapy, initiated based on clinical experience and educated guesses when complete information about a patient's condition is unavailable, before a definitive diagnosis is established or when the exact cause of an infection is not yet known. Gentamicin, an aminoglycoside, is another important option due to its potent activity against a range of aerobic gram-negative bacteria and certain gram-positive organisms (Krause et al., 2016). The choice to use these antibiotics as second-line treatments should be guided by regional resistance trends and the specific circumstances of each patient. For example, awareness of the prevalent microbiological profiles of infections in a particular area can help veterinarians and healthcare providers select the most effective antimicrobial agents while reducing the risk of aggravating resistance issues. The reliance on broad-spectrum antibiotics, like ciprofloxacin and gentamicin as second-line treatments, underscores a significant challenge in antimicrobial stewardship. While these medications can be lifesaving, their overuse may contribute to the emergence of resistant strains, complicating future treatment options. Healthcare providers must prioritize not only the immediate clinical response but also long-term implications for public health. This includes conducting thorough evaluations of treatment failures to identify whether they stem from inappropriate antibiotic selection, resistance issues, or other factors. Such evaluations can result in more customized strategies that take into account individual patient factors and relevant epidemiological data.

In the present survey, the intravenous (IV) and intramuscular (IM) routes were the most frequently used methods for administering antimicrobials. This trend is primarily due to the widespread use of oxytetracycline and metronidazole as the main antimicrobial agents, as indicated by the respondents. This is in agreement with Adebowale et al. (2023), who also documented I/V and I/M as the most frequent routes of administration at the veterinary teaching hospitals surveyed. However, these findings from the present survey contrast with those of Buckland et al. (2016), who reported that the oral route was the most popular method for administering antimicrobial agents. Most cases of infectious and parasitic gastroenteritis in dogs and cats can be effectively treated using the intravenous (IV) or intramuscular (IM) routes, particularly in instances of vomiting. Given that many veterinarians often choose to avoid administering medications orally when an animal is vomiting, the oral route may not be the most suitable option for administering oxytetracycline

and metronidazole, which were the most commonly used antimicrobials by companion animal veterinarians in this study (Elwood et al., 2010).

Over half of the participants in this study reported obtaining up-to-date information on antimicrobials (AMs) and antimicrobial use (AMU) from textbooks, drug handbooks, and continuing educational courses. Other sources included practice policy, pharmaceutical companies, veterinary medicine directorates, peer-reviewed scientific literature, the internet, and empirical knowledge, which encompasses insights and practices that veterinarians have learned through their experiences in treating animals and observing outcomes in clinical settings. This type of knowledge is crucial as it allows practitioners to make informed decisions based on real-world evidence rather than solely relying on established theories or guidelines. By integrating empirical knowledge with other sources of information, veterinarians can enhance their understanding of antimicrobial use and improve treatment strategies for diseases in animals. It is critical that CAVs practice appropriate AMS, given that they are fully aware that intimate contact between humans and their pets affords excellent potential for interspecies transfer of resistant bacteria and resistance genes in both directions. A comparable study conducted in Kentucky found that most veterinarians obtained information about antimicrobial therapy from textbooks, drug handbooks, and continuing educational courses (Odoi et al., 2021). This finding provides insight into the need to intensify continuing veterinary education in Nigeria, as it provides veterinarians with opportunities to connect with other veterinarians in the field for valuable collaboration and sharing of best practices.

