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Application of the One Health Approach to Reduce Antimicrobial Resistance in Bovine Mastitis

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Abstract

Bovine mastitis continues to be an important issue for the dairy sector, worsened by the increasing threat of antimicrobial resistance (AMR), which threatens animal welfare, public health, and environmental sustainability. This manuscript highlights bovine mastitis, particularly recent developments in diagnostic techniques and use of the One Health approach to address AMR in management of this disease. The One Health framework highlights the interdependence of human, animal, and environmental health, promoting collaboration among veterinarians, farmers, public health officials, and environmental and social scientists to formulate integrated strategies. Presently, mastitis treatment predominantly depends on antimicrobials; however, their widespread use (and abuse) has hastened the rise of resistant bacterial strains, complicating treatment and heightening public health risks through dissemination of antimicrobial residues and resistant pathogens via milk, meat, and environmental pathways. In this review, we emphasize mechanisms of AMR gene transfer and stress the necessity of selective antimicrobial use for clinical mastitis and dry cow therapy, as well as prevention of transmission and enhanced diagnostics. Economic and environmental repercussions of AMR are considerable, requiring coordinated efforts to monitor resistance trends, educate stakeholders, and eliminate non-therapeutic antimicrobial use in livestock. The One Health approach facilitates interdisciplinary collaboration that is crucial for sustainable mastitis control, prevention of zoonotic diseases, and protection of global food security. In summary, integration of advanced diagnostics, responsible antimicrobial stewardship, and the One Health framework is a promising route to alleviate challenges posed by mastitis and AMR. This comprehensive strategy is essential for safeguarding livestock productivity, human health, and environmental integrity, ultimately ensuring resilient and sustainable dairy production systems on a global scale.

Keyword(s): Antimicrobial resistance, Dairy cattle, Mastitis, One Health, Strategies

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Introduction

Despite efforts to prevent and control bovine mastitis, it remains an important challenge. Furthermore, mastitis-causing bacteria are a public health concern regarding transmission from cattle to humans (Naserkheil et al., 2022). The primary route of transmission to humans is most likely the environment, i.e., run-off and the use of cattle excreta to fertilize fields. Transmission via milk or meat is possible but largely eliminated by pasteurization and cooking.

Transmission of pathogens from animals to humans through the environment highlights the importance of the One Health concept, which emphasizes the interconnectedness of human, animal, and environmental health (Collignon, 2012; Manyi-Loh et al., 2016; Dong et al., 2022). Thus, there is a need for novel, innovative, and integrated strategies using a One Health approach to combat antimicrobial resistance (AMR) in mastitis management (Anholt and Barkema, 2021).

The One Health approach recognizes the interconnectedness of human, animal, and environmental health and aims to address health issues through a collaborative, transdisciplinary approach. For bovine mastitis, this would involve collaboration among veterinarians, dairy farmers, public health officials, and social and environmental scientists to develop effective strategies for preventing and treating the disease and minimizing AMR (Robinson et al., 2016). The escalating problem of AMR is exacerbated by widespread antimicrobial use (AMU). Between 2000 and 2015, there was a 65% global increase in consumption of antimicrobials (total of 34.8 billion tons). Globally, 73% of this use was in animals, with many antimicrobials used in both animals and humans, underscoring a vital area of concern (Pires et al., 2024).

The World Health Organization (WHO) has stated that "any successful strategy to combat AMR must include actions that address the animal and environmental reservoirs of resistant microorganisms." AMR is a growing concern in management of bovine mastitis (World Health Organization, 2014; Solomon and Oliver, 2014). Antimicrobial use in the dairy industry has contributed to development of AMR, particularly in low- and middle-income countries. Therefore, novel strategies are being formulated, including selective dry cow therapy and selective treatment of clinical mastitis, to diminish AMU. Alternative therapies, e.g., nanoparticles and bacteriophages, are also being investigated. Improved waste management is essential for reducing environmental dissemination of antimicrobial substances and bacteria, particularly those with genes for AMR. Therefore, a One Health approach is needed to minimize AMU, while ensuring appropriate treatment of mastitis cases. Alternative mastitis prevention and control, precision mastitis management, integrated management, and selective use of antimicrobials are promising strategies to enhance bovine mastitis and reduce AMR (Velazquez-Meza et al., 2022; Pires et al., 2024; Ala'a et al., 2025). Further research and evaluation are needed to optimize their effectiveness and ensure long-term sustainability. This manuscript is an overview of bovine mastitis, advances in mastitis diagnostic methods, and applying a One Health approach to decrease AMR in bovine mastitis.

