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EMERGING ANTIMICROBIAL RESISTANCE IN COMPANION, FARM ANIMALS AND POULTRY: A VETERINARY CONCERN

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ABSTRACT

Antimicrobial resistance (AMR) development in companion, farm animals and poultry represents a vital worldwide problem because it threatens veterinary medicine alongside public health and threatens food security. Accumulated resistant bacterial strains in both livestock production and pet healthcare are primarily caused by overusing antibiotics thus making traditional antibiotic treatments less effective. The global AMR crisis worsens because zoonotic transmission of resistant pathogens between animals and humans makes the problem more complex. Poultry sector is one of the most intensive livestock sectors and a major reservoir for emergent and dispersal of antimicrobial resistant bacteria. Because of the widespread use of antibiotics in poultry for therapeutic, metaphylactic, prophylactic, and growth promoting purposes, selective pressures have been created which support MDR pathogens. Significant concerns related to zoonotic transmission through food and environmental routes make these resistant strains not only veterinary problems, but also public health risks. This review evaluates the complete set of factors responsible for animal antibiotic resistance through antibiotic distributions for therapeutic measures and disease prevention as well as their use for animal growth promotion. The study provides extensive analysis of the most problematic resistant bacterial species including Escherichia coli and Salmonella spp. Staphylococcus aureus and Enterococcus spp. which investigates their resistance mechanisms through horizontal gene transfer and efflux pumps and enzymatic antibiotic degradation mechanisms. Through scientific review of modern research and policy progress, this paper demonstrates the critical importance of combating AMR in companion and farm animals by implementing sustainable science-backed interventions for preventing pathogen resistance spread.

INTRODUCTION

Antimicrobial resistance (AMR) presents itself as a crucial global health threat that creates problems for both human medicine practitioners and veterinary professionals. The capability of microorganisms to survive and multiply under antimicrobial treatment belongs to the definition of antimicrobial resistance. The main health concern of antimicrobial resistance continues to impact human care yet advances the growing health risk to veterinary medicine as well as animal populations and poultry. Companions, Farm animal and poultry specimens with new resistant bacterial strains create two main dangers: they threaten the health of animals, poultry and the safety of food products which harms public health (Amann *et al.*, 2019).

Animals and poultry develop antimicrobial resistance primarily because of the irresponsible use of antimicrobial medications in veterinary care. Antibiotic treatments given to livestock populations as both preventive medicine and therapeutics and growth enhancers encourage antibiotic resistance development through selective evolutionary pressures (Marston *et al.*, 2016). The regular antibiotic prescriptions given to companion animals and poultry for routine infections directly contribute to developing multidrug-resistant (MDR) pathogens which cause treatment complications. Antibiotic resistance continues to worsen due to several improper antibiotic usage practices which include giving inadequate amounts of medication along with continued treatments beyond medical needs and skipping withdrawal protocols (Moo *et al.*, 2020).

Health authorities consider the transfer of resistant bacteria between animals and humans as an important public health issue. Numerous zoonotic pathogens like *Escherichia coli, Salmonella spp. Staphylococcus aureus, and Enterococcus spp*. Exist among animal populations, poultry stock and transmit human infections through person-to-person contact together with foodborne pathogens and environmental contact (Saharan *et al.*, 2020). A comprehensive approach to fight AMR requires understanding the interconnectedness between human, animal, and environmental health which experts identify as "One Health." The transmission of resistant bacteria from animal and poultry reservoirs to human populations happens primarily through eating meat as well as water contaminations and occupational exposure affecting farmers' veterinarians and those working with pets (Ferraz, 2024).

AMR in animals and poultry produces serious economic effects and threatens environmental well-being. Resistant infections within livestock operations cause three harmful effects: lowered productivity levels and greater veterinary expenses combined with higher mortality statistics. Food production facilities suffer safety problems when resistant bacteria are present because this frequently leads to international trade regulations. Antibiotic residue elimination through animal and poultry waste creates challenges for soil and water ecology because resistant bacteria along with their DNA travel through environmental pathways (Singh *et al.*, 2024). The continued presence of resistance in environmental reservoirs now challenges veterinary professionals in their efforts to handle the AMR problem.

Effective prevention of growing animal and poultry antimicrobial resistance requires the implementation of multiple strategies including standardization rules and monitoring systems along with antibiotic administration management programs and alternative therapy evaluation. Multiple worldwide health bodies led by WHO and accompanied by WOAH and FAO advocate enhanced limitations on animal antibiotic use along with improved antibiotic resistance monitoring methods (World Health Organization, & World Organisation for Animal Health, (2024). Research teams use alternative ways to prevent antibiotic dependency such as probiotics and bacteriophage treatments alongside immune modulators to develop new antimicrobial treatment methods (Li *et al.*, 2024).

