ORIGINAL RESEARCH ARTICLES

Prevalence, Bacterial Isolation, and Antimicrobial Susceptibility of Clinical Mastitis in Lactating Camels in Southern Algeria (Illizi and Oued Souf)

Prevalencia, Aislamiento Bacteriano y Susceptibilidad a los Antimicrobianos de la Mastitis Clínica en Camellos Lactantes en el Sur de Argelia (Illizi y Oued Souf)

Prevalência, Isolamento Bacteriano e Suscetibilidade a Antimicrobianos da Mastite Clínica em Camelos Lactantes no Sul da Argélia (Illizi e Oued Souf)

Djeddi Khaled[1*]; Houssou Hind[1]; Guoasmia Yassine[2]

[1]*Souk-Ahras University, Institute of Agronomic and Veterinary Sciences, Laboratory of Sciences and Techniques of the Living, Taoura, Soukahras, Algeria*

[2]*Biotechnology Research Center - C.R.Bt , Constantine, Algeria*

Received: November 27, 2024. Accepted: August 15, 2025

***Corresponding author:** Djeddi Khaled. Institute of Agronomic and Veterinary Sciences, Laboratory of Sciences and Techniques of the Living, Taoura, University of Souk Ahras, 41000 – Algeria. Email: k.djeddi@univ-soukahras.dz*

eISSN: 2256-2958

Rev Colomb Cienc Pecu
https://doi.org/10.17533/udea.rccp.e358933

To cite this article:

Djeddi Khaled; Houssou Hind; Guoasmia Yassine. Prevalence, Bacterial Isolation, and Antimicrobial Susceptibility of Clinical Mastitis in Lactating Camels in Southern Algeria (Illizi and Oued Souf). Rev Colomb Cienc Pecu *Year, Vol, number, and pages pending.* DOI: https://doi.org/10.17533/udea.rccp.e358933

Abstract

Background: Clinical mastitis in she-camels (*Camelus dromedarius*) is a significant concern for camel farming, particularly in regions such as Oued Souf and Illizi provinces in Algeria. Mastitis affects the health of the animals and the quality of milk, impacting productivity and herd management. Understanding the prevalence, bacteriological characteristics, and risk factors associated with mastitis is critical for developing effective management strategies. **Objective:** This study aims to investigate the prevalence, risk factors, and bacteriological characteristics of clinical mastitis in Sahraoui she-camels in the Oued Souf and Illizi regions of Algeria, with a focus on antimicrobial susceptibility patterns of the pathogens involved. Methods**:** A total of 170 multiparous Sahraoui she-camels were clinically examined. Milk samples were collected from affected animals, and bacterial isolates were obtained and identified. Antimicrobial susceptibility testing was performed on the isolates to determine resistance patterns. Risk factors, such as tick infestation, udder lesions, and the use of anti-suckling devices, were also assessed. **Results:** Gram-positive cocci were the predominant pathogens, with *Streptococcus agalactiae* accounting for 85% of bacterial isolates. The antimicrobial susceptibility testing revealed that oxytetracycline, doxycycline, erythromycin, and cotrimoxazole showed 100% efficacy. Sulfamethazine/trimethoprim and tylosin exhibited 85% susceptibility, while penicillin and amoxicillin were effective in 60% of cases. Enrofloxacin demonstrated moderate efficacy, with a 50% susceptibility rate. The study also identified key risk factors such as tick infestation, udder lesions, and anti-suckling devices. **Conclusions:** The study underscores the importance of monitoring bacterial resistance in camel mastitis and suggests that appropriate treatment strategies, including the use of oxytetracycline, doxycycline, and erythromycin, should be prioritized. Effective management of mastitis in Algerian camel herds requires addressing the identified risk factors, such as tick infestations and udder injuries, and implementing appropriate prevention and treatment strategies to improve animal health and milk quality.

Keyword: *Antimicrobial susceptibility; Bacterial Isolation; Clinical mastitis; Lactating Camels; Risk factors, Prevalence; She-camels (Camelus dromedarius); Southern Algeria; Streptococcus agalactiae.*

Resumen

Antecedentes: La mastitis clínica en camellas (*Camelus dromedarius*) es una preocupación significativa para la cría de camellos, especialmente en regiones como las provincias de Oued Souf e Illizi en Argelia. La mastitis afecta la salud de los animales y la calidad de la leche, impactando la productividad y el manejo de los rebaños. Comprender la prevalencia, las características bacteriológicas y los factores de riesgo asociados con la mastitis es fundamental para desarrollar estrategias de manejo efectivas. **Objetivo**: Este estudio tiene como objetivo investigar la prevalencia, los factores de riesgo y las características bacteriológicas de la mastitis clínica en camellas saharianas en las regiones de Oued Souf e Illizi de Argelia, con un enfoque en los patrones de susceptibilidad antimicrobiana de los patógenos involucrados. **Métodos**: Se examinaron clínicamente un total de 170 camellas saharianas multíparas. Se recolectaron muestras de leche de los animales afectados, y se obtuvieron e identificaron aislamientos bacterianos. Se realizó una prueba de susceptibilidad antimicrobiana en los aislamientos para determinar los patrones de resistencia. También se evaluaron factores de riesgo, como la infestación de garrapatas, lesiones en la ubre y el uso de dispositivos anti-amamantamiento. **Resultados**: Los cocos grampositivos fueron los patógenos predominantes, con *Streptococcus agalactiae* representando el 85% de los aislamientos bacterianos. La prueba de susceptibilidad antimicrobiana reveló que la oxitetraciclina, doxiciclina, eritromicina y cotrimoxazol mostraron una eficacia del 100%. La sulfametazina/trimetoprima y la tilosina presentaron una susceptibilidad del 85%, mientras que la penicilina y la amoxicilina fueron efectivas en el 60% de los casos. La enrofloxacina mostró una eficacia moderada, con una tasa de susceptibilidad del 50%. El estudio también identificó factores de riesgo clave, como la infestación de garrapatas, lesiones en la ubre y dispositivos anti-amamantamiento. **Conclusiones**: El estudio destaca la importancia de monitorear la resistencia bacteriana en la mastitis camellar y sugiere que las estrategias de tratamiento adecuadas, que incluyan el uso de oxitetraciclina, doxiciclina y eritromicina, deben ser priorizadas. La gestión eficaz de la mastitis en los rebaños de camellos en Argelia requiere abordar los factores de riesgo identificados, como la infestación de garrapatas y las lesiones en la ubre, e implementar estrategias de prevención y tratamiento adecuadas para mejorar la salud animal y la calidad de la leche.

