

Mastitis in Camels in African and Middle East Countries

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Abstract

Mastitis has been and still is the first health concern regarding dairy animals and their milk production industry. Mastitis affects all dairy animals without discrimination, even camels. It causes great economic losses if not detected and treated promptly. The major causes of both contagious and environmental mastitis are; *Staphylococcus aureus*, *Streptococcus agalactiae*, *Streptococcus uberis*, *E. coli*, and *Klebsiella*. Mastitis could be acquired by animal either contagiously or through the environment, each type has their own causative agents but the same pathogenic mechanism. The pathogen usually enters through the teat end and continues to reach the mammary gland inside the udder, then starts multiplying and producing toxins that evoke the immune responses in the animal to fight the infections, which eventually causes the mastitis symptoms from fever, inflammation, swelling, milk composition and color changes, and presence of somatic cells etc. This inflammation might differ in severity due to many factors such as pathogen type, animal health status and age, and lactation cycle of the animal as well. Inflammation could be either clinical, subclinical, or the most severe chronic mastitis. There are many techniques that detect the presence of mastitis, but still culturing techniques are considered the most accurate techniques to be used. Camels are the most important dairy animal in the Middle Eastern Countries as well as the African Horn Countries because of the desert areas they have which are mostly inhabited by Arabic tribes.

Camels are considered the major source for both milk and meat production in these areas. Also, they are considered as wealth investment and insurance against natural disasters that usually occur in the desert and lead to livestock mortality. Camels represent high significance in the lives of people living in the desert and protecting them and their products from mastitis is the most challenging task they are facing. Although, it was always believed that camels are immune against many different infectious diseases, it was shown that they could acquire mastitis. Literature for the exact prevalence of camel mastitis is few, but indicates its presence almost in all Arabic countries. Practicing good sanitization techniques and control and management procedures as recommended by the respective organizations helps preventing mastitis infection in camels and ensures their healthy survival. In conclusion, camel mastitis although represent lower prevalence compared to other concerning disease within camels, it must be addressed carefully to avoid its spread and transformation into endemic infection in order to protect the camel population in these countries because of their extreme importance.

Keywords: Mastitis; Camels; Middle east; Africa

Mastitis

The word stands for breast inflammation (mast=breast, it is=inflammation); it is the inflammation of the mammary gland or udder of the dairy animals such as cows, camels, etc. This inflammation could occur as a result of physical force, chemicals, thermal injury or from body's immune response against bacteria and their toxins which infected the teat canal and damaged the gland [1-3].

Mastitis causes a major loss in the dairy industry economy, because it affects the farm profitability through affecting milk quality and quantity. Although, there have been a lot of efforts to educate about it and manage it since the 1970's, it still represents the first concern when it comes to milk industry [4].

If detection and treatment were done quickly, both tissue damage and milk production loss could be limited. However, prevention and control are always better to accomplish because treatment is not always as successful as required [5].

Mastitis could be caused by more than 100 different pathogens, each having their distinct infection route to infect the animal and causing different stages of the disease. The farm's environment determines the pathogen types that might infect the animal and the animal's ability to resist them. Environmental mastitis could be controlled and reduced by practicing the control and management measures (Table 1) [3].

There are two types of mastitis; the first is contagious, and the second is environmental. Contagious mastitis is caused by *Staphylococcus aureus*, *Streptococcus agalactiae* & *uberis*. These pathogens usually located at the inside of the udders or on its skin. They spread through infected milk splashes and sprays while stripping, milk cross flow between teat cups, the hands of the person milking the animal. Environmental mastitis is caused by bacteria living in soil, bedding, water, manure, calving pads. Examples of these bacteria include *Streptococcus uberis*, *Streptococcus dysgalactiae*, Coliforms such as *E. coli* and *Klebsiella*, while the first can sometimes persist and spread though the milking process, the second does not survive in the udder and does not persist [6,7].

Milk Component	Normal Milk	Mastitis Milk (with high Somatic Cells Count (SCC))
Fat	3.5	3.2
Lactose	4.9	4.4
Total protein	3.61	3.56
Total casein	2.8	2.3
Whey protein	0.8	1.3
Serum albumin	0.02	0.07
Lactoferrin	0.02	0.1
Immunoglobulin	0.1	0.60
Sodium	0.057	0.105
Chloride	0.091	0.147

Table 1: Comparison between normal milk and mastitis milk with high SCC concentration [6] (values indicated in percentage).

Inflammation severity is divided into; clinical, subclinical, and the rare form of chronic mastitis. The degree of inflammation of each type

depends on many factors such as; pathogen nature, animal's breed, animal age, and animal health and immunity status [8].

Clinical mastitis is defined as the type of mastitis that cause clinical and visible signs in the udder and milk, and it is divided to three forms mild, moderate, and severe according to the International Dairy Federation (IDF) in 1999. The mild form is defined by a sudden onset, flakes and clots in the milk which could be accompanied by slight infection and swelling of the quarter. While moderate and severe forms include abnormal secretion of the milk, udder redness, swelling, and animal might have fever, depression, dehydration, rapid pulse, and loss of appetite, and it could lead to death if it became the last severe form of mastitis. In this situation, the milk usually has watery consistency. Subclinical mastitis doesn't cause visible changes in udder or the milk; that's why it is difficult to diagnose early and it is only known through laboratory testing. However, it causes cost loss because the quantity production decreases through Somatic Cells Count (SCC) increase. Also, it affect the older lactating animals rather the younger ones. Presence of SCC affects milk production reversibly, so when it increases the milk yield decrease and vice versa. If SCC count in the milk increases over 300,000 it is considered abnormal and udder inflammation exist. Subclinical mastitis is more common than clinical mastitis (clinical: subclinical 1:14-15 cases), so it is more important.

