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ARTICLE

Alterations in Quality Parameters of Mastitic Milk

Maria Azam[1] Muhammad Aamir Naseer[3] Kiran Mumtaz[1] Iqra Muzammil[2] Khazeena Atta[2] Rais Ahmed[1] Amjad Islam Aqib[1*]

1. Cholistan University of Veterinary and Animal Sciences, Bahawalpur, 63100, Pakistan
2. University of Veterinary and Animal Sciences Lahore, 54000, Pakistan
3. University of Agriculture Faisalabad, 38000, Pakistan

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ABSTRACT

Quality milk production in modern dairy systems is facing many challenges. Salient in them is mastitis which is responsible for decline in milk production, altered milk composition and compromised udder health. The malaise consists of multiple bacterial etiologies which can be broadly classified into contagious pathogens and environmental pathogens *S. aureus* is being isolated invariably in all epidemiological studies, followed by *E. coli*. Pathogenic virulence in mastitis is often accounted due to microbial ability of producing wide array of virulence factors that enhances pathogenicity and sustainment potential in the epithelial linings of udder. Mastitis affects quality parameters of milk *i.e.* constitutional as well as mineral profile due to local damage and inflammatory mediators. It decreases the lactose secretion because of oxidative stress generated due to the formation of free radicals in the milk. In mastitic milk, IgG2 becomes the predominant antibody which is thought to be the main opsonin supporting neutrophil phagocytosis in the bovine mammary gland. Therefore, it plays a significant role in the battle against mastitis pathogens. Mastitis infected cow shows a notable elevated level of the sodium and chloride and demoted level of calcium, potassium and inorganic phosphorus. In micro minerals, mastitis effects are pretty much same as in most macro minerals *i.e.* lower down their concentration in milk secretion. Consistent preventive strategy alongside strict surveillance and biosecurity is recommended for combating this challenge.

1. Introduction

Milk is a rich source of minerals, high quality proteins with essential amino acids, fat- and water-soluble vitamins. Quality milk production in modern dairy systems is facing many challenges. Salient in them is mastitis which is responsible for decline in milk production, altered milk composition and compromised udder health [1]. Mastitis is inflammation of parenchymatous tissue of mammary gland irrespective of cause. It is described as tissue alteration resulting into progressive impairment in the secretory apparatus and decrease milk yield in both clinical and sub clinical form of mastitis [2]. White blood cells are released in the local area to tackle the invading pathogenic entities, resulting in clinical symptoms *i.e.* udder swelling, heat, redness, hard-

**Corresponding Author:*
Amjad Islam Aqib,
Cholistan University of Veterinary and Animal Sciences, Bahawalpur, 63100, Pakistan;
Email: amjadislamaqib@cuvas.edu.pk

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ness, pain, flakes or clots in the milk [3].

Mastitis is a devastating challenge of global dairy industry. The malaise consists of multiple bacterial etiologies where *S. aureus* is being isolated invariably in all epidemiological studies, followed by *E. coli* [4]. Mastitis can also occur through chemical, mechanical, or thermal injury. Mastitis usually appears in two forms *i.e.* clinical and subclinical. Clinical mastitis includes all signs like inflammation, pain, redness, affected milk quantity and quality. In subclinical mastitis, no obvious signs are present, but it is 15 to 40 times more extensive than clinical mastitis and exist for long time, difficult to detect, adversely affects milk quality and quantity [5]. Subclinical mastitis is difficult to diagnose as indirect detection methods are needed for this purpose such as electrical conductivity, California mastitis test, detection of body enzymes in milk released due to tissue damage [6]. It is 2nd most important disease of dairy animals after FMD [7].

