

A Comprehensive Analysis of Antibiotic Resistance in Food Grade Bacteria

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Antimicrobial resistance (AMR) arises from the constant exposure of bacteria to microbial agents. Some microbes through adaptation become able to survive and persist in the presence of antimicrobial agents, which would normally suppress or kill them. The challenging global problem of antimicrobial resistance (AMR) has enormous effects on health worldwide. Even ordinary diseases are getting harder to cure because of rising AMR in widespread bacteria. AMR genes are extensively dispersed in a variety of contexts and serve as a source of resistance-related genes as well as a means of dissemination for AR pathogens, which is one of the main causes of the rapid development of the AMR challenge. However, less is available regarding the source as well as the distribution pattern of these genes. Livestock is regarded as one of the major sources of antimicrobial resistance (AMR), along with to the widespread use of antibiotics in humans. According to reports, humans only eat 30% of antibiotics, whereas animals consume 70% of them. Currently, a number of international organizations are striving to control antibiotic resistance, including the World Health Organization's Global Antimicrobial Resistance Surveillance System. Other institutions, such the CDC and Food and Agriculture Organization, are working hard to combat the issue of antibiotic resistance (Gurieva *et al.*, 2012).

Antimicrobial resistance scenario in India

Recent studies conducted across multiple Indian regions has found residues of antibiotics in food livestock products (such chicken meat and dairy), suggesting that the use of antibiotics is common in the production of food animals (Boeckel *et al.*, 2015). The study conducted by Gandra *et al.* (2016) revealed that *Pseudomonas aeruginosa* had an antibiotic resistance rate of more than 50%, whilst *E. coli* and *Klebsiella pneumonia* had a resistance rate of more than 70% to the wide-spectrum antibiotic fluoroquinolones and third-generation cephalosporin. In 2010, Kumarasamy *et al.* undertook an investigation with the goal of examining Enterobacteriaceae isolates

from two significant Indian centres: Chennai (South India) and Haryana (North India).

Furthermore, a paper evaluated by Dixit *et al.* (2011) revealed that, since their release in 2010, resistance to even novel antimicrobial medicines like carbapenems has been developing across a variety of Gram both positive and negative microorganisms at an alarming rate. By 2050, it's predicted that AMR will cause 2 million fatalities annually in India (Laxminarayan *et al.*, 2012). Furthermore, they found that 70–80% of India's Enterobacteriaceae included ESBLs. All of these research and investigations show how quickly the antimicrobial resistance (AMR) issue is expanding in India and the necessity for various organisations to take decisive action in order to control AMR.

Antimicrobial Resistance in food grade bacteria

One of the primary channels via which antimicrobial resistance spreads from animals to humans is the food chain. Food-grade bacteria primarily helpful organisms that are recognised to play significant roles in the fermentation of food and many of them are also recognised to promote health. One of the significant categories of microorganisms found in vast quantities in both human and animal gastrointestinal tracts is food-grade bacteria. The US FDA has granted them the GRAS (Generally Recognised as Safe) designation because of their extensive history of safe use in fermented products. Globally, FAO/WHO (FAO/WHO, 2002) has sufficiently established the guidelines (including safety and security aspects) for the use of the food-grade bacteria group of bacteria as probiotics. The European Food Safety Authority (EFSA, 2018) has regulated the safety issues associated to the dissemination of antibiotic resistance via the use of food-grade bacteria in food and feed.

As per EFSA the lactobacilli intended for human consumption should be evaluated for their antibiotic resistance to gentamycin, kanamycin, streptomycin, tetracycline, erythromycin,

clindamycin, chloramphenicol, ampicillin and vancomycin. The majority of the earlier reports on AMR in food-grade food-grade bacteria were solely focused on lactobacilli because of their usage in fermented foods and as probiotics for human health. This work on these bacteria was started earlier. Antimicrobial resistance in food-grade bacteria species is currently the subject of numerous investigations. One such study was conducted in 2012 by Thumu and Halami, who identified erythromycin-resistant food-grade bacteria from a variety of Indian food samples. *Leuconostoc mesenteroides*, *P. pentosaceus*, *L. salivarius*, *L. reuteri*, *L. plantarum*, *L. fermentum*, *E. durans*, *E. faecium*, *E. lactis*, and *E. casseliflavus* were the isolates that were detected (Deshmukh *et al.*, 2023). Many fermented food products use *Leuconostoc* spp. as auxiliary cultures to provide aromas.

According to a study by Florez *et al.* (2016), these species also carry resistance characteristics that can be passed on to different species. Virginiamycin, tetracycline, streptomycin, and kanamycin resistance was demonstrated by *Leuconostoc mesenteroides* LbE16. Numerous investigations have provided adequate evidence of the prevalence of AMR in lactococci. The majority of *Lactococcus* species exhibit inherent resistance to gentamicin, trimethoprim, metronidazole, and kanamycin, according to Katla *et al.*'s 2002 study.

