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Impact of Mastitis on Reproductive Performance of Dairy Cattle (Review)

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Abstract: Bovine mastitis is an inflammation of the mammary gland parenchyma due to infection with a pathogen (intramammary infection), injury, allergy and neoplasm. Mastitis is considered to be the most costly disease of dairy animals worldwide. It is a multi etiological complex disease as it is the outcome of interaction of various associated factors: including the host, the pathogens and the environmental factors. The disease is characterized by physical, chemical and bacteriological changes in the milk and associated with several pathological changes in the glandular tissue of the udder. Mastitis (both clinical and subclinical) can affect conception rates, compromise embryo development, embryonic death and calf health, as well as, it increases the risk of calving complications. Detection of the mastitis is often complicated due to the subclinical nature of the mammary infection. Sound husbandry practices and sanitation, post-milking teat dipping, treatment of mastitis during no lactating period of the dairy cow and culling of chronically infected cow are the key elements to be recommended in the control and prevention of mastitis.

Key words: Clinical Mastitis · Mastitis · Subclinical Mastitis

INTRODUCTION

The total livestock population for the country is estimated to be 50.8 million cattle, 25.9 million Sheep, 21.9 million goats, 1.9 million horses, 5 million donkeys, 0.3 million mules, 0.8 million camels and the total poultry population at country level is estimated to be about 42 million [1].

Dairy products, especially milk, are among the most essential food sources for most of the world's population. The growing global demand for dairy products is driving the need to increase the average milk yield per cow. The increase in milk yield results from genetic selection as well as improved cow nutrition and management. One of the greatest problems impacting high milk yield is the poor udder health, particularly due to mastitis [2].

Mastitis, which manifests as inflammation of the mammary gland, is currently one of the most widespread diseases affecting dairy cattle. Approximately 60-70% of all antimicrobials administered on dairy farms are for preventing and treating mastitis. Public health is potentially at risk because mastitis may transmit zoonosis and sicknesses associated with food toxins. For this reason, the direct consumption of raw milk is not recommended due to the high probability of contamination with microorganisms from the cow, pasture, milking machine and containers. Hence, milk pasteurization is mandatory for ensuring its safety as well as to prolong its shelf life [3].

Inflammation is defined as a reaction of tissue to injury [4]. In cases of mastitis caused by Bacteria, microorganisms such as Escherichia coli, Streptococcus uberis and Staphylococcus aureus infect the mammary gland and the prevalence of specific pathogens varies around the world. In some herds, the most serious problem is caused by coagulase-negative staphylococci (CNS) [5], which may or may not appear as an issue in other herds. Thus, the listed causative agents in this review may not be the most common in every area and in every herd. Somatic cell count (SCC) can be used as an indicator of udder health. Cows that are healthy or that have already recovered from mastitis should have SCC below 200, 000 cells/mL and cows with counts over 400, 000 cells/mL should be considered as having an intra-mammary infection [6].

Mastitis is a global problem as it adversely affects animal health, quality of milk and the economics of milk production, affecting every country, including developed ones and causes huge financial losses [7].

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Objectives: Review bovine mastitis, Assess mastitis causing major microorganism and associated risk factors, to understand economic impact of mastitis on dairy cattle, finally recommend some possible solution on prevention and control of the disease

Bovine Mastitis

Types of Mastitis Based upon the Etiological Agents: Depending on the causative agent, mastitis in cows can be categorized into three main types: Contagious, Environmental and Summer Mastitis [8].

Contagious Mastitis: Contagious mastitis is caused by *Streptococcus agalactiae* (*S. agalactiae*) *Staphylococcus aureus* (*S.aureus*) *Streptococcus dysgalactiae* (*S. dysgalactiae*). It is caused by bacteria living on the skin of the teat and inside the udder. Contagious mastitis can be transmitted from cow to another during milking and can further be classified into as:

Clinical Mastitis: It is characterized by the presence of gross inflammation signs (swelling, heat, redness, pain). Visually, clots or discolorations of the milk often observed in combination with tender and swollen udder, sometimes in combination with fever, loss of appetite *etc*. Clinical mastitis can again be divided into Peracute mastitis which is characterized by gross inflammation, reduction in milk yield and alteration in milk composition. Systemic signs like fever, depression, shivering and loss of appetite and loss of weight were also observe. Acute mastitis that is similar to per-acute mastitis but with lesser systemic signs like fever and mild depression. Sub-acute mastitis showed minimal mammary gland inflammation signs and were not accompanied with visible systemic signs [9].