This study presents an extensive review of how and what occurs when AMR emerges in animals used for farming and as pets. The article explains resistance mechanisms while investigating antibiotic usage patterns in veterinary clinics as well as analyzing how bacteria spread between animals and humans. This research investigates present-day AMR countermeasures and presents the necessity of teamwork between veterinarians and farmers and policymakers and researchers. The crucial nature of evidence-based solutions for AMR control stands because this trend has extended its adverse effects throughout animal health management and worldwide public health security.

1. Antibiotic Usage Patterns in Poultry

Tetracyclines, macrolides, aminoglycosides, beta-lactams, and fluoroquinolones, are all antibiotics used by commercial poultry farms on a regular basis. Used to manage respiratory diseases (e.g., Mycoplasma gallisepticum), enteric diseases (e.g. Caused by necrosis enteritis Clostridium perfringens), septicemia bacterial (e.g. E. coli), these antibiotics (Sari, 2025). Nevertheless, its routine and usually unregulated use results in the development and selection of resistant strains, especially in broiler operations where herds may turn over rapidly.

As in low and middle income countries where over the counter antibiotic availability is common, prophylactic administration either in feed or water alone exaggerates resistance development (Ojotu et al., 2025). The continuous low-dose exposure fosters subtherapeutic resistance across bacterial populations.

2. Resistant Pathogens in Poultry

Escherichia coli, Salmonella enterica, and Campylobacter jejuni resistant strains are usually isolated from poultry flocks. E. coli isolates in poultry are many ESBL producers and make cephalosporins ineffective (NWANKWO et al., 2025). Ampicillin, tetracycline and nalidixic acid resistance are common in Salmonella spp. and C jejuni is becoming resistant to erythromycin and fluoroquinolones (Ed Dra et al., 2024). In addition to being virulent to birds, these pathogens are a major means of human exposure to AMR via contaminated meat, eggs and environmental waste.

3. Zoonotic Transmission of AMR from Poultry to Humans

AMR in this case mainly comes via the human food chain where AMR transmission from poultry is the most important pathway. Resistant pathogens are introdused in the human gut microbiota with improper meat handling, and consumption of undercooked chicken products (Ferraz, 2024). This transmission is exacerbated by slaughterhouse contamination, cross contamination during processing, poor kitchen hygiene (Zhang et al., 2024). In addition to occupational risks of current MDR strains in poultry farms, there is also importance to study these in the context of One Health (Mekonen et al., 2024).

4. Environmental Dissemination of Resistance

Ordinary organic fertilizer is usually poultry litter, a mixture of bedding material and bird droppings. It is often this litter that contains unmetabolized antibiotics and resistant bacteria that contaminate the environment. Leaching of antibiotic residues and resistance genes into groundwater or transport into local ecosystems through runoff can affect wildlife, companion animals or humans (Singh et al., 2024). Because bla_CTX-M and tetA genes persist in the environment, they can be horizontally transferred by other bacterial communities (Diarra et al., 2024; Saharan et al., 2020).

5. Cross-Species Transfer Between Poultry and Companion Animals

Poultry associated resistant bacteria and mobile genetic elements have recently been identified to be transferable to companion animals and in particular rural or peri urban households in which dogs and cats scavenge poultry litter or consume raw poultry meat. On the other hand, resistant strains of companion animals may spread to poultry either via common environment or human mediated spread (Tokuda & Shintani, 2024; Nocera & Martino, 2024).

The exchange of resistance determinants between animal species has been identified in E. coli strains from both poultry and dogs since plasmids encoding resistance to fluoroquinolones, aminoglycosides, and ESBLs have been demonstrated (Marco-Fuertes et al., 2024). AMR genes have complicated surveillance and require integrated monitoring using the One Health framework, because of this bidirectional flow of AMR genes.

6. Mitigation Strategies in Poultry

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7. Regulatory and Surveillance Gaps

Regions such as EU and USA have had established systems such as ESVAC and NARMS, but there are no consistent monitoring systems in place in poor countries regarding the usage and resistance trends in poultry (World Health Organization & WOAH, 2024). Harmonizing data collection and enforcement of policies that reduce critical antimicrobial use in poultry requires international collaboration.

The Rising Trend of Antimicrobial Resistance in Veterinary Medicine

Antimicrobial resistance (AMR) has grown significantly intentional veterinary medicine creating major health problems for both animals and human populations and food production. Animals have received broad and unplanned applications of antibiotics during both livestock and pet farming operations. The extensive use of antimicrobials in veterinary medicine as intervention, preventive, and growth-enhancing agents selects for bacterial strains that develop resistance against them (Ahmed *et al.*, 2024). Multidrug-resistant (MDR) pathogens are rising at a critical rate because of this leading to more challenging treatments and increased death rates which jointly fuel the worldwide AMR emergency.