	Contagious Mastitis	Environmental Mastitis
Caused by	<i>Streptococcus agalactiae</i> (<i>S. agalactiae</i>) <i>Staphylococcus aureus</i> (<i>S. aureus</i>) <i>Streptococcus dysgalactiae</i> (<i>S. dysgalactiae</i>)	Coliforms: <i>Escherichia coli</i> <i>Klebsiella pneumonia</i> <i>Klebsiella oxytoca</i> <i>Enterobacter aerogenes</i> Environmental streptococci <i>S. uberis</i> <i>S. bovis</i> <i>S. dysgalactiae</i> <i>Enterococcus faecium</i> <i>Enterococcus faecalis</i>
Primary source	Udders of infected animals (from one quarter to another during milking).	The environmental of the cow
Problem indicators	Somatic cell count >300,000 cells /ml in bulk tanks. DHIA SCC score >3.2 Animal DHIA SCC score ≥ 5 in 15% of them Recurrent episodes of mastitis infection in same animals Presence of <i>S. agalactiae</i> or <i>S. aureus</i> in bacterial cultures	High rate of clinical mastitis especially during lactation or hot weather, where SCC score could be <300,000
Control recommendations	Develop program to prevent the spread of bacteria at milking time Eliminate existing infections by treating infected animals at drying off and eliminating chronic cases among them.	Reduce the number of bacteria to which the teat end is exposed Improve cleanliness of cow surroundings, especially in late dry period and calving Improve prepping procedures to ensure clean, dry teats are being milked
	Eradicate <i>S. agalactiae</i> from herd Reduce <i>S. aureus</i> infection to <5% in herd	Reduce clinical mastitis to <3% of milking animals/month

Table 2: Comparison between contagious and environmental mastitis [3]

Usually subclinical mastitis comes before clinical, and it lasts for a long period of time without detection but slowly affecting the quality and production of the milk and also providing an environment for infectious microorganisms to grow in and infect the animal later on. The more rare form; chronic mastitis produces persistent inflammation in the mammary gland [3,6,8,9] (Table 2).

Epidemiological data collected during the past two decades shows that clinical mastitis prevalence in Finland during 1995 was 38%, and during 2001 was 31%, while in Uruguay during 2001 it was 31% [10].

The most susceptible periods for infection with environmental pathogens are in the dry period particularly during the first two weeks, and early lactation of the last 10 days before calving. The incidence prevalence is twice during calving than on drying off period [6].

Mastitis effects on the dairy industry include; Loss in the animal ability to produce milk either temporary or permanent, the milk quality is reduced with less favorable characteristics, reduction in milk price due to high SCC presence, milk loss because of antibiotic treatment, treatment and veterinary care costs, labor costs increase, laboratory testing cost to control the milk quality and animal status, reduced productive life of the animal, less meat value of the animal after slaughter, annual losses due to reduce overall production of dairy product for the needs of the country [2].

Mastitis Pathogenesis

Once the bacteria invade the teat canal and the mammary glands, mastitis starts. The bacteria start to multiply and release their toxins which will affect the tissue which secretes the milk, leading to increased SCC in the milk and consequently affecting milk's quantity and products, and reducing its quantity. To avoid infection, the udder is protected by teat as the first defense mechanism, because the teat canal contains a sphincter that prevents bacteria from entering and milk from exiting. Also, the canal is covered by keratin from the inside; it is a waxy material that binds pathogens causing mastitis. After milking process is complete, the teat canal could be partially opened for about 1 to 2 hours, giving bacteria existing near the teat opening the chance to enter the canal and cause keratin damage and consequently affecting the mucous membrane which protect the inside of the canal. If bacteria were successful in entering the teat canal, they will face the second defense mechanism which is the mammary gland itself. Once bacteria reaches the gland it can multiply and start producing toxins, but the gland will start stimulate the release of inflammatory mediators to attract phagocytes to clear the pathogens. Factors which determine the severity of inflammatory response depend on the host and the pathogen. For the host; the age, immune status, SCC, lactation stage, and parity are all factors that play a role in determining disease severity. For the pathogen; the species, strain, virulence, and inoculum size, determine the disease severity as well. As the number of leukocytes increases in the milk as a result of inflammatory response, the number of somatic cells increases also. The dead leukocytes, dead mammary epithelial cells, along with clotting factors are secreted in the milk forming aggregations that lead to clots formation. These clots cause duct blockage and prevention of milk removal, and finally cause formation of scars that form small pockets which are difficult to be cured by antibiotics. Practice that increases trauma of the animal's mammary glands include; improper preparation of animal for milk stimulation, excessive milking, use of infected tubes and canulae with mastitis, handling wet teats and not using teat dips, improper usage of udder washes, physical trauma, and

injuries of infectious agents and their toxins. Persistence of inflammation cause an internal swelling of the mammary epithelium but it could not be detected by external examination. This inflammation causes damage to gland alveoli that eventually loses shape. When the blood-milk barrier is broken, then components of the extracellular fluid will enter the gland such as; sodium, chloride, hydrogen, potassium, and hydroxide ions. Once these elements enter the gland, they will mix with milk which could also include blood if the damage is severe. At this stage, visible signs could be observed on the udder such as swelling, redness, as well as the milk such as color, pH, water content, and presence of flakes and clots [2,6].

