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Managing Mastitis in Dairy Cows: Assessing Current Challenges, New Strategies, and Future Prospects for Economic Sustainability and Herd Health

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ABSTRACT

Background/Objective- *Mastitis is considered one of the most costly and common diseases in the dairy cow industry, which, in addition to direct economic losses due to reduced milk production and quality, treatment costs, and premature culling, has profound effects on public health, food security, and animal welfare. It is becoming increasingly apparent that old management tactics need to be reexamined in light of emerging diseases and the worrying rise in antibiotic resistance. The purpose of this systematic review is to provide an in-depth analysis of the issues currently being faced, assess the efficacy of novel solutions, and provide an overview of the future prognosis for the management of mastitis to establish a sustainable dairy farming system.*

Method- *This study used a narrative review approach, with a structured search across databases including PubMed, Scopus, Web of Science, and Google Scholar. Keywords used included "bovine mastitis", "mastitis management", "antimicrobial resistance", "new diagnostic approaches", and "mastitis prevention". Relevant articles published between January 2019 and August 2025 in this field were collected, screened, and qualitative content analyzed based on predefined criteria.*

Results- *Based on the data, the most successful techniques for treating mastitis are those that incorporate diverse, integrated approaches. Milking cleanliness, teat dipping, feeding management, and environmental management are among the preventive methods that continue to form the foundation of illness prevention. In addition, the development of novel diagnostic technologies, such as polymerase chain reaction (PCR), biosensors, and infrared imaging, has enabled the timely and reliable identification of pathogens, even at the subclinical stage. Furthermore, the sensible use of antibiotics guided by culture and antibiogram results, in conjunction with other treatments such as phage therapy, antimicrobial peptides, nanodrug delivery, probiotics, and essential oils, is a potential approach to combat antimicrobial resistance. According to economic studies, the rates of return on investments in preventive programs are much higher than those on treatment expenses.*

Conclusion- *The future of mastitis management in cattle depends on adopting a "prevention-oriented, technological and responsible" paradigm. Combining effective traditional management with rapid diagnostic technologies and alternative treatments will be key to reducing antibiotic dependence, increasing productivity, and ensuring economic and environmental sustainability in dairy herds. Continuous education of farmers and interdisciplinary collaboration between veterinarians, researchers, and industry are also crucial for success in this direction.*

Keywords: *Bovine mastitis, Antimicrobial resistance, Prevention strategies, Economy, Diagnosis*

1. INTRODUCTION

The dairy industry, as one of the main pillars of food security and the global agricultural economy, has always faced numerous challenges [1]. Mastitis, defined as inflammation of the mammary glands, is undoubtedly one of the most fatal and costly health problems in dairy herds [2, 3]. Mastitis is not only a simple health concern for livestock, but also a complex economic, public health, and welfare problem that threatens the foundations of sustainable milk production. The importance of mastitis is such that its mismanagement can lead to the bankruptcy of smallholder farmers and create volatility in the dairy market [4] (Figure 1).

