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Camel Mastitis: Preventive and therapeutic management through herbal and husbandry approaches

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Abstract
Mastitis is a prevalent and economically significant disease affecting camel dairies worldwide. It results in inflammation of the mammary glands, leading to a reduction in milk yield and quality. The camel (*Camelus dromedarius*), a resilient animal adapted to harsh, arid environments, is particularly important in regions where other dairy livestock cannot survive. Camel milk is not only a vital food source but also a potential therapeutic agent in treating various ailments, such as asthma, tuberculosis, and gastrointestinal disorders. Despite the advantages, camel milk production is severely hindered by mastitis, which poses a considerable threat to the livelihoods of pastoral and nomadic communities.
Mastitis in camels, while less studied compared to other livestock, presents distinct challenges due to the unique physiological characteristics of camels and the environmental factors they face. Understanding the pathology, causes, prevalence, and effective management strategies for camel mastitis is essential for minimizing its economic impact.

Keywords: Camel, mastitis, pathology, husbandry, economic impact, nomadic com

1. Introduction

1.1 Importance of Camels in Dairy Farming

Camels have become indispensable in many arid and semi-arid regions, providing essential milk, meat, and transport. In regions such as the Horn of Africa, the Middle East, and parts of Central Asia, camels are vital for the survival of local populations. Camel milk is prized for its rich nutritional content, including proteins, vitamins (especially vitamin C), minerals, and unique bioactive compounds like lactoferrin, which help boost the immune system.
Compared to cow's milk, camel milk is often considered a healthier option due to its lower fat content, hypoallergenic properties, and higher levels of beneficial fatty acids and minerals. Additionally, camel milk is considered a potential remedy for certain medical conditions such as food allergies, diabetes, and asthma. As the demand for camel milk increases, especially in regions where other dairy animals struggle to survive, mastitis in camels presents a critical challenge.
Despite the nutritional and therapeutic benefits, mastitis in camels remains an under-researched issue, and it poses severe economic consequences for camel farmers. The disease leads to significant losses in milk production, lowers milk quality, and increases treatment costs, which threatens the viability of camel dairies. Understanding the complexities of camel mastitis is thus essential for improving animal health and ensuring sustainable milk production.

2. Pathophysiology of Camel Mastitis

Camel mastitis, like in other dairy animals, is caused by an inflammatory response of the mammary gland to infection, injury, or other pathological factors. The disease can be caused by bacterial, fungal, or environmental factors that affect the udder tissue. The primary response to mastitis is an increase in somatic cells, which are produced by the immune system to fight off infection. These cells are normally present in milk in small amounts, but their numbers increase dramatically during inflammation.

Types of mastitis in camels

Mastitis in camels can be broadly categorized into clinical and subclinical forms, each with its own set of characteristics and diagnostic challenges.

- **Clinical Mastitis:** Clinical mastitis in camels presents with visible signs of infection. The udder becomes swollen, warm, and painful, and the milk often changes in color, consistency, and appearance. Common changes in milk include the presence of clots, pus, or blood. Camels with clinical mastitis may also display systemic signs such as fever, lethargy, and reduced appetite. This form is more easily detectable, and the reduction in milk yield is often immediate and dramatic.
- **Subclinical Mastitis:** Subclinical mastitis is the most common form of the disease in camels. In this type, the animal does not show visible symptoms, and the milk appears normal to the naked eye. However, an elevated Somatic Cell Count (SCC) in the milk and changes in its biochemical composition indicate underlying inflammation. Subclinical mastitis can go unnoticed for extended periods but can significantly impact long-term milk production and quality, making early detection critical.