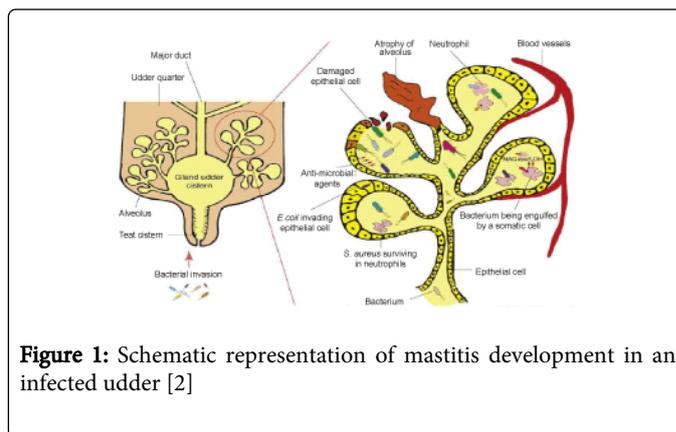


Figure 1: Schematic representation of mastitis development in an infected udder [2]

Bacteria that cause Mastitis

There many pathogens implicated in mastitis in dairy animals. From the many bacterial and fungal species associated with bovine mastitis include; for bacteria *Staphylococcus aureus*, *Streptococcus* spp., *Escherichia coli*, *Arcanobacterium pyogenes*, *Mycoplasma bovis*, *M. californicum*, *Pseudomonas* spp., *Corynebacterium*, *Streptococcus dysgalactia*, and *Mycobacterium tuberculosis*, and for fungal infection *Aspergillus* spp., *Candida* spp., *Cryptococcus neoformans* [6,10].

Symptoms and Signs of Mastitis

Symptoms and signs differ according to the type of mastitis wither it is clinical, subclinical, or even chronic. Also, in each type the severity of the disease and the causative pathogen will control the observable symptoms. Clinical mastitis could be diagnosed as mild (sub-acute) when the disease symptoms are restricted only to minor alteration of the milk with presence of clots and flakes in the affected quarter, and if the secreted milk was discolored, and slight swollen and tenderness of the quarter. Clinical mastitis could be diagnosed as acute when there is a sudden onset, presence of heat, swelling, pain, redness, along with reduced and changed milk production, also there could be accompanying fever, weakness, and depression. Sever clinical mastitis could be fatal for the animal so immediate intervention is necessary. Subclinical mastitis is undetected usually because its symptoms are less visible, and it is diagnosed only though testing the Somatic Cell Count (SCC) of the milk. SCC increase in the presence of injury and inflammation. This type is important because it usually precedes the clinical form for a long period of time and it is difficult to detect it, and it affects both the milk's quality and quantity. Subclinical mastitis is more prevalent than the clinical form (15 to 40 times), and unfortunately the affected animal could affect other animals because it acts as microorganism reservoir [5].

Detection of Mastitis

Mastitis must be detected early to avoid the costly effects that accompany its presence. For that, there are many different methods to detect mastitis though laboratory testing for both the milk as well as for the animal itself. Research is still ongoing for studying the bacteria causing mastitis to the species and subspecies level through the use of a different phenotyping and genotyping techniques. The genotyping methods include simple techniques such as restriction digest and PCR, as well as more advanced techniques such as micro-arrays to whole genome sequencing [11].

Detection is made by using methods to examine milk quality, mammary gland status, and pathogen involved. Most method up till now depends on measuring the concentration of SCC, the enzymatic analysis, and the California milk clotting test. SCC levels are determined by using haemocytometers or cell counters, and if the level was 200,000 cells/ml is considered an evidence for mastitis presence, this according to the European regulations. Other techniques include measuring the concentration of enzymes in the milk through the use of colourimetric and fluorometric assays. Also, techniques that examine changes in the milk conductivity or its pH could be used to detect mastitis. The best technique for detecting mastitis remains the detection of causative agents though culturing technique regardless of the time, effort, and cost it requires. Another old yet still favorable technique is the California mastitis test (CMT), but the result is subjective and could give false positives and negatives depending on the technician. There is however advances in laboratory methods for mastitis detections due to the advances in technology, genomic, and proteomic information. So, assays sensitivity has improved and they are being used in mastitis detection such as; ELISA, and nucleic acid based test [2]. The SCC is converted sometimes into a score for comparison purposes with results from other testing methods. So, their score is categorized from (0-4) as shown in the table 3 below [12].

SCC Score	SCC Score ranges
Score 0	$0 \leq \text{SSC} < 30,000$
Score 1	$30,000 \leq \text{SSC} < 50,000$
Score 2	$50,000 \leq \text{SSC} < 100,000$
Score 3	$100,000 \leq \text{SSC} < 200,000$
Score 4	$200,000 \leq \text{SSC} < 4$

Table 3: Classification of the SCC scoring system [12]

Methods used for SCC detection to confirm mastitis

California mastitis test (CMT)

It measures indirectly the SCC score in milk samples. It uses a bromocresol-purple-containing detergent to break down somatic cell membrane to release nucleic acid and aggregate it to form a gel-like matrix in which its viscosity is proportional to the leukocyte number.

- **Advantages:** It is cost effective (~US \$12 for 350 tests), fast, user friendly, and could be done both on-site or in the laboratory.
- **Disadvantages:** Its interpretation could be difficult and its sensitivity is low.

Portachek

It uses an esterase catalyzed enzymatic reaction for SCC detection in milk.

- **Advantages:** It is cost effective (~US \$3 per test), fast, and user friendly.
- **Disadvantages:** Its sensitivity is low with low SCCs.

Fossomatic SCC

It is a counter based on optical fluorescence principle. It uses ethidium bromide that infiltrates the nuclear DNA and intercalates with it, then a fluorescent signal is produced corresponding to the SCC in milk.

- **Advantages:** It is an automated technique and it is rapid.
- **Disadvantages:** It is an expensive device (~US \$7000) and its use is complex.

Delaval cell counter

It is based on optical fluorescence principle. It uses propidium iodide to stain nuclear DNA and determine the SCC in milk.

- **Advantages:** It is transportable device, easy, and fast.
- **Disadvantages:** The device is relatively expensive.

