



ANTIMICROBIAL USE PRESCRIPTION GUIDELINES FOR VETERINARIANS IN PAKISTAN



Foreword

Antimicrobial resistance (AMR) is a global health issue and is considered a silent pandemic because of the emergence, transmission, and persistence of multidrug resistance (MDR) microbes across animals, humans, and the environment. The irrational use of antibiotics in human and veterinary medicine is one of the major factors for accelerated drug resistance at an extremely high rate. There is a need for collaborative efforts toward the containment of AMR by monitoring, surveillance, disease diagnostics, diagnostic harmonization and above all rationalizing the treatment of diseased animals in the field.

The basic principle for the treatment of animals is carefully defining the patient's problem (the diagnosis), followed by specifying the therapeutic objectives and choosing a treatment of proven efficacy and safety from different alternatives. For the execution of this principle in the field condition, continuous education of veterinarian practitioners is highly important. Ministry of National Food Security and Research (MoNFS&R) conducted the Knowledge, Attitude and Practices (KAP) surveys of field veterinarians for the first time in Pakistan which identified the need for the development of local veterinary prescription guidelines for antibiotics in the animal health sector.

Also, according to Pakistan National Action Plan for AMR 2017-22, it is the responsibility of MoNFS&R to ensure the prudent use of antimicrobials in the veterinary sector of Pakistan. Different countries have developed their drug prescription guidelines for reducing the use of antibiotics in conditions where not needed. Therefore, MoNFS&R through the support of Fleming Fund Country Grant Pakistan has developed these guidelines for use of antibiotics in food animals for veterinarians in Pakistan. These guidelines would help veterinarians to use antibiotics prudently in food animals which are essential for the control of AMR. We are committed to developing evidence-based policies and programs for the containment of AMR in the animal health sector for the welfare of animals as well as humans.

Dr Muhammad Akram

Animal Husbandry Commissioner

Ministry of National Food Security and Research

Government of Pakistan

Message from Team Lead, Fleming Fund Country Grant Pakistan (DAI)

The overuse or misuse of antibiotics is considered the most important factor responsible for the emergence of antimicrobial resistance (AMR). AMR is not only an important public health concern but is also a threat to the Sustainable Development Goals especially related to poverty, hunger and health. The emergence and spread of drug-resistant pathogens that have acquired new resistance mechanisms, leading to antimicrobial resistance, continue to threaten our ability to treat common infections. Moreover, during the COVID-19 pandemic, the injudicious use of antimicrobial agents for both prophylactic and treatment purposes has substantially increased. This is expected to have a compounding effect on increasing resistance to critical drugs that are in common use. Therefore, to save the world from another global crisis we must adopt a collaborative and innovative approach of One-Health to find the solution to this complex issue.

The animal health sector is an important pillar of the One-Health approach. Therefore, it is essential to define and integrate the role of the animal health sector in One Health to understand the role of the animal health sector in the emergence and transmission of AMR. The Fleming Fund, a UK-Aid funded program, is committed to continuing the crucial work on AMR and has provided support for establishing the “National Surveillance Strategy for Antimicrobial Resistance in Healthy Food Animals” in Pakistan. The Fleming Fund also supported Pakistan in setting up AMR reference laboratories at the National Institute of Health, the National Veterinary Laboratories (NVL) and the National Reference Laboratory for Poultry Diseases (NRLPD) through refurbishments, equipment, and consumable support. In addition, support was provided for staff capacity development on basic and advanced microbiology techniques for reference lab staff.

To bridge the data gaps that were identified as a result of the engagements, the Fleming Fund Country Grant Pakistan provided the support to Government of Pakistan to develop the ‘Antimicrobial Use Prescription Guidelines for Veterinarians in Pakistan’. These guidelines may help in rationalizing the use of antibiotics in conditions where these are not required and thus may help in tackling AMR. In Pakistan, no specific guidelines are available for use of antibiotics in animals for veterinarians. Therefore, these guidelines are developed for use of antibiotics in food animals for veterinarians.

I would like to appreciate the MoNFS&R team and the provincial livestock departments for their continuous support in this exercise.

Dr Qadeer Ahsan
Team Lead
Fleming Fund Country Grant Pakistan
DAI Private Limited
Islamabad, Pakistan

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Collaborating Partners

The Ministry of National Food Security and Research, Animal Husbandry Commissioner Office, National Veterinary Laboratories, National Reference Laboratory for Poultry Diseases, Animal Health Program, Provincial Livestock and Dairy Development Departments, the Fleming Fund Country Grant – Pakistan.

