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Insights into Bacterial Diversity and Chemical Composition of Milk in She-Camel Mastitis: For Diagnosis and Management

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Abstract

MASTITIS is a complex challenge that affects different animals including camels causing a significant economic repercussion worldwide. This study aimed to understand the bacterial causes of mastitis in camels, evaluate antibiotic susceptibility, and assess the impact of infection on physico-chemical milk properties. Ninety-two raw milk samples from 46 healthy and 46 mastitic camels were collected and analysed. Bacteriological and chemical analyses identify the presence of 65 bacterial isolates Most *Staphylococcus aureus*, *Streptococcus agalactiae*, and *Klebsiella pneumoniae*, at a prevalence rate of 21%, 22%, and 22%, respectively: with a lack of positivity regarding *Mycobacterium bovis*. Camel mastitis was seen to be caused solely by various bacterial species or in combination. Analysis of the milk's physico-chemical properties revealed significant decreases in total protein, casein, fat, and lactose levels, accompanied by elevated pH values. Moreover, fat-soluble vitamins (A, D_3, E) and vitamin C were notably reduced. Mastitic milk exhibited higher levels of Na and Cl, while K and Mg levels decreased compared to healthy milk. An increase in c-reactive protein (CRP) was observed. In conclusion, the findings highlight the importance of mastitis in camel husbandry within pastoral communities. As a result, pastoralists should be educated and informed about mastitis prevention and management to avoid potential economic losses.

Keywords: Chemical Evaluation, C reactive protein, Mastitic milk, microbial isolation.

Introduction

The dromedary camel (Camelus dromedarius) is a remarkable species with unique adaptations for surviving in harsh environments, such as limited water availability and the ability to eat thorny plants. This animal is highly valued in arid and semi-arid areas as a crucial source of meat and milk, as well as for transportation. Impressively, camels can sustain milk production even in adverse conditions such as droughts, which is in stark contrast to other lactating animals that may halt milk production. Camels demonstrate remarkable lactation longevity, consistently producing about 5-6 liters of milk daily even during periods of water shortage.[1, 2].

The nutritional profile of camel milk makes it a valuable dietary component, especially in regions where access to certain nutrients may be limited. The higher levels of essential minerals and lower sugar and cholesterol content can contribute to a balanced diet. The significantly higher levels of vitamin C in camel milk can help in meeting the daily requirements for immune function and overall health. Camel milk can be considered a nutrient-dense food source that can help support health and wellness [3]. Additionally, the inclusion of vitamin C in camel milk aids in its preservation by elevating the acidity level, thereby prolonging its usability [4].

Mastitis, the swelling of the mammary tissue, is recognized globally as a major economic issue within the dairy sector. It impacts a range of domestic animals and is common in many regions [5]. The condition results in significant economic detriment due to decreased milk yield, treatment and veterinary care costs, and the necessity to discard milk. Additionally, mastitis presents health hazards to humans and nursing calves owing to the possible contamination of milk with virulent pathogens, including Mycobacterium and Brucella species [6].

A variety of elements can precipitate the onset of mastitis, such as microbial invasions, trauma to the udder, or blockages within the lactiferous ducts [7].

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Common indicators of mastitis in camels include engorgement and warmth of the udder, discomfort, a reduction in milk output, and changes in the visual and tactile properties of the milk. In acute cases, the impacted region may become visibly inflamed and warm. Moreover, camels suffering from this condition might exhibit systemic symptoms like fever and general fatigue [8].

Although extensive research has been carried out on the causes, transmission, and treatment of camel mastitis, there is a lack of detailed knowledge about the immune and clinical-pathological changes associated with the disease. Gaining insight into these changes is crucial for developing effective management strategies that can reduce the prevalence and mortality of the disease. Consequently, this study's objective is to pinpoint the exact bacterial pathogens causing mastitis in she-camels and to investigate the resulting physicochemical changes in the milk of mastitic she-camels.

Material and Methods

Ethical approval

The present study was approved by the Institutional Animal Care and Use Committee at the Veterinary Medicine Faculty and Agriculture Research Center (IACUC approval no.: ARC/AHRI/117/24).

Samples:

Healthy milk (HM): Collected from 46 healthy she-camels exhibiting normal body temperatures, respiration rates, and pulse rates, along with visibly normal udder texture.

Mastitic milk (MM): Derived from 46 diseased she-camels experiencing hyperthermia, elevated pulse rates, anorexia, and increased respiratory rates. The udder examination revealed congestion, swelling, heat, pain, a noticeable reduction in milk output, and irregular consistency and appearance. Milk specimens exhibited a positive reaction to the California Mastitis Test (CMT), characterized by an immediate thickening of the mixture, indicative of a gelatinous consistency, as documented by Quinn et al. [9].

The samples were collected from Aswan, Upper Egypt, between September 2022 and January 2023. Each collected sample, approximately 500 mL in volume, was carefully transferred into sterile opaque plastic tubes. These tubes were promptly dispatched to the Animal Health Research Institute in Dokki to undergo rigorous bacteriological and chemical analyses.