Electrical conductivity (EC) test

It uses the elevation in levels of ions such as sodium, potassium, calcium, magnesium and chloride in the milk due to inflammation, to measure the increase in conductance

- **Advantages:** It can be done on-site.
- **Disadvantages:** EC variation due to non-mastitis infections can affect the diagnosis.

Culture tests

It is a laboratory-based which uses selective culturing to determine the various microorganisms that cause mastitis.

- **Advantages:** It accurately determines the specific mastitis causative pathogens.
- **Disadvantages:** It is laboratory based and cannot be done on-site, and results take days.

pH test

It measures the increase in the pH of the milk due to mastitis through the use of bromothymol blue.

- **Advantages:** It is cost effective, user friendly, and fast.
- **Disadvantages:** Its sensitivity is lower than other tests.

Enzymes

Some enzymes such as NAGase and LDH are detected by certain assays.

- **Advantages:** They are fast assays.
- **Disadvantages:** Mostly they are laboratory based [2].

CMT score	Interpretation	Visible reaction	Total cell count
0	Negative	Milk fluid is normal	0-200,000 (0-25% neutrophils)
T	Trace	Slight precipitation	(1.5-5) $\times 10^5$ (30-40% neutrophils)
1	Weak positive	Distinct preeipitation but not gel formation	(4-15) $\times 10^5$ (40-60% neutrophils)
2	Distinct positive	Mixture thickens with gel formation	(8-50) $\times 10^5$ (60-70% neutrophils)
3	Strong positive	Strong gel that is cohesive with a conex surface	$\geq 5,000,000$ (70-80% neutrophils)

Table 4: Interpretation for California mastitis test [13].

While all the previous techniques mentioned are easy to perform, yet they are insensitive, so there is still a need for other techniques that can measure biomarkers with more specificity, easy to perform, very sensitive at the earliest stages of the disease, and could be applied on site of infection (Table 4).

Other studies are also being done in order to define other proteins that could serve as a marker of mastitis, such as lactoferrin. Lactoferrin is a protein, and it is one of the family of transferrin because it is an iron binding glycoprotein. It is found in most the body's fluids as well as the milk, and it has an antimicrobial activity agianst bacteria, fungi, viruses, parasites, and some yeast which was investigated. This protein change the immune system response towards inflammation, because it chelate iron and preventing its use by the pathogen thus aiding immune reponse against these pathogens. Lactoferrin concentration levels differ from one specie to another, but they are already established as in some dairy animals such as cows but not camels. That's why, studies are investigating lactoferrin levels in camels milk in both normal and mastitis conditions, such as an epdemiologic study done in Jordan in 2007. It showed strong inverse association between camel age and lactoferring concentration, where higher levels were seen in younger ones. Also, the results indicated a strong association between low SCC scores and udder inflammation, which could be useful as an indicator where camels with low SCC scores will be in risk of developing either clinical or subclinical mastitis [12].

Continuous researches though advanced techniques such as two dimensional gel electrophoresis (2D-GE), proteomics techniques, and mass spectrometry (MS), led to the discovery of many proteins related to mastitis. So, these proteins could serve as biomarkers for the detection of mastitis at early stage of the infection, but the challenge is in designing the device that could detect these proteins and offer diagnosis on site [2].

Camels in the Middle East and African Horn Countries

Camel is one of the most important animals of the Arab countries and it is deeply imbedded in their culture to the degree you can find more than 160 words that identify camels in the Arabic language. The number of camels around the world is about 11.24 million, and 61% of them are located in the Arab countries, while the remaining is distributed across the rest of the world. In the Arab world, they are important producers of meat, milk, and wool (9%, 24%, and 8%, respectively). In Saudi Arabia, camel meat constitutes about 30% of the total, and it is considered a source of wealth and investment to individuals still located in the desert parts of the country [14]. Saudi Arabia contains about 600,000 camel head, as any other animal they are threatened by various diseases [15].

This is also true for many other desert or semi-desert Middle Eastern counties as well as the African horn countries, where camels are used for transportation, racing competition, and investment. The main type is dromedary camles (*Camelus dromedarius*), they are the most important livestock animal. Camels population differ from one country to the next, in UAE they constitute about 459,242 located mainly Abu Dhabi, Al Ain and the Western region, all of them are of the one-humped type [16]. Because of the difficult climate and constant changes, only camels can survive and adapt to these changes while other livestock is lost dramatically. That's why, camels are essential for humans in these areas [17].

One of the largest countries of the African horn is Sudan, and they have the largest animal population among Arab counties and second largest among African countries. For camel population, it is considered the second largest country containing camels they have about 4 million camel head and constitute 22% of Sudan animal population, and 26.3% of Arab camel population. Sudan contains many well-known Arabic trips which depend on camels for their life style, because camel herds are insurance when living in the desert against natural disasters [8].

For these countries, camels are important not only for milk production but also for the husbandry system. Camels have been identified as source of milk and meat with the increased human population in the developing countries. For these desert countries, camels are the best animals to sustain the hard situation of the desert such as heat, and water and food scarcity. Camels have advantage over other cattle in their ability to provide sustained average milk production over the year. Also, camels milk is more nutritious than other types due the high presence of proteins, fats, vitamins (especially Vitamin C), and minerals (especially phosphorus). Another advantage of the camel milk is its medicinal characteristics and helps cure some diseases such as; jaundice, asthma, anemia, food allergies, dropsy, spleen diseases and piles [2].

Continuous care and attention to improve the breeds of the camels and their health as well will ultimately conserve their value and increase it as source of meat and milk. That's why, camel disease raises many concerns in order to fight and overcome them as much as possible to avoid losing this industry. Originally, camels were thought to be immune against most diseases which usually affect other livestock, but it was found out that they are subject to large group of microorganisms that could threaten calves live [14].