Lead Authors

Dr Hamid Irshad (Principal Scientific Officer, Animal Health Program, Animal Sciences Institute, National Agricultural Research Centre, Islamabad, Pakistan)

Dr Muhammad Usman Zaheer (Animal Health Surveillance Specialist, Fleming Fund Country Grant – Pakistan, Islamabad, Pakistan)

Dr Javaria Alam (Health Promotion Specialist, Health Security Partners, Fleming Fund Country Grant- Pakistan, Islamabad, Pakistan)

Dr Mo Salman (Professor of Infectious Animal Diseases and Veterinary Preventive Medicine, Animal Population Health Institute, Colorado State University, USA)

Editors

Dr Muhammad Akram (Animal Husbandry Commissioner, Ministry of National Food Security and Research, Government of Pakistan, Islamabad, Pakistan)

Dr Riasat Wasee Ullah (Assistant Animal Husbandry Commissioner, Ministry of National Food Security and Research, Government of Pakistan, Islamabad, Pakistan)

Dr Khursheed Ahmed (Director General, National Veterinary Laboratories, Islamabad, Pakistan)

Dr Muhammad Afzal (FMD Management Specialist, Food and Agriculture Organization of the United Nation, Country Office, Islamabad, Pakistan)

Dr Khalid Naeem (One Health Expert, Ex-Deputy Director General, National Agricultural Research Centre, Islamabad, Pakistan)

Dr Muhammad Abubakar (Senior Scientific Officer, National Veterinary Laboratory, Islamabad, Pakistan)

Dr Muhammad Athar Abbas (Senior Scientific Officer, National Reference Laboratory for Poultry Diseases, Animal Sciences Institute, National Agriculture Research Center, Islamabad, Pakistan)

Dr Usman Talib Gill (Consultant, Fleming Fund Country Grant – Pakistan, DAI, Islamabad, Pakistan)

Dr Sami Ullah Khan Bahadur (Consultant, Health Security Partners, Fleming Fund Country Grant- Pakistan, Islamabad, Pakistan)

Dr Muhammad Farooq Tahir (Animal Health Specialist, Fleming Fund Country Grant – Pakistan, Islamabad, Pakistan)

Fardad Baig (Program Officer, Health Security Partners, Fleming Fund Country Grant- Pakistan, Islamabad, Pakistan)

Alle Taylor (Senior Program Manager, Health Security Partners, USA)

Cover Design

Rafia Rajput (Communications Specialist, Fleming Fund Country Grant, DAI, Islamabad, Pakistan)

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List of Acronyms

AHC	Animal Husbandry Commissioner
AMR	Antimicrobial Resistance
AMU	Antimicrobial Use
CDC	Centers for Disease Control and Prevention
DRAP	Drug Regulatory Authority of Pakistan
FAO	Food and Agriculture Organization of the United Nations
GAP	Global Action Plan
L&DD	Livestock and Dairy Development Department
MoNFS&R	Ministry of National Food Security & Research
MDR	Multidrug resistance
NAP	National Action Plan
NARC	National Agricultural Research Center
NIH	National Institute of Health
NVL	National Veterinary Laboratory
NRLPD	National Reference Laboratory for Poultry Diseases
WOAH	World Organization for Animal Health
PARC	Pakistan Agricultural Research Council
WHA	World Health Assembly
WHO	World Health Organization
WOAH	World Organization for Animal Health

Background

Antimicrobial resistance (AMR) is considered an important public health concern due to the emergence, transmission and persistence of superbugs or multidrug resistance (MDR) microbes across animals, humans and the environment. It has been estimated that antimicrobial-resistant bacterial infections were responsible for the death of 1.27 million humans in 2019¹ and this number is expected to increase to 10 million lives each year by 2050.² AMR is also a potential threat to almost all sustainable development goals (SDGs) especially those are focused on poverty, hunger, health and economic growth.^{3,4} Antimicrobials are used in animals especially food animals for therapeutic purposes (prevention, control and treatment) and non-therapeutic purposes (as growth promoters).

To meet the growing demand for meat for the growing global population, production of meat may increase from 200 million tons to 470 million tons in 2050.⁵ It is likely that farmers may depend more on antimicrobials for the treatment and control of livestock diseases. Several human cases of AMR have been linked to AMR microbes originating from livestock.^{2, 3} Consumption of contaminated meat or direct contact with infected animals or the environment are considered important ways of transmission of AMR bacteria from livestock to humans.²

The recent data suggests a reduction in the use of antimicrobials by 27% took place from 2016 to 2018.⁶ This can be attributed to the strong collaborative AMR control efforts which have been initiated by the World Health Organization (WHO), Food and Agriculture Organization (FAO), World Organization for Animal Health (WOAH) and United Nations Environment Programme (UNEP) utilizing a One-Health approach to handle this issue.^{7,8} Addressing AMR, requires a more coordinated and multifaceted approach. If global action plans to combat the AMR issue are not adopted and implemented in near future then there might be serious medical, social and economic consequences worldwide due to the emerging AMR threat.