Bacteriological examination

Positive milk samples identified through the California Mastitis Test (CMT) underwent bacteriological analysis. Each milk sample was centrifuged and then subjected to aerobic cultivation on various media including sheep blood agar, nutrient agar, MacConkey agar, Staph 110, and Edwards media. Inoculated plates were then aerobically incubated at 37°C and assessed for bacterial growth after 24 hours of incubation. Individual colonies were selected and biochemically identified following the procedure outlined by Quinn et al. [9]. All media utilized in this study were procured from HiMedia®, India.

Suspected *Klebsiella* spp Isolates were subjected to biochemical testing using the Microbact system from Oxoid®. Similarly, suspected *Streptococcus* spp. isolates were biochemically tested using the API system from Oxoid®, United Kingdom.

Isolation and identification of *Mycobacteria* were conducted following the Marks technique as using Middle Brook ager media and Lowenstein Jensen media outlined by Quinn et al. [9]. The samples underwent examination using conventional methods, including direct smear, culture, and biochemical tests, to isolate and identify *M. bovis*.

Antibiotic susceptibility testing

Isolates were cultured on Müller-Hinton broth tubes and subsequently aerobically incubated at 37°C for 18 hours. Following incubation, the cultures were plated onto Müller-Hinton agar plates and further incubated for antimicrobial susceptibility testing utilizing the standard disk diffusion technique according to CLSI [10].

Antimicrobial susceptibility testing using different types of antibiotic discs were employed, including Ampicillin (AMP, 15µg), Cephalexin (CL, 30µg), Clindamycin (DA, 10µg), Gentamicin (CN, 10µg), Imipenem (IMP, 10µg), Ofloxacin (OFX, 10µg), Rifampicin (RF, 5µg), Streptomycin (S, 10µg), and Tobramycin (TOB, 10µg). The antibiotic sensitivity interpretation about the zone of inhibition was done according to the instructions provided by the manufacturing company, HiMedia®, India.

Physicochemical characteristics of she-camel milk:

The pH values were measured with a pH meter manufactured by Hanna Instruments in Italy (Model HI) [11]. The content of fat in milk was analyzed by applying the Gerber method, as mentioned by Andrade et al. [12]. Protein content was determined based on the method outlined by the British Standards Institution (BSI) [13]. To determine the lactose content, IR spectroscopy was used, following the Association of Official Analytical Chemists (AOAC) Method 972.16 from 2005. The casein and chloride concentrations were estimated following the methods specified by the AOAC [14,15].

Macrominerals content of she-camel milk

The mineral concentration in milk was quantified using an Atomic Absorption Spectrophotometer (AAS) (Perkin Elmer®, model 2380, Germany) as described by Yildiz Küçük and Gökçek [16]. The phosphorus concentration in milk samples was determined using the colorimetric spectrophotometric molybdenum blue method of Gliszczyńska-Świgło and Rybicka [17].

Vitamins content of she-camel milk

Fat-soluble vitamins (A, D_3, and E) were analyzed using a simple, sensitive HPLC-MWD assay [18], the extraction was simple and summarized in a few steps as shown in Figure 1 and the vitamins were separated at 280 nm in a short time of less than 5 minutes as shown in Figure 1 with a mobile phase of 95% methanol with a 1.8 mL/min flow rate.

The vitamin C content was measured using a spectrophotometer (Spectro Quant Pharo 300 – Merck) at 520 nm as described by Tomovska [19].

The concentration of C-reactive protein (CRP) in she-camel milk

The level of CRP was determined using Camel C-Reactive Protein ELISA Kit; Cat.No: MBS055862 (MyBiosource, Inc., San Diego, USA).

Statistics

In this study, descriptive statistics and graphical representations of the data were conducted in Microsoft Excel following the methodology outlined by Kumar [20]. The variance between the means of the two groups was evaluated through an independent t-test in Excel, following the approach described by Abbott [21]. A significance level of $P \leq 0.05$ was employed for determining statistical significance in the analysis.

Results

Bacteriological results:

Among the 46 mastitic milk samples analyzed, a sum of 65 bacterial isolates were identified. The prevalence rates of the isolates were determined to be 21% for *S. aureus*, 22% for *S. agalactia*, and 22% for *K. pneumoniae*, as depicted in Figure 1. However, *M. bovis* was not detected. It was noted that 32.6% of the mastitic samples exhibited single infections, whereas 67.4% displayed mixed infections, as outlined in Table 1 and Figure 3.

The isolated bacteria demonstrated varying sensitivity levels toward the tested antibiotics, as summarized in Table 2. Specifically, *S. aureus* exhibited high sensitivity to streptomycin, gentamicin, and cephalothin, while displaying resistance to ciprofloxacin. On the other hand, *S. agalactia* showed sensitivity to amikacin, streptomycin, gentamicin, and tetracycline, but was resistant to ciprofloxacin and trimethoprim-sulfamethoxazole. *K. pneumonia*e displayed sensitivity to ampicillin, cephalothin, and trimethoprim-sulfamethoxazole while resistant to gentamicin and ciprofloxacin antibiotics (Figure 4).