Despite of the great advancements in genetics, milking, housing and feeding systems of high producing flocks, there is a noteworthy increase in set of multi-factorial diseases called as production diseases. In these illnesses "Mastitis" is an economically significant disease that leads to serious milk losses, premature culling of genetically superior cows, veterinary cost, medication cost, milk withholding after care, increase in labour and decrease in genetic development [8]. Pathogenic virulence in mastitis is often accounted due to microbial ability of producing wide array of virulence factors that enhances pathogenicity and sustainment potential in the epithelial linings of udder. These virulence factors contribute in microbial attachment, colonization, longer persistence and escaping the immune response [9]. Mastitis is most costly disease of dairy animals. Its losses include direct losses due to lower milk production, lower milk quality and milk rejection at consumer or processing level. Indirect losses include animal culling, lower animal price, diagnostic tools cost, veterinary and medication costs [1]. This review covered the effects of mastitis on milk quality parameters, in terms of constituents and mineral profile.

2. Mastitis causing Bacteria

Mastitis etiologies account for more than 140 pathogens which can be broadly classified into contagious pathogens and environmental pathogens. *S. aureus* is on top in the list of contagious pathogens followed by *Streptococci, Mycoplasma* and *Corynebacterium* while *E. coli* is the prominent challenge in case of environmental pathogens, followed by coagulase negative *Staphylococci, Klebsiella, Listeria* and clostridial infections. Other etiological entities are reported to be least common [2-4,10].

3. Milk Quality Parameters Deterioration in Mastitis

Mastitis has significant impact on milk quality parameters. Alteration in protein, fat, carbohydrates (Figure 1), and mineral profile has been measured in multiple studies [1,11-14]. This review briefly covers these aspects.

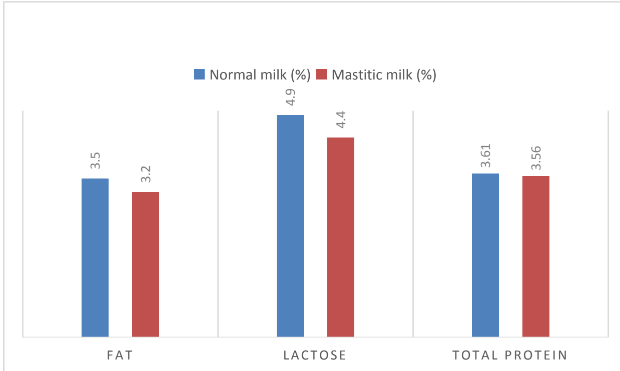

Figure 1. Milk constituents' alterations associated with mastitis

3.1 Alteration in Carbohydrates

In milk, lactose is a major carbohydrate. Lactose is composed of two components named as glucose and galactose. Average content of lactose in milk varies between 4.3 and 4.9% (Figure 2). Mastitis decreases the lactose secretion [15]. Decrease in lactose concentration increases the plasmin activity. Plasmin activity not only decreases the milk secretion but also changes the production of organic compound such as lactose [16,17].

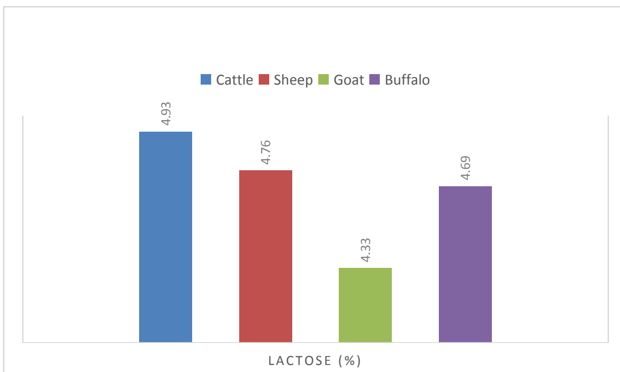

Figure 2. Lactose variation in different species

The decline in milk lactose is due to the damage of alveolar epithelial cells. The important role of lactose is to regulate milk production [18]. The reduced concentration of lactose is due to reduced synthesis at cellular level and inflammatory mediators. There is an increased influence of electrolytes on lactose synthesis during mastitis. This is because sufficient water would be drawn into the cell to

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maintain normal osmotic equilibrium [18,19]. Other reason in the reduction of lactose is leakage of lactose out of milk during mastitis. Lactose concentration depressed if concentration of the major ions *i.e.* potassium, sodium, chloride and bicarbonate is disrupted. Mammary cells can alter the concentration of ions to maintain osmotic equilibrium and lactose accumulation [20,21].