AMR Control Efforts in Pakistan

Recently Pakistan has developed AMR National Strategic Framework in accordance with the WHO-AMR Global Action Plan. Pakistan has also established AMR National Action Plan (NAP) as a commitment to World Health Assembly (WHA) resolution 68.7 utilizing a comprehensive One-Health approach to tackle the AMR problem in Pakistan. Pakistan's AMR NAP emphasizes the phasing out of the use of antibiotics as growth promoters in food-producing animals, effective disease control strategies using biosafety and vaccination and the establishment of an AMR surveillance system to reduce the level of AMR in food-

¹Chaudhry S, 2022. India's AMR burden has reached alarming proportions. Available from: <http://bwhealthcareworld.businessworld.in/article/India-s-AMR-Burden-Has-Reached-Alarming-Proportions-Saransh-Chaudhary-/23-06-2022-433804/>.

²Tackling drug-resistant infections globally: final report and recommendations. London: The Review on Antimicrobial Resistance; 2016. Available from: https://amr-review.org/sites/default/files/160525_Final%20paper_with%20cover.pdf.

³Paphitou NI, 2013. Antimicrobial resistance: action to combat the rising microbial challenges. *Int J Antimicrob Agents*, 42 Suppl: S25–28.

⁴Mamun M, Hassan J, Nazir K, Islam A, Zesmin K, Rahman B, 2017. Prevalence and molecular detection of quinolone-resistant *E. coli* in rectal swab of apparently healthy cattle in Bangladesh. *Int J Trop Dis Health*, 24:1–7.

⁵2050: A third more mouths to feed. Rome: Food and Agriculture Organization of the United Nations; 2009. Available from: <http://www.fao.org/news/story/en/item/35571/icode/>

⁶Use of antimicrobials in animals trends downwards: World Organization for Animal Health; 2022. Available from: <https://www.thepigsite.com/news/2022/06/use-of-antimicrobials-in-animals-trends-downwards-woah-report>

⁷Sirijatuphat R, Sripanidkulchai K, Boonyasiri A, et al., 2018. Implementation of global antimicrobial resistance surveillance system (GLASS) in patients with bacteremia. *PLoS One*, 13(1): e0190132.

⁸Belay ED, Kile JC, Hall AJ, et al., 2017. Zoonotic disease programs for enhancing global health security. *Emerg Infect Dis*, 23(13).

producing animals in Pakistan. All the AMR-related activities in the animal health sector are led by the Animal Husbandry Commissioner Office, Pakistan.

Under the Fleming Fund Country Grant on AMR, a National AMR surveillance strategy for healthy and diseased food animals has been established and two National Reference laboratories i.e., National Reference Laboratory for Poultry Diseases (NRLPD) and National Veterinary Laboratory (NVL) and nine peripheral laboratories have been identified and subsequently assessed for their AMR-related capacity for AMR monitoring and surveillance in the animal health sector. The purpose of this report is present guidelines on the use and application of antibiotics by animal health practitioners in food-producing animals of Pakistan.

Rationale

Pakistan has a population of 78.2 million goats, 31.2 million sheep, 49.6 million cattle and 41.2 million buffaloes. Pakistan is one of the top 10 livestock-producing countries. Livestock plays a significant role in the socioeconomic development of the country. In the year 2020-21 livestock sector contributed 11.5% of GDP to the national economy.⁹ Livestock sector employs 30 million people, especially in rural areas.¹⁰ The increasing demand for livestock due to urbanization, increase in population and export opportunities leads to the increasing trend of intensive farming in Pakistan. Therefore, farmers are extensively using antibiotics in food-producing animals (FPAs) as growth promoters and for treatment and prophylaxis purposes.

The livestock sector is, therefore, considered an important source of the emergence of AMR in low- and middle-income countries including Pakistan. Livestock especially poultry, the animals of whole flock or pens are given antimicrobials through feed and water for the treatment of infections.¹¹ In addition, the use of antimicrobials as growth promoters for long duration and at low dosage provides suitable conditions for the emergence and spread of AMR bacteria.¹² FPAs, therefore, play a significant role in the transmission of AMR bacteria and antimicrobial resistance genes (ARGs) into the surrounding environment through faeces and urine. Animal waste is also used as organic fertilizer for soil and ponds which also helps in the transmission of AMR bacteria and ARGs into the environment.

The National Action Plan on AMR emphasizes the prudent use of antibiotics in human and veterinary sectors to tackle the issue of AMR. The prudent or responsible use of antibiotics means using antibiotics only when required and in minimum quantity. To make sure that antibiotics are used judiciously different countries have developed guidelines for use of antibiotics in animals for veterinarians. The use of these guidelines may help in reducing the use of antibiotics in conditions where these are not required and thus may help in tackling AMR. In Pakistan, no specific guidelines are available for use of antibiotics in animals for veterinarians. Therefore, it is of great significance to develop guidelines for use of antibiotics in food animals for veterinarians. These guidelines would help veterinarians in Pakistan to use antibiotics prudently in food animals and thus reducing AMR. To support this activity, a consultant was onboarded in April 2022 to conduct activities like desk review, facilitate a consultative meeting with relevant

⁹Govt. of Pakistan, 2021. Economic Survey of Pakistan. Finance Division, Economic Advisor's Wing, Islamabad.