Physicochemical characteristics of she-camel milk:

It was observed that mastitic milk exhibited a noteworthy increase in pH value at a significance level of $P < 0.05$. Moreover, there was a significant reduction in the percentages of total protein (T.P.), casein, fat, and lactose at a significance level of $P < 0.05$, as illustrated in Table 3 and Figure 5.

Macrominerals content of she-camel milk

In Table 4, it is clear that mastitic milk from she-camels showed a significant increase in levels of sodium (Na) and chloride (Cl) compared to control milk obtained from apparently healthy she-camels. On the other hand, levels of potassium (K) and calcium (Ca) were significantly decreased in the mastitic milk. However, there were no significant differences observed in magnesium (Mg) and phosphorus (Ph) levels between mastitic and control milk.

Vitamins contents of she-camel milk

Table 5 shows that all vitamins analyzed in mastitic milk significantly decreased compared to control milk.

The level of CRP of she-camel milk:

In the case of mastitis, the level of CRP in the milk was highly significant, as illustrated in Table 6 and Figure 6.

Discussion

Bacteriological examination of milk samples has shown that out of 46 mastitic milk samples, there were 65 bacterial isolates, with 45.7% identified as *S. aureus*, 47.8% as *S. agalactia*, and 47.8% as *K. pneumoniae*.

Similar species of bacteria have already been discovered in various nations, including Egypt, the United Arab Emirates, Iraq, Rwanda, Ethiopia, and Kenya, in seemingly healthy, clinical, and subclinical mastitic she-camels (with variable isolation rates) [22,23,24,25].

In Egypt Abo Hashem et al. [22] proved that *S. agalactiae* emerged as the most frequently identified Gram-positive isolate in mastitic she-camels, showing a prevalence of 47.8%. On the other hand, Aml et al. [26] and Memon et al. [27] observed lower prevalence rates of 27% and 13.2%, respectively, for *S. agalactiae* isolates. In terms of *S. aureus*, Abo Hashem et al. [22], Husein et al. [28], and Hanaa et al. [29] reported relatively low prevalence figures of 4.05%, 4.2%, and 3.33%, respectively. Contrasting these findings, Mogeh et al. [30] noted a

considerably higher prevalence of 24.2% for *S. aureus.*

The variation in the isolation rate could be attributed to conventional taboos on heat treatment of camel milk, as well as the practice of maintaining milk at high ambient temperatures after milking and during transportation. Additionally, the milk samples contamination by the teat skin or teat canal, and problems associated with the milking procedure, such as the use of anti-suckling devices that can cause trauma and infection through wounds, could also contribute to the variation in isolation rates [31].

Antibiotic sensitivity assays revealed that *S. agalactiae* isolates exhibited susceptibility to amikacin, streptomycin, gentamicin, and tetracycline while showing resistance to ciprofloxacin and trimethoprim-sulfamethoxazole. Conversely, *S. aureus* isolates were found to be susceptible to amikacin, streptomycin, gentamicin, and cephalothin, but exhibited resistance to ampicillin, tetracycline, ciprofloxacin, and trimethoprim-sulfamethoxazole.

K. pneumoniae isolates showed sensitivity to ampicillin, cephalothin, and trimethoprim-sulfamethoxazole. On the other hand, isolated *K. pneumoniae* exposed resistance to gentamicin and ciprofloxacin.

Abdel-Ra'ouf et al. [26] demonstrated that *S. aureus* was sensitive to streptomycin, gentamicin, ciprofloxacin, tetracycline, erythromycin, and nitrofurantoin, but resistant to vancomycin, penicillin, and ampicillin.

Mogeh et al. [30] and Memon et al. [27] found that *S. aureus* was sensitive to gentamicin, while Ali et al.[32] reported resistance to gentamicin. Additionally, the study showed sensitivity to streptomycin, aligning with previous studies by Al-Tofaily and Rodhan [33] and Badria et al. [34], although Ali et al. [32] reported resistance to streptomycin. The current research also indicated sensitivity to tetracycline, in line with Ismail [35], while Mogeh et al. [30] reported resistance.

Furthermore, the study revealed sensitivity to ciprofloxacin, consistent with Yam et al. [36], but Ali et al. [32] reported resistance. Resistance to ampicillin, penicillin, and vancomycin was also observed, consistent with Ali et al. [32] although Subramaniyan et al. [37] reported sensitivity to ampicillin.

The *Staphylococcus* species isolated in this study are highly sensitive to ampicillin, tetracycline, gentamycin, and streptomycin, and less sensitive to the other tested antibiotics. This finding partially opposes the findings of Alqurashi, et al. [38]. The results also show that the *Staphylococcus* species' sensitivity to tetracycline and ampicillin is higher than previously reported [38] and in agreement with reports by Amel [39] and Suheir [40]. Hawari and Hassawi [41] reported that *Streptococcus* species are very sensitive to ampicillin.