The recent survey revealed that more than half of the respondents were aware of the WHO-OIE Critically Important Antimicrobials (CIAs). This finding underscores a growing recognition of the significance of antimicrobial stewardship among veterinary professionals. Such awareness is essential, as it demonstrates an understanding of the importance of responsible antibiotic use in addressing antimicrobial resistance (AMR), which is a significant global health challenge. The survey findings indicated that the most commonly prescribed first- and second-line antibiotics for companion animals fell into the Access and Watch categories of the WHO's AWaRe (Access, Watch, Reserve) classification system also reported by Adebowale et al. (2023). The WHO's AWaRe classification system is a framework designed to promote the responsible use of antibiotics and combat antimicrobial resistance (AMR). Developed in 2017 and revised in 2019 and 2021 by the WHO Expert Committee on Selection and Use of Essential Medicines, the system categorizes antibiotics into three distinct groups: Access, Watch, and Reserve. Each category reflects the antibiotics' potential for resistance and their recommended usage in clinical settings (WHO, 2019 and 2021; Zanichelli et al., 2023). The Access category includes antibiotics that are widely available and effective for treating common infections, while the Watch category comprises antibiotics that are recommended to be used with caution due to their potential for resistance development (Zanichelli et al., 2023). The absence of antibiotics from the Reserve category of the WHO's AwaRe classification in companion animal treatments is particularly noteworthy. The Reserve group is designated for last-resort use, reserved for situations where other alternatives have failed or are unsuitable (Zanichelli et al., 2023). This absence of the Reserve category suggests that veterinarians are adhering to guidelines aimed at preserving the efficacy of these critical drugs. The implications of these findings are significant for antimicrobial stewardship and public health. By primarily utilizing antibiotics from the Access and Watch categories, veterinarians show a dedication to responsible prescribing practices. This approach not only helps mitigate the risk of developing resistant bacterial strains but also supports public health initiatives aimed at reducing AMR across both human and veterinary medicine. The awareness of CIAs among veterinarians can lead to more informed decision-making regarding antibiotic selection. Understanding which antimicrobials are critically important allows practitioners to prioritize their use judiciously, ensuring that these medications remain effective for both animal and human health.

In the present study, a greater proportion of veterinarians demonstrated awareness of the necessity for laboratory testing prior to prescribing antimicrobial agents. This finding indicates that CAVs are increasingly knowledgeable about the significance of susceptibility or sensitivity tests in preventing antimicrobial resistance (AMR). Such awareness is crucial, as previous research has shown that inadequate laboratory diagnostics can lead to inappropriate antimicrobial use, which is a significant contributor to AMR (WHO, 2023b). For instance, a study conducted in Nigeria revealed that only a small percentage of veterinarians routinely performed antibiotic susceptibility testing alongside laboratory diagnosis, highlighting a gap in practice that could foster AMR (Adekanye et al., 2020). Similarly, research from South Africa indicated that many veterinarians relied on clinical judgment rather than laboratory results when prescribing antibiotics, which may inadvertently contribute to resistance patterns (Samuels et al., 2021). Moreover, a multi-country survey across Nigeria, South Africa, and Sudan emphasized the need for improved training and resources for veterinary professionals regarding antimicrobial stewardship (Fasina et al., 2020). This aligns with findings from other countries like Kenya and Cambodia, where the lack of access to laboratory facilities has been identified as a barrier to effective AMR management (Moirongo et al., 2022; Mao et al., 2023). Globally, the issue of AMR is exacerbated by the widespread and often indiscriminate use of antimicrobials in both human and veterinary medicine. Studies have shown that the development and spread of resistant pathogens are significantly influenced by prescription practices among

veterinarians (Prestinaci et al. 2015; Caneschi et al., 2023). Therefore, the increased awareness among veterinarians in this study is a positive step towards mitigating AMR, but it must be supported by adequate laboratory infrastructure and ongoing education to ensure that knowledge translates into practice effectively.

CONCLUSION

Oxytetracycline and metronidazole were the most frequently prescribed antimicrobial agents for treating dogs and cats, followed by ciprofloxacin and gentamicin when the first choice failed. The choice of antimicrobials may be influenced by the infectious and parasitic diseases that are frequently encountered. In order to promote optimal health outcomes for animals and humans, it is crucial to employ antimicrobial agents judiciously, considering the results of laboratory tests and the guidelines and policies related to antimicrobial use. This study suffers from limitations that should be noted. First, the sample size appears low; however, the majority of veterinarians in Nigeria are not actively practicing, with only a small proportion of them being small animal companion practitioners. Given the 110.8% response rate from 23 states, the present sample size could generalize the current situation in the country. Second, this was conducted as an online survey, which may have contributed to a lack of engagement among some companion animal veterinarians. Third, the study did not differentiate between the antimicrobial agents prescribed for dogs and those used for cats, nor did it quantify the amounts of antimicrobial agents administered. These factors may limit the comprehensiveness of the findings and their applicability to specific veterinary practices. Future studies should prioritize longitudinal assessments of antimicrobial usage patterns in companion animals. Such research is crucial for understanding how antimicrobial use (AMU) impacts antimicrobial resistance (AMR) over time. Longitudinal studies can help identify trends and correlations between specific antimicrobial agents used and resistance patterns, providing valuable data for developing effective stewardship strategies. By focusing on these aspects, future research can contribute significantly to the responsible use of antimicrobials in veterinary medicine and help address the growing challenge of AMR.

