



# Strategies for Preventing Environmental Mastitis in Dairy Farming: A Review

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## **Authors' contributions**

*This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.*

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## **ABSTRACT**

The dairy industry must adhere to stringent international standards due to the growing demand for healthy, high-quality, and affordable dairy products worldwide. To ensure the quality of raw milk, key markers such as Bulk Milk Somatic Cell Count (BMSCC) and Total Bacterial Count (BMTBC) have become standard benchmarks. However, mastitis, the most common disease affecting dairy cows, poses a significant risk to both animal welfare and the long-term sustainability of the dairy sector. Mastitis leads to reduced milk production, increased treatment costs, milk withholding during treatment, higher labor requirements, and premature culling of affected cows. In India alone, mastitis costs the dairy industry 2.37 billion rupees annually, with subclinical mastitis accounting for approximately 70% of this loss. While contagious infections have been effectively controlled, environmental mastitis pathogens such as *Streptococcus uberis*, *Escherichia coli*, and *Klebsiella* spp now pose the primary concern for mastitis control. The management of cow bedding materials

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is crucial as they serve as a significant source of exposure to these environmental infections. This review study provides a detailed discussion of environmental mastitis pathogen control, emphasizing the critical role of bedding materials in reducing the risk of exposure to these pathogens.

**Keywords:** Environmental mastitis; bedding material; udder health; dairy cows.

## 1. INTRODUCTION

Consumers increasingly seek healthy, high-quality, and affordable dairy products produced through socially responsible practices, driving global demand [1,53]. To meet these demands, dairy processors now require milk that adheres to stringent international standards, with Bulk Milk Somatic Cell Count (BMSCC) and Total Bacterial Count (BMTBC) serving as key benchmarks [6,46]. However, mastitis, a prevalent ailment among dairy cows, remains a significant and costly challenge for the dairy industry [51,50]. Mastitis, characterized by inflammation of the mammary glands, threatens both animal welfare and the financial stability of dairy operations [29]. Factors affecting incidence of mastitis has been illustrated in Fig. 1. Impact of mastitis is evident through reduced milk production, treatment expenses, milk withholding post-treatment, increased labor requirements, and premature culling of affected cows. Of particular concern is subclinical mastitis, which is challenging to detect and manage due to its high prevalence, prolonged incubation period, and potential progression to clinical mastitis [51,54]. In India alone, mastitis inflicts an annual economic loss of approximately 2,37,00,00,000 rupees, with

subclinical mastitis accounting for around 70% of this financial burden [51]. Additionally, subclinical mastitis results in substantial lactation losses ranging from INR 21,677 to 88,340 including reduced milk production, changes in milk quality and treatment cost [41]. Furthermore, mastitis stands as the primary driver of antibiotic usage in dairy farming, contributing to the emergence of antibiotic-resistant pathogens and posing significant public health risks [38]. Depending on their primary source of infection Addressing mastitis requires differentiation between contagious and environmental sources of infection within dairy herds [30]. While contagious bacteria spread mainly during milking procedures, environmental pathogens, including *Streptococcus uberis*, *Escherichia coli*, and *Klebsiella spp*, thrive in the cross breed cow's surroundings, particularly in bedding materials [29]. Given the significant role of bedding materials in transmitting environmental mastitis pathogens, proper housing and management practices are critical for minimizing exposure to these bacteria [56,29]. This underscores the importance of maintaining clean, well-drained dry cow areas and implementing routine cleaning protocols to mitigate the risk of mastitis transmission [22].