Badria et al.[34] in Sudan, investigated that the most causative agent of mastitis in lactating camels in the Red Sea State of Sudan is *Staphylococcus* species, and the most active antibiotics against the isolated bacterial species are ampicillin, kanamycin, tetracycline, and gentamycin. Based on these findings, it is recommended to use these antibiotics in combination to avoid bacterial resistance.

Alamin et al. [42] and Hadef et al. [43] documented a diminished prevalence of *Streptococcus* species, noting rates of 1.52% in North Kordofan State, Sudan, and 2.38% in Southeastern Algeria.

The current study's findings align with the isolation rates observed by Saleh and Faye [44] in Al-Jouf, Saudi Arabia, which were recorded at 42.9%. In contrast, the present study reports a notably lower prevalence of *S. agalactiae* at 3.21%, corroborating the findings of Husein et al. [28], who noted a 3.5% prevalence in Jijiga town, Ethiopia. However, these figures are significantly less than those reported by Seligsohn et al. [45], Mehmood et al. [46], and Al-Tofaily and Al Rodhan [33], who documented prevalences of 72%, 10%, and 9.52% in Isiolo, Kenya, the Gursum district of eastern Hararghe, Ethiopia, and certain regions of the middle Euphrates in Iraq, respectively.

The detection of the Mycobacterium tuberculosis complex (MTC) in camel milk is a significant concern for public health due to the potential transmission of tuberculosis (TB) from animals to humans. Our study, where MTC was not detected, contrasts with the findings of Mwangi et al. [47], who reported MTC presence in raw and fermented camel milk samples. This discrepancy could be due to various factors such as differences in the sample size, geographic location, the health status of the camels, or the sensitivity of the detection methods used.

Mastitis is a common infection in she-camels that can significantly increase the pH levels of their milk. Normally, healthy camel milk has a pH ranging from 6.4 to 6.8, but mastitic milk can have a higher pH due to the infection [48]. Several factors contribute to this pH alteration infection, the presence of bacteria in the udder due to mastitis can lead to a rise in milk pH; inflammation, the inflammatory response to the infection can cause changes in the milk's composition, including an increase in pH; and somatic cell count (SCC), a higher SCC, which is indicative of mastitis, can be associated with higher milk pH levels.

Monitoring the pH of camel milk is crucial in managing mastitis. A higher pH value can affect the quality and shelf life of the milk, and it can also

serve as a diagnostic tool for detecting subclinical mastitis, which is not visible through physical examination [48]. Effective mastitis control is essential not only for animal welfare but also for maintaining the quality of milk produced for consumption.

Mastitis is a condition that can affect she-camels, leading to major changes in the composition of their milk. These alters include reductions in the percentages of casein, total protein, fat, and lactose in the milk. These changes are a result of the mammary gland's response to the infection and inflammation caused by mastitis.

The decrease in total protein and casein can be attributed to the damage to the mammary tissue, which impairs its ability to synthesize these milk components. The reduction in fat content may result from altered metabolism and the energy demands of the immune response to fight the infection. Lactose levels drop because of the decreased synthesis and increased mammary epithelium permeability, allowing lactose to leak into the bloodstream. Ogola et al. [49] have mentioned that in the case of mastitis, there is a significant decline in lactose and casein levels.

In a study by Bochniarz et al. [50], it was found that cows with mastitis caused by *Streptococcus spp*. experienced a significant decrease in the levels of total protein (TP), casein (CAS), fat, and lactose (LAC) in their milk, compared to healthy cows. This decrease was observed not only in cows with obvious mastitis symptoms but also in those with subclinical mastitis. Such a reduction has negative effects on the quality of dairy products and production processes. Additionally, subclinical mastitis often goes unnoticed and untreated due to the absence of visible symptoms. It's important to note that parameters like lactose (LAC) can indicate udder health in cows, while the CAS/TP ratio can provide information about the milk's suitability for specific processing operations.

The changes in milk composition can have several implications. Firstly, milk's nutritional value is compromised, affecting the health benefits it provides. Secondly, the changes in milk composition can impact the quality, taste, and processing properties of the milk. Lastly, monitoring these parameters can help in diagnosing mastitis and assessing the severity of the infection. Effective management of mastitis is crucial to ensure the health of the she-camels and the quality of milk they produce [51,52,53,48].

Mastitis, an inflammation of the mammary gland in she-camels, can lead to significant changes in the mineral content of their milk. Mastitic milk often shows higher levels of Sodium (Na) and Chloride (Cl) compared to milk from healthy camels. This is because the inflammatory response to infection causes the influx of these ions from the bloodstream into the milk [48]. On the other hand, levels of Potassium (K) and Calcium (Ca) are typically decreased in mastitic milk. The decrease in potassium may be linked to the disturbance of the cellular ion balance within the inflamed mammary gland. At the same time, the reduction in calcium could be due to the altered secretion processes during mastitis [48]. The findings are consistent with El Zubeir et al. [54] study, which discovered that the milk of cows with mastitis had significantly lower potassium levels and significantly higher levels of sodium and calcium than that of healthy cows. However, their study differs from ours in that they found a significant increase in phosphorus content and a significant decrease in magnesium. It is possible that the observed differences could be attributed to variations in animal species.