Camel Mastitis in Middle Eastern and African Horn Countries

Just like other dairy animals, mastitis causes the same to camels by reducing their milk production and affecting its quality, subjecting the animal to a costly process of treatment and care to cure the mastitis, and that eventually causes economic loss. Although there is little data from the Middle Eastern and the African horn countries, all the reports that were found indicated that camels from different countries had suffered from udder mastitis just as much as other dairy animals; such as Saudi Arabia, Egypt, Somalia, India, Sudan, Kenya, other African countries and the UAE. Same pathogens are also implicated for the camels' mastitis as other dairy animals, for example *Staphylococcus aureus*, *Streptococcus spp.*, *Micrococcus spp.*, *Streptococcus agalactiae*, *coagulase negative staphylococci*, *Escherichia coli* and *Corynebacterium spp.* [16,18].

Camel clinical mastitis can be determined using the same methods on other dairy animals, but the subclinical mastitis is difficult to detect. Subclinical mastitis detection is done through using different test procedures that determine the presence of inflammation in milk. Such methods include the microbiological investigation, level of SCC, California mastitis test, and other routine tests used for other dairy animals. Identification of subclinical mastitis is extremely important because of the importance of camels in the desert countries to ensure the safety and health of these dairy animals [18].

A study done over a period of 9 years (1987-1995) in the eastern province of Saudi Arabia had shown that mastitis prevalence in camels has been decreasing throughout that period of time, and that mastitis in camels is not the main health issue. The most common diseases that were recorded are present in the table 5 below. The rate went from high incidence (39 cases) during 1987 to very low (0-6 cases/year). This indicates that mastitis prevalence was 4.0% though the 9 years of the study. The study showed that the clinical cases that were recorded were either chronic or acute and needed surgical intervention. This low percentage of mastitis could be attributed to the protection provided to the camel udder through its setting posture, making exposure to udder infection very minimum [15].

	Year									Total
	1987	1988	1989	1990	1991	1992	1993	1994	1995	
Total number of infected cases	488	206	168	85	124	66	79	196	306	1718
Mastitis cases	39	12	6	1	2	0	3	2	2	67
Percent age %	8	5.8	3.6	1.2	1.6	0	3.8	1	0.7	4

Table 5: Number of cases and percentage incidence of camel mastitis in eastern province of Saudi Arabia from 1987-1995 [15].

*Among the 6 different camel diseases screened, mastitis ranked at the sixth place.

The study done in Jordan in 2007, showed that the mean of the log concentration of lactoferrin in mastitic milk was significantly higher than that in normal milk. According to the bacteria implicated in

mastitis, *S. aureus* and CoNS isolates showed the highest increase in the log concentration of lactoferrin in the mastitic milk among other bacteria, and the increase was significant. While, milk mastitis due to *E. coli* infection had the lowest lactoferrin concentration. Lactoferrin log concentration showed significant increase among the younger camels (3-4 year of age) compared to the older ones, while stage of lactation had no difference regarding to age. So, there was significant correlation between the camel age and lactoferrin concentration, and the levels were higher in subclinical mastitic quarters, which could be attributed to inflammation severity. Also, the strong association observed between the low SCC scores and udder inflammation, could be used as an indicator for risk factor for udder infection in camels that could develop into mastitis. Concentration of lactoferrin was found to vary due to pathogen implicated in infection, with highest levels attributed to CoNS and lowest with *E. coli*. Furthermore, antimicrobial activity of lactoferrin was not useful against the bacteria and mostly didn't inhibit the bacterial growth of the pathogens, which might be attributed to the presence of receptors on pathogen surfaces for lactoferrin [12] (Table 6).

Parameter	Number of camels		
Age (years)	Examined	Infected	Prevalence %
5-7	45	15	33.33
8-10	51	27	52.94
11-13	39	15	38.46
14-16	15	12	80.00
Parity			
1-2	69	25	36.23
3-4	51	22	43.14
5-6	33	22	66.67
Lactation stage (months)			
0-1	33	18	54.55
1-3	21	6	28.57
3-10	24	9	37.50
10-12	72	39	54.17
Production system			
Sedentary system	123	64	52.03
Semi-nomadic system	27	17	62.96
Milking process Hygien			
Good	57	22	38.60
Poor	93	88	94.62

Table 6: Different determinants influencing the prevalence of mastitis in Pakistan desert during (2008-2009) [18].

A study done in UAE in 2013 showed that camel mastitis prevalence rate was 18.52%, with subclinical mastitis being more common (24.7%) than clinical mastitis (11.67%). The main causing pathogens were *Staphylococcus* for both types of mastitis (41.67%),

then came *Streptococcus spp.* (21.67%), *Enterobacter spp.* (15.00%), *C. pyogenes* (10.00%), *Micrococcus spp.* (5.00%), *Pasteurella spp.* (5.00%) and *Pseudomonas aeruginosa* (1.66%) [16].

A study was done in 2013 in Kenya to investigate the genetic pattern diversity of (Group B Streptococcus, GBS) which was isolated from camels of East Africa. One of this pathogen is *Streptococcus agalactiae*, which can affect humans if transmitted to them from camel milk. Also, the wrong use of antimicrobial drugs usually leads to presence of resistant genes that represent a real threat if transmitted from one organism to another affecting camels' responsiveness to treatment. So, this study focused on investigating the camel GBS genotype present in Africa and to provide better antimicrobial treatment and vaccination strategies. This study chosen *Streptococcus agalactiae* for investigation because it contains a capsule which has 10 different molecular types and some of its types are associated with invasive presentation of the disease, such as Type III and V where the first is invasive neonatal infection and the second is invasive for humans in North America. A 92 GBS isolated from camel sample were examined and studied for type of capsule present, resistance genes, and antibiotic resistance profile [17].