Acute, Chronic, and Gangrenous Mastitis

Mastitis can present in various forms, ranging from mild to severe. These include:

- **Acute Mastitis:** Acute mastitis is typically a sudden onset condition that causes severe pain, swelling, and heat in the udder. Milk may appear abnormal, with the presence of clots, pus, or blood. The bacteria commonly responsible for acute mastitis in camels are *Escherichia coli* and *Klebsiella pneumoniae*, which can cause rapid and widespread infection (Tuteja *et al*., 2013) [6]. Acute mastitis requires prompt veterinary intervention to prevent the spread of infection and further damage to the udder tissue.
- **Chronic Mastitis:** Chronic mastitis develops over time due to persistent infections, often caused by *Staphylococcus aureus*, a bacterium capable of forming biofilms on the mammary tissue. Chronic mastitis leads to long-term inflammation, fibrosis, and the eventual atrophy of the affected quarter (Barbour *et al*., 1985) [11]. Over time, the infected udder becomes firm and produces significantly reduced milk yields. Chronic cases are often difficult to treat, and prevention is key.
- **Gangrenous Mastitis:** Gangrenous mastitis is the most severe form of mastitis and is characterized by rapid tissue necrosis. The udder becomes discolored, swollen, and cold to the touch, and the milk may contain blood. This form of mastitis is often caused by highly virulent bacteria, such as *Streptococcus agalactiae* (El Tigani *et al*., 2020) [7]. If left untreated, gangrenous mastitis can result in irreversible damage to the udder, leading to the loss of the infected quarter.

3. Prevalence of Camel Mastitis

The prevalence of camel mastitis varies significantly across regions. Factors such as management practices, climate, and local veterinary infrastructure all influence the rate of mastitis in camel herds.

- **Somalia:** A study conducted in Somalia found that 34.4% of lactating camels were affected by mastitis. Of these, 29.2% were subclinical cases, and 5.2% were clinical. The high prevalence of subclinical mastitis highlights the importance of diagnostic testing, as the disease often goes undetected without appropriate screening methods (Mohamud *et al*., 2020) [8].
- **Sudan:** In Sudan, the prevalence of mastitis was found to be 18.98%. Chronic and acute forms of mastitis were most commonly observed. This prevalence underscores the need for improved management and early detection strategies in camel dairies (Hussein & Saad, 2017) [9].
- **United Arab Emirates (UAE):** The UAE has reported significant cases of gangrenous mastitis, particularly caused by *Streptococcus agalactiae*. In some herds, up to 80% of lactating camels were affected, demonstrating the severity of the disease in certain regions (El Tigani *et al*., 2020) [7].
- **Pakistan:** In Pakistan, the prevalence of mastitis among lactating camels was found to be as high as 90.5%, with both subclinical and clinical cases being common. The high prevalence in Pakistan highlights the importance of focused research and intervention strategies in regions with high camel populations (Qamar *et al*., 2011) [10].

4. Aetiology of Camel Mastitis

Mastitis in camels is caused by an interplay of infectious agents, environmental factors, and management practices. While bacterial infections are the most common cause, other factors such as physical trauma, poor hygiene, and environmental stressors also contribute to the disease's onset and progression. Understanding the aetiology of camel mastitis is essential for the development of effective preventive and therapeutic strategies.

Infectious Agents

The primary pathogens responsible for camel mastitis are bacteria, but fungal infections and other microorganisms can also contribute to the disease. The type of pathogen involved often dictates the severity and progression of mastitis, ranging from mild inflammation to severe tissue damage.

Bacterial Pathogens

The most common bacterial agents that cause mastitis in camels include Staphylococcus aureus, *Streptococcus agalactiae*, *Escherichia coli*, and *Klebsiella pneumoniae*. Each of these bacteria has unique characteristics that make it capable of causing infection in the udder.

Staphylococcus aureus

Staphylococcus aureus is a major pathogen in camel mastitis, often associated with chronic infections. This bacterium is particularly dangerous because it can form biofilms on the udder tissue, making it difficult for the immune system to clear the infection and for antibiotics to be effective. Biofilms are protective layers that surround bacterial cells and shield them from the host's immune response, allowing the bacteria to persist in the mammary gland for long periods. This persistence leads to chronic mastitis, which can result in irreversible damage to the udder. *S. aureus* is also responsible for the formation of abscesses and fibrosis in infected quarters, reducing milk production over time (Tuteja *et al*., 2013) [6].

- ***Streptococcus agalactiae:*** *Streptococcus agalactiae* is known for its ability to cause acute mastitis and gangrenous mastitis in camels. This bacterium is highly virulent and can spread quickly through the udder, leading to severe tissue necrosis and loss of udder function. Infected udders may show signs of bluish

discoloration, indicating lack of blood flow due to the rapid destruction of tissue. The milk produced by infected camels often contains blood and has a foul odour, which makes it unsuitable for human consumption (El Tigani *et al*., 2020) [7]. *Streptococcus agalactiae* is typically transmitted through contaminated milking equipment, unsanitary conditions, or contact with infected animals.