DECLARATIONS

Ethical considerations

The authors took into account the ethical considerations and obtained consent from respondents prior to their recruitment for the study. This article was originally written without any material sourced from other publications.

Availability of data

The data supporting the findings of this study are available within the paper and its supplementary information. The raw data, however, are available from the corresponding author upon reasonable request.

Funding

This study was self-funded by the authors.

Authors' contributions

Mary Idowu Olasoju and Oluwawemimo Oluseun Adebowale conceptualized the study, Mary Idowu Olasoju, Pius Olagunju, Afeez Jimoh, Taiwo Israel Olasoju, Olufunke Adebayo, and Adenike Adeleye implemented the study. Mary Idowu Olasoju, and Taiwo Israel Olasoju conducted data analysis. Mary Idowu Olasoju and Pius Olagunju wrote the manuscript's original draft. Mary Idowu Olasoju, Aderonke Oluwakemi Alamu, Hezekiah Kehinde Adesokan, Taiwo Israel Olasoju, Olufunke Adebayo, and Oluwawemimo Oluseun Adebowale dealt with manuscript reviewing and editing. All the authors have read and agreed to the final version of the manuscript.

Conflict of interests

The authors declare no conflicts of interest.

Acknowledgments

The authors wish to acknowledge the Small Animal Veterinary Association of Nigeria (SAVAN) for their assistance in completing the questionnaire.

REFERENCES

Adebowale OO, Jimoh AB, Adebayo OO, Alamu AA, Adeleye AI, Fasanmi OG, Olasoju M, Olagunju PO, and Fasina FO (2023). Evaluation of antimicrobial usage in companion animals at a Veterinary Teaching Hospital in Nigeria. Scientific Reports, 13: 18195. DOI: https://www.doi.org/10.1038/s41598-023-44485-w

Adekanye UO, Ekiri AB, Galipó E, Muhammad AB, Mateus A, La Ragione RM, Wakawa A, Armson B, Mijten E, Alafiatayo R et al. (2020). Knowledge, attitudes and practices of veterinarians towards antimicrobial resistance and stewardship in Nigeria. Antibiotics, 9(8): 453. DOI: https://www.doi.org/10.3390/antibiotics9080453

Allerton F and Russell J (2023). Antimicrobial stewardship in veterinary medicine: A review of online resources. JAC-Antimicrobial Resistance, 5(3): dlad058. DOI: https://www.doi.org/10.1093/jacamr/dlad058

Boerlin P and White DG (2013). Antimicrobial resistance and its epidemiology. In: S. Giguère, J. F. Prescott, and P. M. Dowling (Editors), Antimicrobial therapy in veterinary medicine, 5th Edition. John Wiley and Sons, pp. 21-40. DOI: https://www.doi.org/10.1002/9781118675014.ch3

Briyne ND, Atkinson J, Borriello SP, and Pokludová L (2014). Antibiotics used most commonly to treat animals in Europe. Veterinary Record, 175(13): 325. DOI: https://www.doi.org/10.1136/vr.102462

Bronzwaer SL, Cars O, Buchholz U, Mölstad S, Goettsch W, Veldhuijzen IK, Kool JL, Sprenger MJ, and Degener JE (2002). European antimicrobial resistance surveillance system. A European study on the relationship between antimicrobial use and antimicrobial resistance. Emerging Infectious Diseases, 8(3): 278-82. DOI: https://www.doi.org/10.3201/eid0803.010192

Buckland EL, O'Neill D, Summers J, Mateus A, Church D, Redmond L, and Brodbelt D (2016). Characterization of antimicrobial usage in cats and dogs attending UK primary care companion animal veterinary practices. Veterinary Record, 179: 489. DOI: https://www.doi.org/10.1136/vr.103830