The study identified 3 GBS clonal populations, the first and largest population with 64 isolates both from healthy and diseased animals, and this population showed different sequence types and 4 types of capsule. The second population with 26 isolates from camel's milk clinical mastitis, all of them showed ST-616 and type III capsule only. The last and smallest population showed two sequence types ST-609 and ST-614, and also one type of capsule, type V. Results from the study are shown in the figures 1-3. Through comparison, the last two sequence types were found to cluster in the same population as human GBS which was isolated from Kenya; this could indicate for mixed ancestry and possibility of genetic exchange rendering the high plasticity of *S. agalactiae*. Still these information do not confirm the transmission of strains between human and camel or the reverse, but it suggest more detailed research and study especially with human in close contact with camels for long periods of time to check the possibility of genetic exchange between the two. Furthermore, antibiotic investigation resulted in resistance to the antibiotic tetracycline (34%) but not in all isolates of all sequence types. The most resistant isolates (71%) were from the second population (ST-616) which were isolates represent the clinical mastitis group. The resistance was due to the presence of the tetM gene, which is the tetracycline resistance gene. Although, tetracycline is a broad spectrum antibiotic used commonly to treat many different infections, in the case of camel mastitis caused by GBS in East Africa; it is not useful due to high resistance pattern and other antibiotic and antimicrobial drugs should be considered [17].

A study done in Saudi Arabia in 2011 at Al Jouf city, examined a 120 samples from 30 healthy camels for the presence of subclinical udder infection using culture technique SCC measurement, and California Mastitis Test (CMT). This study aimed to investigate the correlation between SCC and CMT with intra-mammary gland infections in the healthy subjects to establish a reference. The study found that gram positive cocci were the main microorganism in udder infection, and the SCC mean value was 125,000 cells/mm³ in the healthy subjects while the infected ones had higher SCC mean as well as CMT value. So, both tests showed that they are useful in predicting the udder status regarding mastitis infection, so they are useful as routine test to detect subclinical mastitis [19] (Table 7).

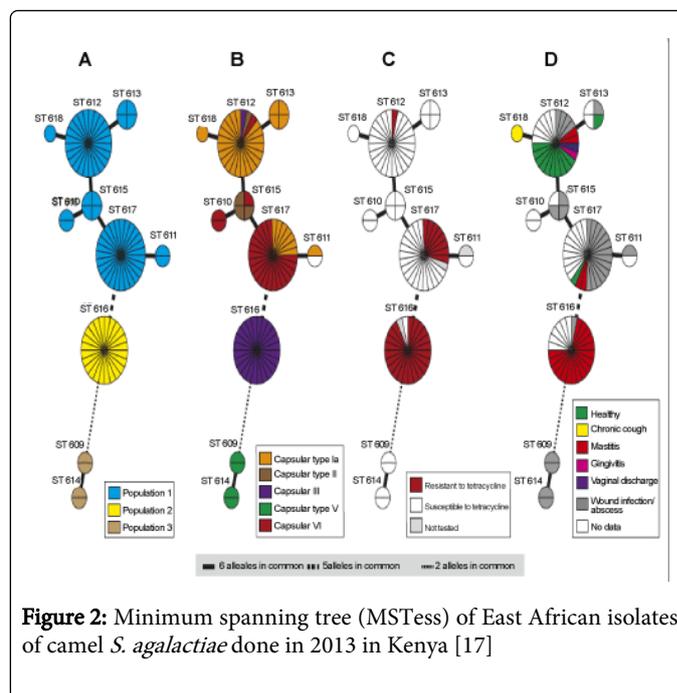


Figure 2: Minimum spanning tree (MSTess) of East African isolates of camel *S. agalactiae* done in 2013 in Kenya [17]

Bacteria	Isolates	
	Number	Percentage %
<i>Streptococcus spp.</i>	30	42.9
<i>S. aureus</i>	5	7.1
Other <i>Staphylococcus</i>	19	27.1
<i>Micrococcus</i>	4	5.7
<i>E. coli</i>	9	12.9
Other gram negative rods	3	4.3
Total	70	100

Table 7: Isolates distribution and prevalence of pathogens found in Al Jouf, Saudi Arabia in 2011 [19].

Another study was done in Sudan in 2013 and it focused on determining mastitis incidence in the lactating camel located in North Kordofan, and isolates the implicated microorganisms. The study investigated 60 lactating camel for clinical mastitis, so the incidence rate was found to be 25% when clinically examined but the rate was 13.3% and 15% using other techniques such as SCC and WST, respectively. Furthermore, when the milk samples were investigated for mastitis the rate was significantly high 41.66% (p<0.001). Pathogens isolated were mainly as follow; *Staphylococcus spp.* (80.30%), *Bacillus spp.* (9.09%), *Pasteurella spp.* (6.06%), *Corynebacteria spp.* (3.03%) and *Streptococcus spp.* (1.52). So, the study indicates that mastitis is predominant in lactating camels with *Staphylococcus* species being the major cause of it.

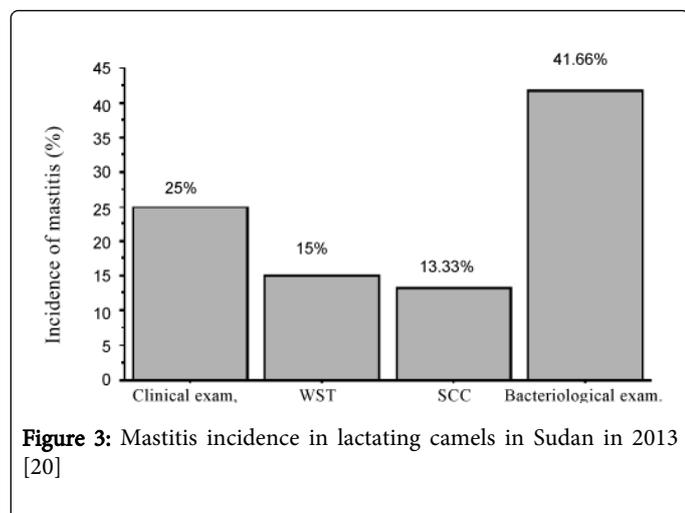


Figure 3: Mastitis incidence in lactating camels in Sudan in 2013 [20]

Hence, mastitis is a serious issue that is in an increasing rate and must be addressed properly using a national program to control and manage its occurrence [20] (Table 8).