¹⁰Rehman A, L Jingdong, A A Chandio and I Hussain, 2017. Livestock production and population census in Pakistan: Determining their relationship with agricultural GDP using econometric analysis. *Info Process in Agric* 4(2): 168-177.

¹¹Rousham EK, Unicomb L, Islam MA, 2018. Human, animal and environmental contributors to antibiotic resistance in low-resource settings: integrating behavioural, epidemiological and One Health approaches. *Proc Biol Sci*, 285: 1-9.

¹²World Health Organization, 2004. Joint. FAO/OIE/WHO expert workshop on non-human antimicrobial usage and antimicrobial resistance: scientific assessment: Geneva, December 1-5, 2003.

stakeholders, develop holistic antimicrobial prescription guidelines and support the design and dissemination of the guidelines. **(Annexe – I)**

The 5R's rule

This document relies on the principle of the 5 R's, i.e., reduction, refinement, replacement, Responsibility, and review.

- Reduction:
 - Reduction means minimizing the use of antimicrobials by reducing the occurrence of diseases in the animals through proper husbandry practices, vaccination and early diagnosis. Reduction in diseases in animals means a reduction in the need to use antibiotics.
- Refinement:
 - Refinement means that existing therapeutic practices and prescription guidelines should be continuously evaluated and refined based on the outcome of treatment in comparison with the desired outcome. This can also be done through clinical trials and a review of local AMR data.
- Replacement:
 - Replacement means the use of alternative treatment if available. However, alternatives to those should only be used if there is scientific and peer-reviewed evidence that alternatives are at least equally or more effective than the current conventional ones. In addition, alternatives should be assessed in terms of the health and welfare of the animals.
- Responsibility:
 - Everyone responsible for prescribing antibiotics and treatment of animals should make sure that the advantage of their application outweighs the risks attached to their use. This can be achieved through proper training of veterinarians, para-veterinary staff and farmers so that they understand the principles of prudent use of antibiotics.
- Review:
 - The guidelines for the prudent use of antibiotics should be reviewed from time to time (at least once a year) to incorporate the latest available information. This would help in achieving the objective of keeping AMR at a minimum level without compromising the health and welfare of animals.

General Guidelines for Veterinarians for Prudent Use of Antibiotics in Food Animals

Through a consultative process, the following general guidelines have been developed to equip veterinary professionals with the information needed for the prudent and rational use of antimicrobials in food-producing animals.

- The basic responsibility of veterinarians should be to assist farmers/clients in making efforts so that animals remain healthy. This can be done through proper immunization, management and nutritional programs.
- Therapy alternatives to antibiotics (supportive care e.g., electrolyte therapy and symptomatic care e.g., anti-inflammatory treatment) should be used to avoid the use of antibiotics.
- Veterinarians should prescribe antibiotics only when required.
- Veterinarians should be able to distinguish between bacterial, viral, parasitic and fungal infections and non-infectious or nutritional deficiency diseases. Efforts must be made to diagnose the disease using the laboratory and antibiotics should be prescribed, preferably, after antimicrobial susceptibility testing (AST).
- Veterinarians should use history, clinical signs, previous experience, lab results, and AST results to choose antibiotics.
- Veterinarians should prescribe and dispense antibiotics only within the confines of a valid veterinary-client-patient relationship (VCPR).
- Veterinarians should minimize the use of therapeutic antimicrobials by treating only for an appropriate duration and they should prescribe the correct or required dose of antibiotic to treat the animals. The use of antimicrobials in chronic, nonresponsive clinical cases should be discouraged.
- Veterinarians should continuously educate themselves about the use of various antibiotics, combining antibiotics, their side effects, pharmacological information and withdrawal periods etc. They can get this information through consulting package insert information and participating in continuous education programs relating to AMR and AMU.
- Veterinarians should minimize the risk of environmental contamination with antibiotics e.g., in the case of oral administration of antibiotics through water or feed by making sure that drinkers or feeders are properly adjusted to avoid spillage and waste. In the case of medicated feed, make sure that proper steps are taken to avoid cross-contamination of medicated and non-medicated feed.
- Veterinarians should encourage farmers to keep records of treatments/antibiotics used and the outcome of treatment. The information would help in evaluating the effectiveness of treatment, ensuring that treatment was used on the correct animal or group of animals and compliance with withdrawal periods.
- Veterinarians should not recommend the use of critically important antimicrobials (CIAs) for prophylaxis purposes through feed and water.
- In case of disease, the veterinarian should avoid the use of antibiotics in the entire herd or flock. If possible, sick animals should be isolated from healthy animals and treated.
- Before choosing antibiotic, necessary information such as type of animal, cause and nature of infection and availability of different antibiotics must be taken into consideration.
- A narrow-spectrum antibiotic should be the first choice unless the available epidemiological data indicate its ineffectiveness.