3.2 Effect of Mastitis on Immunoglobulin

Pathogenic invasion in the mammary tissue and pathogen-specific activation of the immune response influence the permeability of the blood-milk barrier [22]. In addition to the local immune response, systemic immunoglobulins are also an important component that transfer from blood to milk during mastitis. The increase of IgG in milk seems to be pathogen-dependent. The increase of this IgG is mostly observed in response to gram negative bacteria but not from gram positive [23]. Hence, the transmission of IgG from blood to milk seems to be an important indicator for the type of bacteria that is present in the udder and also, the expected course of the disease. This information can provide insight about therapies for particular cases of mastitis and help in prudent use of antibiotics. The calculation of IgG, however is complex and not readily accessible to farmers [24].

During the transfer of passive immunity from mother to the offspring, antibodies are considered to be the central part in the immunological association, as they are the most important component that linked to the immunological response and are present in the milk and colostrum [25,26]. Antibodies found in the secretion of mammary gland are basically preserved in the form of memory to the antigen whom once mother exposed and respond by the immune system. In mastitic animal, particularly during the lactation period, oxidative stress is generated due to the formation of free radicals in the milk. This formation of free radicals is linked to both the clinical and subclinical mastitis [27].

Immunoglobulin G is the major immunoglobulin in ruminant milk. The subclass IgG1 is the major antibody present in milk from healthy quarters because of an active, selective IgG1 transport across the blood milk barrier via the neonatal Fc receptor (FcRn) system. In mastitic milk, IgG2 becomes the predominant antibody which is thought to be the main opsonin supporting neutrophil phagocytosis in the bovine mammary gland. Therefore, it plays a significant role in the battle against mastitis pathogens [28]. But in case of mastitis, the increase in IgG concentration of milk from infected quarters is involved in humoral immune mechanisms in the process of elimination of infection. Such failure against infections increases the substantially humoral or local immunity, which may contribute to the establishment of persistent infections [17].

3.3 Effect of Mastitis on Mineral Profile of Milk

Milk is a wholesome food comprised of macronutrients (carbohydrates, proteins and lipids) along with the micronutrients (minerals, enzymes and vitamins). Levels of minerals and enzymes in the milk are important factors that can be used to detect and diagnose a disease [29-31]. Similarly, minerals and vitamins are used for ameliorated production, reproduction and treatment of different diseases [32]. Likewise, in mastitis treatment, feeding of minerals to the animals boosts their immunity by reducing the oxidative stress [33]. Normally both micro and macro minerals have specific concentration present in milk and this level or concentration is affected by any abnormality (intrinsic or extrinsic) to the animal body. Mastitis affects the concentration of minerals in milk that affects the quality of milk from dairy animals results in lower quality dairy products [20,21].

3.3.1 Macro Minerals

Summarizing the studies, it is clear that concentration of potassium is lower and sodium is higher in the milk of mastitis infected cows either of subclinical or clinical cases. Sodium and potassium ratio (Na: K) of the milk with respect to that of blood can be used to detect and diagnose the mastitis [31,34]. Mastitis uplifts the milk sodium level in buffalo (38.92±0.20 to 46.60±0.26mg/100ml) and lowers down the potassium (23.08±0.56 to 13.62±1.33mg/100ml) [8].

As compared to the healthy cow, milk from mastitis infected cow shows a notable elevated level of the sodium and chlorine and demoted level of calcium, potassium and inorganic phosphorus. Similarly, higher sodium and chloride and lowered potassium level has been seen in the Holstein cows infected with mastitis. Correlation or relative ratio of sodium and chlorine (Na: Cl) can also be used for diagnostic tool [19,24].