**Fig. 1. Factors affecting udder health status and occurrence of mastitis**

Whereas Contagious bacteria, like *Staphylococcus aureus* and *Streptococcus agalactiae*, spread primarily during milking from infected udders to clean ones. Effective control measures such as teat dipping and dry cow therapy are generally used to manage these diseases [56]. Environmental mastitis can arise from various sources in the cow's environment, with the highest risk during the dry period, especially in the two weeks before and after calving. Due to advancements in managing contagious pathogens, environmental infections have become the main concern for mastitis control in modern dairy farming [55,48]. Environmental pathogens, including *Streptococcus uberis*, *Escherichia coli*, and *Klebsiella spp*, often lead to high rates of mastitis, particularly in herds with controlled infectious diseases [30]. Bedding materials, where cows spend much of their time lying down, serve as a significant reservoir for environmental mastitis bacteria [28]. To prevent environmental mastitis, it's crucial to design housing and management systems that minimize exposure to environmental infections at the teat end [56,31]. Clinical mastitis during lactation is often linked to infections during the dry period [16]. This underscores the importance of prioritizing cleanliness and effective management in maternity and dry cow housing. To reduce the risk of illness for both cows and calves, it's recommended to maintain well-drained, dung-free dry cow areas, regularly clean loose housing, and avoid manure packs [20]. This review paper delves into controlling environmental mastitis pathogens, which are increasingly causing intramammary infections in dairy cows. It emphasizes the critical role of bedding components in minimizing exposure to these pathogens. By enhancing mastitis management strategies and preserving udder health, these insights will assist dairy farmers in maintaining high-quality milk output and the long-term sustainability of the dairy industry.

### 1.1 Effects of Different Bedding Types on Mastitis Incidence in Dairy Cows

Mastitis in dairy cows can be influenced by various factors, including the type of bedding used. Studies have shown significant variations in bacterial counts not only between different bedding materials in dairy farming but also across seasons [42,34]. Correlations between pathogen populations in bedding and teat skin have been observed, emphasizing the potential for teats to pick up bacteria (*Streptococcus*,

*Staphylococcus*, *E.coli* etc.) from the environment [63,7,5]. As teats are in direct contact with bedding for a substantial duration daily, contamination is likely to affect [63,7,5].

Organic bedding materials, such as straw and sawdust, often have higher moisture content and are associated with elevated counts of gram-negative bacteria, including *Coliform spp*, *Klebsiella spp*, and *Streptococci spp*. Sawdust, a common organic bedding material, is preferred in confinement housing due to its availability and compatibility with manure treatment systems. However, the use of sawdust can lead to increased moisture and manure content, raising the pH of the bedding and promoting the growth of environmental organisms [64,63]. The escalating costs of traditional straw bedding have led to interest in alternative solutions, including recycled manure solids (RMS) bedding, which offers benefits such as improved cleanliness, reduced lesions, enhanced cow comfort, and economic advantages [17,2,10,11]. However, some studies have highlighted concerns about increased undesirable bacterial populations with RMS bedding [4,47]. An innovative bedding material called box compost, made from composted biodegradable household trash, has been introduced [18]. Subjected to a stringent heat treatment process, box compost contains added *Lactobacillus* species to inhibit the growth of harmful bacteria. Despite containing a higher concentration of gram-positive bacteria, deliberate inoculation with *Lactobacillus* species helps prevent the development of potentially harmful gram-negative environmental bacteria [59].

It has been reported that BMSCC was lower (186 000 cells/ml) on farms using inorganic bedding (compared to farms using organic bedding) when bedding was provided at intervals of more than 7 days and value of each unit of milk produced may rise if it were produced on farms utilizing inorganic bedding at a higher grade. Soft free-stall bases and foam mattresses have been shown to decrease the frequency of clinical mastitis and teat lesions. Rubber mats and multilayer mats also demonstrate lower hazard ratios for clinical mastitis compared to concrete, highlighting the importance of flooring in mastitis prevention [49,14,46]. Sand bedding is often considered the best option for dairy cows due to its superior cushioning and traction. Sand bedding has been associated with lower bacterial growth and extended lying time, contributing to increased cow comfort [32]. While challenges

exist in handling sand in manure systems, advancements in separation technologies have made it more manageable [30]. However, studies have indicated higher bacterial counts on teat ends for cows on sand bedding compared to sawdust ( $r = 0.47, 0.69, \text{ and } 0.60$  for coliforms, *Klebsiella* spp., and streptococci, respectively) and in sand ( $r = 0.35$  for coliforms and  $r = 0.40$  for *Klebsiella* spp.), emphasizing the importance of proper management [63,15].