- ***Escherichia coli*:** *Escherichia coli* is a gram-negative bacterium that is commonly found in the intestines of animals, including camels. It is a major cause of environmental mastitis, meaning it is often introduced to the udder from contaminated bedding, manure, or unclean milking equipment. *E. coli* is responsible for acute mastitis, leading to rapid inflammation and significant reductions in milk quality and yield. It often causes a marked drop in milk production in the affected quarter, and in severe cases, it may lead to the death of the infected tissue.
- ***Klebsiella pneumoniae:*** *Klebsiella pneumoniae* is another gram-negative bacterium that plays a significant role in acute mastitis in camels. Like *E. coli*, *Klebsiella* is typically associated with poor hygienic practices, such as contaminated bedding and dirty milking equipment. It can also cause rapid onset of inflammation, leading to a dramatic decrease in milk yield and changes in milk composition. *Klebsiella* is particularly notorious for its ability to survive in moist environments, which makes it a common pathogen in humid climates (Tuteja *et al*., 2013) [6].

Other Microorganisms

While bacteria are the primary causative agents of mastitis, fungal infections have also been implicated in some cases. Species of Candida (e.g., *Candida albicans*) have been identified as contributors to mastitis in camels, particularly in regions with inadequate hygienic practices and high environmental stressors. Fungal infections tend to occur in more chronic cases and may lead to mycotic mastitis, which requires antifungal treatment for resolution (Rahmeh *et al*., 2022) [1].

Environmental Factors

Environmental conditions play a significant role in the development and spread of mastitis in camels. These factors can influence both the likelihood of pathogen exposure and the camels' susceptibility to infection.

Hygiene and Milking Practices

One of the most critical environmental factors influencing the prevalence of camel mastitis is the sanitation of the milking environment. Inadequate milking hygiene, such as the use of unclean milking equipment, unsanitary hands, and dirty udders, is a key factor in the transmission of mastitis-causing bacteria. Contaminated bedding and manure can also be sources of bacterial contamination, particularly for E. coli and *Klebsiella pneumoniae*, which thrive in such environments (Barbour *et al*., 1985) [11].

Poor milking practices, including the use of improper techniques or equipment that cause trauma to the udder, can also increase the risk of infection. Physical injuries to the udder create entry points for bacteria, facilitating the development of mastitis. In traditional systems where camels are often restrained and anti-suckling devices are used, the risk of udder injury is heightened (Hussein & Saad, 2017) [9].

Climate and Environmental Stress

The climate plays a role in the development of mastitis in camels, particularly in regions with high humidity or extreme temperatures. Humid environments promote the growth of bacteria such as *Klebsiella pneumoniae*, which thrives in wet conditions. Moreover, extreme heat can cause stress in camels, weakening their immune system and making them more susceptible to infections. Stress-induced immunosuppression is a known factor that increases the likelihood of mastitis (Tuteja *et al*., 2013) [6].

Risk Factors Related to the Host (Camel)

The susceptibility of camels to mastitis is also influenced by host-related factors, including age, lactation stage, and immune status.

- **Age:** Older camels tend to be more susceptible to mastitis, as their immune systems become less efficient at fighting off infections. This makes it harder for older animals to clear bacterial infections once they take hold in the udder. Additionally, older animals may experience a reduction in the structural integrity of the udder tissue, making it more prone to damage.
- **Lactation Stage:** Camels in early lactation are at a heightened risk of developing mastitis due to the increased blood flow to the mammary glands and the physiological changes occurring in the udder during this period. Early lactation also places stress on the udder, which may create a window of vulnerability for pathogen entry.
- **Immune Status:** A weakened immune system due to stress, poor nutrition, or disease can predispose camels to mastitis. The immune system plays a crucial role in defending the mammary glands against pathogens, and any compromise in this defense increases the risk of infection.