- To avoid unnecessary use of antibiotics, their use should be reassessed on regular basis.
- Aseptic surgical techniques should be adopted to avoid the use of antibiotics.
- The outcome of treatment should be noted to determine the effectiveness of antibiotics (if antibiotics do not work in a particular condition, they should not be reused in that condition).
- Many antibiotics are used in humans and animals to treat infections. Some of these antibiotics are considered critical for the treatment of life-threatening infections in humans. While using such antibiotics extra care should be taken to avoid the development of AMR and keep them efficacious. In this situation, the veterinarian should assess the cases based on clinical signs, antimicrobial susceptibility testing and relevant epidemiological information. Veterinarians should strongly justify using critically important antibiotics and record them.

Categorization of Veterinary Importance of Antimicrobials

The WOA used the following criteria for the categorization of veterinary antimicrobials.

- **Criterion 1.** The response rate to the questionnaire regarding Veterinary Important Antimicrobial Agents
 - This criterion was met when a majority of the respondents (more than 50%) identified the importance of the antimicrobial class in their response to the questionnaire.
- **Criterion 2.** Treatment of serious animal diseases and availability of alternative antimicrobial agents
 - This criterion was met when compounds within the class were identified as essential against specific infections and there was a lack of sufficient therapeutic alternatives.

Based on these criteria, antibiotics of veterinary significance can be divided into three categories:

Veterinary Critically Important Antimicrobial Agents (VCIA): The antibiotics which meet both criteria 1 and criteria 2.

Veterinary Highly Important Antimicrobial Agents (VHIA): The antibiotics which meet either criteria 1 or criteria 2.

Veterinary Important Antimicrobial Agents (VIA): The antibiotics that neither meet criteria 1 nor criteria 2.

Some antibiotics are considered to be critically important both for humans and animals e.g., Fluoroquinolones and the third and fourth generation of Cephalosporins. In 2016 Colistin has been added to the WHO category of Highest Priority Critically Important Antimicrobials. Therefore, Fluoroquinolones, the third and fourth generation of Cephalosporins and Colistin should be used in accordance with the following recommendations:

- Not to be used as a preventive treatment applied by feed or water in the absence of clinical signs in the animal(s) to be treated
- Not to be used as a first-line treatment unless justified, when used as a second-line treatment, it should ideally be based on the results of bacteriological tests
- Extra-label/off-label use should be limited and reserved for instances where no alternatives are available. Such use should agree with the national legislation in force

- Urgently prohibit their use as growth promoters.¹³

The list of antibiotics according to WOAHA categorization is given in Annexure 1.

Antimicrobials Currently in Use for Major Infectious Diseases of Food Animals

Based on the feedback of practising field veterinarians, the following list of antimicrobials is compiled (Table 1). These antimicrobials are currently used in food animals for therapeutic purposes.

Bacterial pathogen/disease	Antibiotic Used for Treatment
Poultry	
Avian pathogenic <i>Escherichia coli</i> (Extra-intestinal colibacillosis)	Gentamycin, Fosfomycin, Ceftiofur Sodium, Ampicillin, Florfenicol, Flumiquine, Norfloxacin, Enrofloxacin, Amoxicycline, Doxycycline, Furazolidone, Colistin
Salmonella Gallinarum (Fowl typhoid)	Ceftiofur sodium, Ampicillin, Florfenicol, Ciprofloxacin
Salmonella Pullorum (Fowl typhoid)	Flumiquine, Norfloxacin, Enrofloxacin, Amoxicycline, Doxycycline, Colistin, Furazolidone
<i>Pasteurella multocida</i> (Fowl Cholera)	Chlortetracycline, Enrofloxacin, Sulfachloropyridazine, Trimethoprim, Ceftiofur sodium

Table 1. Currently Used Antimicrobials in Poultry.¹⁴

List of potentially selected diseases of large ruminants that can be treated by specifically identified antibiotics

Bacterial pathogen/disease	Antibiotic used for treatment
<i>Staphylococcus aureus</i> (mastitis)	Ampicillin, Amoxicillin, Oxytetracycline, Tribriassin, Enrofloxacin, Norfloxacin, Gentamicin
<i>Pasteurella multocida</i> (Hemorrhagic septicemia)	Ceftiofur sodium, Tylosin, Sulphadimidine, Tribriessen, Florfenicol, Oxytetracycline,
<i>Clostridium chauvoei</i> (Black quarter)	Penicillin, Streptomycin, Amoxicilline

Table 2. Currently Used Antimicrobials in Large Ruminants

Way Forward

The following are the next steps for this specific activity:

¹³ OIE, 2019. OIE list of antimicrobial agents of veterinary importance (July 2019)

¹⁴ Note: The above list of antibiotics was generated with consultation of stockholder meeting and reflect neither the manufacturer nor the animal health authorities. This suggested list requires regular monitoring of the government authority for any additional information about their application.

- These guidelines will be designed and disseminated to stakeholders in November 2022.
- A communications package will be developed based on key recommendations for veterinary professionals and disseminated in March 2023.