Caneschi, A, Bardhi A, Barbarossa A, and Zaghini A (2023). The use of antibiotics and antimicrobial resistance in veterinary medicine, a complex phenomenon: A narrative review. Antibiotics, 12(3): 487. DOI: https://www.doi.org/10.3390/antibiotics12030487

Chem ED, Anong DN, and Akoachere JFKT (2018). Prescribing Patterns and Associated Factors of Antibiotic Prescription in Primary Health Care Facilities of Kumbo East and Kumbo West Health Districts, Northwest Cameroon. PLoS ONE, 13: e0193353. DOI: https://www.doi.org/10.1371/journal.pone.0193353

De Briyne N, Atkinson J, Pokludová L, and Borriello SP (2014). Antibiotics used most commonly to treat animals in Europe. Veterinary Record, 175(13): 325. DOI: https://www.doi.org/10.1136/vr.102462

Dias MC, Alpizar-Jara R, Lavrador C, Marques C, Broens EM, and Duarte EL (2024). Companion Animal Owners' Knowledge, Attitudes and Perceptions Regarding Antibiotic Use in Portugal. Antibiotics, 13(6): 533. DOI: https://www.doi.org/10.3390/antibiotics13060533

Elwood C, Devauchelle P, Elliott J, Freiche V, German AJ, Gualtieri M, Hall E, den Hertog E, Neiger R, Peeters D, Roura X, and Savary-Bataille K (2010). Emesis in dogs: A review. The Journal of Small Animal Practice, 51(1): 4-22. DOI: https://www.doi.org/10.1111/j.1748-5827.2009.00820.x

Escher M, Vanni M, Intorre L, Caprioli A, Tognetti R, and Scavia G (2011). Use of antimicrobials in companion animal practice: A retrospective study in a veterinary teaching hospital in Italy. Journal of Antimicrobial Chemotherapy, 66: 920-927. DOI: https://www.doi.org/10.1093/jac/dkq543

Fasasi KA, Rufai MA, Surakat OA, and Adojutelegan JI (2022). Ownership and health care status of pets in Osun State, Nigeria. Nigerian Journal of Basic and Applied Sciences, 30(2): 54-57. DOI: https://www.doi.org/10.4314/njbas.v30i2.7

Fasina FO, LeRoux-Pullen L, Smith P, Debusho LK, Shittu A, Jajere SM, Adebowale O, Odetokun I, Agbaje M, Fasina MM et al. (2020). Knowledge, attitudes, and perceptions associated with antimicrobial stewardship among veterinary students: A multi-country survey from Nigeria, South Africa, and Sudan. Frontiers in Public Health, 8: 517964. DOI: https://www.doi.org/10.3389/fpubh.2020.517964

Fowler H, Davis MA, Perkins A, Trufan S, Joy C, Buswell M, McElwain TF, Moore D, Worhle R, and Rabinowitz PM (2016). Survey of veterinary antimicrobial prescribing practices, Washington State. Veterinary Record, 179: 651. DOI: https://www.doi.org/10.1136/vr.103916

Galarce N, Arriagada G, Sánchez F, Venegas V, Cornejo J, and Lapierre L (2021). Antimicrobial use in companion animals: Assessing veterinarians' prescription patterns through the first national survey in Chile. Animals, 11: 348. DOI: https://www.doi.org/10.3390/ani11020348

Habboush Y and Guzman N (2024). Antibiotic resistance. StatPearls. Treasure Island (FL), StatPearls Publishing. Available at: https://www.ncbi.nlm.nih.gov/books/NBK513277/

Hambolu SE, Dzikwi AA, Kwaga JKP, Kazeem HM, Umoh JU, and Hambolu DA (2014). Dog ecology and population studies in Lagos State, Nigeria. Global Journal of Health Science, 6(2): 209-220. DOI: https://www.doi.org/10.5539/gjhs.v6n2p209

Hardefeldt LY, Selinger J, Stevenson MA, Gilkerson JR, Crabb H, Billman JH, Thursky K, Beiley KE, Awad M, and Browning GF (2018). Population wide assessment of antimicrobial use in dogs and cats using a novel data source - A cohort study using pet insurance data. Veterinary Microbiology, 225: 34-39. DOI: https://www.doi.org/ 10.1016/j.vetmic.2018.09.010