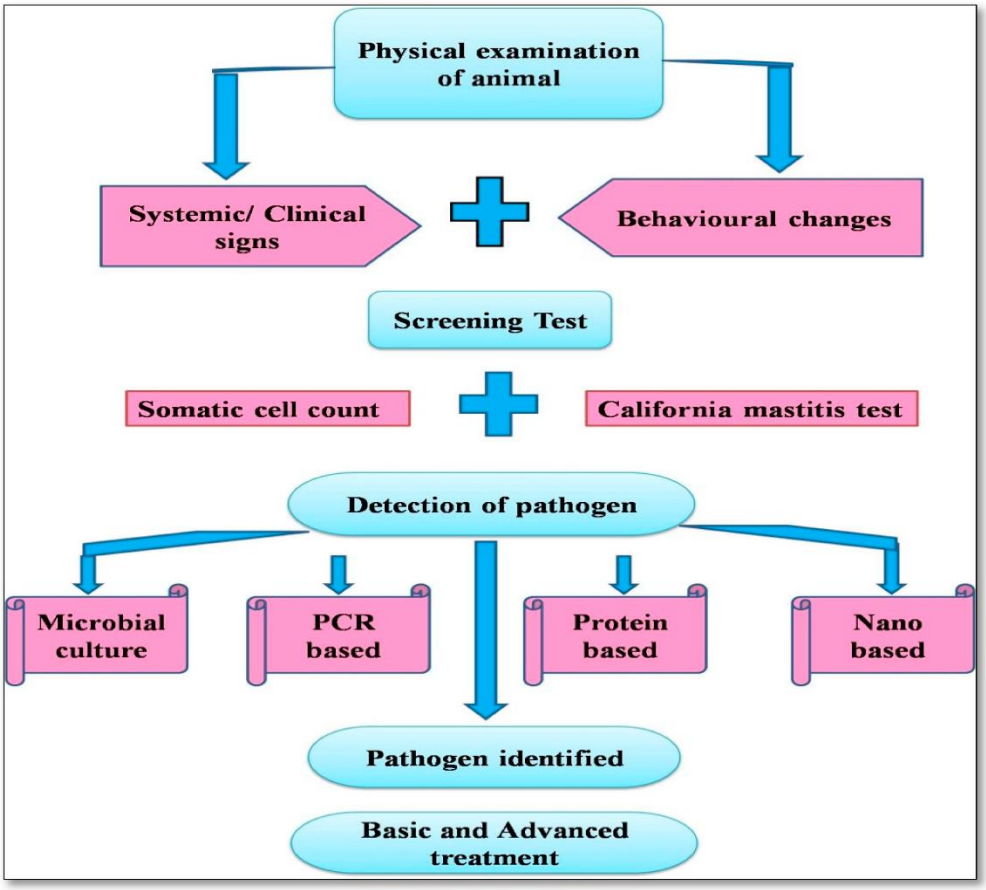


Figure 1. Overview of diagnoses of bovine mastitis (MDPI Copyright, 2023) [5].

From an economic perspective, the consequences of mastitis are multidimensional and profound. The direct costs of this disease include reduced milk production, the disposal of contaminated milk during treatment, veterinary and antimicrobial costs, and the forced and early culling of infected cows from the herd [6, 7]. In terms of quality, adverse changes in milk composition, such as reduced fat, protein, and lactose, and increased somatic cell count (SCC), lead to reduced quality and commercial value of the final product [8, 9]. In addition, indirect losses, such as reduced reproductive efficiency, increased calving interval, and additional labor costs associated with managing diseased animals, further increase the economic burden of this disease.

In addition to its economic dimensions, mastitis is a serious threat to public health and food security. The widespread and sometimes irresponsible use of antibiotics to treat this disease has contributed significantly to the emergence and spread of antimicrobial-resistant bacteria (AMR) [10, 11]. Antibiotic residues in milk and dairy products have also raised growing concerns among consumers [12].

Although traditional management of mastitis has been based on antibiotic treatment after the onset of the disease for decades, this paradigm is now facing a dead end [13-15]. The rising rate of treatment failures due to antibiotic resistance, changing pathogen patterns (with the increasing prevalence of environmental and emerging pathogens), and the growing pressure from regulatory agencies and consumers to reduce drug use in livestock all indicate the need for a fundamental shift in mastitis control strategies (Figure 2).