Palabras clave: *Aislamiento bacteriano; Camellas (Camelus dromedarius); Camellas lactantes; Factores de riesgo; Mastitis clínica; Prevalencia; Sur de Argelia; Susceptibilidad antimicrobiana; Streptococcus agalactiae.*

Resumo

Contexto: A mastite clínica em camelas (*Camelus dromedarius*) é uma preocupação significativa para a criação de camelos, particularmente em regiões como as províncias de Oued Souf e Illizi, na Argélia. A mastite afeta a saúde dos animais e a qualidade do leite, impactando a produtividade e o manejo do rebanho. Compreender a prevalência, as características bacteriológicas e os fatores de risco associados à mastite é essencial para desenvolver estratégias de manejo eficazes. **Objetivo**: Este estudo visa investigar a prevalência, os fatores de risco e as características bacteriológicas da mastite clínica em camelas saharianas nas regiões de Oued Souf e Illizi, na Argélia, com foco nos padrões de suscetibilidade antimicrobiana dos patógenos envolvidos. **Métodos**: Um total de 170 camelas saharianas multíparas foram examinadas clinicamente. Amostras de leite foram coletadas dos animais afetados, e os isolados bacterianos foram obtidos e identificados. Testes de suscetibilidade antimicrobiana foram realizados nos isolados para determinar os padrões de resistência. Também foram avaliados fatores de risco, como infestação por carrapatos, lesões na glândula mamária e o uso de dispositivos antiamamentação. **Resultados**: Os cocos gram-positivos foram os patógenos predominantes, com *Streptococcus agalactiae* representando 85% dos isolados bacterianos. Os testes de suscetibilidade antimicrobiana revelaram que a oxitetraciclina, doxiciclina, eritromicina e o cotrimoxazol mostraram 100% de eficácia. Sulfametazina/trimetoprima e tilosina apresentaram 85% de suscetibilidade, enquanto a penicilina e a amoxicilina foram eficazes em 60% dos casos. A enrofloxacina demonstrou eficácia moderada, com uma taxa de suscetibilidade de 50%. O estudo também identificou fatores de risco-chave, como infestação por carrapatos, lesões na glândula mamária e dispositivos antiamamentação. **Conclusões**: O estudo destaca a importância de monitorar a resistência bacteriana na mastite em camelos e sugere que estratégias de tratamento adequadas, incluindo o uso de oxitetraciclina, doxiciclina e eritromicina, devem ser priorizadas. O manejo eficaz da mastite em rebanhos de camelos na Argélia exige que se abordem os fatores de risco identificados, como a infestação por carrapatos e as lesões na glândula mamária, e que se implementem estratégias de prevenção e tratamento apropriadas para melhorar a saúde animal e a qualidade do leite.

Palavras-chave: *Camelas (Camelus dromedarius); Camelas lactantes; Fatores de risco; Isolamento bacteriano; Mastite clínica; Prevalência; Sul da Argélia; Suscetibilidade antimicrobiana; Streptococcus agalactiae.*

INTRODUCTION

The dromedary camel is a versatile creature renowned for its exceptional ability to thrive in arid and semiarid regions where water and vegetation are limited. This animal plays a vital role in supporting human existence and the utilization of these harsh environments (Abera et al. 2010; Geresu et al. 2021) . The camel's unique physiological adaptations have made it a symbol of resilience in these challenging areas (El-Agamy 2006).

Similar to other milk-producing animals, dromedary camels are prone to mastitis (Abdel Gadir et al. 2005; Alamin et al. 2013; Al-Juboori et al. 2013; Djeddi et al. 2024), a prevalent condition that threatens both animal health and the economic stability of pastoralists (Matofari et al. 2003). Given its potential to cause significant financial losses, preventing mastitis is crucial for safeguarding the livelihoods of pastoral communities (Archana et al., 2014). Mastitis is characterized by inflammation of the mammary gland tissue, resulting in physical and chemical alterations in milk composition and pathological changes in the udder, including swelling, warmth, pain, and fluid retention. Notable milk changes include discoloration, clot formation, and increased leukocyte counts (Hadef et al. 2018).

Mastitis can present in two primary forms: clinical and subclinical. Clinical mastitis is identifiable through visible signs and abnormalities in the animal's udder and milk (Djeddi et al. 2025). Conversely, subclinical mastitis leads to decreased milk production without apparent (Ruegg 2017). The absence of visible indicators makes subclinical mastitis difficult to diagnose, allowing it to persist undetected. This can result in greater economic losses compared to clinical mastitis, as farmers may only become aware of the issue once milk quality and production have significantly declined. Consequently, early and targeted milk testing is essential for promptly detecting and addressing subclinical mastitis, thereby minimizing economic losses and ensuring herd health and productivity (Mohamoud et al. 2024). Furthermore, camel mastitis may pose risks to human health and the well-being of nursing calves (Jilo et al. 2017).

Mastitis is observed to be comparatively infrequent in camelids relative to bovines; however, its prevalence may escalate in lactating camels as a consequence of manual milking practices

and teat deformities (Abo Hashem et al. 2020; AL-Tofaily and Al rodhan, 2011). It is approximated that over 25% of lactating female camels are afflicted by mastitis (Alamin et al. 2013; Faye and Saleh 2011). While an array of infectious agents may incite mastitis in camels, bacterial pathogens are predominantly recognized as the principal offenders (Seifu and Tafesse 2010). The Gram-positive bacterial isolates comprise *Staphylococcus aureus*, *Staphylococcus hycus*, *Streptococcus agalactiae*, *Micrococcus luteus*, and *Arcanobacterium pyogenes*. Concurrently, Gram-negative isolates such as *Mannheimia haemolytica*, *Salmonella spp*., and *Klebsiella pneumoniae* are also implicated in the pathology (AL-Tofaily and Al rodhan, 2011). Clinical mastitis is readily discerned through palpation and visual inspection of the affected udder quarter, which typically exhibits signs of swelling, erythema, increased temperature, and tenderness. Modifications in the milk, including alterations in consistency and visual characteristics, can be assessed utilizing a strip cup. A variety of indirect diagnostic tests are utilized for the identification and monitoring of the condition, including the California Mastitis Test (CMT), Somatic Cell Count (SCC), and ATP test (Hussein 2021). Acute mastitis frequently manifests within the initial days postpartum, characterized by clinical signs such as anorexia, pyrexia, generalized depression, udder edema, alongside pronounced inflammation and discomfort (Obied et al. 1996). Chronic mastitis, on the other hand, can be identified by the presence of pus, a high bacterial cell count detected through the CMT, atrophy of one or more quarters, and pustules on the udder surface (AL-Tofaily and Al rodhan, 2011).

The objective of this investigation was to explore the various forms of clinical mastitis within camel populations in the Oued Souf and Illizi region. This study evaluated the influence of multiple factors including seasonal variations, age, stage of lactation, frequency of calvings, application of antisuckling devices, and the presence of udder lesions on the incidence of mastitis-inducing agents. Furthermore, the antibiotic susceptibility profiles of bacterial isolates obtained from mastitic female camels were systematically assessed.

MATERIALS AND METHODS

Ethics statement

This study included a questionnaire-based survey of camel breeders, along with examinations of their animals and the collection of milk samples from those showing signs of illness. The research was approved by the Committee of the Algerian Association of Sciences in Animal Experimentation (http://aasea.asso.dz/articles/) under Law No. 88-08/1988, concerning veterinary medical activities and the protection of animal health (NºJORA: 004/1988). Experimental permissions were granted by Mohamed Cherif University in Souk

Ahras, the Institute of Agriculture and Veterinary Sciences, and the Biotechnology Research Center in Constantine. Participants provided verbal informed consent for milk sample collection and survey participation. All procedures followed regulations on animal

Study area

This investigation was carried out in the Illizi and Souf regions, with Souf positioned in the southeastern part of Algeria at coordinates 33°22′16.823″ N and 6°50′52.686″ E. The region is characterized by a Saharan climate, which is distinguished by pronounced temperature fluctuations between diurnal and nocturnal periods, as well as seasonal variations between summer and winter. The month of January represents the lowest temperature period, averaging 10.9°C, whereas July is recognized as the peak temperature month, frequently surpassing 36.4°C. Precipitation is predominantly observed during the winter months and exhibits considerable interannual and interweekly variability, with an annual average rainfall of 61.1 mm (Figure 1).

The province of Illizi functions as both a town and a commune, which coincides with the boundaries of Illizi District, located in the southeastern region of Algeria, serving as the administrative capital of Illizi Province. As per the 2008 census, it ranks as the most populous commune within the province, with a recorded population of 17,252, an increase from 10,163 in 1998, reflecting an annual population growth rate of 5.5%, the highest in the province (Figure 1).

