THE SCIENCE WORLD
A Monthly e Magazine
ISSN:2583-2212
Popular article
August, 2026 Vol.6(8), 2342-2346

The Superbug Challenge in Meat Safety: Antimicrobial Resistance from Farm to Fork

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https://doi.org/10.5281/zenodo.22064577

Abstract

The meat production chain involves several interconnected stages, from animal rearing to processing and consumption, where food safety challenges can emerge. Among the emerging challenges, antimicrobial resistance (AMR) has become a serious global concern affecting humans, animals, and the environment. AMR occurs when bacteria develop the ability to survive medicines that were previously effective against them. Livestock production plays an important role in this issue because food-producing animals can carry resistant bacteria that may enter the food chain during farming, slaughter, processing, and handling. Factors such as inappropriate antibiotic use, intensive farming practices, poor hygiene, and environmental contamination contribute to the spread of resistant microorganisms. Addressing AMR requires a coordinated approach involving human health, animal health, and environmental sectors. Responsible antibiotic use, improved livestock management, food safety practices, and alternatives such as probiotics, prebiotics, and vaccines can help reduce the threat of AMR and protect the effectiveness of antibiotics for future generations.

Keywords: Antimicrobial resistance, meat safety, farm-to-fork, livestock, foodborne pathogens, One Health

Introduction

From farm to fork, meat passes through several stages, including livestock production, slaughter, processing, and handling, where food safety can be influenced. However, antimicrobial resistance (AMR) has emerged as a major concern for public health and animal production.

Antibiotics have greatly improved the treatment of infections in humans and animals and support livestock health. However, their inappropriate use can lead to the development of resistant bacteria, often called “superbugs,” which can spread through animals, food products,

humans, and the environment. Since resistant bacteria from livestock may enter the food chain, controlling AMR is an important part of ensuring meat safety.

What is Antimicrobial Resistance?

Antimicrobial resistance (AMR) occurs when microorganisms, particularly bacteria, survive and multiply despite the presence of antibiotics. Inappropriate antibiotic use eliminates susceptible bacteria while allowing resistant ones to survive and spread. Bacteria can also transfer resistance genes through horizontal gene transfer, aided by genetic elements such as plasmids, leading to the emergence of multidrug-resistant bacteria (Elbehiry & Marzouk, 2025).

AMR and Meat Production: A Farm to Fork Concern

Food-producing animals can carry antimicrobial-resistant bacteria that may enter the food chain and pose risks to public health. Livestock such as cattle, poultry, pigs, sheep, and goats may harbour resistant microorganisms without showing disease symptoms. These bacteria can persist in farm environments and spread through animal-derived foods, making meat safety an important part of AMR control.

Common foodborne bacteria associated with AMR include *Escherichia coli, Salmonella, Campylobacter, Listeria monocytogenes, Staphylococcus aureus, and Enterococcus* species. These organisms may contaminate animals, feed, water, equipment, and farm environments. Antibiotic use can create selective pressure, allowing resistant bacteria to survive and spread through manure, wastewater, soil, and water systems. Intensive farming practices may further increase transmission (Gomes et al., 2026).

During slaughter and processing, contamination can occur through intestinal contents, equipment, workers, or processing environments, emphasizing the need for proper hygiene and sanitation. Consumers can also influence transmission through improper meat handling, cross-contamination, or inadequate cooking. The presence of resistant bacteria and resistance genes in meat products highlights the need for AMR control throughout the farm-to-fork chain (Samtiya et al., 2022).

Factors Contributing to Antimicrobial Resistance

- Inappropriate Use of Antibiotics
- Antibiotic Use in Livestock
- Poor Farm Management and Biosecurity
- Environmental Contamination
- Lack of Awareness and Surveillance