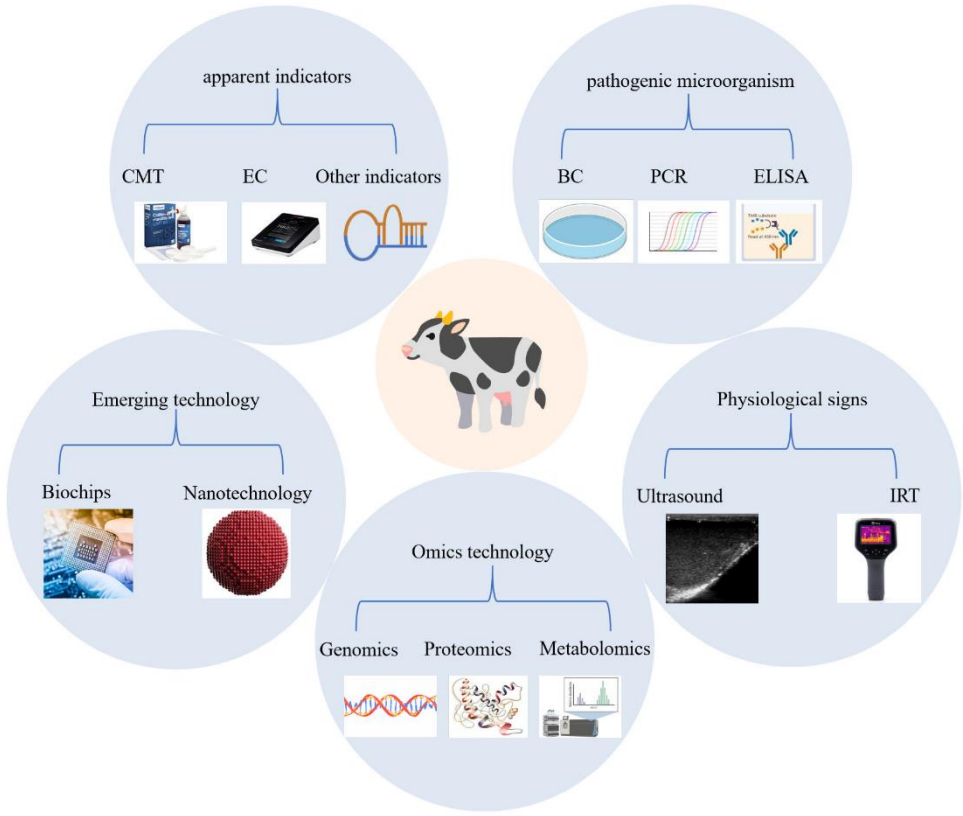


Figure 2. Diagnostic methods for mastitis in dairy cows (MDPI Copyright, 2025) [16].

The purpose of this systematic review is to provide an in-depth analysis of the issues currently being faced, assess the efficacy of novel solutions, and provide an overview of the future prognosis for the management of mastitis to establish a sustainable dairy farming system.

2. *METHODS AND MATERIALS*

This study was designed and conducted as a narrative review with a qualitative approach. The study search and selection protocol was predefined and developed to prevent any bias in the review process. The study population of this review included all original research articles, review articles, theses, and reputable scientific documents published in English between January 2019 and August 2025.

This study used a narrative review approach, with a structured search across databases including PubMed, Scopus, Web of Science, and Google Scholar. After the initial retrieval of studies, all records were transferred to the EndNote reference management software, and duplicates were automatically and then manually removed. In the first stage, screening was performed based on the title and abstract and according to predefined inclusion and exclusion criteria. Inclusion criteria included the article's focus on novel strategies for the prevention, diagnosis, or treatment of bovine mastitis, the provision of relevant experimental or analytical data, and access to the full text of the article. Exclusion criteria included studies with unavailable full text, articles that reported only cases, general review articles without new analysis, and studies not relevant to the topic. In the second stage, the full texts of the remaining articles were carefully reviewed, and only those that fully met the inclusion criteria were selected for data extraction and final analysis.

3. *RESULTS*

A comprehensive analysis of the selected studies clearly demonstrated that the most effective strategy for mastitis control is to adopt an integrated, multifaceted approach that prioritizes prevention. Strong and consistent evidence in the literature emphasizes that rigorous implementation of a five-pronged management program, including post-milking teat dips, high-dose antibiotic treatment of teat dryness and teat liners, timely

management of clinical mastitis, timely maintenance and repair of milking machine liners, and removal of chronically infected cows from the herd, are the undisputed cornerstones of reducing the incidence of the disease, especially in its subclinical form [17-39]. Economic studies have demonstrated that investing in these preventive measures has a much higher and more reliable economic return than paying the exorbitant costs of treatment, milk disposal, and culling [4, 40-45]. Rigorous implementation of these programs can reduce the incidence of new cases of clinical mastitis. In addition, the role of environmental and stress management, including providing dry, clean bedding, adequate ventilation, and reducing heat stress, has been repeatedly emphasized as key factors in reducing environmental pollution pressure and strengthening the animal's immune system [2, 46-48].

There has been a significant movement toward technologies that are quick, sensitive, and accurate in the field of diagnosis and monitoring. Although conventional screening techniques, such as the California test and somatic cell count, remain useful primary screening tools, the introduction of new diagnostic technologies has completely transformed early detection and accurate pathogen identification. Mastitis infections can be identified within hours using conventional and real-time polymerase chain reaction methods [49-56]. This is possible even in milk samples from mixed herds, and the procedures are highly sensitive and specific. At the same time, the development of biosensors based on nanotechnology and rapid diagnostic kits that can detect particular antigens or inflammatory markers in situ has opened new vistas for diagnostics in animal husbandry [57-63].