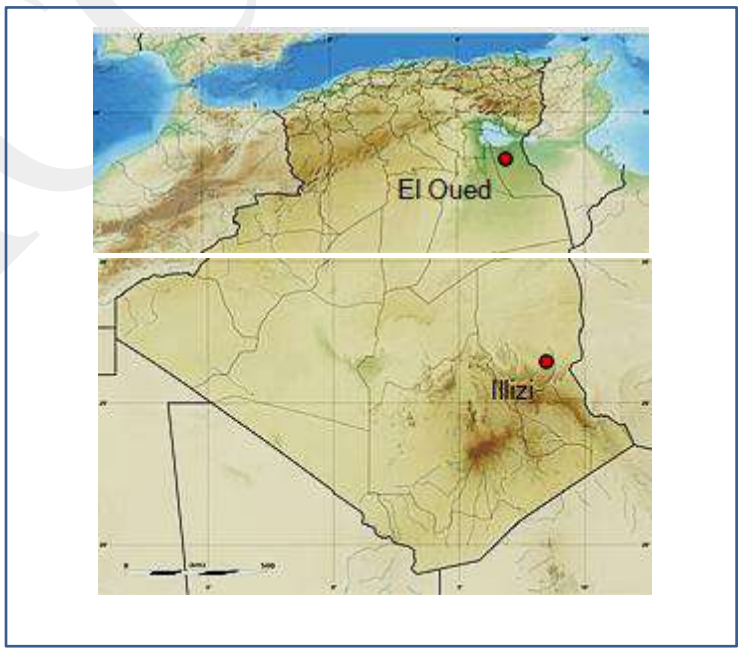

Figure 1. Map of the Study Area: Illizi and Oued Souf in Southeastern Algeria

Animals of study

This investigation was carried out during the period from 2023 to 2024 and encompassed a cohort of 170 multiparous Sahraoui female camels, with ages ranging from 5 to 27 years. A comprehensive assessment of 680 lactating mammary quarters from these 170 female camels was performed to identify instances of clinical mastitis. The camels in question were part of herds that were managed by nomadic pastoralists adhering to traditional husbandry practices.

Questionnaire survey

During each data collection phase, a structured questionnaire was developed utilizing closed-ended inquiries (dichotomous format), which underwent refinement through both formal and informal validation processes (Thrusfield 2007). The questionnaire elicited data pertaining to husbandry management practices, encompassing factors such as lactation stage, parity number, animal age, herd health management, udder sanitation and preparation during milking, utilization of antisuckling devices, milk production levels, milking frequency, calf mortality rates, overall herd condition, feeding methodologies, herd size, frequency of proprietor visits, understanding of camel mastitis, treatment endeavors and their results, accessibility of veterinary services, as well as the prevalence and economic ramifications of mastitis. Interviews were executed with an individual possessing substantial knowledge regarding the herd, who was present at the time of the visit to provide precise responses to the inquiries posed.

Clinical examination

Prior to the initiation of sampling, a thorough palpation and inspection of the udder were conducted to identify any clinical manifestations of mastitis, including but not limited to swelling, elevated temperature, tenderness, induration, and abnormal discoloration. Additionally, observations were made concerning the presence of lesions, structural deformities, ectoparasites such as ticks on the udder or teats, symmetry and dimensions of the udder, as well as alterations in the consistency and color of the milk, alongside the implementation of antisuckling devices. Teats that were non-functional were classified as clinical cases, given that teat obstruction represents a protracted phase of mastitis that is amenable to clinical diagnosis. All female camels exhibiting signs of clinical mastitis underwent comprehensive clinical evaluations, which encompassed the monitoring of body temperature and an assessment of their appetite.

Milk Sample Collection

Milk samples were collected following the sterile milk sampling protocol outlined by Kirk (kirk 2000). Initially, a sterile container was appropriately labeled, and the udder was meticulously cleansed and dried utilizing cotton. Subsequently, each teat orifice was disinfected with a 70% alcohol solution, commencing with the most distal teat and progressing towards the proximal one, followed by the disposal of 1–2 streams of milk from each teat. Milk specimens were then obtained, achieving a fill level of 75% within the sterile container, commencing with the proximal teat. The specimens were conveyed to the laboratory within an insulated container and preserved in a refrigerated environment at 4°C for a duration not exceeding 72 hours prior to subsequent analysis. The milk specimens underwent examination for homogeneity, coloration, and other discernible irregularities. The diagnosis of clinical mastitis was established based on the presence of abnormal milk, indicators of udder infection, and the identification of mastitis pathogens through bacteriological culturing.

Bacteriological examinations culturing

Milk specimens from nine clinical quarters were systematically selected for bacteriological examination. A loopful of each specimen was inoculated onto 5% defibrinated sheep blood agar and subsequently incubated at 37°C for a duration of 48 hours. Seven colonies that emerged were arbitrarily chosen for additional analysis in accordance with the National Mastitis Council (NMC) guidelines (1987). The colonies were assessed for morphological characteristics, hemolytic patterns, and Gram staining properties. Gram-positive cocci were subjected to catalase testing, and those identified as catalase-positive underwent subsequent coagulase testing. Streptococci were characterized utilizing CAMP, esculin, raffinose, salicin, mannitol, and inulin assays. Gram-negative rods were distinguished based on motility assessments, lactose fermentation (evidenced by growth on MacConkey agar), and the oxidase reaction test.

Statistical analysis

The prevalence of clinical mastitis was determined by dividing the number of camels that tested positive for clinical mastitis by the total number examined. Statistical evaluations were conducted utilizing the SPSS software (Version 16). A confidence level of 95% was used, with a probability value of $P < 0.05$ considered statistically significant.

RESULTS

Study Population

A total of seven herds were surveyed, encompassing the examination of one hundred seventy animals. The reported sizes of the herds varied between thirteen and seventy animals, while the quantity of lactating individuals within each herd fluctuated from five to thirty-five camels. The median age of the camels included in the study was fifteen years, with a median parity of three, and a median duration of lactation of three months.

Herd Management

Animal husbandry practices within the Zone are characterized by a system of extensive pastoral production and seasonal migratory patterns, as affirmed by all respondents. Every participant engaged in the interviews reported consumption of the milk derived from their camels, perceiving it as an essential nutritional resource. All inspected herds were provided with feed comprising wheat bran for their animals.

Camels were accommodated in either open or closed enclosures, contingent upon their age. All respondents confirmed that calves and adult camels were housed in distinct areas. Adult camels were maintained in open camps located in proximity to the homestead, whereas camel calves were sheltered in zeriba, a local term denoting enclosures specifically designed to segregate them from the adult herd. These enclosures were primarily erected to safeguard the calves from nocturnal predators and to inhibit suckling from the dam. The remaining herd was deemed capable of self-defense against potential predators.

Household's Questionnaire Survey Result

In the designated study region, pastoralists elucidated a variety of factors linked to udder health complications and systematically classified them according to perceived etiological origins and clinical manifestations. The predominant classifications encompassed tick infestations and lesions of the udder. Among the 60 participants surveyed, 85% exhibited awareness of clinical mastitis occurring in lactating female camels; however, none acknowledged the existence of subclinical mastitis in camels appearing to be in good health. A significant proportion of respondents (80%, or 32 out of 40) indicated that mastitis predominantly manifested during the wet, rainy season and in the initial phases of lactation. In addressing mastitis, 35% of the respondents utilized contemporary veterinary pharmaceuticals, whereas 65% depended on

traditional remedies, especially those prescribed by seasoned camel proprietors. The vast majority of participants (98%) reported having access to veterinary services.