Impact of Factors Other Than Pathogens on Bovine Mastitis

1. Purpose and Use of Antimicrobials in Managing Bovine Mastitis

Antimicrobials are used to control intramammary infections in lactating and non-lactating cattle (Zduńczyk and Janowski, 2020), accounting for 60–70% of antimicrobial use in dairy cattle (Stevens et al., 2016; Stanek et al., 2024). Ideally, bacterial isolation and antimicrobial sensitivity should be done before treatment. Common antibiotics for bovine mastitis include β-lactams and macrolides, e.g., penicillin G and erythromycin, respectively (Nader-Macías et al., 2011). Antimicrobial functions have five main mechanisms: inhibition of cell wall synthesis, suppression of nucleic acid synthesis, repression of ribosome function, alteration of cell membrane function, and inhibition of folate metabolism (Dowling et al., 2017). As antimicrobial residues have been detected in animal products, including meat and milk, appropriate withdrawal periods should be enforced prior to sale of milk or meat (Paramasivam et al., 2023).

2. Emergence and Threat of AMR

Excessive use of antimicrobials has promoted emergence of AMR. Antimicrobials are used to treat and prevent animal and crop diseases and AMR is an important challenge in management of microbial infections in food production and treatment of human diseases (Kapoor et al., 2017). AMR poses an imminent threat to animal and human health, as bacterial infections are becoming more difficult to manage (Prestinaci et al., 2015). One of the most important consequences of AMR is poor response to standard treatments; it is predicted that >10 million human deaths from bacterial infections alone will occur by 2050 (de Kraker et al., 2016).

3. Mechanisms and Spread of Antimicrobial Resistance Genes (ARGs)

AMR genes (ARGs) are often on plasmids, transposons, and integrons and can be transferred horizontally between bacteria by conjugation, transformation, or transduction. Most ARGs destroy the antibiotic and do not alter the target site (Brüssow et al., 2004; Ibrahim et al., 2019). In some countries, >50% of mastitis pathogens are resistant to at least some antimicrobials, e.g., β-lactams or penicillin (Jamali et al., 2014). Sul1 and sul2 genes are the most

important ARGs in isolates from bovine mastitis (Keane, 2016; Alawneh et al., 2020; Nobrega et al., 2021).

4. Public Health Risks of Antimicrobial Residues in Livestock Products

Livestock products containing antibiotics, especially milk, can cause allergic reactions, alter intestinal microbial composition, and promote emergence of AMR strains in animals and humans (Kassa et al., 1999; Enshaie et al., 2025). As pathogens causing diseases like bovine mastitis have developed AMR, the WHO has published guidelines limiting use of antimicrobials for application in livestock farming (Aidara-Kane et al., 2018). Furthermore, it has been recommended to isolate cattle treated with antimicrobials from other animals and discard their milk (Virdis et al., 2010; Shamila-Syuhada et al., 2016). Additionally, milk should be pasteurized before consumption (World Health Organization, 2020). As dairy farmers and their families are in close contact with their cows and with their pathogens, AMR is a concern for dairy farmers and their families (Werner et al., 2023).

5. Economic and Environmental Challenges of AMR

The impact of AMR is considered an externality, as it is unlikely to affect antimicrobial suppliers or consumers directly, although it can affect livestock and human welfare (Kaier and Frank, 2010). It is difficult to measure the economic burden of AMR (Howard et al., 2001; Reynolds et al., 2014; Naylor et al., 2019; Jit et al., 2020). Governments often underestimate impacts of AMR on environmental, animal, and human health, leading to insufficient investments in investigation and mitigation (Smith et al., 2006). Regardless, measures required for public health and defining strategies to deal with AMR are trivial compared to future economic challenges (Coast et al., 1996; Salam et al., 2023).

6. Strategies to Combat AMR in Livestock

Pharmacists, veterinarians, health professionals, policymakers, producers, and the general public must consider appropriate use of available antimicrobials, as well as production of new antimicrobials, as a potential strategy to address AMR, implemented through several steps.

First, it is essential to identify and produce new antimicrobials; however, that is unlikely, as development costs are very high, and treatments for cancer or neurological disorders are more profitable. Secondly, it is crucial to monitor AMR patterns of bacteria, increase accredited laboratories, and use a nationwide evaluation and control system that records veterinary antibiotic use, resistance, and residues. Thirdly, careful application of established and newly formulated antimicrobials can assist in managing disease, enhancing animal health and boosting productivity. Fourthly, educating producers, veterinarians, and pharmacists regarding the threats of AMR is necessary, and the use of antimicrobials in animals for non-therapeutic purposes should be eliminated, while ensuring adequate prevention and control of livestock diseases. However, appropriate oversight is difficult in most low- and middle-income countries. Reaching an equilibrium, improving disease prevention and controlling, managing current antimicrobials and developing new ones is crucial to reduce AMR and resulting losses (Cooper and Okello, 2021; Paramasivam et al., 2023).