Hoelzer K, Bielke L, Blake DP, Cox E, Cutting SM, Devriend B, Erlacher-Vindel E, Goossens E, Karaca K, Lemiere S et al. (2018). Vaccines as alternatives to antibiotics for food producing animals. Part 1: Challenges and needs. Veterinary Research, 49(1): 64. DOI: https://www.doi.org/10.1186/s13567-018-0560-8

Hughes LA, Williams N, Clegg P, Callaby R, Nuttall T, Coyne K, Pinchbeck G, and Dawson S (2012). Cross-sectional survey of antimicrobial prescribing patterns in UK small animal veterinary practice. Preventive Veterinary Medicine, 104: 309-316. DOI: https://www.doi.org/10.1016/j.prevetmed.2011.12.003

Hur BA, Hardefeldt LY, Verspoor KM, Baldwin T, and Gilkerson JR (2020). Describing the antimicrobial usage patterns of companion animal veterinary practices; Free text analysis of more than 4.4 million consultation records. PLoS ONE, 15: e0230049. DOI: https://www.doi.org/10.1371/journal. pone. 0230049

Jacob ME, Hoppin JA, Steers N, Davis JL, Davidson G, Hansen B, Lunn KF, Murphy KM, and Papich MG (2015). Opinions of clinical veterinarians at a US veterinary teaching hospital regarding antimicrobial use and antimicrobial-resistant infections. Journal of American Veterinary Medical Association, 247: 938-944. DOI: https://www.doi.org/10.2460/javma.247.8.938

Jolaoso AO, Agbaje M, Awoyomi O, Onoja B, and Ojo OE (2024). Awareness of antimicrobial resistance and antimicrobial drugs prescription pattern in small animal clinical practice in Ogun State, Nigeria. Nigerian Veterinary Journal, 45(1): 17-27. DOI: https://www.doi.org/10.4314/nvj.v45i1.2

Joosten P, Ceccarelli D, Odent E, Sarrazin S, Graveland H, Gompel LV, Battisti A, Caprioli A, Franco A, Jaap A et al. (2020). Antimicrobial usage and resistance in companion animals: A cross-sectional study in three European countries. Antibiotics, 9(2): 87. DOI: https://www.doi.org/10.3390/antibiotics9020087

Krause KM, Serio AW, Kane TR, and Connolly LE (2016). Aminoglycosides: An overview. Cold Spring Harbor Perspectives in Medicine, 6(6): a027029. DOI: https://www.doi.org/10.1101/cshperspect. a027029

Kwaghe AV, Okomah D, Okoli I, Kachalla MG, Aligana M, Alabi O, and Mshelbwala GM (2019). Estimation of dog population in Nasarawa state Nigeria: A pilot study. Pan African Medical Journal, 34: 25. DOI: https://www.doi.org/10.11604/pamj.2019.34.25.16755

Li Y, Fernández R, Durán I, Molina-López RA, and Darwich L (2021). Antimicrobial resistance in bacteria isolated from cats and dogs from the Iberian Peninsula. Frontiers in Microbiology, 11: 621597. DOI: https://www.doi.org/10.3389/fmicb.2020.621597

Livorsi D, Comer A, Matthias MS, Perencevich EN, and Bair MJ (2015). Factors influencing antibiotic-prescribing decisions among inpatient physicians: A qualitative investigation. Infectious Control and Hospital Epidemiology, 36: 1065-1072. DOI: https://www.doi.org/10.1017/ice.2015.136

Lum EPM, Page K, Whitty JA, Doust J, and Graves N (2018). Antibiotic prescribing in primary healthcare: Dominant factors and trade-offs in decision-making. Infectious Diseases and Health, 23: 74-86. DOI: https://www.doi.org/10.1016/j.idh.2017.12.002

Maillard JY, Bloomfield SF, Courvalin P, Essack SY, Gandra S, Gerba CP, Rubino JR, and Scott EA (2020). Reducing antibiotic prescribing and addressing the global problem of antibiotic resistance by targeted hygiene in the home and everyday life settings: A position paper. American Journal of Infection Control, 48(9): 1090-1099. DOI: https://www.doi.org/10.1016/j.ajic.2020.04.011