Clinical Examination

The results of the study on the prevalence of mastitis in lactating camels across Oued Souf and Illizi reveal significant insights into the health status of these animals. In Oued Souf, the highest prevalence was observed in Hassi Khalifa, with 10% of the 30 camels examined testing positive for mastitis, followed by a prevalence of 6.66% in Sidi Abd Allah, where 2 out of 30 camels were affected. In contrast, Ouedi Elalanda showed a much lower prevalence of 1.53%, with only 1 positive case out of 65 examined. In Illizi, the prevalence rates were generally lower, with Debdeb reporting a prevalence of 2.22% among 45 camels. Overall, across both study areas, a total of 170 camels were examined, resulting in 8 positive cases and an overall prevalence of 4.70% (Table 1).

The findings demonstrate that the proportion of clinical mastitis observed among the total population of examined female camels was 1.31%. The results encompass acute, chronic, and bland teat conditions, representing 55.55%, 33.33%, and 11.11% of the affected teat quarters, respectively. Among the cohort of 170 subjects, 4.69% manifested udder pathologies, with 50% experiencing the acute variant, 37.5% displaying chronic mastitis, and 12.5% exhibiting bland teat conditions (Table 2).

Table 1. Prevalence of Mastitis in Lactating Camels in Oued Souf and Illizi Regions

Study area	Number of animals examined	Number of positives	(%) Prevalence
Oued Souf			
Sidi Abd Allah	30	02	6.66%
Ouedi Elalanda	65	01	1.53%
Hassi Khalifa	30	03	10%
Illizi			
Debdeb	45	02	2.22%
Total	**170**	**08**	**4.70%**

Table 2. Prevalence of clinical mastitis at Oued Souf and Illizi level in the selected study area.

	Quarters			She-camels	
	Number of positives		**Prevalence (%)**	**Number of positives**	**Prevalence (%)**
Acute mastitis	Right front	01	20%	04	50%
	Right hind	01	20%		
	Left front	02	40%		
	Left hind	01	20%		
	Total	05	100%		
Chronic mastitis	Right front	00	/	03	37.5%
	Right hind	01	33.33%		
	Left front	00	/		
	Left hind	02	66.66%		
	Total	03	100%		
Bland teats	Right front	00	/	01	12.5%
	Right hind	00	/		
	Left front	00	/		
	Left hind	01	100%		
	Total	01	100%		
Total		09	1.32%	08	4.70

Acute mastitis

The prevalence of acute mastitis was documented at 2.35%. The clinical manifestations associated with this variant of mastitis were distinguished by edema, swelling, and erythema of the udder. Pain was observed upon palpation, and the milk demonstrated discernible changes in color and consistency, appearing dilute and containing coagulated particles. The affected subjects exhibited mild systemic responses, which included a marginal elevation in body temperature reaching 37.7°C (Table 2).

Chronic mastitis

The findings indicated that 2.35% of the udders demonstrated chronic mastitis, specifically classified as chronic non-suppurative mastitis. This pathological condition was characterized by tissue atrophy and an absence of discomfort in the affected udder. Female camels with chronic mastitis exhibited no systemic manifestations, maintaining a normal body temperature, a satisfactory appetite, efficient rumination, and pink mucous membranes. Furthermore, the investigation revealed that 0.14% of the assessed quarters presented bland teats, which were characterized by obstruction of the teat canal, leading to nonproductive quarters (Table 2).

Quarter Level Prevalence of Clinical Mastitis in Traditionally Managed Lactating Camels.

Among the 680 quarters examined, 9 (1.32%) tested positive for clinical mastitis through comprehensive physical assessment, with the exclusion of blind teats and atrophied quarters from which milk samples were not procured. Further analysis revealed that the left front quarter (LFQ), left hind quarter (LHQ), and right front quarter (RFQ) were the most prevalently affected by mastitis, whereas the right hind quarter (RHQ) exhibited the lowest incidence of affliction, as delineated in (Table 2).

The findings demonstrated that tick infestation, lesions of the udder and teat, as well as the implementation of antisuckling devices exhibited a significant correlation ($p < 0.05$) with the occurrence of mastitis in lactating camels. These elements were delineated as critical risk factors within the research, as illustrated in (Figure 2) (Figure 3).

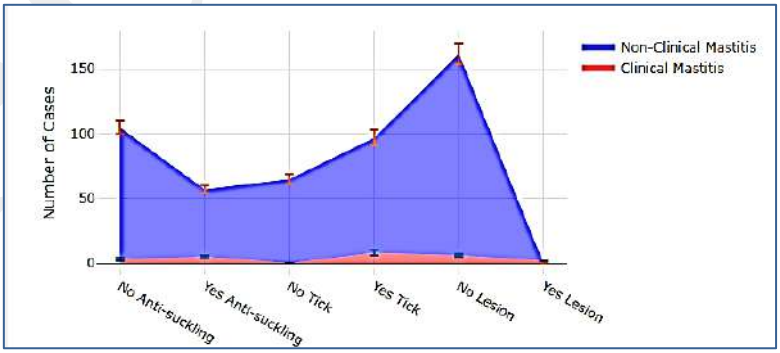

Figure 2. Logistic regression on the prevalence of the overall clinical mastitis with respect to exposure variables in studied lactating camels (N=170) univariate logistic regression

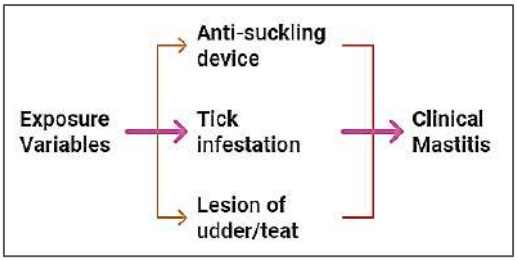

Figure 3. Correlation between tick infestation, udder lesions, antisuckling devices, and the occurrence of clinical mastitis in lactating camels

The age of camels assessed ranged from 5 to 25 years; the findings indicated that the prevalence of clinical mastitis in female camels aged 5-10 years, 11-15 years, and ≥ 16 years was recorded at 1.76%, 1.17%, and 1.76% respectively. Statistically, the analysis revealed no significant differences (P>0.05) among the age groups, as illustrated in (Figure 4).

The findings of the study indicated that the correlation between the number of calvings and the incidence of mastitis was documented, with the prevalence of clinical mastitis recorded at 12.5%, 12.5%, 25%, and 50% for 1, 2, 3, and ≥ 4 calvings respectively. Statistically, there were no significant differences (P>0.05) among the varying numbers of calvings, as presented in (Figure 4).

The results regarding the stages of lactation and their impact on the occurrence of clinical mastitis indicated that the proportions of clinical mastitis occurrence were 62.5%, 12.5%, and 25% at the lactation stages of 1 day to 3 months, 4 to 6 months, and ≥ 7 months respectively. Statistically, there were no significant differences among the categorized lactation stages (P < 0.19), as shown in (Figure 4).