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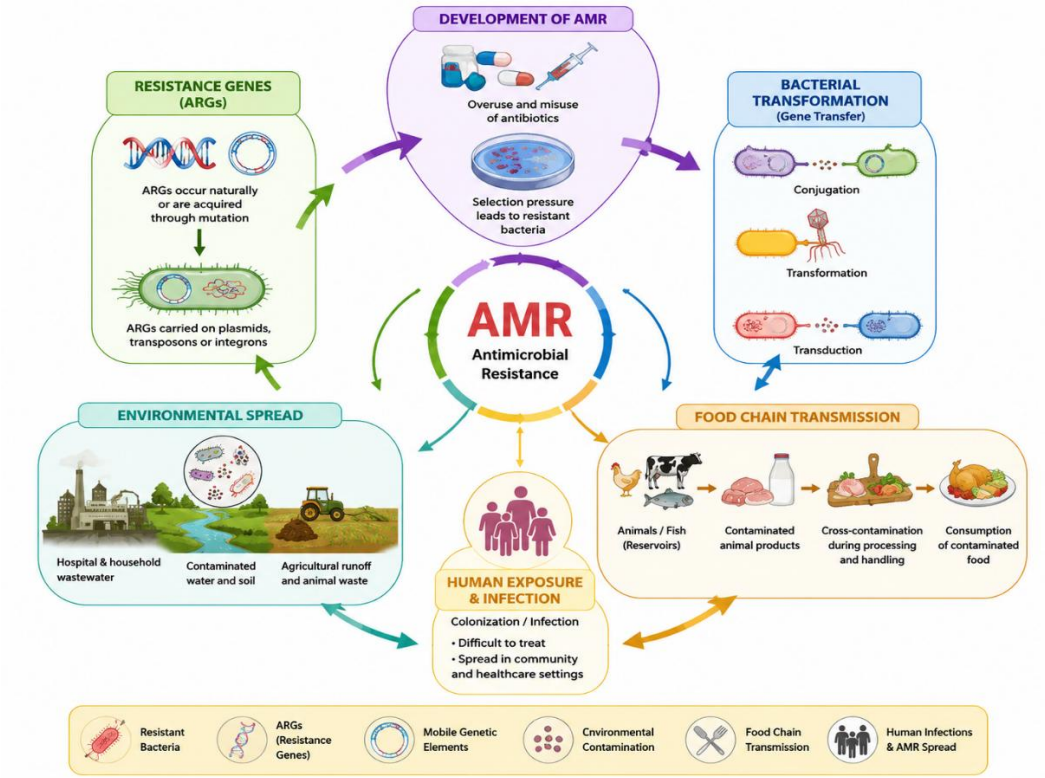

Fig. 1 Graphical representation of the development and spread of AMR

What is the way forward against AMR?

AMR is a complex challenge that requires collaboration across animal, human, food, and environmental sectors. Preventing its spread involves improving animal health, maintaining hygiene, using antibiotics responsibly, and adopting sustainable practices. This integrated strategy, involving farmers, veterinarians, healthcare professionals, researchers, industries, and policymakers, is known as the One Health approach and is central to global AMR control efforts.

What Is One Health?

One Health recognizes the interconnectedness of human, animal, and environmental health. AMR is a key One Health challenge, as resistant bacteria can spread between livestock, humans, food products, and the environment. Effective control therefore requires collaboration across multiple sectors.

Globally, the One Health approach is led by the Quadripartite organizations:

- World Health Organization (WHO)
- Food and Agriculture Organization of the United Nations (FAO)
- World Organisation for Animal Health (WOAH)
- United Nations Environment Programme (UNEP)

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These organizations work together to promote global cooperation, surveillance, and strategies to address AMR (Lautan et al., 2025).

Strategies of One Health to Combat AMR

Antimicrobial Stewardship

Antimicrobial stewardship promotes the responsible use of antibiotics by ensuring that the right antimicrobial is used at the right dose and for the appropriate duration. In veterinary medicine, stewardship helps maintain animal health while preventing unnecessary antibiotic exposure.

Reducing Antibiotic Dependence in Livestock

Healthy animals require fewer antibiotics. Vaccination, improved nutrition, proper housing, hygiene, and strong biosecurity measures can prevent infections and reduce antibiotic dependence. The WHO recommends limiting unnecessary antimicrobial use in animals, especially avoiding routine use for growth promotion and reducing preventive use without proper justification (Ferraz, 2024).

Improving Meat Safety Practices

Good hygiene practices during slaughter, processing, storage, and preparation are essential to prevent the spread of resistant bacteria through meat. Food safety systems and consumer awareness also play important roles in reducing contamination risks.

Alternative Approaches to Reduce AMR

The search for antibiotic alternatives has gained importance due to rising AMR concerns. Probiotics, prebiotics, and synbiotics can support gut health and limit harmful bacteria. Other strategies, including vaccines, bacteriophages, improved nutrition, and better disease prevention practices, can help reduce infections and antibiotic use in livestock production (Moračanin et al., 2025).

Fig 2: Schematic representation of the One Health approach illustrating the interconnected relationship between human, animal, and environmental health

Challenges in Controlling AMR

Despite global efforts, AMR control remains challenging due to differences in regulations, limited surveillance, lack of awareness, and inadequate diagnostic facilities. Effective management requires balancing appropriate antibiotic access with preventing misuse through strong collaboration among stakeholders in animal production, food safety, and public health.

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Conclusion

Antimicrobial resistance is a silent but growing challenge that extends beyond hospitals and into our food systems. The journey from farm to fork highlights the importance of responsible antibiotic use, healthier livestock practices, and safer food handling methods. Controlling AMR requires a collective effort involving farmers, veterinarians, scientists, policymakers, food industries, and consumers. By embracing the One Health approach and promoting responsible antimicrobial use, we can slow the spread of resistant bacteria, strengthen meat safety, and preserve the effectiveness of life-saving antibiotics for future generations.

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