The etiology of camel mastitis is complex, involving a combination of infectious agents, environmental factors, and host-related risk factors. While bacterial pathogens such as *Staphylococcus aureus*, *Streptococcus agalactiae*, *Escherichia coli* and *Klebsiella pneumoniae* are the most common causes of mastitis, environmental factors such as poor hygiene, improper milking practices, and climate conditions also contribute to the onset of the disease. Host-related factors, including the camel's age, stage of lactation, and immune status, further influence susceptibility to infection.

Effective control and management of camel mastitis require an understanding of these various risk factors. This involves not only addressing bacterial infections through proper treatment but also implementing preventive measures such as improved hygiene, better milking practices, and regular health checks for early detection. Understanding the full range of factors contributing to mastitis is crucial for minimizing its impact and ensuring the sustainability of camel dairies.

5. Risk Factors for Camel Mastitis

Several risk factors contribute to the development of mastitis in camels. These factors can be broadly categorized into environmental, management, and biological factors:

- **Milking Hygiene:** Poor hygiene during milking is the most significant risk factor. Contaminated milking equipment and unclean udders increase the chances of introducing pathogens to the mammary glands (Tuteja *et al*., 2013) [6].

- **Injuries:** Trauma to the udder, either from rough handling or the use of anti-suckling devices (e.g., *surar* and *gourab*), can create open wounds that allow bacteria to enter the udder, increasing the risk of mastitis (Hussein & Saad, 2017) [9].
- **Tick Infestation:** Ticks are a significant risk factor because they can cause physical damage to the udder, increasing the likelihood of infections. Ticks also harbor various pathogens, which can further exacerbate the risk of mastitis (El Tigani *et al*., 2020) [7].
- **Age and Lactation Stage**: Older camels and those in early lactation are more susceptible to mastitis due to the physiological changes occurring in the udder. As camels age, their immune system weakens, making them more vulnerable to infections.

6. Diagnosis of Camel Mastitis

Diagnosing camel mastitis involves both clinical observation and laboratory tests:

- **California Mastitis Test (CMT):** The CMT is a cost-effective tool for detecting subclinical mastitis by measuring the presence of somatic cells in milk. This test is widely used in field conditions to identify potentially infected camels (Abdurahman *et al*., 1995) [12].
- **Somatic Cell Count (SCC):** An elevated SCC indicates inflammation in the udder. While SCC levels for camels have not been universally standardized, higher counts are indicative of mastitis (Seligsohn *et al*., 2020) [13].
- **Biochemical Markers:** N-acetyl-β-D-glucosaminidase (NAGase) and lactate dehydrogenase (LDH) are enzymes that increase during mastitis and can serve as additional diagnostic markers. They are especially useful for identifying early-stage or subclinical mastitis (Al-Majali *et al*., 2007) [14].

7. Treatment and preventive management of camel mastitis

Mastitis in camels continues to be one of the most important health and productivity challenges in camel dairying. While treatment of affected animals is vital, the real key to sustainable control lies in management-oriented prevention, as mastitis is largely influenced by hygiene, husbandry, and environmental conditions. A combined approach of early therapeutic intervention and long-term preventive management is therefore essential.

7.1 Treatment Overview (Concise)

Therapeutic intervention in mastitis-affected camels generally involves antimicrobial therapy supported by symptomatic care.

- **Antimicrobials:** Penicillins, cephalosporins, tetracyclines, and fluoroquinolones are used depending on the pathogen profile and sensitivity testing. Intramammary preparations are beneficial in localized cases, while systemic therapy is required for severe or gangrenous mastitis.
- **Supportive Therapy:** NSAIDs (e.g., meloxicam, flunixin meglumine) reduce inflammation, while IV fluids restore hydration and electrolyte balance in septic cases.
- **Nutritional Support:** Adequate feeding during illness strengthens immunity and promotes recovery.

While these measures are important for sick camels, the economic and welfare impact of mastitis is best reduced by preventing new infections, which depends on robust management practices.

7.2 Management Aspects to Prevent Mastitis in Camels

Preventive management in camels addresses housing, hygiene, nutrition, stress reduction, parasite control, and early detection. Unlike cattle, camels are often reared in arid or semi-arid conditions under nomadic or semi-intensive systems, so strategies must be adapted to these unique environments.