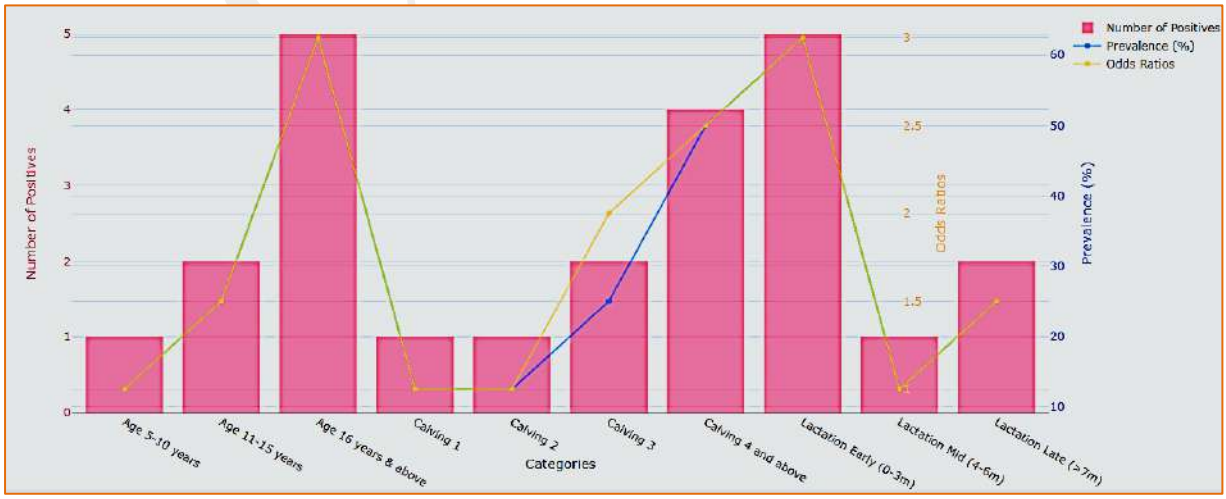

Figure 4. Prevalence of Clinical Cases in Lactating Camels: Influence of Age, Number of Calvings, and Lactation Stages

Bacterial Analysis and Intramammary Infection

The findings demonstrated that within the seven samples identified as positive for bacterial isolation, a complete 100% exhibited gram-positive bacteria. The particular isolates comprised *Streptococcus agalactiae* (74%) and *Staphylococcus aureus* (26%) (Table 3).

Isolate	**Clinical cases**	
	Number of positives	**Prevalence (%)**
Streptococcus agalactiae	6	86%
Staphylococcus aureus	1	14%
Total	07	100%

Table 3. Mastitis causing pathogens isolated from camels with clinical mastitis

Antimicrobial susceptibility testing

The results of antimicrobial susceptibility tests performed on bacterial isolates from mastitic she-camels diagnosed in this study showed that the isolates were highly susceptible to oxytetracycline, doxycycline, erythromycin, and cotrimoxazole, all exhibiting a 100% mean susceptibility rate (Figure 5). Other antibiotics demonstrated slightly lower efficacy, with sulfamethazine/trimethoprim and tylosin both showing an 85% susceptibility rate, followed by penicillin and amoxicillin at 60% each. Enrofloxacin exhibited moderate sensitivity at 50%.

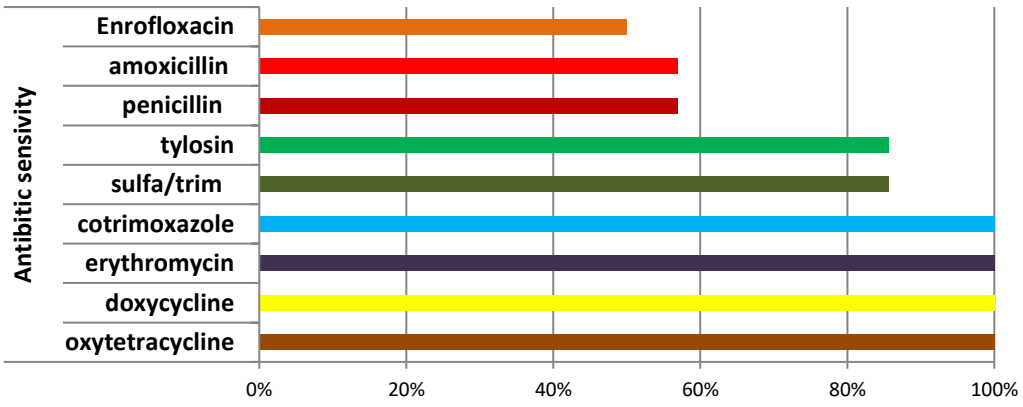

Figure 5. Antimicrobial susceptibility testing

DISCUSSION

The herd located within the four designated areas of the Oued Souf and Illizi region exhibits a minimal occurrence of clinical mastitis, a phenomenon that can be ascribed to their organic dietary regimen, as camels forage on pastures abundant in medicinal flora. It is noteworthy that a complete consensus of 100% (7/7) among the surveyed pastoralists affirmed that clinical mastitis does not constitute a significant concern and that they possess an understanding of the ailment. This observation diverges from the conclusions drawn by (Husein et al. 2013), who indicated that roughly 70% of respondents were cognizant of clinical mastitis, and (Geresu et al. 2021) who reported that approximately 85% were informed about the condition in camels. The affliction is generally not subjected to therapeutic measures and frequently advances naturally to a chronic phase, culminating in irreversible cessation of milk yield. Moreover, as posited (AL-Tofaily and Al rodhan, 2011)**,** the majority of acute mastitis incidents manifest during the weaning process, which occurs when camel calves are detached from their mothers, resulting in the accumulation of milk within the udder, thereby heightening susceptibility to bacterial intrusion and subsequent mastitis development..

The prevalence rate of clinical mastitis documented in the present investigation stands at 4.70%, which is congruent with findings reported (Saidi et al. 2021) in Laghouat and Djelfa regions of southern Algeria, (Geresu et al. 2021) in Gomole District of Borena Zone, southern Ethiopia, (Husein et al. 2013) in Jijiga town of eastern Ethiopia, who reported prevalence rates of 4.44%, 4.3%, and 4.9%, respectively. This prevalence is closely aligned with several antecedent studies, such as a 5.4% prevalence in the Borena zone of Oromia Regional State (Regassa et al. 2013), 5.7% in pastoral area of Borena lowland (Zeryehun et al. 2017), 5.9 % prevalence report of
(Abdurahman et al. 1995) in Sudan, 6.3% in Abu Dhabi, United Arab Emirates (Mehamud et al. 2017), 6.3% in Gursum district of eastern Hararghe zone (Mehamud et al. 2017).

Nonetheless, the overall prevalence of clinical mastitis among camel herds (at the animal level) identified in the current study, which is 4.70%, is inferior to the prevalence rate of 7.5% reported in M'sila and Biskra, two districts in Algeria (Barka et al. 2023), 8.3% in Jijiga, Eastern Ethiopia (Abera et al. 2010)**,** 10 to 17 % in dromedary camels in Borana area of Southern Ethiopia (Megersa 2010), 12.5% in pastoral area of Borena lowland (Wubishet, Dabaso, and Getachew 2016), 18.98 in tamboul area, Sudan (Hussein and Saad 2017), 19.5% in Eastern Sudan(Wanjohi et al. 2013).

Conversely, a comparatively lower prevalence of 2.1% clinical mastitis has also been documented by (Woubit et al. 2001)**,** as well as a 1% prevalence in the Afar Regional State district, Northeastern Ethiopia (Alebie et al. 2021)**.**

The present investigation revealed a notable prevalence of chronic mastitis among camels, with 50% of the identified cases categorized as chronic. This observation is consistent with the findings of (Abeer et al. 2018) who indicated that 48% of mastitis occurrences in camels were chronic, highlighting a significant correlation between udder texture and chronic mastitis, with hard udders exhibiting a 3.61-fold increased likelihood of being affected. Conversely, a study conducted in Iraq reported that chronic mastitis was identified in merely 20% of the cases (Al-Hakak 2023).

Conversely, this study indicated that acute mastitis was prevalent, accounting for 50% of the cases in camels. In contrast, research on Iraqi camels found that acute mastitis occurred in only 13% of cases, with *Staphylococcus aureus* being a common isolate (Al-Hakak 2023), Additionally, acute mastitis was diagnosed in 24.14% of cases in the Butana region of Sudan, making it the second most common form after chronic mastitis (Abdella and Mohammed 2014). Furthermore, (Abeer et al. 2018) reported that acute mastitis constituted 22% of the observed mastitis cases in camels, alongside chronic and neoplastic types.