Our study results align with those reported by Amer et al., [55] and Pisanu et al. [56], who observed that mastitic milk contains lower calcium levels than healthy cow's milk. This reduction in calcium concentration could be attributed to damage caused by pathogens to the mammary gland. These pathogens often disrupt the junctional complex of the secretory epithelium, which is typically impermeable to calcium transport from milk to blood [57]. Reduced casein concentrations may explain the lowered calcium levels in infected quarters, as most milk Ca is related to casein [49]. However, it's important to note that our findings contrast with the results reported by Mahran et al. [58]. Their study indicated higher calcium concentrations in both clinically and sub-clinically mastitic milk compared to healthy cow's milk. The reasons for this discrepancy warrant further investigation.

Ogola et al. [49] reported significantly higher levels of chloride and sodium, while potassium and calcium levels were lower in mastitic quarters compared to normal quarters ($p < 0.05$). It is interesting to note that the levels of Magnesium (Mg) and Phosphorus (Ph) do not show significant differences between mastitic and healthy milk. This suggests that the regulatory mechanisms for these minerals remain relatively stable despite the infection [48]. These changes in mineral content can be essential indicators of mastitis and may have implications for the diagnosis and management of the condition, as well as for the nutritional value of the milk produced. Dairy producers must monitor these levels regularly to ensure the health of their camels and the quality of the milk.

Mastitis in she-camels has been shown to significantly reduce the levels of all analyzed vitamins in the milk compared to control milk from healthy animals. Several factors contribute to this decline, stemming from the infection and inflammation caused by mastitis. These factors include disruptions in vitamin synthesis and

metabolism within the mammary gland, heightened nutrient demand due to the immune response combating the infection, and alterations in secretion processes affecting vitamin transfer into the milk [24].

A study performed by Semsmia et al. [59] revealed that there was a significant decrease in the amount of vitamin C in camel milk, particularly when it interacted positively with the California test. The average vitamin C content in milk from healthy udders was 35.01±9.8 mg/L, whereas milk from infected udders had an average concentration of 22.99±1.3 mg/L.

Vitamins play critical roles in bodily functions, including immune responses, cell growth, and overall health. Consequently, diminished vitamin levels not only impact the nutritional quality of camel milk but also serve as indicators of the health status of the female camel. Dairy producers must diligently monitor vitamin levels as part of their mastitis management protocols to safeguard animal health and maintain milk quality. The significance of mastitis-induced changes in vitamin content underscores the need to prioritize the well-being of dairy camels. In many cultures, camel milk is highly esteemed for its rich vitamin composition. Therefore, effective mastitis prevention and management are essential to uphold both animal health and the nutritional benefits of camel milk. [60,48,61,24].

In cases of mastitis in she-camels, the level of C-reactive protein (CRP) in the milk is found to be significantly elevated. CRP is an acute-phase protein that is produced by the liver in response to inflammation, and its levels rise in the presence of acute infections or inflammation, such as mastitis.

The role and significance of CRP in mastitic milk is that it serves as an indicator of inflammation. CRP levels are a sensitive marker for inflammation, and in mastitic camels, an inflamed mammary gland triggers an increase in CRP production as part of the body's immune response. Elevated levels of CRP in milk can serve as a diagnostic tool for detecting mastitis, especially in subclinical cases where physical symptoms may not be evident [62,63,64,65,66]. The degree of increase in CRP levels can help assess the severity of the mastitis, with higher levels indicating more severe inflammation or infection [67,68]. CRP levels can also be monitored over time to evaluate the effectiveness of treatment for mastitis. A decrease in CRP levels would suggest that the treatment is working, and the inflammation is subsiding. High CRP levels can affect the quality of milk, making it unsuitable for consumption and dairy production, and also impact the shelf life and safety of the milk. Therefore, the measurement of CRP levels in camel milk could be a valuable addition to the current methods used for mastitis detection and management, providing a non-invasive way to monitor udder health and ensure the quality of milk produced for consumption [69,48].

Mastitis in she-camels can lead to a cascade of complications that mirror those seen in other dairy livestock, with significant repercussions for animal health and farm economics. The condition can drastically reduce milk yield, compromising both the nutritional supply for animals and the financial returns for farmers. The infection may also alter the milk's composition and quality, potentially affecting its suitability for consumption and processing. Chronic or severe cases can inflict tissue damage and fibrosis on the udder, sometimes resulting in permanent functional loss. Moreover, if the infection disseminates, it can cause septicemia, where pathogens spread through the bloodstream, posing a severe systemic threat. These health issues are further compounded by economic losses due to increased veterinary costs, treatment expenses, and the potential culling of affected animals [61,70]. To mitigate these risks, maintaining good hygiene, conducting regular udder inspections, and employing proper milking techniques are essential. Prompt treatment upon detection of mastitis is imperative to avert these complications and ensure the well-being and productivity of the she-camel.