Calcium and phosphorus levels are decreased in case of major mastitis pathogens namely *E. coli* and *S. aureus*. While no or very little changes have been seen in case of other less pathogenic organisms like *Corynebacterium* and *Streptococcus* strains [10,35]. That’s why, no any definitive pattern of calcium level has been concluded. Cattles suffering from mastitis showed no remarkable variation in blood mineral level except that of calcium which depicted noteworthy boost [18,30]. In some subclinical mastitis cases of cows, goat and sheep, demoted level of calcium and inorganic phosphorus has been observed. Higher phosphorus level has also been seen in clinical mastitis. Mastitis in buffalo lowers the calcium (49.45±0.62 to 37.80 ±0.50mg/100ml), magnesium (15.78±0.27 to 14.41 ±0.18mg/100ml) and manganese (21.20±0.39 to 20.02 ±0.77mg/100ml). Similar findings have been obtained in Cholistani cattle [36].

3.3.2 Micro Minerals

Micro minerals although needed in lower concentration by the body but they are equally crucial for proper body functioning. All these minerals help animal body in maintaining physiological functions and boost immunity such as enhancing phagocytic activity by selenium, improving antioxidant role by copper and protecting epithelial barrier against infection by zinc [33]. In micro minerals, mastitis effects are pretty much same as in most macro minerals, means it lower down their concentration in mastitis infected buffalos as iron (22.06±0.36 to 18.87±0.27), zinc (43.24±1.02 to 37.10±1.22) and copper (13.18±0.38 to 9.07±0.22) [29]. Similarly, in Cholistani cattle concentration of zinc and iron lowers down in milk and blood of the mastitis infected animals [36]. Human milk composition also varies by mastitis and with reference to the mineral composition it reduces phosphorus and increases selenium in the milk [37].

4. Conclusion

Quality milk production in modern dairy systems is facing many challenges. Salient in them is mastitis which is responsible for decline in milk production, altered milk composition and compromised udder health. Mastitis is a devastating challenge of global dairy industry. Mastitis usually appears in two forms *i.e.* clinical and subclinical. The malaise consists of multiple bacterial etiologies which can be broadly classified into contagious pathogens and environmental pathogens. *S. aureus* is being isolated invariably in all epidemiological studies, followed by *E. coli*. Pathogenic virulence in mastitis is often accounted due to microbial ability of producing wide array of virulence factors that enhances pathogenicity and sustainment potential in the epithelial linings of udder. Mastitis is most costly disease of dairy animals. Its losses include direct losses due to lower milk production, lower milk quality and milk rejection at consumer or processing level. Indirect losses include animal culling, lower animal price, diagnostic tools cost, veterinary and medication costs. Mastitis decreases the lactose secretion due to the damage of alveolar epithelial cells. In mastitic animal, particularly during the lactation period, oxidative stress is generated due to the formation of free radicals in the milk. Moreover, the transmission of IgG from blood to milk seems to be an important indicator for the type of bacteria that is present in the udder and also, the expected course of the disease. Mastitis affects the level of concentration of minerals in milk that affects the quality of milk from dairy animals results in lower quality dairy products. Mastitis infected cow shows a notable elevated level of the sodium and chlorine and demoted level of calcium, potassium and inorganic phosphorus. In micro minerals, mastitis affects are pretty much same as in most macro minerals *i.e.* lower down their concentration in milk secretion. Consistent preventive strategy alongside strict surveillance and biosecurity is recommended for combating this challenge.

References

[1] Petrovski KR, Buneski G, Trajcev M. A review of the factors affecting the costs of bovine mastitis. J S Afr Vet Assoc., 2006, 77(2): 52-60.

[2] Radostits OM, Gay CC, Hinchcliff KW, Constable PD. Veterinary Medicine E-Book: A textbook of the diseases of cattle, horses, sheep, pigs and goats. Elsevier Health Sciences, 2006.

[3] Vakkamäki J, Taponen S, Heikkilä A-M, Pyörälä S. Bacteriological etiology and treatment of mastitis in Finnish dairy herds. Acta Vet Scand [Internet], 2017, 59(1): 33. Available from: https://pubmed.ncbi.nlm.nih.gov/28545485

[4] Al-Dughaym AM, Fadlelmula A. Prevalence, etiology and its seasonal prevalence of clinical and subclinical camel mastitis in Saudi Arabia. Br J Appl Sci Technol., 2015, 9(5): 441-9.