Annexe – I: STTA Recruitment

Activity	Task	Deliverable
1.4.3	Develop a plan of action with timelines, including desk review.	Inception report
	Facilitate consultative meeting with relevant stakeholders.	Meeting minutes
	Develop holistic antimicrobial prescription guidelines for food animals.	Draft and final guidelines report
	Support design and dissemination of guidelines to relevant stakeholders.	Memo on dissemination

Figure 1. STTA ToRs for Antimicrobial Prescription Guidelines in Food Animals

Annexe – II: Categorization of Veterinary Important Antibiotics for Food-Producing Animals

ANTIMICROBIAL AGENTS(CLASS, SUB-CLASS, SUBSTANCE)	SPECIES	Specific comments	VCIA	VHIA	VIA
AMINOCOUMARIN Novobiocin	BOV, CAP, OVI, PIS	Novobiocin is used in the local treatment of mastitis and in septicaemias in fish This class is currently only used in animals			X
AMINOCYCLITOL Spectinomycin	AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI	Used for respiratory infections in cattle and enteric infections in multiple species	X		
AMINOGLYCOSIDES Dihydrostreptomycin Streptomycin	AVI, BOV, CAP, EQU, LEP, OVI, SUI API, AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI	The wide range of applications and the nature of the diseases treated make aminoglycosides extremely important for veterinary medicine. Aminoglycosides are of importance in septicaemias; digestive, respiratory and urinary diseases. Gentamicin is indicated for <i>Pseudomonas aeruginosa</i> infections with few alternatives. Apramycin and Fortimycin are currently only used in animals. Few economic alternatives are available.	X		
AMINOGLYCOSIDES + 2 DEOXYSTREPTAMINE Amikacin Apramycin Fortimycin Framycetin Gentamicin Kanamycin Neomycin Paromomycin Tobramycin	EQU AVI, BOV, LEP, OVI, SUI AVI, BOV, LEP, OVI, SUI BOV, CAP, OVI AVI, BOV, CAM, CAP, EQU, LEP, OVI, SUI AVI, BOV, EQU, PIS, SUI API, AVI, BOV, CAP, EQU, LEP, OVI, SUI AVI, BOV, CAP, OVI, LEP, SUI EQU				
AMPHENICOLS Florfenicol Thiamphenicol	AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI AVI, BOV, CAP, OVI, PIS, SUI	The wide range of applications and the nature of the diseases treated make phenicols extremely important for veterinary medicine. This class is of particular importance in treating some fish diseases, in which there are currently no or very few treatment alternatives. This class also represents a useful alternative in respiratory infections of cattle, swine and poultry. This class, florfenicol, is used to treat pasteurellosis in cattle and pigs.	X		
ANSAMYCIN – RIFAMYCINS Rifampicin Rifaximin	EQU BOV, CAP, EQU, LEP, OVI, SUI	This antimicrobial class is authorised only in a few countries and with a very limited number of indications (mastitis) and few alternatives. Rifampicin is essential in the treatment of <i>Rhodococcus equi</i> infections in foals. However, it is only available in a few countries, resulting in an overall classification of VHIA.			X

ARSENICAL					
Nitarsonsone	AVI, SUI	Arsenicals are used to control intestinal parasitic coccidiosis. (<i>Eimeria</i> spp.).			X
Roxarsone	AVI, SUI				
BICYCLOMYCIN					
Bicozamycin	AVI, BOV, PIS, SUI	Bicyclomycin is listed for digestive and respiratory diseases in cattle and septicaemias in fish.			X
CEPHALOSPORINS					
CEPHALOSPORINS FIRST GENERATION		Cephalosporins are used in the treatment of septicemias, respiratory infections, and mastitis.			
Cefacetrile	BOV				
Cefalexin	BOV, CAP, EQU, OVI, SUI				
Cefalonium	BOV, CAP, OVI				
Cefalotin	EQU				
Cefapryrin	BOV				
Cefazolin	BOV, CAP, OVI				
CEPHALOSPORINS SECOND GENERATION					
Cefuroxime	BOV				
CEPHALOSPORINS THIRD GENERATION		The wide range of applications and the nature of the diseases treated make cephalosporin third and fourth generation extremely important for veterinary medicine.			
Cefoperazone	BOV, CAP, OVI				
Ceftiofur	AVI, BOV, CAP, EQU, LEP, OVI, SUI				
Ceftriaxone	AVI, BOV, OVI, SUI				
CEPHALOSPORINS FOURTH GENERATION		Cephalosporins are used in the treatment of septicemias, respiratory infections, and mastitis. Alternatives are limited in efficacy through either inadequate spectrum or presence of antimicrobial resistance.		X	
Cefquinome	BOV, CAP, EQU, LEP, OVI, SUI				
FUSIDANE					
Fusidic acid	BOV, EQU	Fusidic acid is used in the treatment of ophthalmic diseases in cattle and horses.			X
IONOPHORES					
Lasalocid	AVI, BOV, LEP, OVI	Ionophores are essential for animal health because they are used to control intestinal parasitic coccidiosis (<i>Eimeria</i> spp.) where there are few or no alternatives available. Ionophores are critically important in poultry. <u>This class is currently only used in animals.</u>			
Maduramycin	AVI				
Monensin	API, AVI, BOV, CAP				
Narasin	AVI, BOV				
Salinomycin	AVI, LEP, BOV, SUI				
Semduramicin	AVI				
LINCOSAMIDES					
Lincomycin	API, AVI, BOV, CAP, OVI, PIS, SUI	Lincosamides are essential in the treatment of Mycoplasmal pneumonia, infectious arthritis and hemorrhagic enteritis of pigs.			
Pirlimycin	BOV, SUI, AVI				
MACROLIDES					
MACROLIDES 14-MEMBERED RING		The wide range of applications and the nature of the diseases treated make macrolides extremely important for veterinary medicine.			
Erythromycin	API, AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI				
Oleandomycin	BOV				
MACROLIDES 15-MEMBERED RING		Macrolides are used to treat Mycoplasma infections in pigs and			