Mao S, Soputhy C, Lay S, Jacobs J, Ku GM, Chau D, Chhea C, and Ir P (2023). The barriers and facilitators of implementing a national laboratory-based AMR surveillance system in Cambodia: Key informants' perspectives and assessments of microbiology laboratories. Frontiers in Public Health, 11: 1332423. DOI: https://www.doi.org/10.3389/fpubh.2023.1332423

Mateus ADC, Brodbelt N, Barber KDC, and Stärk A (2011). Antimicrobial usage in dogs and cats in first opinion veterinary practices in the UK. Journal of Small Animal Practice, 52(10): 515-521. DOI: https://www.doi.org/10.1111/j.1748-5827.2011.01098.x

Moirongo RM, Aglanu LM, Lamshöft M, Adero BO, Yator S, Anyona S, May J, Lorenz E, and Eibach D (2022). Laboratory-based surveillance of antimicrobial resistance in regions of Kenya: An assessment of capacities, practices, and barriers by means of multi-facility survey. Frontiers in Public Health, 10: 1003178. DOI: https://www.doi.org/10.3389/fpubh.2022.1003178

Morel CM, de Kraker MEA, Harbarth S, and Enhanced surveillance expert consensus group (CANSORT-SCI) (2021). Surveillance of resistance to new antibiotics in an era of limited treatment options. Frontiers in Medicine, 8: 652638. DOI: https://www.doi.org/10.3389/fmed.2021.652638

Odoi A, Samuels R, Carter CN, and Smith J (2021). Antibiotic prescription practices and opinions regarding antimicrobial resistance among veterinarians in Kentucky, USA. PLoS ONE, 16(4): e0249653. DOI: https://www.doi.org/10.1371/journal. pone.0249653

Papich MG (2020). Antimicrobial use and resistance in small animal practice: A review. Veterinary Medicine: Research and Reports, 11: 271-288. DOI: https://www.doi.org/10.2147/VMRR.S257386

Pokharel S, Shrestha P, and Adhikari B (2020). Antimicrobial use in food animals and human health: Time to implement 'One Health' approach. Antimicrobial Resistance and Infection Control, 9: 181. DOI: https://www.doi.org/10.1186/s13756-020-00847-x

Pomba C, Rantala M, Greko C, Baptiste KE, Catry B, van Duijkeren E, Mateus A, Moreno MA, Pyörälä S, Ružauskas M et al. (2017). Public health risk of antimicrobial resistance transfer from companion animals. Journal of Antimicrobial Chemotherapy, 72(4): 957-968. DOI: https://www.doi.org/10.1093/jac/dkw481

Prestinaci F, Pezzotti P, and Pantosti A (2015). Antimicrobial resistance: A global multifaceted phenomenon. Pathogens and Global Health, 109(7): 309-318. DOI: https://www.doi.org/10.1179/2047773215Y.0000000030

Rodríguez-Rojas A, Rodríguez-Beltrán J, Couce A, and Blázquez J (2013). Antibiotics and antibiotic resistance: A bitter fight against evolution. International Journal of Medical Microbiology, 303: 293-297. DOI: https://www.doi.org/10.1016/j.ijmm.2013.02.004

Samuels R, Qekwana DN, Oguttu JW, and Odoi A (2021). Antibiotic prescription practices and attitudes towards the use of antimicrobials among veterinarians in the City of Tshwane, South Africa. Peer Journal, 9: e10144. DOI: https://www.doi.org/10.7717/peerj.10144

Schnepf A, Kramer S, Wagels R, Volk HA, and Kreienbrock L (2021). Evaluation of antimicrobial usage in dogs and cats at a veterinary teaching hospital in Germany in 2017 and 2018. Frontiers in Veterinary Science, 8: 689018. DOI: https://www.doi.org/10.3389/fvets.2021.689018

Sharma D, Patel RP, Zaidi STR, Sarker MMR, Lean QY, and Ming LC (2017). Interplay of the quality of ciprofloxacin and antibiotic resistance in developing countries. Frontiers in Pharmacology, 8: 546. DOI: https://www.doi.org/10.3389/fphar.2017.00546