[5] Baloch H, Rind R, Umerani AP, Bhutto AL, Abro SH, Rind MR, et al. Prevalence and Risk Factors Associated with Sub-Clinical Mastitis in Kundhi Buffaloes. J Basic Appl Sci., 2016, 12: 301-5.

[6] El-Sayed A, Awad W, Abdou N-E, Vázquez HC. Molecular biological tools applied for identification of mastitis causing pathogens. Int J Vet Sci Med., 2017, 5(2): 89-97.

[7] Sharma N, Maiti SK, Sharma KK. Prevalence, etiology and antibiogram of microorganisms associated with Sub-clinical mastitis in buffaloes in Durg, Chhattisgarh State (India). Int J Dairy Sci., 2007, 2(2): 145-51.

[8] Batavani RA, Asri S, Naebzadeh H. The effect of subclinical mastitis on milk composition in dairy cows. Iran J Vet Res., 2007, 8(3): 205-11.

[9] Marques VF, Motta CC, Soares BD, Melo DA, Coel-

  DOI: https://doi.org/10.30564/vsr.v2i2.2638

ho SM, Coelho ID, et al. Biofilm production and beta-lactamic resistance in Brazilian Staphylococcus aureus isolates from bovine mastitis. Braz J Microbiol., 2016/12/04. 2017, 48(1): 118-24.

[10] Amer S, Gálvez FLA, Fukuda Y, Tada C, Jimenez IL, Valle WFM, et al. Prevalence and etiology of mastitis in dairy cattle in El Oro Province, Ecuador. J Vet Med Sci [Internet], 2018/04/10. 2018, 80(6): 861-8. Available from: https://pubmed.ncbi.nlm.nih.gov/29643295

[11] Obied AI, Bagadi HO, Mukhtar MM. Mastitis in Camelus dromedarius and the somatic cell content of camels' milk. Res Vet Sci., 1996, 61(1): 55-8.

[12] Firth CL, Laubichler C, Schleicher C, Fuchs K, Käsbohrer A, Egger-Danner C, et al. Relationship between the probability of veterinary-diagnosed bovine mastitis occurring and farm management risk factors on small dairy farms in Austria. J Dairy Sci [Internet], 2019, 102(5): 4452-63. Available from: http://www.sciencedirect.com/science/article/pii/S002203021930219X

[13]Janzen JJ. Economic losses resulting from mastitis. A review. J Dairy Sci., 1970, 53(9): 1151-60.

[14] Ibrahim N. Review on Mastitis and Its Economic Effect. Can J Sci Res., 2017, 6: 13-22.

[15] AL-Ayadhi L, Halepoto DM. Chapter 30 - Camel Milk as a Potential Nutritional Therapy in Autism. In: Watson RR, Collier RJ, Preedy VRBT-N in D and their I on H and D, editors. Academic Press, 2017: 389-405. Available from: http://www.sciencedirect.com/science/article/pii/B9780128097625000309

[16] Blum SE, Heller ED, Leitner G. Long term effects of Escherichia coli mastitis. Vet J., 2014, 201(1): 72-7.

[17] Doymaz MZ, Sordillo LM, Oliver SP, Guidry AJ. Effects of Staphylococcus aureus mastitis on bovine mammary gland plasma cell populations and immunoglobulin concentrations in milk. Vet Immunol Immunopathol., 1988, 20(1): 87-93.

[18] Leitner G, Merin U, Silanikove N. Changes in milk composition as affected by subclinical mastitis in goats. J Dairy Sci., 2004, 87(6): 1719-26.

[19] Coulona J-B, Gasquib P, Barnouin J, Ollier A, Pradel P, Pomiès D. Effect of mastitis and related-germ on milk yield and composition during naturally-occurring udder infections in dairy cows. Anim Res., 2002, 51(05): 383-93.

[20] Auldist MJ, Hubble IB. Effects of mastitis on raw milk and dairy products. Aust J dairy Technol., 1998, 53(1): 28.

[21] Bruckmaier RM, Ontsouka CE, Blum JW. Fractionized milk composition in dairy cows with subclinical mastitis. Vet Med (Czech Republic), 2004.