In the present study, the correlation of clinical mastitis with various influencing factors, such as tick infestation, lesions, parity, stage of lactation, and seasonal variation, was systematically assessed for potential associations (Table 1). Significantly, a 100% prevalence of clinical mastitis was noted in female camels infested with ticks. This research emphasizes tick infestation on the udder as a critical risk factor contributing to the incidence of mastitis, with the observed variation in prevalence demonstrating statistical significance ($P < 0.05$). This finding is corroborated by previous research conducted (Djeddi et al. 2024; Husein et al. 2013). Prior investigations have recognized the udder as a preferred locus for tick infestation, which may lead to the development of skin and teat lesions (Younan and Abdurahman 2004; Obied et al.1996). Researchers have noted that tick infestations may predispose the udder to mastitis-causing microorganisms by creating an environment conducive to infection (Husein et al. 2013; Megersa 2010; Mengistu et al. 2010). Additionally, (Ahmed 2005) proposed that teat lesions arising from tick infestations and the application of anti-suckling devices could heighten the vulnerability of udders to bacterial infections, potentially leading to chronic conditions. However, (Abdel Gadir et al. 2005) presented contrasting findings regarding the

relationship between tick infestation and teat lesions. This discrepancy may stem from differences in sample size, with their study examining a larger population of camels infested with ticks compared to a smaller group with teat lesions.

The existence of lesions on the udder or teats has been recognized as a risk factor associated with the manifestation of clinical mastitis in camels; however, it was not classified as a pivotal factor in the context of this investigation. Such lesions facilitate the onset of mastitis by promoting the ingress of bacteria and inflicting irreversible tissue damage (Younan and Abdurahman 2004). Among the sole camel exhibiting udder or teat lesions in this research, there was a complete positivity rate of 100% (1/1) for mastitis. Both penetrating and non-penetrating superficial dermal lesions affecting the udder and teats were documented. A higher incidence of mastitis (72.2%) in camels exhibiting udder lesions has been reported in the Afar region, as indicated by (Woubit et al. 2001)**,** and also in the Borana lowlands of Southern Ethiopia. Similarly, (Abdurahman et al. 1995) highlighted that trauma could directly lead to mastitis by predisposing the udder to bacterial invasion. In our study, udder lesions may have occurred due to accidental wounds inflicted by the camels rubbing their udders on hard plants or from tick infestations.

A positive correlation was identified between the incidence of mastitis and the stage of lactation within the context of this investigation, with a heightened prevalence observed during the initial stages. This phenomenon is frequently ascribed to the predominance of new infections occurring in the initial phase of the dry period and the first two months of lactation, particularly involving environmental pathogens (AL-Tofaily and Al Rodhan, 2011). Nevertheless, this study did not reveal any statistically significant variation in the distribution of mastitis cases across the various stages of lactation ($P > 0.05$). Research conducted by indicates that the peak prevalence of clinical mastitis manifests during the late lactation phase, specifically in the final two months, with rates soaring to as high as 55% during this timeframe. Conversely, an alternative study by (Ahmad et al. 2012) documented that the early lactation period (0 to 1 month) also exhibits a substantial prevalence of mastitis, reaching 54.55%. Furthermore, (Gramay and Ftiwi 2018) ascertained that the initial stage of lactation in camels is linked to an elevated risk of mastitis, attributed to immune suppression, hormonal fluctuations, and stress factors. Elevated rates of mastitis around calving and during the early lactation phases may also be attributable to infections acquired during the dry-off period that exacerbate post-calving. Throughout the periparturient phase and the early lactation period, the

immune system's efficacy in combating pathogens is diminished, exacerbated by the physiological stresses associated with gestation and calving (AL-Tofaily and Al rodhan, 2011).

The findings of this study indicated a relationship between the age of she-camels and the prevalence of mastitis, although age did not exert a significant influence on the incidence of clinical mastitis. Nonetheless, the probability of developing clinical mastitis was found to be two to four times greater in camels in their third or fourth parity when contrasted with those in their first parity. Numerous studies corroborate the assertion that the frequency of mastitis escalates with increasing parity or age (Ahmad et al. 2012; Ranjan et al. 2021; Seligsohn et al. 2020). Additionally, camels exceeding 14 years of age exhibited heightened susceptibility to clinical mastitis (Schukken et al. 2003). This observation stands in contrast to the findings of (Abdurahman 2006), who reported alternative results. In the current study, camels exhibiting high milk yield potential appeared to be more vulnerable to clinical mastitis, a finding that aligns with the results of (Ranjan et al. 2021).

She-camels within the age range of 10 to 27 years demonstrated a greater incidence of mastitis, likely correlated with their peak milk production occurring during this age span. According to (Jain 1979) , the elevated milk content, which serves as a protective mechanism within the mammary gland, is diminished, resulting in lower somatic cell counts during this age, thereby rendering them more susceptible. The augmented rate of mastitis associated with aging is likely not attributable to heightened intramammary vulnerability but rather to the ease with which pathogens penetrate through the teat duct, coupled with the accumulation of prior infections. Moreover, (Zeryehun et al. 2017) posited that the notable escalation in clinical mastitis prevalence associated with aging and parity could be ascribed to inadequate treatment efficacy, culminating in chronic mastitis and the potential for bacterial persistence across successive parities. This increased susceptibility can also be attributed to a decline in immunity with old age (Ahmad et al. 2012).

The microbiological examination of camel milk samples indicated that Gram-positive cocci were the main culprits behind camel mastitis, constituting 100% (7/7) of the isolated organisms. This high occurrence of Gram-positive cocci is consistent with previous research by (Abdel-Gadir et al. 2006), who noted a 75% prevalence in Dire Dewa and Gewane, and Woubit et al. 2001), who observed a 74% prevalence in Negele Borana. In this study, *Streptococcus agalactiae* dominated among Gram-positive isolates at 85%, which differs from the findings of (Woubit et al. 2001) where *Staphylococcus aureus* was reported at 21.1% prevalence.

Additionally, *S. agalactiae* has been recognized as a notable pathogen (16.2%, 32/197). Research conducted in eastern Sudan (Obied et al. 1996) and Kenya (Younan et al. 2001) also identified *S. agalactiae* and *S. aureus* as frequent causes of camel mastitis, with *S. aureus* at 12% and *S. agalactiae* at 11%, respectively.

The antimicrobial susceptibility results from this study provide key insights into the effectiveness of antibiotics for treating clinical mastitis in she-camels. Oxytetracycline, doxycycline, erythromycin, and cotrimoxazole exhibited 100% efficacy, suggesting they could be optimal first-line treatments due to their broad-spectrum activity. Sulfamethazine/trimethoprim and tylosin showed 85% susceptibility, making them reliable alternatives in some cases. However, the reduced efficacy of penicillin and amoxicillin (60%) may indicate emerging resistance in common pathogens, while enrofloxacin's moderate sensitivity (50%) raises concerns about resistance development. These findings emphasize the need for ongoing monitoring of antibiotic resistance, strategic use of antibiotics, and the potential implementation of rotational treatment plans to preserve the effectiveness of these drugs in veterinary care.

Declarations

Acknowledgment

Special thanks and appreciation to the veterinary inspector Abdelatif Miloudi and Youssef Maamara at the Directorate of Agricultural Services of El Oued province for their support

Funding statement

This study didn't receive any funding support. The resources used for the execution of this study were from the authors.

Conflicts of interest

The authors declared no competing interests.

Author contributions

All authors participated in the formation and design of this study. Khaled Djeddi: conceptualization, investigation, methodology, Formal analysis, and writing – original draft. Hind Houssou: supervision, proposed the subject, designed the study review & editing, validation, and approved the final version of this article. Yassine Gouasmia: supervision,

review and editing, validation. All authors have read and approved the final version of this article.