Skajaa N, Gehrt L, Nieminen H, Laake I, Englund H, Sönksen UW, Feiring B, Benn CS, Trogstad L, Palmu AA et al. (2022). Trends in antibiotic use in Danish, Finnish, Norwegian and Swedish children. Clinical Epidemiology, 14: 937-947. DOI: https://www.doi.org/10.2147/CLEP.S362262

Smoglica C, Vergara A, Angelucci S, Festino AR, Antonucci A, Moschetti L, Farooq M, Marsilio F, and Di Francesco CE (2022). Resistance patterns, mcr-4 and OXA-48 genes, and virulence factors of *Escherichia coli* from apennine chamois living in sympatry with domestic species, Italy. Animals, 12: 129. DOI: https://www.doi.org/10.3390/ ani12020129

Sobkowich KE, Weese JS, Poljak Z, Plum A, Szlosek D, and Bernardo TM (2023). Epidemiology of companion animal AMR in the United States of America: Filling a gap in the one health approach. Frontiers in Public Health, 11: 1161950. DOI: https://www.doi.org/10.3389/fpubh.2023.1161950

Thomson KH, Rantala MHJ, Viita-Aho TK, Vainio OM, and Kaartinen LA (2009). Condition-based use of antimicrobials in cats in Finland: results from two surveys. Journal of Feline Medicine and Surgery, 11: 462-466. DOI: https://www.doi.org/10.1016/j.jfms.2008.10.005

Thrushfield M (2005). Veterinary epidemiology, 2nd Edition. Blackwell Science., Oxford, pp. 117-198. Available at https://www.scirp.org/reference/ReferencesPapers?ReferenceID=606318

Van Cleven A, Sarrazin S, de Rooster H, Paepe D, Van der Meeren S, and Dewulf J (2018). Antimicrobial prescribing behavior in dogs and cats by Belgian veterinarians. Veterinary Record, 182: 324. DOI: https://www.doi.org/10.1136/vr.104316

Watson AD and Maddison JE (2001). Systemic antibacterial drug use in dogs in Australia. Australian Veterinary Journal, 79: 740-746. DOI: https://www.doi.org/10.1111/j.1751-0813.2001.tb10888.x

Wayne A, McCarthy R, and Lindenmayer J (2011). Therapeutic antibiotic use patterns in dogs: Observations from a veterinary teaching hospital. Journal of Small Animal Practice, 52: 310-318. DOI: https://www.doi.org/10.1111/j.1748-5827.2011.01072. x

World health organization (WHO) (2021). AWaRe classification .WHO access, watch, reserve, classification of antibiotics for evaluation and monitoring of use. World health organization, Geneva. Available at: https://www.who.int/publications/i/item/2021-aware-classification

World health organization (WHO) (2023a). Antimicrobial resistance diagnostic initiative: Strengthening bacteriology and mycology diagnostic capacity, laboratory systems and service delivery. Licence: CC BY-NC-SA 3.0 IGO. Available at: https://iris.who.int/bitstream/handle/10665/377962/9789240072015-eng.pdf

World health organization (WHO) (2023b). Antimicrobial resistance. Available at: https://www.who.int/health-topics/antimicrobial-resistance

World organization for animal health (WOAH) (2024). Annual report on antimicrobial agents intended for use in animals. Available at: https://www.woah.org/app/uploads/2024/05/woah-amu-report-2024-final.pdf

World medical association declaration of Helsinki (WMADH) (2013). Ethical principles for medical research involving human subjects. Journal of the American Medical Association, 310(20): 2191-2194. DOI: https://www.doi.org/10.1001/jama.2013.281053

Zanichelli V, Sharland M, Cappello B, Moja L, Getahun H, Pessoa-Silva C, Sati H, van Weezenbeek C, Balkhy H, Simão M et al. (2023). The WHO AWaRe (access, watch, reserve) antibiotic book and prevention of antimicrobial resistance. Bulletin World Health Organization, 101(4): 290-296. DOI: https://www.doi.org/10.2471/BLT.22.288614