Conclusion and recommendations

The study investigated the causes of mastitis in she-camels, its antibiotic susceptibility, and its impact on milk physicochemical properties. A total of 92 raw milk samples were analyzed, resulting in the identification of 65 bacterial isolates. The most prevalent species were *Staphylococcus aureus*, *Streptococcus agalactiae*, and *Klebsiella pneumoniae*. The physicochemical properties of the milk showed significant decreases in total protein, casein, fat, and lactose levels, elevated pH values, and reduced levels of fat-soluble vitamins. Mastitic milk exhibited higher levels of Na and Cl, decreased levels of K and Mg, and an increase in C-reactive protein (CRP). Based on the findings of this study, several recommendations can be made as follows:

- Hygienic Practices: Handlers must ensure proper handling of she-camels, maintain personal hygiene, treat udder infections, and use sanitary processing and milking equipment. Proper transportation and milk storage are also crucial.
- Antibiotic Stewardship: Remember to use antibiotics responsibly to avoid the emergence of multidrug-resistant (MDR) strains.
- Quality Assessments: Conduct regular assessments of udder health and milk quality to ensure the supply of high-quality milk to consumers.

- Isolation Protocols: Isolate suspected and diseased she-camels, as well as those under treatment, to prevent the spread of infections.
- Milk Disposal: Ensure public health safety by disposing of infected milk hygienically to prevent contamination.

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Conflicts of interest

According to the authors, there isn't a conflict of interest.

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TABLE 1. Single and mixed infection of examined raw she-camel milk samples

Type of infection	Bacteria spp.	
Single infection (n= 15)	2	*S. aureus*
	3	*S. agalactia*
	10	*K. pneumoniae*
Mixed infections (n= 31)	12	*S. agalactia* + *K. pneumoniae*
	2	*S. aureus* + *S. agalactia*
	17	*S. aureus* + *S. agalactia.* + *K. pneumoniae*

TABLE 2. Antibiotic susceptibility testing of isolated bacteria species. (n=10 each).

Antibiotic class	Antimicrobial Agent	*S. agalactia*		*S. aureus*		*K. pneumonia*	
		S.	R.	S.	R.	S.	R.
Aminoglycosides	Amikacin	10	-	6	4	6	4
	Streptomycin	10	-	10	-	4	6
	Gentamicin	8	2	8	2	2	8
β Lactamases	Ampicillin	6	4	4	6	10	-
Tetracyclines	Tetracycline	10	-	4	6	6	4
Quinolones	Ciprofloxacin	-	10	2	8	2	8
Cephalosporins	Cephalothin	6	4	8	2	10	-
Sulfonamides	Trimethoprim-Sulfamethoxazole	-	10	4	6	8	2

TABLE 3. Effect of mastitis on Physicochemical characteristics of she-camel milk (n= 46).

	Control milk		Mastitic milk	
	mean± SE	Range	mean± SE	Range
pH	6.2± 0.02	6- 6.4	7.1± 0.05*	6.6- 8.1
T.P. (%)	3± 0.04	2.3- 3.5	1.4± 0.02*	1.2- 1.6
Casein (%)	2.4± 0.04	1.9- 2.8	1.04± 0.03*	7- 1.4
Fat (%)	3± 0.03	2.7- 3.4	0.02± 0.0004*	0.014- 0.03
Lactose (%)	5± 0.03	4.7- 5.4	2.4± 0.03*	1.93- 2.7

SE: standard error.
*Significant differences at *P value*<0.05 using independent t-test in Excel.

TABLE 4. Comparison of Mineral Levels in Mastitic and Control Milk from She-Camels (n=46).

Mineral	Control milk		Mastitic milk	
	mean± se	Range	mean± se	Range
Na	45.3± 1	36- 62	76.4± 0.9*	70- 91
Cl	96.3± 10.2	80-115	189.8± 2*	185- 168
K	168.2± 1.7	138- 182	79.5± 14*	65- 91
Ca	104.9± 2.3	80- 132	91.2± 1.1*	95- 81
Mg	11.5± 0.3	8- 15	11.8± 0.5	8-020
Ph	34.3± 0.8	24- 45	34± 0.8	24- 46

*Significant differences at *P value*<0.05 using independent t-test in Excel.

TABLE 5. Effect of mastitis on vitamins (mean± SE) contents (mg/100 mL) of she-camel milk (n= 46).

Vitamin	Control milk		Mastitic milk	
	mean± se	Range	mean± se	Range
Vit. A (µg/100 mL)	38.1± 0.2	36- 42	22.9± 0.3*	19- 30
Vit. D_3 (µg/100mL)	1.26± 0.02	1- 1.5	0.63± 0.02*	0.46- 0.85
Vit. E (µg/100mL)	65.8± 0.8	56- 72	32.5± 0.5*	26.4- 40
Vit. C (mg/L)	66.7± 0.5	62- 72	26.3± 0.6*	18- 33

*Significant differences at *P value*<0.05 using independent t-test in Excel.