Use of artificial intelligence (AI)

No AI or AI-assisted technologies were used during the preparation of this work.

Data availability

The data sets used in the current study are available from the corresponding author on request.

References

Abdel Gadir A, Hidebrandt G, Kkeer J, Molla B, Kyule M, Baumann M. Prevalence and risk factors of camel (*Camelus dromedarius*) mastitis based on bacteriological examinations in selected regions of Ethiopia. J Camel Pract Res. 2005;12(1):33-36. https://camelsandcamelids.com/uploads/journal-manuscript/PG%20033-036%20Prevalence%20and%20risk.pdf

Abdel Gadir A, Hidebrandt G, Kkeer J, Molla B, Kyule M, Baumann M. Comparison of California Mastitis Test (CMT), Somatic Cell Counts (SCC) and bacteriological examinations for detection of camel *(Camelus dromedarius)* mastitis in Ethiopia. Berl Munch Tierarztl Wochenschr. 2006;119(1-2):45-49. https://pubmed.ncbi.nlm.nih.gov/16450708/

Abdella ME, Mohammed GE. Clinical study on camel mastitis (*Camelus dromedarius*) at Butana region, Sudan. SUST J Agric Vet Sci. 2014;15(2):82-94. https://repository.sustech.edu/handle/123456789/16916

Abdurahman OS, Agab H, Abbas B, Astrom G. Relations between udder infection and somatic cells in camel *(Camelus dromedarius)* milk. Acta Vet Scand. 1995;36:423–431. https://doi.org/10.1186/BF03547657

Abdurahman O. Udder health and milk quality among camels in the Errer Valley of Eastern Ethiopia. Livest Res Rural Dev. 2006;18(8):110. http://www.lrrd.org/lrrd18/8/abdu18110.htm

Abeer AM, Elshafie EI, Zakia AM, Muna EA, Sabiel YA. Epidemiological, bacteriological and histopathological investigations of mastitis in camels *(Camelus dromedarius)* in Tumbool

abattoir, Sudan. Journal of Camel Research and Production. 2018;2(1):1858-8263. https://repository.sustech.edu/handle/123456789/23611

Abera M, Abdi O, Abunna F, Megersa B. Udder health problems and major bacterial causes of camel mastitis in Jijiga, Eastern Ethiopia: Implication for impacting food security. Trop Anim Health Prod. 2010;42(3):341-347. https://doi.org/10.1007/s11250-009-9424-6

Abo Hashem M, Ibrahim S, Goda A, Enany M. Diversity of microorganisms associated to she camels' subclinical and clinical mastitis in South Sinai, Egypt. Suez Canal Vet Med J. 2020;25(2):307-319. https://doi.org/10.21608/scvmj.2020.145315

Ahmad S, Yaqoob M, Bilal MQ, Muhammad G, Yang L-G, Khan MK, Tariq M. Risk factors associated with prevalence and major bacterial causes of mastitis in dromedary camels *(Camelus dromedarius)* under different production systems. Trop Anim Health Prod. 2012;44(1):107-112. http://doi:10.1007/s11250-011-9895-0

Ahmed SOY. Bacterial diseases of the reproductive system of camels *(Camelus dromedarius)* in Eastern Sudan. J Anim Vet Adv. 2005;4(7):642-644. https://www.makhillpublications.co/files/published-files/mak-java/2005/7-642-644.pdf

Alamin M, Alqurashi, Elsheikh A. Mastitis incidence and bacterial causative agents isolated from lactating she-camel *(Camelus dromedarius)*. IOSR J Agric Vet Sci. 2013;2(3):7-10. https://adsc.nu.edu.sa/documents/618654/16880905/Mastitis+incidence+and+bacterial+causative+agents+isolated+from.pdf

Alebie A, Molla A, Adugna W, Tesfaye A, Ejo M. Prevalence, isolation, identification, and risk factors of major bacterial cause of camel subclinical mastitis. Biomed Res Int 2021;2021(1):1-6. https://doi.org/10.1155/2021/5522331

Al-Hakak Z. The extent response of bacteria isolated from cases of acute, subacute and chronic mastitis in Iraqi camels to some antibiotics used in treatment. IOP Conf Ser Earth Environ Sci. 2023;1259:012081. https://doi.org/10.1088/1755-1315/1259/1/012081

Al-Juboori AA, Kamat NK, Sindhu JI. Prevalence of some mastitis causes in dromedary camels in Abu Dhabi, United Arab Emirates. Iraqi J Vet Sci. 2013;27(1):9-14. https://pdfs.semanticscholar.org/bd68/996788db75f95aff48be5a8725472e2dc2a8.pdf

AL-Tofaily YI Kh and Al rodhan MAN. Study on clinical mastitis (bacteriological) in she-camels *(Camelus dromedarius)* in some areas of middle Euphrates in Iraq. Al Qadisiyah Journal of Veterinary Medicine Sciences. 2011;10(2):66-76 https://iasj.rdd.edu.iq/journals/uploads/2025/03/19/40ff967f2441c7d6d6165e8d9c8cd547.pdf

Archana PI, Mai A, Baghallab IB. Mastitis in camels in African and Middle East countries. J Bacteriol Parasitol. 2014;5(3):1-11. http://doi:104172/2155-9597.1000188

Barka I, Akkou M, Khelef D, Bentayeb L, Bouchami A, Boudrissa AK, et al. Prevalence of mastitis in Algerian dromedary camels and antimicrobial resistance of the causative staphylococci. Mljekarstvo. 2023;73(4):271-280. https://doi.org/10.15567/mljekarstvo.2023.0406

Djeddi K, Houssou H, Gouasmia Y, Rahab H, Miloudi L, Belgith M, et Allag L. Clinical study on camel mastitis *(Camelus dromedarius)* at Beni Guecha area, Algeria. Egypt J Vet Sci. 2024:1-11. http://doi.org/10.21608/ejvs.2024.305760.2266

Djeddi K, Houssou H, Rabah S, et al. Prevalence and risk factors related to the mastitis in camels (Oued Souf, Algeria). Trop Anim Health Prod. 2025;57:107. https://doi.org/10.1007/s11250-025-04360-4

Djeddi K, Houssou H, Rabah S, Ouchtati D, Djeddoubenabid A, Miloudi A, et Khenenou T. Review on subclinical mastitis in dairy camels. J Appl Vet Sci. 2024;9(3):50-63. http://doi.org/10.21608/javs.2024.287387.1334

El-Agamy E. Camel milk. In: Park YW, Haenlein GFW, editors. Handbook of milk of non-bovine mammals: camel milk production and utilization. Ames, lowa: Blackwell Publishing; 2006. p. 297-344 . https://doi.org/10.1002/9780470999738.ch12

Faye B, Saleh SK. Detection of subclinical mastitis in dromedary camels *(Camelus dromedarius)* using somatic cell counts, California mastitis test and udder pathogen. Emir J Food Agric. 2011;23(1):48-58. https://agritrop.cirad.fr/558810/1/document_558810.pdf

Geresu MA, Leliso SA, Liben GW. Camel mastitis: prevalence, risk factors, and isolation of major bacterial pathogens in Gomole District of Borena Zone, Southern Ethiopia. Vet Med Int. 2021;2021:9993571. https://doi.org/10.1155/2021/9993571

Gramay S, Ftiwi M. Camel milk production, prevalence and associated risk factors of camel mastitis in Aysaita Woreda Afar Regional State, North East Ethiopia. ARC J Anim Vet Sci. 2018;4(3):17-37. https://www.arcjournals.org/pdfs/ajavs/v4-i3/2.pdf