The Role of Antibiotic Use in Livestock and Companion Animals

Livestock producers employ antibiotics for active medical treatment of bacterial diseases and for disease prevention as well as to increase animal growth speeds. The deployment of antibiotics for animal growth enhancement purposes draws considerable criticism due to the extended antibiotic delivery method that establishes optimal conditions for bacteria to acquire resistance. The agricultural sector of numerous countries utilizes antimicrobial drugs such as tetracyclines macrolides aminoglycosides and beta-lactams mainly in their poultry farming sector whereas swine and cattle receive similar treatment (Sari, 2025). Excessive drug use among farm animals has led to pathogen resistance which now includes Escherichia coli, Salmonella spp., Staphylococcus aureus, and Clostridium perfringens. These pathogens cause harm to humans through contaminated food products and direct animal contact.

Veterinary professionals commonly utilize antibiotics to treat skin infections along with respiratory infections and urinary system infections in domestic pets. The excessive use of broad-spectrum antimicrobials in veterinary medicine has created conditions that allow resistance to bacterial species like methicillin-resistant Staphylococcus *pseudintermedius* (MRSP), *carbapenem*-resistant *Enterobacteriaceae*, and multidrug-resistant Pseudomonas aeruginosa to emerge. A combination of resistant strains leads to unsuccessful treatment of pets' diseases while creating special health risks for pet handlers and veterinary staff together with the wider community (Wright *et al.,* 2024). The transmission chances between resistance genes increase because of human companion animal interactions thus creating uncertainty about how pets act as AMR pathogen reservoirs.

Notable Resistant Pathogens in Veterinary Medicine

Medical authorities identified numerous bacterial strains that develop high levels of resistance to vital human-use antibiotics within both farm animals and companion animals. Scientists express particular concern regarding methicillin-resistant Staphylococcus aureus (MRSA) since this strain has been discovered in livestock populations as well as pets and professionals who frequently deal with animals (Marco-Fuertes et al., 2024). Animals with MRSA become sick from this infection through severe wounds in their skin and respiratory system as well as deep wounds that need advanced medical treatments.

The veterinary field shows a high prevalence of Extended-Spectrum Beta-Lactamase (ESBL)-producing Enterobacteriaceae strains which mainly infect cattle and poultry populations. Bacteria with resistance enzymes against cephalosporins and penicillins demonstrate high treatment difficulty (Stefanetti et al., 2024). The detection of ESBL-producing Escherichia coli and Klebsiella pneumoniae strains in food-producing animals creates serious risks because these bacteria might transmit from animals to humans through the food supply chain.

Salmonella spp. and Escherichia coli pathogens have developed drug resistance in intensive as well as small-scale farming environments specifically found in poultry and swine populations. The identified pathogens send animals to infection with gastrointestinal diseases while leading directly to dangerous illnesses in humans who consume affected food products (Diarra et al., 2024). The medical treatment of MDR Salmonella cases becomes challenging since patients require final-line antibiotics including fluoroquinolones and carbapenems.

Companion animals show rising occurrences of multidrug-resistant Pseudomonas aeruginosa which affects their otitis externa conditions alongside urinary tract infections and it also causes complications after surgical wounds (Higuera-Ciapara et al., 2024). Healthcare providers face great challenges when treating this pathogen because it demonstrates resistance against beta-lactams aminoglycosides and fluoroquinolones therefore creating effective therapies. Pet owners need to be cautious because vets detected carbapenem-resistant Enterobacteriaceae (CRE) bacteria in their patients which pose risks to human bacterial transmission (Irekeola et al., 2024).

Impact of AMR on Veterinary Medicine and Animal Health

AMR development in veterinary medicine creates multiple challenges for providing proper treatment and management of bacterial infections in animals. The treatment of resistant infections becomes expensive and challenging because medical professionals must use extended treatment options along with various medications and scarce alternative antimicrobial medications (Irekeola *et al.,* 2024). Malpractice in antimicrobial use generates higher rates of death and illness among livestock and pets thus endangering animal welfare in addition to diminishing economic productivity.

In food-producing animals, AMR results in significant economic losses due to decreased productivity, higher veterinary costs, and trade restrictions on animal products. The medical management of infected livestock demands long-term treatment protocols and intensified culling practices as well as strengthened biosecurity protocols that produce elevated operational expenses for farmers. The detection of antibiotics in meat products and dairy and egg commodities leads to public health risks that trigger export bans for the affected regions (Horvat and Kovačević, 2025). Resistant infections that affect companion animals lead to lengthy illness periods and repeated infections which produce inadequate response to treatments. The search for appropriate therapeutic treatments against MDR infections proves difficult for veterinarians since they depend instead on costly medical alternatives that could have toxic side effects (Zhang *et al.,* 2024). The emotional costs and financial expenditures to pet owners demonstrate how AMR affects clinical practices along with emotional welfare.