TABLE 6. Effect of mastitis on CRP of she-camel milk (n= 46).

	Control milk	Mastitic milk
Mean	1- 1.8	35.3± 0.9*
Range	1- 1.8	24- 43

*Significant differences at *P value*<0.05 using independent t-test in Excel.

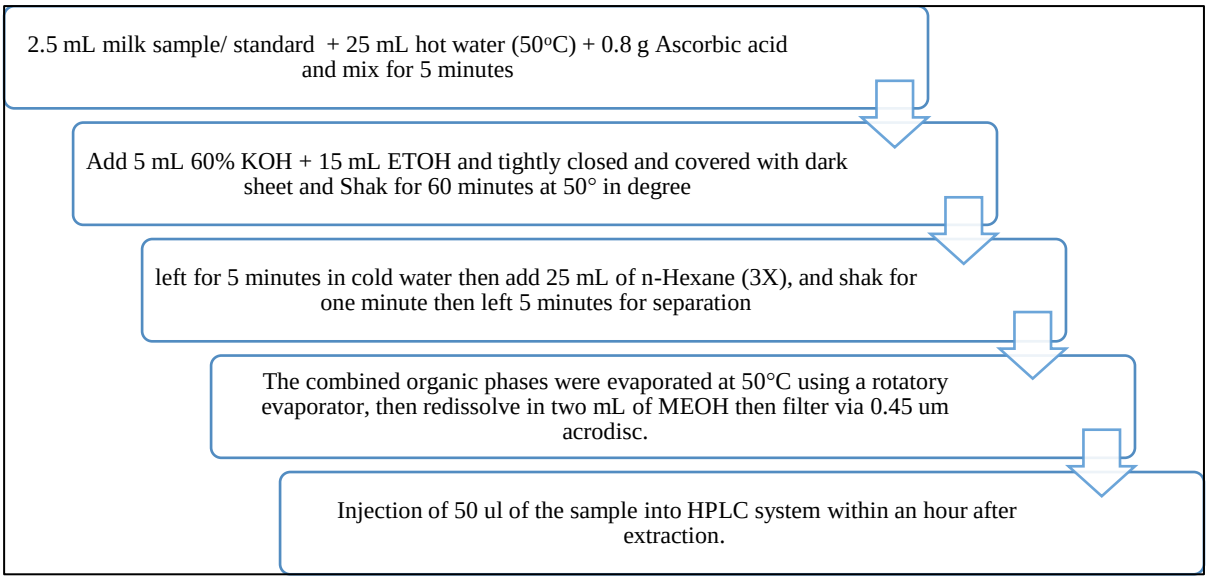

Fig. 1. Chart for standard and sample preparation.

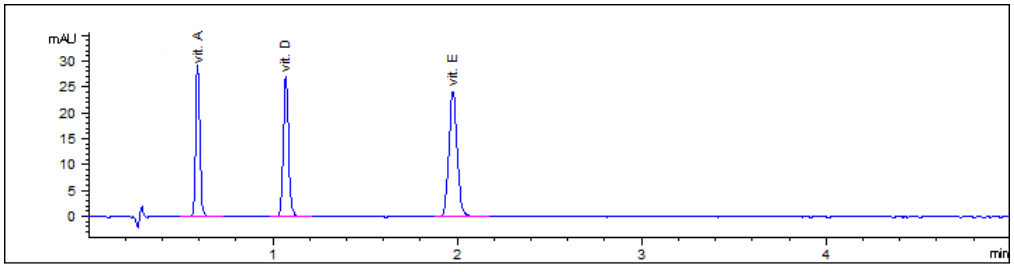

Fig. 2. The Chromatogram shows A, D_3, and E vitamins at 0.561, 1.069, and 1.976 minutes, respectively at 280 nm.