Hadef L, Aggad H, Hamad B. Bacterial causative agents associated with subclinical mastitis in dromedary she-camels in southeastern Algeria. Jordan J Biol Sci. 2018;11(2):209-214 . https://jjbs.hu.edu.jo/files/v11n2/Paper%20Number%2013.pdf

Husein A, Haftu B, Hunde A, Tesfaye A. Prevalence of camel *(Camelus dromedarius)* mastitis in Jijiga town, Ethiopia. Afr J Agric Res. 2013;8(24):3113-3120. https://academicjournals.org/journal/AJAR/article-full-text-pdf/1E402ED36308

Hussein MF. Mastitis. In: Infectious Diseases of Dromedary Camels. Cham: Springer; 2021. p. 153–157. https://doi.org/10.1007/978-3-030-79389-0_24

Hussein NA, Saad AM. Pathological study of camel mastitis in Tamboul area, Sudan. J Camel Pract Res. 2017;24(3):257-261. https://doi.org/10.5958/2277-8934.2017.00044.3

Jain NC. Common mammary pathogens and factors in infection and mastitis. J Dairy Sci. 1979;62(1):128-134. https://doi.org/10.3168/jds.S0022-0302(79)83214-2

Jilo K, Wako G, Mata W. Camel mastitis: A review. MOJ Ecology & Environmental Sciences. 2017;2(5):194-202. https://doi.org/10.15406/mojes.2017.02.00034

Kirk J. Sterile milk sampling. 2000.

Matofari JW, Younan M, Mwatha EW, Okemo PO. Microorganisms associated with sub-clinical mastitis in the Kenyan camel *(Camelus dromedarius).* J Trop Microbiol Biotechnol. 2003;2(1):11-16. https://doi.org/10.4314/jtmb.v2i1.35419

Megersa B. An epidemiological study of major camel diseases in the Borana Lowland, Southern Ethiopia. Oslo: Drylands Coordination Group; 2010. https://www.academia.edu/download/83305906/1042-dcg_report_no._58.pdf

Mehamud J, Megersa M, Abebe Y, Ahmed M. Prevalence, risk factors and major bacterial causes of camel mastitis, in Gursum District, Eastern Hararghe, Ethiopia. Global Veterinaria. 2017;18(3):203-208. https://www.idosi.org/gv/gv18(3)17/8.pdf

Mengistu F, Molla B, Ali A. Camel mastitis, associated bacterial pathogens and its impact on milk quality in Gewane District, a far Regional State, Northeastern Ethiopia. Bull Anim Health Prod Afr. 2010;58(3):249-259. https://doi.org/10.4314/bahpa.v58i3.64213

Mohamoud MJ, Hassan AH, Ziad AD, Abdullahi AA. Determination of prevalence of subclinical mastitis, characterization of intra-mammary infection-causing bacteria, and antibiotic susceptibility in dairy camels in Jigjiga City, Somali Region, Ethiopia. Front Vet Sci. 2024;11:1398118. https://doi.org/10.3389/fvets.2024.1398118

Obied AI, Bagadi HO, Mukhtar MM. Mastitis in *Camelus dromedarius* and the somatic cell content of camels' milk. Res Vet Sci. 1996;61(1):55-58. https://doi.org/10.1016/S0034-5288(96)90111-3

Ranjan R, Narnaware SD, Prakash V. Incidence, risk factors and economic impact of clinical mastitis in dromedary camel *(Camelus dromedarius)*. Trop Anim Health Prod. 2021;54(1):31. https://doi.org/10.1007/s11250-021-03035-0

Regassa A, Tesfaye D, Golicha G, Megersa B, Abunna F. Prevalence, risk factors, and major bacterial causes of camel mastitis in Borana Zone, Oromia Regional State, Ethiopia. Trop Anim Health Prod. 2013;45(7):1589-1595. https://doi.org/10.1007/s11250-013-0403-6

Ruegg PL. A 100-year review: Mastitis detection, management, and prevention. J Dairy Sci. 2017;100(12):10381-10397. https://doi.org/10.3168/jds.2017-13023

Saidi R, Mimoune N, Benaissa MH, Baazizi R. Mastitis u Deva u Južnom Alžiru. Vet Stanica. 2021;52(3):315-322. https://veterinarska-stanica-journal.hr/pdf/52/52-3/09-camel-mastitis-in-southern-algeria.pdf

Schukken YH, Wilson DJ, Welcome F, Garrison-Tikofsky L, Gonzalez RN. Monitoring udder health and milk quality using somatic cell counts. Vet Res. 2003;34(5):579-596. https://doi.org/10.1051/vetres:2003028

Seifu E, Tafesse B. Prevalence and etiology of mastitis in traditionally managed camels *(Camelus dromedarius)* in selected pastoral areas in Eastern Ethiopia. Ethiop Vet J. 2010;14(2):103-114 .https://doi.org/10.4314/evj.v14i2.63887

Seligsohn D, Nyman A-K, Younan M, Sake W, Persson Y, Bornstein S, Maichomo M, et al. Subclinical mastitis in pastoralist dairy camel herds in Isiolo, Kenya: Prevalence, risk factors,

and antimicrobial susceptibility. J Dairy Sci. 2020;103(5):4717-4731. https://doi.org/10.3168/jds.2019-17701

Thrusfield M. Veterinary epidemiology. 3rd ed. London: Blackwell Science; 2007. https://www.academia.edu/103112083/Veterinary_Epidemiology_Michael_Thrusfield

Wanjohi M, Gitao G, Bebora L. Subclinical mastitis affecting hygienic quality of marketed camel milk from North-Eastern Province, Kenya. Microbiol Res Int. 2013;1(1):6-15. https://www.netjournals.org/pdf/MRI/2013/1/13-012.pdf

Woubit S, Bayleyegn M, Bonnet P, Jean-Baptiste S. Camel *(Camelus dromedarius)* mastitis in Borena lowland pastoral area, Southwestern Ethiopia. Rev Elev Med Vet Pays Trop. 2001;54(3-4):207-212. https://doi.org/10.19182/remvt.9774

Wubishet Z, Dabaso A, Getachew G. Prevalence, associated risk factors and bacterial pathogens of camel mastitis in Borena Zone Oromia Regional State, Ethiopia. Int J Vet Sci. 2016;5(4):280-284 .https://www.ijvets.com/pdf-files/Volume-5-no-4-2016/280-284.pdf

Younan M, Abdurahman O. Milk hygiene and udder health. In: Farah Z, Fischer A, editors. Milk and meat from the camel: handbook on products and processing. Zurich: Vdf Hochschulverlag AG, ETH Zürich; 2004. p. 67-76 . https://books.google.com/books?hl=es&lr=&id=wZ6AYtmRDJUC&oi=fnd&pg=PA9&dq=Younan+M,+Abdurahman+O.+Milk+hygiene+and+udder+health.+In:+Farah+Z,+Fischer+A,+editors.+Milk+and+meat+from+the+camel:+handbook+on+products+and+processing.&ots=IPVkPcy7m1&sig=1r9F1Tr9XsP-RiyvRvhSqY53dmo

Younan M, Ali Z, Bornstein S, Muller W. Application of the California mastitis test in intramammary *Streptococcus agalactiae* and *Staphylococcus aureus* infections of camels *(Camelus dromedarius)* in Kenya. Prev Vet Med. 2001;51(3-4):307-316. https://doi.org/10.1016/s0167-5877(01)00228-8

Zeryehun T, Haro G, Adane B. A cross-sectional study on the prevalence of mastitis and associated bacterial pathogens in one-humped camels *(Camelus dromedarius)* in pastoral area of Borena lowland, Southern Ethiopia. Global Veterinaria. 2017;18(2):108-115. https://www.idosi.org/gv/gv18(2)17/6.pdf