A study was done in Jordan during 2008 to establish data on camel mastitis and infecting pathogens. The study included about 90 camels from the south providence, and samples were tested using CMT. Clinical symptoms of mastitis were seen in 21% of the camels, and the main bacterial pathogens were *Micrococcus spp.*, *Staphylococcus aureus*, *Streptococcus spp.*, and *Corynebacterium spp.* Isolates were sensitive to the main antibiotics such as gentamycin, ampicillin, and tetracycline. The study concluded that mastitis were actually prevalent in Jordan and mainly of the gram positive cocci. So, efforts must be exerted to improve the health of camels and to establish a program for mastitis infection control [21] (Table 9).

A study was carried out in Ethiopia during 2010 in the eastern regions to investigate the prevalence of mastitis and pathogens causing it. The tests were done using the CMT technique. Ethiopia contains about 1 million camel head and most of them are located in the

country's eastern part, and their annual milk production is about 75, 000 tons. The study included 161 camels from three different areas in the east region, and they all differ in their ages, lactation stage.

Species	Isolates number	Percentage %
<i>Staphylococcus aureus</i>	15	22.75
<i>S. hyicus</i>	2	3.03
<i>S. intermedius</i>	5	7.56
<i>S. epidermidis</i>	8	12.12
<i>S. delphini</i>	2	3.03
<i>S. simulans</i>	4	6.06
<i>S. kloosii</i>	3	4.55
<i>S. carnosus</i>	1	1.52
<i>S. chromogenes</i>	1	1.52
<i>S. lentus</i>	3	4.55
<i>S. lugdunensis</i>	2	3.03
<i>S. sacchrolytics</i>	1	1.52
<i>S. saprophyticus</i>	2	3.03
<i>S. haemolyticus</i>	4	6.06
<i>Strep. dysgalactiae</i>	1	1.52
<i>Corynebacteriumbovis</i>	2	3.03
<i>Bacillus cereus</i>	6	9.09
<i>Pasteurellahaemolytica</i>	4	6.06

Table 8: Different bacterial species isolated from lactating she-camels with subclinical mastitis in Sudan in 2013 [20].

Isolated bacterial species	Isolates number	CMT positive cases percentage (%)	CNT negative cases percentage (%)
<i>Microsoccus spp.</i>	15	67.22	32.78
<i>Staphylococcus aureus</i>	12	75.00	25.00
<i>Streptococcus spp.</i>	7	89.80	10.20
<i>Corynebacterium pyogenes</i>	2	100.00	0.00
<i>Corynebacterium pseudotuberculosis</i>	2	100.00	0.00
<i>Escherichia coli</i>	3	0.00	100.00
<i>Momeimia haemolytica</i>	2	0.00	100.00
<i>Pasteurella multocida</i>	2	0.00	100.00
<i>Pseudomonas aeruginosa</i>	2	100.00	0.00

Table 9: Bacteria identified in camel milk samples in Jordan in 2008 [21].

Prevalence rate according to the CMT test was 76% which is very high, and was attributed to lack of hygienic and sanitized milking

procedure in that areas. The main pathogens implicated were the coagulase negative *staphylococci* (39.6%), *Streptococcus dysgalactiae*

(22.2%), *Corynebacteria spp.* (9%), *Bacillus spp.* (7.6%), *Streptococcus uberis* (7.6%), *Escherichia coli* (6.3%), *Staphylococcus aureus* (4.2%) and *Streptococcus agalactiae* (3.5%). The study concluded that major changes must be taken to reduce the high incidence of the disease, and to establish an adequate management and control programs to detect, monitor, and reduce camel's mastitis [22] (Table 10).

Isolated bacterial species	Isolates number	Isolates percentage (%)
Coagulase negative <i>staphylococci</i>	57	39.6
<i>Streptococcus dysagalactiae</i>	32	22.2
<i>Corynebacteria spp.</i>	13	9
<i>Bacillus spp.</i>	11	7.6
<i>Streptococcus uberis</i>	11	7.6
<i>Escherichia coli</i>	9	6.3
<i>Staphylococcus aureus</i>	6	4.2
<i>Streptococcus agalactiae</i>	5	3.5
Total	144	100

Table 10: Bacterial species isolated from milk samples in Ethiopia in 2010 [22-25].

A study was done in Jijiga region, Ethiopia during (2011-2012) to detect camel mastitis on 384 animals and its prevalence, risk factors, and causes. This is because of the high presence of camel mastitis in these areas although there is only limited data and literature on camel mastitis compared to other dairy animal mastitis such as cows. Since mastitis prevalence and causes differ depending on species, geographical area, and control and management done, so the study aimed to find these information for camel mastitis to better provide control and intervention programs. California mastitis test (CMT) was used to detect mastitis prevalence which was 30.2% (116 out of 384), and prevalence of clinical mastitis was 4.9% (19 out of 384) while subclinical was 25.3% (97 out of 384). Prevalence in quarter was 25.8% (397 out of 1536). The study showed significant increase in the prevalence of mastitis among the camels with teat lesion, tick infestation, and parity or age compared to camels without previous factors. A selected CMT positive group of samples was examined to detect the causative pathogen, and majority of cases were due to coagulase negative *Staphylococci* (39.6%), then *Streptococcus dysagalactiae* (22.2%), *Corynebacteria spp.* (9%), *Bacillus spp.* (7.6%), *Streptococcus uberis* (7.6%), *Escherichia coli* (6.3%), *Staphylococcus aureus* (4.2%) and *Streptococcus agalactiae* (3.5%) [13].