A) Housing and Ventilation

Housing structures, when used, must be adapted to desert climates:

- Natural ventilation through open-sided sheds and raised roofs allows airflow, reduces humidity, and minimizes bacterial growth in bedding.
- Shade provision is critical to reduce heat stress, which otherwise suppresses immunity and predisposes camels to mastitis. In intensive farms, mechanical ventilation or water-sprinkling may be introduced during extreme heat waves.

B) Bedding and Environmental Hygiene

Camels often lie on sand, which is advantageous due to its dryness and low bacterial load. However, management lapses can still create infection risk:

- Bedding areas must remain dry, clean, and free of accumulated dung or urine.
- In semi-intensive dairies, pens should be cleaned daily, and drainage must be adequate to avoid muddy or stagnant areas where pathogens proliferate.

C) Milking Hygiene and Teat Care

Milking practices remain a central factor in mastitis prevention:

- **Pre-milking:** Wash teats with clean water and dry with separate towels to minimize bacterial transfer. In organized dairies, mild disinfectants may be used.
- **Post-milking:** Teat dipping with iodine or chlorhexidine creates a protective film when the teat sphincter is open and most vulnerable.
- **Milking Technique:** Gentle, rhythmic hand-milking prevents teat injuries. Training herders is crucial, as rough handling is a frequent predisposing factor in nomadic herds.

D) Parasite and Tick Control

Ticks are a **major mastitis risk** in camels, as they cause wounds on the udder surface that serve as bacterial entry points.

- Regular acaricide application, combined with clean and dry bedding, reduces infestation.
- Routine inspection of udders and immediate removal of ticks or treatment of lesions help prevent infections from escalating.

E) Nutrition and Immune Strengthening

A strong immune system is the best natural defense against mastitis.

- Diets must provide balanced energy, protein, and trace minerals.
- Vitamin E, selenium, zinc, and copper play a direct role

in maintaining udder integrity and boosting immune response.
- Clean and ample water is essential, as camels increase water intake after milking and during hot seasons, and dehydration can increase susceptibility.

F) Stress Reduction and Comfort

Stress is a hidden but important risk factor:
- Overcrowding in pens must be avoided, as it increases fighting, faecal contamination, and lying time reduction.
- Shade and loafing areas should be provided to allow animals to rest comfortably and express natural behaviors.
- Calm, consistent handling during milking prevents agitation and teat trauma.

G) Early Detection and Herd-Level Screening

Because **subclinical mastitis** is more common in camels than clinical cases, early detection is vital:
- California Mastitis Test (CMT) and somatic cell count (SCC) should be incorporated into routine herd checks.
- Periodic bacteriological cultures help identify dominant pathogens, allowing for targeted herd-level interventions.

H) Dry Period Management and Vaccination
- Dry period therapy using long-acting intramammary preparations helps eliminate existing infections and prevent new cases in the next lactation. Selective use based on udder health records avoids unnecessary antibiotic use.
- Vaccination: Although not widely applied in camels, ongoing research on *Staphylococcus aureus* and *E. coli* vaccines shows promise for future preventive programs.

While antibiotics and supportive therapy are important in treating camel mastitis, management remains the cornerstone of long-term control. Clean housing, proper ventilation, hygienic milking, tick control, balanced nutrition, and early detection together form a preventive shield that is more effective and economical than repeated treatments. By prioritizing preventive management, camel dairies can ensure better udder health, improved milk yield, and long-term sustainability of camel milk production.

8. Conclusion

Camel mastitis is a significant disease that affects camel dairies worldwide, leading to economic losses due to decreased milk yield and quality, increased treatment costs, and in some cases, the culling of affected animals. The disease is caused by a variety of bacterial and environmental factors, and its detection can be challenging, particularly in subclinical cases. However, early diagnosis, effective treatment, and preventive measures, such as proper milking hygiene, injury prevention, and tick control, can help reduce the prevalence and impact of mastitis in camel herds.

The future of camel dairy farming depends on continued research into effective diagnostic tools, treatment protocols, and preventive strategies. Improved management practices, along with the development of vaccines and new therapeutic agents, will play a crucial role in reducing the impact of mastitis on camel milk production and ensuring the sustainability of camel dairies. By addressing the challenges of camel mastitis, we can protect both animal welfare and the livelihoods of pastoral communities that depend on these magnificent animals.

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Not available

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