Zoonotic Risks and Public Health Implications

Veterinary medicine faces a crucial challenge because antibiotic-resistant organisms obtained from animals can affect human wellness. Pathogens from resistant bacteria which arise in animals spread to humans primarily through contact with infected animals or their products as well as contact with antibiotic-resistant genes in environmental materials like soil and water. The detection of zoonotic AMR pathogens including MRSA and ESBL-producing Enterobacteriaceae requires a unified One Health strategy to execute veterinary medical environmental resistance fighting tactics together (Ahmed et al., 2024). Mekonen et al., (2024) demonstrate higher infection acquisition risks exist among farmworkers and veterinarians because of animal contact together with pet owners due to their proximity to animals. Research shows that workers in intensive livestock farms typically carry animal-like strains of Staphylococcus aureus bacterial resistance. Pet owners facing immunocompromise find it easier for MDR bacteria from their pets to cause infections.

The spread of AMR receives additional support from the environmental dispersal of resistant bacteria through animal manure and agricultural runoff as well as wastewater. Veterinary medicines containing antibiotics cause their release into the environment through animal excretion which allows resistance genes to persist in soil and water ecosystems. Resistance genes stored in the environment function as a transmission pathway that infects wildlife and domestic animals as well as human populations.

The expanding problem of AMR in veterinary medicine generates multiple impacts that affect both animal wellness food supply and human health status. Both agricultural animals and domestic pets have propelled antibiotic resistance by continuing antibiotic over-prescription and misuse thus reducing treatment success rates while exposing humans to zoonotic risks (Horvat and Kovačević, 2025). A complete solution to this problem needs multi-faceted commitment between organizations which includes proper antimicrobial stewardship practices better surveillance programs and alternative methods of treatment. The effective control of AMR progresses when veterinary professionals enhance their prescribing methods while the government enforces tighter regulations and society becomes more aware of AMR risks. Together these measures protect animals and humans from AMR's destructive outcomes.

Mechanisms of Antimicrobial Resistance in Animal Pathogens

Antimicrobial resistance (AMR) in animal pathogens develops as animal bacteria adapt genetically and biochemically to survive after receiving antimicrobial medications. Various mechanisms within resistant bacterial strains empower them to counteract antibiotic effects and carry out their cellular functions despite antimicrobial exposure (Belay *et al.,* 2024). The mechanisms enable bacterial survival of individual cells while simultaneously promoting their ability to persist throughout animal populations until they reach human and environmental ecosystems.

Enzymatic Degradation of Antibiotics

Microorganisms acquire resistance through their production of enzymes that disable antibiotics before their effective action on bacteria. Beta-lactamases function as protease enzymes that cut *penicillins cephalosporins* and *carbapenems* antibiotics by breaking their beta-lactam ring and making these medications useless for treatment (Li *et al.,* 2024). Extending beyond standard beta-lactam antibiotics (ESBLs) and *carbapenemases* remain exceptionally worrisome in veterinary medicine since these enzymes provide substantial resistance against a wide range of *penicillins cephalosporins* and *carbapenems* (Luca, 2024).

The food chain faces a severe transmission risk because ESBL-producing Escherichia coli and *Klebsiella pneumoniae* appear repeatedly in livestock and poultry. CRE and *carbapenem*-resistant *Enterobacteriaceae* (CRE) have shown rising incidence within companion animals which elevates the worry about human exposure from direct bacterial transmission (Nayeem *et al.,* 2024). These enzymes produced by bacteria get their ability to replicate through genes located on mobile genetic elements which help quick dissemination throughout bacterial populations.

Alteration of Target Sites

Bacteria neutralize antibiotic effectiveness through structural changes in their strategic targets. The killing action of antimicrobial agents targets different vital bacterial proteins or cellular structural components including bacterial ribosomes (protein synthesis inhibitors) DNA gyrase (quinolone antibiotics) as well as peptidoglycan synthesis enzymes (beta-lactams) (Neri *et al.*, 2022). Bacteria obtain mutations in their target sites and use natural enzymes to change these areas as an effective countermeasure against antibiotics.

The major concern that veterinary medicine faces in MRSA shows how resistance develops. The mecA gene embedded in MRSA leads bacteria to create PBP2a protein that interacts poorly with beta-lactam antibiotics so they endure exposure to methicillin alongside oxacillin and other penicillin families. The same resistance mechanism that affects S. aureus has been identified in Staphylococcus *pseudintermedius* and generates the difficult-to-treat methicillin-resistant Staphylococcus *pseudintermedius* (MRSP) infections in companion animals (Nocera and Martino, 2024).

The QRDR regions of DNA gyrase (gyrA) and topoisomerase IV (parC) in animal pathogens develop mutations that cause resistance to fluoroquinolone antibiotics. Bacterial targets cannot effectively bind fluoroquinolones due to mutations that render these antibiotics ineffective in treating infections within resistant Salmonella spp. and Escherichia coli and Pseudomonas aeruginosa strains in livestock and pets (Rezaei *et al.,* 2024).