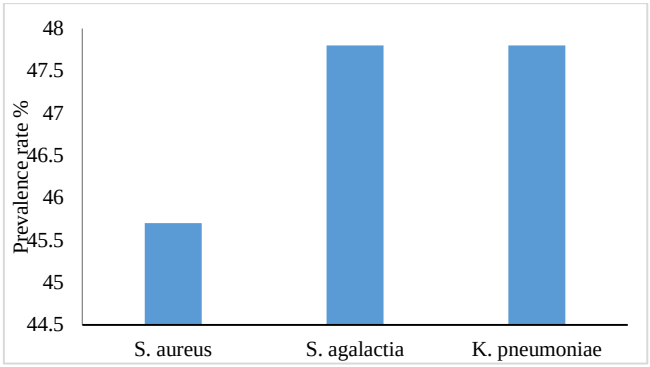

Fig. 3. Prevalence rate of bacterial isolates from mastitic she-camels

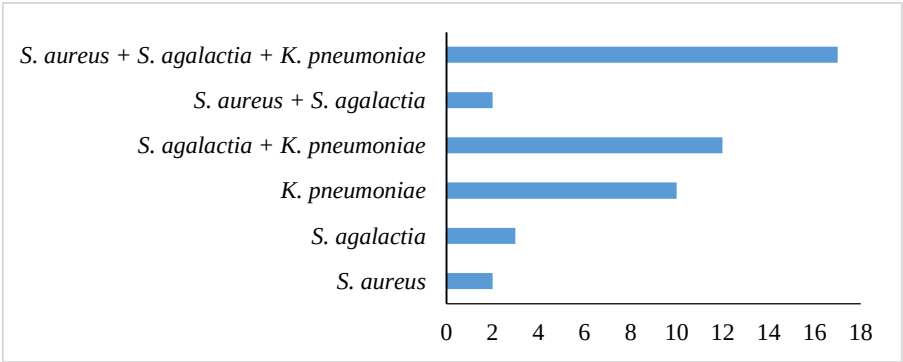

Fig. 4. Chart showing the type of infection in she-camel mastitis

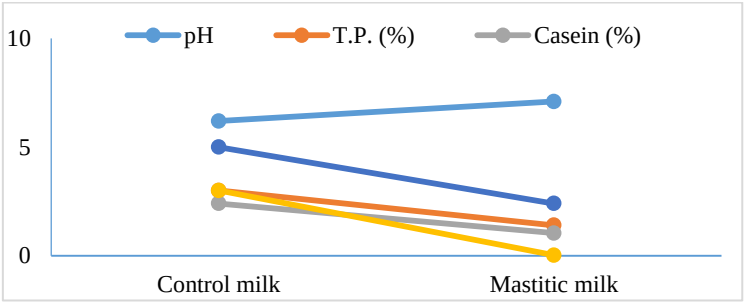

Fig. 5. Chart showing the effect of mastitis on Physicochemical characteristics of she-camel milk.

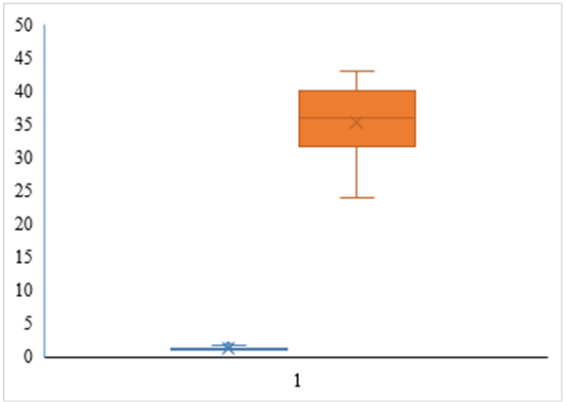

Fig. 6. The chart illustrates the impact of mastitis on the CRP levels in she-camel milk

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نظرة ثاقبة على التنوع البكتيري والتركيب الكيميائي للحليب في التهاب الضرع عند الإبل: للتشخيص والإدارة

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الملخص

التهاب الضرع هو تحدٍ معقد يؤثر على الإبل وله عواقب اقتصادية كبيرة في جميع أنحاء العالم. هدفت دراستنا إلى فهم الأسباب البكتيرية لالتهاب الضرع في الإبل، وتقييم حساسية المضادات الحيوية، وتقييم تأثيرها على الخصائص الفيزيائية والكيميائية للحليب. تم تحليل إجمالي 92 عينة من الحليب الخام، تتكون من 46 عينة صحية و 46 عينة مصابة بالتهاب الضرع. أجريت تحاليل بكتيرية وكيميائية على العينات وحددت 65 عزلة بكتيرية. كانت أكثر أنواع البكتيريا انتشارًا هي المكورات العنقودية الذهبية والمكورات العقدية المجردة والكلبسيلة الرئوية، بمعدل انتشار 21٪ و 22٪ و 22٪ على التوالي. لم يتم الكشف عن المتفطرة البقرية. يحدث التهاب الضرع في الإبل بسبب أنواع بكتيرية مختلفة، إما بمفردها أو مجتمعة. وقد كشف تحليل الخواص الفيزيائية والكيميائية للحليب عن انخفاضات كبيرة في مستويات البروتين الكلي والكازين والدهون واللاكتوز، مصحوبة بقيم pH مرتفعة. وعلاوة على ذلك، انخفضت الفيتامينات التي تذوب في الدهون (أ، د، هـ) وفيتامين ج بشكل ملحوظ. وأظهر حليب الضرع مستويات أعلى من الصوديوم والكلوريد، في حين انخفضت مستويات البوتاسيوم والمغنيسيوم مقارنة بالحليب الصحي. ولوحظت زيادة في البروتين التفاعلي سي (CRP). وتسلط هذه النتائج الضوء على أهمية التهاب الضرع في تربية الإبل داخل المجتمعات الرعوية. ونتيجة لذلك، يجب تثقيف الرعاة وإعلامهم بالوقاية من التهاب الضرع وإدارته لتجنب الخسائر الاقتصادية المحتملة.

الكلمات الدالة: التقييم الكيميائي، البروتين التفاعلي سي، حليب الضرع، عزل الميكروبات.