Finally, the findings emphasize the need for economic analysis and data-based decision-making in mastitis management. Studies show that economic-epidemiological modeling can help farmers choose the most cost-effective combination of preventive and therapeutic strategies tailored to their herd's specific circumstances. For example, these models clearly show that microbial culture and antimicrobial susceptibility testing before starting treatment not only increase the chance of treatment success but are also cost-effective in the long run by preventing unsuccessful experimental treatments and reducing unnecessary antibiotic use. The results also convincingly demonstrate that continuous training and regular performance evaluation of farmers and staff in milking hygiene and overall herd management are among the most valuable and productive investments, since knowledge and the correct implementation of operations are the basis for the success of all technical and technological strategies.

4. DISCUSSION

The current review clearly confirms that the mastitis management paradigm is shifting from a reactive and treatment-oriented model to a preventive, predictive, and integrated one. The strong emphasis of studies on the economic and health advantages of preventive strategies, especially the five-pronged management programs, indicates the maturity of the scientific approach in this area. However, the vast gap between existing knowledge and its practical implementation in many herds remains a central challenge. Several factors, including financial constraints for smallholder farmers, a shortage of skilled workforce, and the inadequacy of extension and education programs, prevent the full deployment of these strategies on a large scale [2, 5, 46, 64]. Therefore, the future of mastitis management depends not only on the development of new technologies but also on the creation of practical mechanisms to facilitate the implementation of this proven knowledge [13, 14, 65, 66].

In the realm of diagnostic innovation, although technologies such as polymerase chain reaction and biosensors have improved the accuracy and speed of diagnosis, substantial constraints still prevent their widespread adoption and local implementation. The high initial cost, the need for specialist human resources to interpret the data, and the difficulties associated with validating these kits across a variety of field conditions are among the issues involved [53, 67, 68]. The development of "plug-and-play" devices capable of autonomously analyzing samples in the milk production line and providing findings in real time, in a manner intelligible to the farmer, is the future ambition for this field of research. The use of artificial intelligence and machine learning in these diagnostic tools has the potential to facilitate the identification of disease outbreak trends and even predict mastitis risk based on historical and environmental data. This would move management closer to a fully predictive model.

Despite its promise, the debate over alternative therapies to antibiotics is nevertheless confronted with significant scientific and practical hurdles. It is necessary to conduct more fundamental research and field testing to address issues such as the stability of bacteriophages in practical formulations, the identification of

adequate doses of antimicrobial peptides, and the potential for bacterial resistance to these alternative agents. Furthermore, establishing transparent regulatory frameworks to grant approval and registration for these innovative goods is an essential precondition for their commercialization and availability to livestock producers.

One of the most profound challenges identified is the need for personalized economic-epidemiological modeling for each herd. The cost of implementing a complete preventive program or purchasing innovative monitoring systems for a small herd with limited budgets can be prohibitive. The future of mastitis management, therefore, requires the development of affordable, accessible decision-support tools that can suggest the most cost-effective combination of solutions to the farmer by inputting simple data from each herd (e.g., herd size, incidence rate, financial status).

5. CONCLUSION

In conclusion, the future of bovine mastitis management depends on moving from traditional, purely treatment-oriented approaches to an integrated model that combines the three pillars of innovative prevention, rapid and accurate diagnosis, and responsible treatment. The findings suggest that focusing on preventive strategies such as adherence to the five management principles, environmental control, and animal stress reduction is not only more cost-effective but also provides a solid foundation for reducing reliance on antibiotics. In addition, new diagnostic technologies, such as PCR, biosensors, and real-time monitoring systems, enable early and targeted intervention. In contrast, alternative therapies, such as antimicrobial peptides, phage therapy, and nanoparticles, have opened new horizons for combating antimicrobial resistance. However, success in this direction requires overcoming challenges such as implementation costs, access to advanced technologies at different levels of herds, and strengthening educational and advisory infrastructure.

Declarations and statements

Funding

No funding was received to conduct this study.

Conflict of interest

The authors declare that they have no conflict of interest.

Data availability

The datasets generated during and/or analyzed during the current study are available from the corresponding author upon reasonable request.

Ethical approval

All applicable international, national, and/or institutional guidelines for writing a review paper were followed.

Author contribution

Conceptualization: [Negar Ababaf Shoushtari], …; Methodology: [All Authors], …; Formal analysis and investigation: [All Authors], …; Writing - original draft preparation: [All Authors]; Writing - review and editing: [Marzieh Saki], …; Funding acquisition: [Self-funding], …; Supervision: [Negar Ababaf Shoushtari].

Consent to participate

Not applicable

Consent for publication

Not applicable

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Declaration of the use of generative AI

Not used to generate any data,

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