Efflux Pump Activation

Membrane transport proteins known as efflux pumps actively remove antibiotics from bacterial cells to prevent their action at their target locations. Efflux pumps help bacteria develop intrinsic resistance and may be passed between different microbial strains through genetic transformations in the bacterial genome or horizontal gene transfer. The main problem with efflux-mediated resistance lies in the fact that it establishes multidrug resistance (MDR) because bacteria develop simultaneous resistance to multiple antibiotic classes (Novelli and Bolla, 2024).

Among the well-known bacterial efflux pump systems exists the resistance-nodulation-division (RND) family which operates in Gram-negative bacteria such as Pseudomonas aeruginosa, Escherichia coli, and Salmonella spp. Bacterial cell pumps successfully eliminate tetracyclines of fluoroquinolones and macrolides from the cells thereby diminishing their antibiotic effectiveness (Zhang *et al.,* 2024).

University veterinarians deal with MDR Pseudomonas aeruginosa infections in dogs and cats which result from increased efflux pump activities rendering these infections unusually hard to treat. Campylobacter which infects poultry relies on efflux pumps to fight against macrolides and fluoroquinolones thus creating difficulties for campylobacteriosis control in human and animal populations. Efflux pumps reduce antibiotic sensitivity and at the same time enable bacteria to survive well in environments containing minimal antibiotic amounts that persist in animal farms and wastewater systems (Ed-Dra *et al.,* 2024).

Biofilm Formation

Biofilms function as a major mechanism that advances antibiotic resistance in veterinary pathogens. A biofilm consists of complex bacterial aggregates that bacteria make into a self-secreted outer matrix to shield themselves from antibiotics and immune responses and environmental stresses. The multiple factors of antibiotic penetration restrictions along with changed metabolic behavior and increased horizontal gene transfer between microbes combine to give bacteria in biofilms much stronger antibiotic resistance abilities than their free-floating (planktonic) populations (Gao *et al.*, 2024).

Medical infections involving biofilms create extensive issues for veterinary care because recurrent and persistent infections prove tough to treat effectively. The antibiotic-resistant form of skin infections and wounds in dogs is attributed to Staphylococcus pseudintermedius which demonstrates strong biofilm production capabilities (NWANKWO *et al.*, 2025). The pathogenic bacterium Pseudomonas aeruginosa develops biofilms to prevent antimicrobial therapy and immune system reactions in pets with otitis externa and urinary tract infections.

Biofilms formed by Salmonella spp. and Listeria monocytogenes on surfaces and equipment from food-producing animals pose elevated hazards for food contamination that leads to outbreaks. Resistant biofilms in slaughterhouses together with dairy processing units require immediate improvement in sanitation practices and alternative antimicrobial approaches to overcome biofilm-associated resistance (Chaves *et al.*, 2024).

Horizontal Gene Transfer (HGT) and Mobile Genetic Elements

Many experts see horizontal gene transfer (HGT) as the primary problematic factor of antimicrobial resistance because it enables bacteria to spread resistance genes within and across species boundaries at high speed. Horizontal gene transfer functions differently than cell division-based vertical gene transfer because bacteria gain resistance genes from unrelated species through three processes: transformation of free DNA and transduction as bacteriophage transport as well as conjugation through plasmid exchange (Tokuda and Shintani, 2024).

Plasmids together with transposons and integrons serve as essential elements to spread resistance genes throughout bacterial communities found in animal reservoir populations. Bacteria developed MDR properties thanks to plasmids because these small, independently replicating DNA molecules transport resistance genes that protect bacteria from multiple antibiotics (Vos *et al.,* 2024). Medical facilities treating animals have documented the spread of plasmids among Enterobacteriaceae including ESBL-producing E. coli and Klebsiella pneumoniae bacteria which exchange resistance genes during conjugative events (Pope, 2024).

The activity of transposons enables the integration of resistance genes into bacterial chromosomes through their jumping ability so the genes become persistent throughout bacterial populations. Several MDR veterinary pathogens like Pseudomonas aeruginosa, Acinetobacter baumannii, and Salmonella spp contain integrons as genetic elements that capture resistance gene cassettes and perform their expression (Saranya *et al.,* 2025). Mobile elements found in bacteria increase their adaptability while speeding up resistance evolution which makes AMR an intricate and changing threat for medical professionals.

Many mechanisms of antimicrobial resistance in veterinary pathogens are complex and highly evolved through enzymologic antibiotic breakdown and target alteration and the use of efflux pumps along with biofilm development and extrachromosomal gene exchange. Bacteria show exceptional capability to transfer resistance genes between various species and environmental areas thus emphasizing the necessity for extensive strategies to combat AMR in veterinary medicine (Kogay *et al.,* 2024). Knowledge about these mechanisms enables the creation of antimicrobial stewardship programs, alternative therapy promotion, and tough biosecurity standards for animal pathogen control in companion animals and food-producing populations. Immediate intervention is essential because AMR development in veterinary pathogens threatens global health in the future thus stressing the importance of One Health approaches in fighting this growing crisis.