Subclinical Mastitis: It is characterized by change in milk composition (SCC, leukocytes and epithelial cells, changes in milk pH and ion concentration) with no clinical signs of gross inflammation or milk abnormalities. In healthy lactating mammary gland, the milk SCC is often <100, 000 cells/ml of milk while can increase to >1, 000, 000 cells/ml of milk during subclinical mastitis. The major factor affecting the SCC at the herd and individual level is the presence of intra-mammary infections (IMM) [2].

Chronic Mastitis: It is an inflammatory process that exists for months and may continue from lactation of one to the other lactation. It exists as subclinical but may exhibit periodical flare-ups sub-acute or acute form that last for a short period of time [10].

Environmental Mastitis: It is caused by Coliforms *Escherichia coli, Klebsiella pneumonia, Klebsiellaoxytoca, Enterobacter aerogenes*. Environmental *streptococci S. uberis S. bovis S. disgalactiae, Enterococcus faecium, Enterococcus faecalis*. It is caused by organisms such as *Escherichia coli* which do not normally live on the skin or in the udder but which enter the teat canal when the cow comes in contact with a contaminated environment. The pathogens normally exist in feces, bedding materials and feed [8].

Summer Mastitis: A third type of mastitis, referred to as summer mastitis, is an acute illness of dry cows and heifers which causes extensive and painful damage to the udder. The infected quarter is permanently damaged resulting in early culling of the cow. Infection is more likely to occur when cows are in environment where the teats can easily be exposed to damage and high fly populations [6].

Patterns of Infection: It is the mode of infection by different pathogens causing Mastitis in dairy cow varies in the mechanism and the resulting clinical subtypes. Three distinct modes of infection in the epidemiology of mastitis can be recognized as Contagious, Opportunistic/ Environmental and Vector infectious Patterns:

Contagious Disease Pattern: It is the first and the most common mode where transfer of a microorganism from cow to cow is essential to propagate the disease. This pattern involves the transmission of disease from a carrier to a susceptible host. This involves mainly the spread of two major microorganisms in the dairy population. These microorganisms are *S. agalactiae* and *S. aureus*. Other epidemic contagious disease outbreaks have been reported and involve *Nocardia* spp, *Mycoplasma* spp. and in some situations environmental streptococci. Contagious diseases only remain endemic when the mean number of susceptible individuals infected by an infected individual is appreciably larger than one [11].

Opportunistic Disease Patterns: It is the second pattern is a pattern where infection is found mainly in housed or closely corralled cattle. Host factors and environmental factors put an animal at risk. A wide range of microorganism can then enter the mammary gland and cause disease. The causation of mastitis involves complex relationship of three major factors and this involves an interaction of microorganism, host factors and the environment and when solving herd problems, this epidemiologic triangle should always be kept in mind [12].

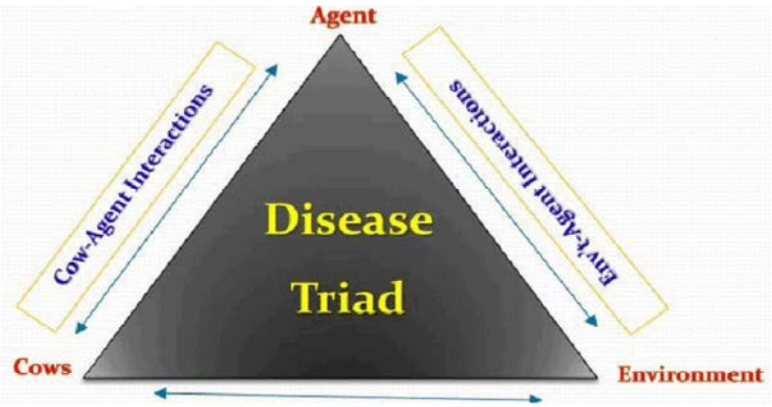

Fig. 1: Epidemiologic disease triad (host, agent and the environment interactions) [14]

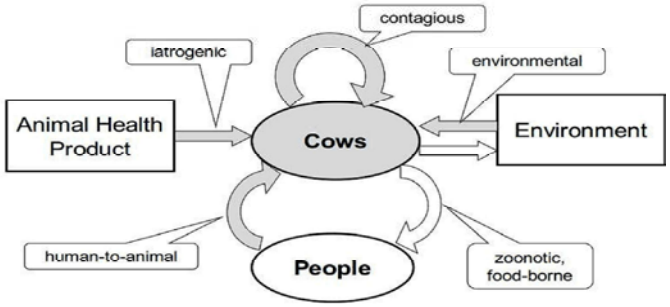

Fig. 2: Possible sources and transmission routes for mastitis pathogens [12]

Vector Based Patterns: The third type of infection pattern is found in non-lactating cows. This type of infection is common in the early part of the dry period particularly with *S. uberis* and continues as clinical mastitis in the following lactation. This is 'summer' or 'heifer' mastitis and its etiology is the exposure to vector based pathogens carried by a species of fly [13].