It has been estimated that by 2050, AMR could reduce global gross domestic product (GDP) by up to 4% and global livestock production by up to 7.5% (Jonas et al., 2017). Annual costs linked to AMR and annual loss of productivity worldwide are estimated to be ~ 20 to 35 billion US dollars (Dadgostar, 2019). Risk analysis apart from traditional economic evaluation methods (i.e., cost-benefit, cost-effectiveness, cost-minimization, and cost-utility analyses), can be done to understand impacts of AMR (Opatowski et al., 2021). Risk analysis is beneficial in examining the level of threat to human health associated with AMR derived from agriculture, livestock, and the environment (O'Flaherty et al., 2019). Identifying pathogens causing mastitis and their antimicrobial sensitivity promotes selective use of antimicrobials, reduces spread of contagious pathogens, and informs culling decisions (Hogan et al., 1999). Furthermore, selective dry cow therapy (SDCT) is a viable management option for udder health, milk production, economics, AMU, and AMR, while improving antimicrobial stewardship (McCubbin et al., 2022).

Importance of the One Health Approach to Control Mastitis

1. Global Health Challenges and Emergence of the One Health Approach

Global challenges include eliminating food insecurity, improving global health, and addressing emerging health crises such as AMR. To effectively address the latter, the One Health approach is a critical component of national and global strategies that prioritize the interconnectedness among the three sectors of human, animal, and environmental health (Robinson et al., 2016). Dr. Calvin Schwabe, considered the father of modern epidemiology, used the term “One Medicine,” the precursor to “One Health.” One Medicine/One Health, an integrative approach to solving complex problems impacting health and conservation, reduces foodborne zoonotic disease and is particularly crucial for developing countries (Schwabe, 1969). Zoonotic diseases are transferred from animals to humans and vice-versa, with detrimental effects on humans, animals, and the ecosystem (Mazet et al., 2009). Hence, the human-animal-environment One Health approach to management of livestock can be vital for successful and

sustainable production of livestock and the ability to improve global food security (O'Ryan et al., 2005).

2. Integrating Biomedical Disciplines to Combat Bovine Mastitis and AMR

The One Health approach enables integration and exchange of ideas among researchers and practitioners trained in various disciplines and would be expected to promote rapid progress in interdisciplinary fields related to bovine mastitis. Moreover, from the One Health outlook, mastitis-causing pathogens have crossed some hierarchical barriers, enabling zoonotic transmission from cattle to humans, complicating disease control (Maity and Ambatipudi, 2021). Although milk and meat can transmit resistant bacteria and AMR genes, these are not the primary pathways of transmission in developed countries, since milk is usually pasteurized and meat is typically cooked before consumption. Instead, environmental transmission, particularly through bacteria and AMR genes excreted in feces and urine that contaminate water sources, likely plays a more important role. Therefore, application of the One Health approach is critical to maintaining the complex relationship among animals, humans, and environmental welfare (Maity and Ambatipudi, 2021).

3. The One Health Framework: Collaborative Strategies for Zoonotic Disease Control and Sustainable Livestock Management

One Health has been determined as "a collaborative, multisectoral, and transdisciplinary approach — working at local, regional, national, and global levels — with the goal of achieving optimal health outcomes recognizing interconnections among people, animals, plants, and their shared environment." Professionals in various disciplines need to communicate, collaborate, and coordinate activities in the One Health approach at various levels to control mastitis (CDC, 2022). Also, this approach enables establishment of long-term, sustainable, and diagnostic modalities close to the local level, alerting public health authorities and potentially avoiding a global pandemic (Gibbs, 2014; Cavalerie et al., 2021).

Conclusions

Bovine mastitis continues to pose a substantial challenge, with far-reaching consequences for animal welfare, public health, and environmental sustainability, especially due to escalating AMR. The One Health approach, which recognizes the intricate connections among human, animal, and environmental health, provides a crucial framework for tackling these multifaceted issues through coordinated, multidisciplinary efforts. Using cutting-edge diagnostic technologies, promoting judicious AMU, prevention of transmission of resistant bacteria and AMR genes to humans, and implementing sustainable management practices—alongside strengthened surveillance and comprehensive education—the dairy sector can more effectively manage mastitis while curbing AMR. Ultimately, adopting a One Health perspective is indispensable not only for protecting livestock productivity and safeguarding human health but also for ensuring environmental stewardship and securing global food systems for future generations. Furthermore, it also appears crucial to incorporate AMR and One Health approaches into breeding strategies to achieve optimal mastitis control.

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