Global Regulatory Frameworks and Policies

The rapid increase of antimicrobial resistance (AMR) requires international organizations together with national governments to put in place veterinary medicine antimicrobial control frameworks and policies. Due to the shared connections between human, animal, and environmental wellness a worldwide organized effort must result to stop resistant pathogens from spreading. The World Health Organization (WHO) together with the World Organisation for Animal Health (WOAH) and Food and Agriculture Organization (FAO) have established complete plans to bolster antimicrobial stewardship while banning important antibiotic abuse and enhancing disease-monitoring systems (World Health Organization, & World Organisation for Animal Health, 2024). The national regulatory framework supports global initiatives by developing guidelines that control antibiotic use throughout livestock and companion animals and food production systems.

International Efforts in AMR Regulation

International organizations have created essential policies against antibiotic resistance by developing organized strategic plans while working together at a worldwide scale. Out of its front-running role in fighting antimicrobial resistance, the World Health Organization developed the Global Action Plan on Antimicrobial Resistance in 2015 (Baekkeskov and Pierre, 2024). By focusing on five critical goals this strategy works to raise general knowledge about AMR and improve disease monitoring and research while minimizing pathogen transmission enhancing antibiotic prescriptions and implementing increased support for developing alternative treatments. The WHO has established antimicrobial categorization based on human health needs while requiring nations to regulate the use of "critically important antimicrobials" (CIAs) in animals to maintain their effectiveness in human medicine (Robbins *et al.*, 2024).

Through the World Organisation for Animal Health (WOAH) which used to operate under the name OIE the establishment of critical measures to control AMR in veterinary medicine took place. The organization sets standard procedures for animal antimicrobial use through its international framework while promoting ethical veterinary medicine together with substitute disease prevention methods including vaccinations and better biosecurity and farm management systems (World Health Organization, 2024). Through the Tripartite Alliance, the Food and Agriculture Organization (FAO) works together with WHO and WOAH to conduct research create policies, and launch awareness initiatives about fighting AMR at the worldwide level. The FAO collaborates with farmers together with veterinarians to put into practice recommended techniques regarding antimicrobial usage in food production systems (World Health Organization, 2024).

National Policies and Regulations

Several nations implemented rigorous regulations after following global recommendations to control improper antibiotic use in veterinary care. The worldwide ban against giving antibiotics for livestock growth promotion stands as the leading action to control antibiotic misuse. The European Union (EU) established a ban against antibiotics for farmer animal growth promotion starting from 2006 (Ojotu *et al.*, 2025). In 2017 the United States introduced the Veterinary Feed Directive that demanded veterinary supervision for animal feed medications that contain medically necessary antibiotics. Three global actors China alongside Brazil and India have launched AMR action plans together with restrictions on using CIAs in food-producing animals (Sarkar and Okafor, 2024).

Different countries maintain advanced surveillance systems which track antimicrobial usage patterns and resistances in their populations. The established initiatives serve to monitor new antibiotic-resistant strains and assess policy implementation and develop recommendations for decision-making processes. Notable surveillance programs include:

Country/Region	Surveillance Program	Key Focus
European Union	European Surveillance of Veterinary Antimicrobial Consumption (ESVAC)	Monitors antimicrobial use in food-producing animals across EU countries.
United States	National Antimicrobial Resistance Monitoring System (NARMS)	Tracks antimicrobial resistance in bacteria isolated from food, animals, and humans.
Canada	Canadian Integrated Program for Antimicrobial Resistance Surveillance (CIPARS)	Analyzes AMR trends in livestock, food products, and human clinical cases.
Australia	Australian Surveillance of Antimicrobial Use and Resistance in Animals (AURA)	Monitors antimicrobial resistance and usage in veterinary settings.

China	National Surveillance System for Antimicrobial Resistance in Animals (CHINET)	Focuses on tracking AMR in livestock and aquaculture.

These programs provide critical data that help authorities assess the effectiveness of antimicrobial stewardship efforts and identify areas where intervention is needed.

Challenges in Implementing AMR Regulations

Multiple barriers prevent the worldwide successful execution of antimicrobial resistance policies even though control mechanisms for resisting bacteria development have shown improvement. The main challenge stems from different levels of regulatory implementation, especially among lower and middle-income nations that permit veterinary pharmaceuticals to be dispensed freely. Inadequate monitoring of antibiotic usage results in improper treatment which sustains resistant bacterial strains throughout the animal population (Ferrara *et al.,* 2024).

Farmers and the livestock industry experience substantial economic difficulties because of the present situation. Food producers who have used antibiotics for disease prevention and growth promotion must now invest in various alternative strategies such as better hygiene practices and vaccines along with probiotics because they need to break their reliance on antibiotics (Kumar *et al.,* 2024). Farming communities in particular areas push back against antibiotic restrictions because they believe such measures will decrease their economic performance.