Methods of Transmission: There are two main modes of transmission for bovine mastitis: contagious and environmental.

Contagious Transmission: Contagious transmission also called cow-to-cow transmission because; cows with mastitis are the main source of infection. Spread of the bacteria that cause the infection primarily happens during milking, e.g. via the milkers' hands, udder cloths, or the milking machine. Use of milking gloves and individual towels will help to prevent this [15].

Environmental Transmission: Environmental mastitis originates in the environment, e.g. in bedding, manure or water. Occasionally, bedding contains high numbers of bacteria even before it is used. Routinely, bedding is contaminated with manure, which contains everything bacteria need moisture, warmth and nutrients. Water can be contaminated with bacteria from manure, or it may accumulate in a milking machine, particularly if hoses don't have the correct slope and if the temperature of the cleaning water is too low. In addition to those common modes of transmission, there is also the possibility of transmission by people [16].

Pathogenesis of Mastitis: A basic knowledge of mammary gland anatomy and physiology is necessary to understand how mastitis develops. The interior of each quarter is composed of a teat cistern, gland cistern, milk ducts and glandular tissue. The glandular tissue or secretory portion contains millions of microscopic sacs called alveoli. Each alveolus is lined with milk-producing epithelial cells and is surrounded by muscle cells that contract and squeeze milk from the alveolus during milking. Blood vessels bring nutrients to each alveolus, where epithelial cells convert them into milk. Between milkings, milk accumulates in the alveolar spaces, milk ducts and cisterns. During milking, the accumulated fluid is removed through the teat ducts [15].

Invasion of the Udder: Mastitis results once bacteria pass through the teat duct and multiply in milk-producing tissues. Microorganisms breach the teat duct in several ways. Between milkings, microorganisms may pass through the teat duct by multiplying inside the duct, or by physical movement resulting from pressure placed on the teat end as the cow moves about. During machine milking, microorganisms may be propelled into or through the teat duct into the teat cistern. The potential for invasion is greatly increased by bacteria that reside in or colonize the teat duct. Such colonization's occur in lactating and dry cows and the colonizing bacteria may survive for months, serving as sources of bacteria for infecting the gland [11].

Effects of Mastitis on Reproductive Performance of Dairy Cattle: The detrimental effects that mastitis can have on fertility are one of the largest indirect costs of the disease. However, Mastitis (both clinical and subclinical) can affect conception rates, compromise embryo development, embryonic death and calf health, as well as increases the risk of calving complications [17]. In addition, to this Clinical mastitis after AI is associated with low conception rate [18], regardless of whether the IMI-induced bacteria are G+ or G- . Poor fertility results in additional costs associated with veterinary services, culling and low production [19].

The Impact of Mastitis on Fertility: The impact is a significant contributor to the reduction of dairy reproductive performance. The premature luteal regression during the first month of gestation would likely result in decreased conception rates or increased pregnancy losses in lactating dairy cows [20].

Effect of Mastitis on Conception: The inflammation caused by mastitis produces hormones called prostaglandins' that are involved with regulating the oestrus cycle. The prostaglandin levels too high or too low at the wrong point in the cycle will prevent regular estrus and ovulation. Literature from the University of Minnesota states that cows without mastitis become pregnant 25% faster than cows with mastitis. As well, calving to conception intervals of cows with mastitis is 26 days longer [9].

Mastitis is also accompanied by fever which may disrupt feed intake by depressing appetite, increasing water intake and decreasing forage digestibility [21]. This decreased feed intake can lead to worsening of body condition and prolongation of energy deficit, which delays resumption of ovarian cycles and follicular maturation [22].

Effect of Mastitis on Maintenance of Pregnancy: Mastitis induction of early regression of the *corpus luteum* (CL) post-AI can potentially lead to termination of pregnancy. There were evidences of reduced progesterone secretion following mastitis. Intravenous infusion of *E. coli* lipopolysaccharide (LPS) decreased plasma progesterone concentration in pregnant cows. This impairs embryo implantation or causes embryo resorption or abortion due to a decline in progesterone levels and increased contractility of the uterine smooth muscle [23].

Effect of Mastitis on Embryo Development and Calf Health: Once a cow is pregnant, mastitis can also increase the risk of abortion. Decreased metabolic health and efficiency make it difficult to maintain pregnancy. Studies showed that even cows that had mastitis and were successfully treated for the clinical infection have a higher risk of abortion than cows that have never had mastitis [20].