Mechanisms of Antibiotic Resistance

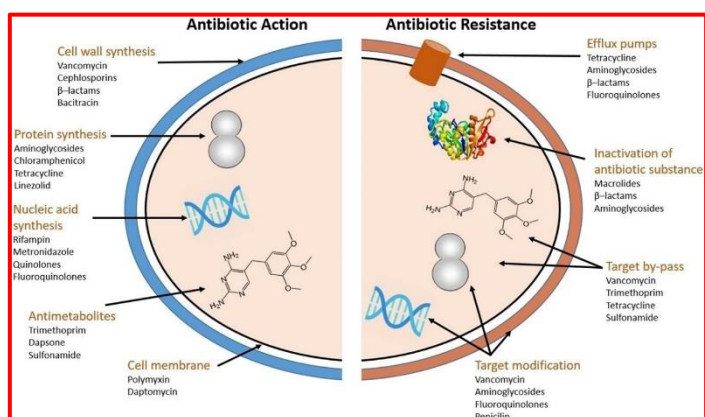


Fig 1. Mechanisms of Antibiotic Resistance in bacteria

Inhibition of Cell Wall Synthesis

Antibiotics like penicillin prevent bacteria from building a strong cell wall. Weakening the cell

wall leads to bacterial cell rupture and death as shown in fig. 1.

Interference with Protein Synthesis

Some antibiotics, such as tetracycline, target bacterial ribosomes. Inhibiting protein synthesis disrupts bacterial growth and replication.

Disruption of Nucleic Acid Synthesis

Certain antibiotics, like quinolones, interfere with bacterial DNA replication and repair. This disrupts bacterial genetic material, hindering reproduction.

Inhibition of Metabolic Pathways

Antibiotics like sulfonamides block specific metabolic pathways in bacteria. Essential processes, such as folic acid synthesis, are disrupted, leading to bacterial death.

Enzymatic Inactivation

Bacteria produce enzymes that modify or destroy antibiotics. Enzymatic inactivation renders antibiotics ineffective against resistant strains.

Alteration of Target Sites

Bacteria may modify target sites (e.g., cell wall or ribosomes) to reduce antibiotic binding. Altered targets prevent antibiotics from disrupting essential cellular processes.

Efflux Pump Activation

Bacteria develop efflux pumps to expel antibiotics from their cells. Pump activation decreases antibiotic concentration within bacterial cells.

Causes of Antibiotic Resistance in Food-grade bacteria

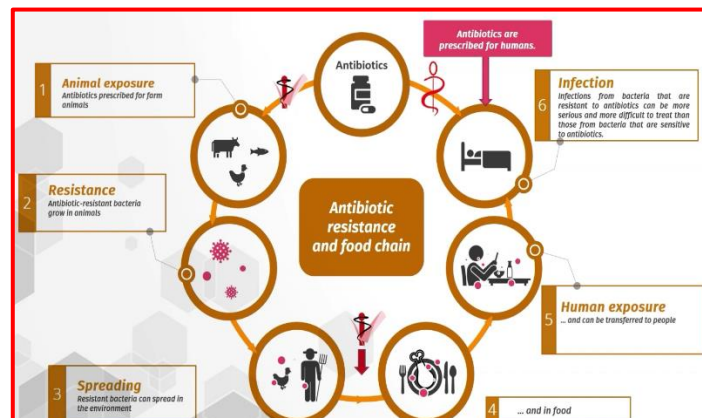


Fig 2. Factors responsible for antibiotic resistance in food chain

Overuse and Misuse of Antibiotics

Excessive use of antibiotics in agriculture for promoting growth or preventing diseases can lead to the development of resistant strains in food-grade bacteria. Inappropriate dosage and duration of antibiotic treatments in both humans and animals contribute to the emergence of resistance, illustrated in fig. 2.

Inadequate Veterinary Practices

Poor management of veterinary antibiotics, including improper prescription practices and lack of adherence to dosage guidelines, can accelerate the development of resistance in bacteria present in food-producing animals.

Horizontal Gene Transfer

Bacteria can transfer genetic material containing antibiotic resistance genes horizontally. This exchange occurs between different bacterial species, potentially spreading resistance among food-grade bacteria.

Cross-Contamination in Food Processing

Inadequate hygiene measures during food processing can result in the transfer of antibiotic-resistant bacteria from contaminated surfaces to the final food product, increasing the risk of antibiotic resistance in the food supply chain.

International Trade and Travel

Global movement of food products can facilitate the spread of antibiotic-resistant bacteria, as resistant strains may be present in food imported from regions with less stringent antibiotic usage regulations.

Environmental Contamination

The release of antibiotic residues into the environment, such as through agricultural runoff or improper disposal of pharmaceutical waste, can contribute to the selection of antibiotic-resistant strains in bacteria.

Incomplete Antibiotic Treatment in Humans

Failure to complete prescribed antibiotic courses in humans may not fully eliminate the targeted bacteria, allowing resistant strains to survive and potentially spread through human contact or the food chain.

Conclusion

In conclusion, the comprehensive analysis of antibiotic resistance in food-grade bacteria sheds light on the critical issue of emerging resistance patterns in these organisms. The study underscores the need for a vigilant and proactive approach to address this growing concern, as antibiotic resistance poses a significant threat to public health. The findings highlight the complex interplay of various factors contributing to resistance, including the use of antibiotics in food production, environmental factors, and the potential transmission of resistant strains to humans through the food chain. Efforts to mitigate antibiotic resistance in food-grade bacteria should be multifaceted, encompassing prudent use of antibiotics in agriculture, enhanced surveillance and monitoring programs, and the development of alternative strategies for disease prevention in food-producing animals. The study underscores the urgency of adopting a One Health approach, recognizing the interconnectedness of human, animal, and environmental health.

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