The shortage of surveillance systems across various parts of the world creates barriers to monitoring AMR developments effectively. Several nations struggle to implement proper antimicrobial resistance monitoring systems due to which they find it challenging to understand the extent of veterinary medical drug resistance (Cutrupi *et al.*, 2024). Standardized data collection procedures create substantial barriers to worldwide comparisons of resistance patterns between different parts of the world.

The Role of Veterinary Antibiotic Use in AMR Development

Antibiotics applied at a broad scale in veterinary medicine served as a vital factor that led to the emergence and dissemination of antimicrobial resistance (AMR). Animals need antibiotics to fight bacterial infections, yet their improper and excessive use produces environmental conditions where antibiotic-resistant bacteria succeed (Singh *et al.,* 2024). Antimicrobial resistance emerged as a major public health concern because of over-the-counter antibiotic practices, inappropriate dosing, and the protective use of antimicrobials in intensive farming operations.

Antibiotic addition to animal feed as a growth-promoting agent represents one of the most contentious veterinary medical practices. Commercial livestock producers widely employ this feeding technique because it boosts rapid animal development along with achieving better animal growth with fewer feed needs. Too much continuous exposure to minimal antibiotic doses creates populations of bacteria that survive through natural selection mechanisms yet eliminate susceptible bacteria that cannot withstand the pressure. Bacteria that demonstrate resistance spread throughout animals and transmit into the human population via food supply networks leading to infections. Economic productivity reasons lead low- and middle-income countries to permit antibiotic use for growth promotion even though countries like those in the European Union and the United States prohibit this procedure (Costa *et al.,* 2013).

Developing resistance to antibiotic medications in veterinary medicine primarily occurs because of antibiotic use in both prophylaxis and metaphylaxis strategies. The preventive approach of giving antimicrobials to healthy animals for infection prevention is called prophylactic antibiotic administration while metaphylactic treatment involves giving antibiotics to the whole group of animals based on exposure in a few animals (Callens *et al.,* 2012). The prevention methods for disease outbreaks in dense animal farming operations raise antibiotic resistance probabilities through their expansive use. Mass antibiotic medication permits resistant bacteria to spread more rapidly because it gives antibiotics to both sick and healthy animals.

Unregulated practices together with incorrect medicine distribution serve to worsen the situation. Without medical supervision, many nations give out antibiotics through over-the-counter sales which promote haphazard antibiotic administration. Farmers together with pet owners and livestock producers tend to provide antibiotics without medical diagnosis and correct dosage information which results in inadequate treatment and preserves resistant bacterial colonies (Yarahmadi *et al.,* 2025). Certain veterinarians experience pressure from their clients in addition to agricultural businesses to distribute antibiotics when their use remains unnecessary and this practice perpetuates the problem.

The combat against this resistance requires veterinary medicine to establish stronger regulations along with proper antimicrobial stewardship programs. International organizations and governments must create firm regulations for antibiotic prescription along with retail restrictions and public education programs on anti-microbial best practices. Kindling alternative animal disease prevention practices between veterinarians and farmers through improved hygiene and vaccination together with optimized nutrition would help decrease antibiotic usage in animal farming operations.

Strategies for Combating Antimicrobial Resistance in Animals

A comprehensive solution to combat AMR in veterinary practices includes responsible antibiotic use combined with infection prevention methods and vaccination improvements as well as new treatment options development. These strategies serve to control antimicrobial drug resistance but preserve the health status of animals alongside food security levels.

Prudent antibiotic use stands as a vital solution for fighting AMR. A protocol exists for antibiotic prescription which requires both necessary treatment and proper diagnoses. Doctors of veterinary medicine should conduct bacterial culture and sensitivity testing to pick the appropriate antibiotic treatment which also reduces antimicrobial exposure to animals. The development of antimicrobial stewardship programs in veterinary clinics along with livestock farms will serve to instruct veterinarians and animal caretakers concerning antibiotic overuse hazards and proper medication distribution methods (Powell *et al.,* 2024).

The implementation of infection prevention and control measures represents an efficient method in animal husbandry. Proper farm management serves to decrease disease occurrences because it lowers antibiotic requirements. Proper biosecurity protocols which manage animal movement conduct proper sanitation and establish quarantine requirements for new animals serve to restrict infectious disease spread between farms (Cena-Navarro *et al.,* 2025). Enhanced animal health results from maintaining proper ventilation systems along with clean water distribution and correct waste disposal practices that mitigate bacterial contaminations.

Vaccination plans function as an essential tool to minimize antibiotic use dependency in healthcare. Vaccines serve as a preventive measure that reduces the number of bacterial illnesses which need antimicrobial treatment. Various vaccine types including the *Salmonella* vaccine *E. coli* vaccine and *Pasteurella multocida* vaccine successfully protect poultry and other livestock against typical infections (Chung *et al.,* 2024). Increased vaccine research along with better accessibility to farmers mainly in developing nations could result in substantial decreases in antibiotic usage.