Effect of Mastitis on Colostrums: Mastitis also alters the quality of the colostrum produced by the dam. Since calves are born with no immune system, it is essential that they receive colostrum within 6 hours of birth. Colostrum from mastitic cows has decreased levels of antibodies, vitamins, minerals and proteins, which compromise the calf's immune system development, GI tract health and overall growth. There is also some evidence that mastitis causing pathogens can be passed from the udder into the calf's mouth through suckling, creating an infection reservoir within the herd [24].

The increased resources required to fight mastitis can also lead to exhaustion during calving, increasing the risk of complications during delivery. It can also be responsible for ketosis and retained fetal membranes after calving. The compromised immune system due to a mastitis infection can increase the risk of uterine infections such as metritis, endometritis and pyometra which increases day open of dairy cows [19].

Economic Impact Associated with Decreased Reproductive Efficiency: The economic impact of mastitis on reproduction failure has only gained attention in the last decade. Reproductive efficiency is an important contributor to dairy farm profitability. However; unfortunately, the reproductive performance of dairy cattle has declined steadily over the last few decades. This decline in reproduction performance is closely associated with occurrence of mastitis in dairy cows. The annual incidence of mastitis was approximately 35% and the median interval from calving to pregnancy

was 26 d longer for cows with mastitis compared with cows without mastitis [17]. The economic loss of reproductive inefficiency is attributable to less milk production, losses in milk quality, medicine costs and costs of veterinary care in cases of metritis, culling high yielding cows because of reduced fertility, decreased and reduced calf number. The reduced calf crop production impairs growth of dairy farms thereby reduces milk production, which causes serious economic loss to dairy farmers [14].

Effect on Production: The Dairy Herd Improvement Association (DHIA) has adopted an SCC scoring system that divides the SCC of composite milk into 10 categories from 0 to 9 known as linear scores. The DHIA programs determine the SCC on each milking cow each month and report the SCC or the linear score. Linear scores can be used to estimate production losses, but the average linear score for the lactation most accurately reflects reduced milk yield. Cows with higher lactation average SCC scores produce less milk [25].Production losses in older cows are about double those of first-lactation cows. Determining the exact amount of milk lost at a specific SCC or linear score or for any one cow is not possible. However, the fact remains that elevated SCCs result in major losses to dairy producers and elevated an SCC is almost always due to the presence of intra-mammary infection [26].

Effect on Milk Composition: Mastitis resulting from major pathogens causes considerable compositional changes in milk including increases in SCC. The types of proteins present change dramatically. Casein, the major milk protein of high nutritional quality, declines and lower quality whey proteins increase which adversely impacts dairy product quality, such as cheese yield, flavor and quality. Serum albumin, immunoglobulin, transferrin and other serum proteins pass into milk because vascular permeability changes. Lactoferrin, the major antibacterial iron-binding protein in mammary secretions, increases in concentration, which is likely because of an increased output by the mammary tissue and a minor contribution from PMN [27].

Effect on Cost: Mastitis is of great economic importance to milk producers, because the disease has negative impact on several important aspects of cow and herd performance. Incurred costs are of both direct and indirect nature [18]. Direct costs include veterinary costs, increased labour requirement, discarded milk (during the course of treatment) and reduced milk yield and quality. Indirect costs are those that are not always obvious to the milk producer and are therefore referred to as hidden costs. They include increased risk of subsequent disorders, reduced fertility (extra services per conception and, as a result of this, an extended calving interval), increased risk of culling and, occasionally, mortality [14].

Effect on Quality: Mastitis not only reduces dairy producer profits but also results in important and costly losses to processors due to poor-quality milk. Reduced quality is detected with herd milk at 400, 000 cells/ml. A variety of dairy products, including cheeses, powdered milk, fermented products and fluid milk, are affected [28].

Diagnosis: Diagnosis of mastitis is based on clinical sings (physical examination of gross abnormality of milk and udder) and identification of the pathogen from milk samples. Tests to detect sub-clinical mastitis include California Mastitis Test, or direct somatic cell count.

Qualitative Milk Examination: According to Quinn *et al*. [29], changes in color of milk can be caused by the presence of blood (red or brownish) or pus (yellow). The consistency may be increased, resulting in thicker, "sticky" milk, or it may be more than usually watery. Flakes and clots are always abnormal. The smell of the secretion may also be altered as a result of mastitis. And, udder Visualization and Palpation, the primary step in preventing mastitis is regular examination (visualization and palpation) of the udder especially during milking. In clinical mastitis, visually the udder may turn red, hard and hot to touch. Udder may be painful to the cow at the time of palpation. These symptoms show the changes in vascularity and blood flow of the gland when inflamed [25].