The cost of high-quality bedding often leads farmers to limit its use or seek alternatives, despite their awareness of the importance of adequate bedding [60]. Potential alternatives like Switchgrass, *Posidonia oceanica*, Miscanthus grass, and spelt husks should be considered for bedding in dairy cow systems [9,52,62]. These alternatives offer various advantages, including adaptability to temperate regions, resilience to diseases and pests, low fertilizer requirements, and economic viability [13,65]; [62].

## 1.2 Optimizing Bedding Management for Improved Udder Health in Dairy Cows

Ensuring the well-being of dairy cows is paramount for both animal welfare and economic efficiency, with the type and quality of bedding material playing a crucial role in providing a comfortable environment in free stalls. The chosen bedding material must possess several qualities, including thermal comfort, softness, durability, and sufficient friction to allow cows to stand and lie down without slipping, while also promoting cleanliness and overall health with minimal daily labor requirements [3, 58]. Observations have indicated that cows exhibit a preference for spending more time in stalls filled with deep-bedded sawdust or sand compared to those with mattresses covered with only a thin layer of sawdust, underscoring the importance of bedding material in ensuring cow comfort [33,57]. Notably, for every kilogram of sawdust or straw added to a mattress, cows increased their daily lying time by 12 minutes [57]. Monitoring lying behavior, with the goal of ensuring cows spend the recommended 12 to 13 hours per day lying down, serves as a useful criterion for assessing freestall comfort [25,19].

Given that cows lie down for a significant portion of the day, the bedding surface serves as one of their primary and direct points of contact with the external environment. The moisture content of the bedding material significantly affects laying behaviors and cow health, with cows kept in

stalls with higher dry matter percentages spending more time lying down compared to those in stalls with lower dry matter percentages [12,43]. For instance, [12] found that cows kept in freestalls with bedding that had a dry matter (DM) percentage of 26.5% spent less time lying down than those kept in stalls with a DM of 86.4%. Similar to this, [44] discovered that cows exposed to beddings with different DM percentages reduced their lying time on the wettest bedding surface, with the reduction in lying time only being moderately affected until the DM was dropped to 34% or below. The importance of bedding quality, particularly in terms of dry matter content, in influencing laying behaviors is evident from these findings.

The use of a propane-fueled flame moving across the surface of recycled sand bedding significantly reduces mastitis pathogens (Gram-negative bacteria, *Coliform*, *Klebsiella*, and *Streptococcal* counts) and moisture content on the surface layer, particularly within the top 25 mm of recycled sand bedding. Fresh recycled sand exhibits higher levels of flaming efficiency in suppressing bacterial populations (Gram-negative bacteria, *Coliform*, *Klebsiella*, and *Streptococcal* counts) compared to sand that has been in use for a longer period of time [22]. Additionally, propane flames offer a useful and environmentally beneficial strategy for reducing disease populations in poultry litter material, enabling the sanitization of animal interaction areas without the need for potentially hazardous chemicals [40].

Environmental bacteria thrive best in a pH range of 4.4 to 8.7, and as the pH falls below this range, the optimal temperature for their growth rises, leading to a significant decline in their growth rate. It has been observed that the ability of bedding conditioners to be effective against mastitis bacteria in bedding for up to 48 hours, with acidic bedding additives proving more effective than alkaline conditioners at reducing bacterial burdens [22,24]. Teat orifice integrity in dairy cows, crucial as the first line of defense against infections, did not show noticeable impacts from either alkaline or acidic bedding additions [35,21]. The addition of a clay-based acidic bedding conditioner led to a significant decrease in environmental counts of various bacterial species, including total gram-negative bacteria, *Streptococci* spp, *Coliforms* spp, and *Klebsiella* spp, both in the bedding material and on the teat ends, without affecting teat structural integrity [39].