Prospective anti-AMR solutions now focus on the combination of vaccines alongside the emerging utilization of probiotics prebiotics and bacteriophage treatments. The introduction of probiotics together with prebiotics triggers positive changes in animal gut microbiota which enables beneficial bacteria to minimize infections without requiring antibiotics. The specific bacterial pathogen targeting virus-based method known as bacteriophage therapy demonstrates the potential to combat bacterial infections effectively while preventing antibiotic resistance (Ikpe *et al.,* 2024). Through the implementation of precision farming technologies such as sensor-based monitoring systems and artificial intelligence-driven disease detection farms can decrease their usage of antibiotics. Farm systems using detection technologies and optimization tools enable specific responses that diminish the necessity of widespread antibiotic treatment.

Recent Advances in Alternative Therapies and Research

The development of new antimicrobial solutions constitutes innovative work in veterinary medicine as it aims to minimize antibiotic use in traditional veterinary practices. The research field has focused on antimicrobial peptides (AMPs) because these natural antibacterial molecules show great potential for new antimicrobial approaches. Studies demonstrate that AMPs destroy bacterial cell membranes and delay pathogen multiplication which makes them an appropriate substitute for established antibiotic medication (Bellucci *et al.,* 2024). Scientists work on improving synthetic AMPs to increase their stability levels for possible veterinarian applications.

Scientists study essential oils and natural plant components for their potential to serve as antimicrobial substances. Natural herb extracts including oregano together with thyme and garlic contain bioactive compounds which demonstrate antibacterial characteristics toward veterinary pathogens (Grigore-Gurgu *et al.,* 2025). The bactericidal agents derived from plants offer two applications in animal health by using them either as dietary additives or as direct skin treatments to avert bacterial infections.

Drug delivery systems benefit from recent advancements that involve nanotechnology applications. The deployment of nanoparticles enhances antimicrobial agent delivery efficiency while achieving directed dosage delivery that helps decrease drug-related adverse effects. Nanomaterials incorporating silver nanoparticles together with lipid-based carriers exhibit robust antimicrobial potential as potential antibiotic alternatives for veterinary practice.

The CRISPR-Cas9 technology enables targeted errors AMR genes to reverse bacterial population resistance thus showing great potential for reversing antimicrobial resistance. CRISPR-based systems eliminate bacterial resistance genes from genomes which restore antibiotic effectiveness and lessen antibiotic-resistant strain transmission (Lee *et al.,* 2025). Current research shows that this technology promises to become a valuable instrument for AMR control in the future.

The One Health approach combining human with animal and environmental health segments provides essential elements needed to develop sustainable responses for combating AMR. A global plan to prevent and control antimicrobial resistance emerges through One Health initiatives which enable veterinarians to join forces with medical professionals environmental scientists and policymakers.

CONCLUSION

Animal and companion animal antimicrobial resistance constitutes an ongoing veterinary and public health threat that generates broad medical effects involving animal well-being food availability and human medical practice. Excessive use and improper administration of antibiotics in veterinary populations have played a major role in generating bacteria that resist treatment. These resistant pathogens link animal populations to human populations through contacts which include direct interactions and environmental contamination along with food delivery systems which creates a complicated issue requiring fast intervention.

Bacteria develop antibiotic resistance through four primary mechanisms which involve enzymatic degradation as well as target site alteration and three mechanisms: efflux pumps and biofilm formation that reflect bacteria's natural ability to adapt to antibiotic stress. The swift transmission of resistance genes utilizing horizontal gene transfer makes AMR control efforts more difficult so regulatory measures and surveillance programs require reinforcement. The WHO WOAH and FAO together with national governments support programs that both track antimicrobial usage in veterinary medicine and limit the use of critical importance antimicrobial agents. The global fight against antimicrobial resistance faces ongoing obstacles because of irregular regulatory supervision and farm production economics together with limited antimicrobial monitoring abilities.

Medical authorities need to tackle AMR in veterinary fields through an integrated plan involving antimicrobial stewardship together with infection prevention methods vaccination enhancements and alternative medical treatments. Strategic antibiotic stewardship combined with better farm protection systems and new approaches in exact agriculture leads to reduced antimicrobial consumption while maintaining the health and productive state of animals in farming operations. Anti-antimicrobial research investigates the potential of AMPs (Antimicrobial Peptides), bacteriophage treatment, essential plant extracts, nanotechnology drug carriers, and CRISPR-Cas system innovations as antibiotic replacement methods. Developing sustainable AMR mitigation strategies depends critically on the One Health approach which identifies the shared health links between humans and animals and their surroundings.

Global AMR prevention requires active long-term teamwork between veterinarians and farmers together with policymakers and researchers as well as pharmaceutical industry representatives. The battle against antibiotic resistance requires improvements to antibiotic regulations expanded tracking networks and funding for new therapies together with widespread education about antibiotic use responsibility. Multiple coordinated disciplines enable the protection of future antimicrobial effectiveness and support the wellness of human beings alongside animal populations.

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