California Mastitis Test (CMT): The CMT is an easily everywhere applicable and reliable screening test for sub clinical mastitis. It has been developed to test milk from individual quarter and also bulk milk samples. Using the CMT, fresh, unrefrigerated milk can be tested for up to 12 hrs and refrigerated milk can be tested for up to 36 hrs to get reliable readings. The test helps to assess the level of infection in each quarter rather than to an overall udder result and the result shows only whether the cell count is high or low [11].

Culture Method: The surest way of diagnosing mastitis is by directly isolating and identifying any pathogenic microorganisms which may be present in the milk. This can be achieved by cultural methods and a number of additional determinative tests. To obtain correct results

and avoid contamination and hence bias, it is important to work as securely and as accurately as possible under the circumstances [29].

Treatment of Clinical Mastitis in Practice: Treatment of mastitis should be targeted towards the causative bacteria whenever possible, but in acute situations, treatment is initiated based on herd data and personal experience. Rapid or on farm bacteriological diagnosis would facilitate the selection of the most appropriate antimicrobial. Treatment protocols and drug selection for each farm should be made by veterinarians familiar with the farm [30].

In general, the use of narrow-spectrum antimicrobials is preferable. Prudent use guidelines have been developed which also include antimicrobial treatment of mastitis. First choice antimicrobials for treating mastitis caused by streptococci and penicillin susceptible staphylococci are â-lactam antimicrobials; particularly penicillin G. Broad-spectrum antimicrobials such as third or fourth generation cephalosporin should not be used as first alternatives for mastitis, as they may increase emergence of broad spectrum â-lactam resistance. Systemic treatment is recommended in clinical mastitis due to *S. aureus* and in severe cases of coliform mastitis, preferably in combination with IMM treatment [31].

Control and Prevention: Speaking of control, it usually meant to refer to contagious mastitis and environmental mastitis. The fundamental principle of mastitis control is controlling the disease by either decreasing the exposure of the teat to potential pathogens or by increasing resistance of dairy animals to infection. It has been suggested that the mastitis control and treatment approach should be in line as in the same way as a surgeon approaches doing for surgery. In view of that, the key elements need to be considered the approach cuddles sound husbandry practices and sanitation, post-milking teat dipping, treatment of mastitis during non-lactating period and culling of chronically infected animals. To speak said approach precisely, washing hands with soap and water, washing teats and udder in sanitizing solution, thoroughly drying teats and udder with individual towels, dipping teats in an effective germicidal teat dip, allowing 30 seconds of contact time before wiping off teat dip with an individual towel, thoroughly scrubbing the teat end with a cotton swab soaked in alcohol. If all four quarters are being treated, start by cleaning the teat farthest from the nearest and work towards the closest teat. Treat teats nearest to the milkers first, then those farthest away to prevent contamination of the clean teat ends and dipping teats in an effective germicidal teat dip after treatment [32].

Conclusion and Recommendation: Mastitis in dairy cows is a serious problem as it is an economically devastating disease causing immense economic losses in the dairy industry and is the worldwide costliest production disease in dairy herds. Subclinical mastitis is the most serious type as the infected animal shows no obvious symptoms and secrets apparently normal milk for a long time, during which causative organisms spread infection in herd, so it is an important feature of the epidemiology of mastitis.

Continuous monitoring of mastitis and its careful management, is essential for the well-being of a dairy herd. This can be achieved through the detection of inflammation at its early stages and, subsequently, the detection and treatment of the mastitis infection. Most bacterial species can spread via more than one route, including from cow to cow or from the environment to the animal. In some cases, an environmental point source such as a treatment product or even a dog, cat or person acts as the source of infection and in those situations, initial introduction from the environment may be followed by cow-to-cow transmission. Both removal of the original source and prevention of further within-herd spread are needed to control such outbreaks.

Age groups, pendulous udder conformation, multiple parity, poor body condition score, bad hygiene score, high milk producers, early lactation stage, previous exposure to mastitis and blind teats are the associated potential risk factors. Based on this, the following points are recommended Dairy producers must have to be willing to change old habits or ineffective/incorrect practices that may be causing or permitting new intra-mammary infections (IMIs) to occur. Milker's should be trained on proper hygienic milking methods, Regular investigation of mastitis especially sub clinical form should be practiced Mastitis treatments should be preceded with identification of the causative agent and susceptibility test profile of pathogens and Culling of old aged and repeatedly infected cows should be done on regular planned basis. Management, housing and environmental sanitation should be improved.

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