Gamithromycin	BOV	<p>poultry, haemorrhagic digestive disease in pigs (<i>Lawsonia intracellularis</i>) and liver abscesses(<i>Fusobacterium necrophorum</i>) in cattle, where they have very few alternatives.</p> <p>This class is also used for respiratory infections in cattle</p>	X		
Tulathromycin	BOV, SUI				
MACROLIDES 16-MEMBERED RING					
Carbomycin	AVI				
Josamycin	AVI, PIS, SUI				
Kitasamycin	AVI, SUI, PIS				
Mirosamycin	API, AVI, SUI, PIS				
Spiramycin	AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI				
Terdecamycin	AVI, SUI				
Tildipirosin	BOV, SUI				
Tilmicosin	AVI, BOV, CAP, LEP, OVI, SUI				
Tylosin	API, AVI, BOV, CAP, LEP, OVI, SUI				
Tylvalosin	AVI, SUI				
MACROLIDES C17					
Sedecamycin	SUI				
ORTHOSOMYCINS		<p>Avilamycin is used for enteric diseases of poultry, swine and rabbit.</p> <p>This class is currently only used in animals.</p>			X
Avilamycin	AVI, LEP, SUI				
PENICILLINS		<p>Penethamate (hydroiodide) is currently only used in animals</p> <p>The wide range of applications and the nature of the diseases treated make penicillins extremely important for veterinary medicine.</p> <p>This class is used in the treatment of septicaemias, respiratory and urinary tract infections.</p> <p>This class is very important in the treatment of many diseases in a broad range of animal species.</p> <p>Few economical alternatives are</p>	X		
NATURAL PENICILLINS (Including esters and salts)					
Benethamine penicillin	BOV				
Benzylpenicillin	AVI, BOV, CAM, CAP, EQU, LEP, OVI, SUI				
Benzylpenicillin procaine / Benzathine penicillin	BOV, CAM, CAP, EQU, OVI, SUI				
Penethamate (hydroiodide)	BOV				
AMIDINOPENICILLINS					
Mecillinam	BOV, SUI				
AMINOPENICILLINS					
Amoxicillin	AVI, BOV, CAP, EQU, OVI, PIS, SUI				
Ampicillin	AVI, BOV, CAP, EQU, OVI, PIS, SUI				
Hetacillin	BOV				
AMINOPENICILLIN + BETALACTAMASE INHIBITOR					
Amoxicillin + Clavulanic Acid	AVI, BOV, CAP, EQU, OVI, SUI				
Ampicillin + Sulbactam	AVI, BOV, SUI				
CARBOXYPENICILLINS					
Ticarcillin	EQU				
Tobicillin	PIS				
UREIDOPENICILLIN					
Aspoxicillin	BOV, SUI				
PHENOXYPENICILLINS					
Phenethicillin	EQU				