Lime treatment emerged as the sole effective approach, significantly reducing bacterial counts [23, 31]. The technique of sprinkling crushed limestone over bedding has been experimented with by some researchers and farmers to reduce bacterial presence, particularly potential mastitis pathogens. However, this method may not achieve thorough distribution of limestone throughout the bedding, limiting its maximum effect on bacterial flora. The habitual, long-term use of more than 0.5 kg of lime on mattresses may be linked to undesirable side effects, despite its benefits in suppressing bacterial growth. A commercial product comprised of 92.5% calcium carbonate, 5% sodium dichloroisocyanurate, and 2.5% aluminum sulfate, with a pH level of 3.7, proved effective in suppressing populations of *Coliform spp.*, *Klebsiella spp.*, and *Streptococcus spp.*, albeit with somewhat less potency compared to hydrated lime [31].

In order to enhance environmental mastitis control, it is imperative to gain a more comprehensive understanding of the interplay between bedding selection, bacterial bed count, and udder health. Additionally, there is a pressing need for evidence-based benchmarks to effectively monitor bedding hygiene. [37] identified attainable benchmarks for bacterial counts using four different types of bedding for lactating cows [new sand, reclaimed sand, manure solids, and organic non-manure materials], indicating that for Coliforms, the recommended levels are  $\leq 500$  colony-forming units per cubic centimeter ( $\text{cfu}/\text{cm}^3$ ) for unused bedding and  $\leq 10,000$   $\text{cfu}/\text{cm}^3$  for used bedding. For *Klebsiella spp.*, both unused and used bedding should ideally register at 0  $\text{cfu}/\text{cm}^3$ . Similarly, *Staphylococcus spp.* should not exceed 0  $\text{cfu}/\text{cm}^3$  for both unused and used bedding. As for *Streptococcus uberis* (SSLO), the suggested benchmarks are  $\leq 500,000$   $\text{cfu}/\text{cm}^3$  for used bedding and 0  $\text{cfu}/\text{cm}^3$  for unused bedding. Minor variations are proposed for SSLO in unused manure solids (MNS), where the recommended benchmark is  $\leq 1,000$   $\text{cfu}/\text{cm}^3$ . These benchmarks offer a reliable framework for monitoring bedding hygiene across a range of bedding materials. The findings indicate that maintaining bedding in a dry and loose condition leads to cleaner animals and reduces the risk of mastitis. Assessing cow cleanliness proves to be a valuable tool in guiding bedding management and evaluating the potential for subclinical mastitis [8]. The experimental trials conducted by [9] underscore the importance of conducting thorough physical, chemical, and biological

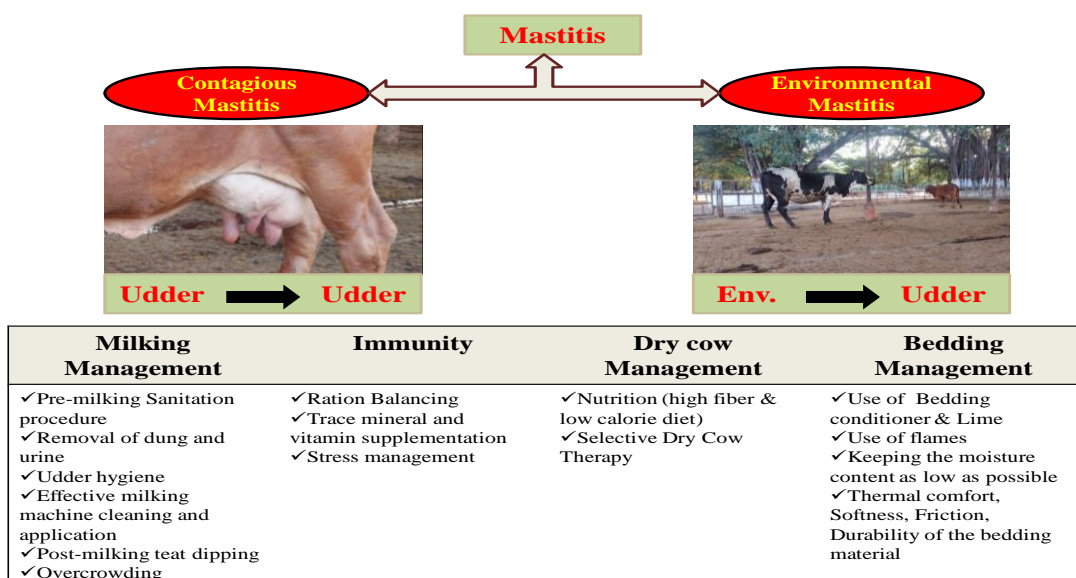
analyses before selecting any material for use as bedding for dairy cattle. This is because the physical attributes of the bedding materials can have significant implications on their chemical and biological properties.