Mastitis Control and Treatment

Prevention is always better than treatment, which in case of mastitis it is difficult to completely eliminate it from the animals in the farms, but with careful and continuous control its incidence could be minimized dramatically. The best treatment period is during the non-lactation (dry) phase which proved it cures about 70% of environmental infection caused by *Streptococci*. Literature suggest to take the following precautions to ensure proper treatment; complete sanitization of the farmer hands with water and soap, as well as the animal's teat and udder with proper sanitizer, ensure dryness of udder

before starting treatment and provide individualized items such as towels for each animal, immerse the teats in a proper teat germicidal solution for at least 30 seconds before removing it with the towel. Then, using alcohol saturated cotton swab clean the teats end, usually if all the four quarters were under treatment, treatment starts with the furthest teat to the closest to avoid contamination between treated and not. If antibiotics are being administered, then treatment starts from the closest teats to the furthest to prevent clean ends contamination. Finally, after treatment has completed teats must be immersed again in an effective germicidal teat solutions [6].

The main idea behind mastitis control is to manage it through limiting pathogen exposure to animal's teat, or increase infection resistance among the dairy animals. The following procedures must be carried out to ensure disease control. First; proper sanitation and husbandry performance, second; mastitis treatment during the non-lactation period, third; teat dipping post milking and forth; chronically infected animals must be removal, fifth; continuous monitoring of SCC and mastitis and immediate treatment [6].

In some countries such as Ethiopia, herbal medicine is still used as preventive and curative traditional medicine for both humans and animals alike [25]. Actually, 80% of humans refer to traditional than medical medicine, and it is used for more than 90% of animals. So, it was also used as a treatment for mastitis in Ethiopia, but although their essential role in both curing and maintaining health of humans and animals, it is at danger of permanent loss. This is due to f the inappropriate passage of information from generation to the next through verbal rather than writing method, other factors for loss also include changes in the environment, agriculture, and urbanization. Documentation of use of these herbal medicines are being done but not in the field of veterinary, but data showed the importance of certain herbal plants as medicine and this study aims to examine them for mastitis. Nine plant species were examined in a study during a two years period (2007-2009) done in the Tigray region of Ethiopia. All plant species used showed antibacterial activity except one plant *S. hastifolium*, and out of the remaining 11 plant, 5 showed promising antibacterial activities. So, the study concluded that the antibacterial activity of plants validates its use by the people as a herbal medicine against mastitis and other diseases, and that they require further assessment to characterize them and identify their appropriate dosage for use [23].

Contagious Mastitis Control

The important points to keep in mind while controlling mastitis is that prevention is number one procedure though ensuring dry teats, presence of liner slips between teat as much as possible, teat dip in effective germicidal solution, and always observing the milking procedure [3].

Contagious mastitis pathogens such as *Staphylococcus aureus* which stands as the major causing agent is difficult to treat and during the lactation period successful is very small and the animal might be removed from the herd. While, *Streptococcus agalactiae* could be cured more successfully with antibiotics and with good management procedures mastitis could be eliminated completely. Another type, *Streptococcus dysagalactiae* which could be found everywhere in the farm itself or the animal, their prevention could be accomplished by following the proper sanitation procedures and antibiotics protocol [6].

Steps used to reduce the level of SCC and control mastitis include; teat dipping, treat during dry period, accurate milking procedure and system, always clean and dry environment, chronically ill animals must be removed, and apply SCC monitoring program according to the DHIA guide [3].

To ensure elimination of the disease, animal's quarters must be treated during dry off phase with appropriately designed antibiotics. Additionally, infected animals must be removed and isolated away from others to prevent cross-infection [3].

Environmental Mastitis Control

Environmental mastitis is controlled by limiting teat end exposure to surrounding bacteria. The animal's environment must be always clean and dry, prevent presence of mud, manure, and settled water. Also, the use of a proper germicidal for teat treatment during drying off periods of the animal and antibiotic administration for all affected teats will aid the control of pathogens infection as *Streptococci* [6].

Prevention of environmental mastitis is done through reducing the teat exposure to bacteria in animal's environment, their bedding, around the teat, during therapy administration, and during milking procedure. Environment could be controlled by keeping it clean and dry as much as possible for both phases dry and lactation, never allow manure, mud, or settled water from accessing the animal, always maintain clean calving area, and always provide clean and free stall. Animals bedding must be cleaned from remaining food and wetness, and must be aired to remove moisture to prevent pathogens from growing on it. The best types of bedding that minimize bacterial deposition are inorganic materials as crushed limestone or sand because of their low nutrient content. While the worst types include shavings, sawdust, recycled manure, seed hulls, and chopped straw because of high nutrient that could be used by bacteria for their growth. Another aspect to control through is teat dipping; it must be dipped in germicidal solution after milking which will limit spread of certain pathogens between teats [3].

Therapy during dry phases is recommended for all quarters, this help really in controlling environmental streptococci, but not coliforms. Also, prior to the period of calving, treatment might not be successful. Practicing proper milking procedure though washing the teats not the udder, and cleaning the machine before attaching it to the teat will definitely reduce environmental mastitis [3,24].

Conclusion

From the previous data we can conclude the extreme importance of camels in these countries for many purposes but for better survival in these difficult conditions associated with the desert. So, mastitis in camels must be investigated in more detail for better application of antibiotic therapy to avoid resistance. Control management must always be a priority for all farm holders and livestock owners to avoid economic losses associated with camel mastitis.

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