Phenoxymethylpenicillin	AVI, SUI	available.			
ANTISTAPHYLOCOCCAL PENICILLINS					
Cloxacillin	BOV, CAP, EQU, OVI, SUI				
Dicloxacillin	BOV, CAP, OVI, AVI, SUI				
Nafcillin	BOV, CAP, OVI				
Oxacillin	BOV, CAP, EQU, OVI, AVI, SUI				
PHOSPHONIC ACID DERIVATIVES					
Fosfomycin	AVI, BOV, PIS, SUI	Fosfomycin is essential for the treatment of some fish infections with few alternatives however it is only available in a few countries, resulting in an overall classification of VHIA.		X	
PLEUROMUTILINS					
Tiamulin	AVI, CAP, LEP, OVI, SUI	The class of pleuromutilins is essential against respiratory infections in pigs and poultry.			
Valnemulin	AVI, SUI	This class is also essential against swine dysentery (<i>Brachyspira hyodysenteriae</i>) however it is only available in a few countries, resulting in an overall classification of VHIA.		X	
POLYPEPTIDES					
Bacitracin	AVI, BOV, LEP, SUI, OVI	Bacitracin is used in the treatment of necrotic enteritis in poultry.			
Enramycin	AVI, SUI				
Gramicidin	EQU				
POLYMYXINS					
Polymixin B	BOV, CAP, EQU, LEP, OVI, AVI	This class is used in the treatment of septicaemias, colibacillosis, salmonellosis, and urinary infections.		X	
Polymixin E (colistin)	AVI, BOV, CAP, EQU, LEP, OVI, SUI	Polymixin E (colistin) is used against Gram negative enteric infections.			
QUINOLONES					
QUINOLONES FIRST GENERATION					
Flumequin	AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI	Quinolones of the 1st generations are used in the treatment of septicaemias and infections such as colibacillosis.		X	
Miloxacin	PIS				
Nalidixic acid	BOV				
Oxolinic acid	AVI, BOV, LEP, PIS, SUI, OVI				
QUINOLONES SECOND GENERATION (FLUOROQUINOLONES)					
Ciprofloxacin	AVI, BOV, SUI	The wide range of applications and the nature of the diseases treated make fluoroquinolones extremely important for veterinary medicine.		X	
Danofloxacin	AVI, BOV, CAP, LEP, OVI, SUI				
Difloxacin	AVI, BOV, LEP, SUI				
Enrofloxacin	AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI				
Marbofloxacin	AVI, BOV, EQU, LEP, SUI	Fluoroquinolones are critically important in the treatment of septicaemias, respiratory and enteric diseases.			
Norfloxacin	AVI, BOV, CAP, LEP, OVI, SUI				
Ofloxacin	AVI, SUI				
Orbifloxacin	BOV, SUI				
Sarafloxacin	PIS				
QUINOXALINES					
Carbadox	SUI	Quinoxalines (carbadox) is used for digestive disease of pigs (e.g., swine dysentery).			
Olaquinox	SUI	This class is currently only used in animals.			X

<p>SULFONAMIDES</p> <p>Phthalylsulfathiazole Sulfacetamide Sulfachlorpyridazine Sulfadiazine Sulfadimethoxazole Sulfadimethoxine Sulfadimidine (Sulfamethazine, Sulfadimerazin) Sulfadoxine Sulfafurazole Sulfaguanidine Sulfamerazine Sulfamethoxine Sulfamonomethoxine Sulfanilamide Sulfapyridine Sulfaquinoxaline</p>	<p>SUI AVI, BOV, OVI AVI, BOV, SUI AVI, BOV, CAP, OVI, SUI AVI, BOV, SUI AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI AVI, BOV, CAP, EQU, LEP, OVI, SUI BOV, EQU, OVI, SUI BOV, PIS AVI, CAP, OVI AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI AVI, PIS, SUI AVI, PIS, SUI AVI, BOV, CAP, OVI BOV, SUI AVI, BOV, CAP, LEP, OVI</p>	<p>The wide range of applications and the nature of the diseases treated make sulfonamides extremely important for veterinary medicine.</p> <p>These classes alone or in combination are critically important in the treatment of a wide range of diseases (bacterial, coccidial and protozoal infections) in a wide range of animal species.</p>	X		
<p>SULFONAMIDES+ DIAMINOPYRIMIDINES</p> <p>Ormetoprim+ Sulfadimethoxine Sulfamethoxy pyridazine Trimethoprim+ Sulfonamide</p>	<p>PIS AVI, BOV, EQU, SUI AVI, BOV, CAP, EQU, LEP, OVI, PIS, SUI</p>				
<p>DIAMINOPYRIMIDINES</p> <p>Baquiloprim Ormetoprim Trimethoprim</p>	<p>BOV, SUI AVI AVI, BOV, CAP, EQU, LEP, OVI, SUI</p>				
<p>STREPTOGRAMINS</p> <p>Virginiamycin</p>	<p>AVI, BOV, OVI, SUI</p>	<p>Virginiamycin is an important antimicrobial in the prevention of necrotic enteritis (<i>Clostridium perfringens</i>)</p>			X
<p>TETRACYCLINES</p> <p>Chlortetracycline Doxycycline Oxytetracycline Tetracycline</p>	<p>AVI, BOV, CAP, EQU, LEP, OVI, SUI AVI, BOV, CAM, CAP, EQU, LEP, OVI, PIS, SUI API, AVI, BOV, CAM, CAP, EQU, LEP, OVI, PIS, SUI API, AVI, BOV, CAM, CAP, EQU, LEP, OVI, PIS, SUI</p>	<p>The wide range of applications and the nature of the diseases treated make tetracyclines extremely important for veterinary medicine</p> <p>This class is critically important in the treatment of many bacterial and chlamydial diseases in a wide range of animal species.</p> <p>This class is also critically important in the treatment of animals against heartwater (<i>Ehrlichia ruminantium</i>) and anaplasmosis (<i>Anaplasma marginale</i>) due to the lack of antimicrobial alternatives.</p>	X		
<p>THIOSTREPTON</p> <p>Nosiheptide</p>	<p>AVI, SUI</p>	<p>This class is currently used in the treatment of some dermatological conditions.</p>			X

Table 3. Veterinary Important Antibiotics for Food-Producing Animals

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