### 1.3 Alternative Approaches to Minimize the Occurrence of Mastitis

Four key factors for preventing incidence of mastitis have been illustrated in Fig. 2. Using the four key foundations defined by [27], environmental mastitis control strategies are designed. (1) Reducing the bacterial burden in the cow's surroundings. (2) Routinely removing bacterial contaminants from teats to prevent invasion. (3) Increasing the resilience and resistance of the host. (4) Improving dry-off processes as well as enhancing mastitis control techniques, including case detection and management. Sound husbandry practices, upholding proper udder hygiene, strict pre-milking sanitation procedures, using post-milking teat dip, performing effective milking machine cleaning, ensuring adequate cooling, storing milk within the temperature range of 0 to 4.4°C, treating mastitis during non-lactating periods, and culling of persistently infected animals are all essential elements in mastitis control [55,45].

Animal overcrowding ultimately increases the risk of disease transmission. In order to limit pathogen exposure to the mammary gland and thereby lower the incidence of mastitis, it is essential to maintain appropriate sanitation and proper ventilation in the farm building. Dung and urine should always be removed as soon as possible because they are common sources of illnesses on farms and should always be given with dry bedding. Ticks breed in the farm's cracks and crevices, and flies reproduce better in chilly, damp environments. For the purpose of preventing the development of lice, flies, and ticks, it is critical to seal any crevices and quickly dry any moist or humid places [55].

In particular, the first 1-2 weeks and the last 7–10 days before calving or early lactation are when there is a higher vulnerability to new environmental streptococci infections during the dry period. Notably, mastitis occurs twice as frequently at calving as it does at drying off [36]. Dry animal antibiotic therapy (Cephalosporin) can be used to treat infections acquired during the early dry period, but its effectiveness declines throughout the late dry period. But according to [26], 70% of environmental streptococcal



**Fig. 2. Four key factors for preventing the occurrence of mastitis**

infections could be cured with dry period therapy. While it may not be possible to completely eradicate environmental pathogen-induced mastitis from a dairy herd, it is possible to effectively manage it using precautions meant to lower exposure and strengthen the cow's immune system. In order to reduce the susceptibility to mastitis while keeping in mind Anti-Microbial Resistant (AMR), it is important to improve housing, nutrition, and immunity in nursing cows by the supplementation of nano minerals [51,61].

**2. CONCLUSION**

Effective management of mastitis in dairy farming hinges on a multifaceted approach encompassing bedding selection, hygiene protocols, and animal husbandry practices. By prioritizing bedding materials with low bacterial contamination and optimal moisture levels, alongside rigorous sanitation measures and early detection strategies, dairy farmers can mitigate the risk of mastitis transmission. Furthermore, incorporating innovative solutions like flame treatment and acidic bedding conditioners, while emphasizing proper ventilation and overcrowding prevention, can further enhance udder health and ensure the sustainability of milk production while addressing public health concerns regarding antibiotic resistance.

**COMPETING INTERESTS**

Authors have declared that no competing interests exist.

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