[22] Hayajneh FM. The effect of subclinical mastitis on the concentration of immunoglobulins A, G, and M, total antioxidant capacity, zinc, iron, total proteins, and calcium in she-camel blood in relation with pathogens present in the udder. Trop Anim Health Prod., 2018, 50(6): 1373-7.

[23] Rainard P, Riollet C. Innate immunity of the bovine mammary gland. Vet Res [Internet], 2006, 37(3): 369-400. Available from: https://doi.org/10.1051/vetres:2006007

[24] Hernández-Castellano L, Wall SK, Stephan R, Corti S, Bruckmaier RM. Milk somatic cell count, lactate dehydrogenase activity, and immunoglobulin G concentration associated with mastitis caused by different pathogens: A field study. Schweiz Arch Tierheilkd, 2017, 159(5): 283-90.

[25] Leitner G, Yadlin B, Glickman A, Chaffer M, Saran A. Systemic and local immune response of cows to intramammary infection with Staphylococcus aureus. Res Vet Sci., 2000, 69(2): 181-4.

[26] Scali F, Camussone C, Calvinho L, Cipolla M, Zecconi A. Which are important targets in development of S.aureus mastitis vaccine? Res Vet Sci., 2015, 100.

[27] Hayajneh FM. The effect of subclinical mastitis on the concentration of immunoglobulins A, G, and M, total antioxidant capacity, zinc, iron, total proteins, and calcium in she-camel blood in relation with pathogens present in the udder. Trop Anim Health Prod., 2018, 50(6): 1373-7.

[28] Wellnitz O, Arnold ET, Lehmann M, Bruckmaier RM. Short communication: Differential immunoglobulin transfer during mastitis challenge by pathogen-specific components. J Dairy Sci., 2013, 96(3): 1681-4.

[29] Erskine RJ, Bartlett PC. Serum concentrations of copper, iron, and zinc during Escherichia coli-induced mastitis. J Dairy Sci., 1993, 76(2): 408-13.

[30] ElOwni OAO, El Zubeir IEM, Mohamed GE. Effect of mastitis on macro-minerals of bovine milk and blood serum in Sudan. J S Afr Vet Assoc., 2005, 76(1): 22-5.

[31] Ahmad T, Bilal MQ, Ullah S, Muhammad G. Impact of mastitis severity on mineral contents of buffalo milk. Pakistan J Agric Sci., 2007.

[32] Rabiee AR, Lean IJ, Stevenson MA, Socha MT. Effects of feeding organic trace minerals on milk production and reproductive performance in lactating dairy cows: A meta-analysis. J Dairy Sci., 2010, 93(9): 4239-51.

[33] Sordillo LM. Nutritional strategies to optimize dairy cattle immunity1. J Dairy Sci [Internet], 2016, 99(6):

4967-82. Available from:
http://www.sciencedirect.com/science/article/pii/S0022030216001004

[34] Singh M, Yadav P, Sharma A, Garg VK, Mittal D. Estimation of Mineral and Trace Element Profile in Bubaline Milk Affected with Subclinical Mastitis. Biol Trace Elem Res., 2017, 176(2): 305-10.

[35] Pisanu S, Cacciotto C, Pagnozzi D, Uzzau S, Pollera C, Penati M, et al. Impact of Staphylococcus aureus infection on the late lactation goat milk proteome: New perspectives for monitoring and understanding mastitis in dairy goats. J Proteomics [Internet], 2020, 221: 103763. Available from:
http://www.sciencedirect.com/science/article/pii/S1874391920301317

[36] Qayyum A, Khan J, Hussain R, Avais M, Ahmad N, Khan M. Investigation of Milk and Blood Serum Biochemical Profile as an Indicator of Sub-Clinical Mastitis in Cholistani Cattle. Pak Vet J., 2016, 36: 275-9.

[37] Sakwinska O, Giddey M, Moreillon M, Morisset D, Waldvogel A, Moreillon P. Staphylococcus aureus host range and human-bovine host shift. Appl Environ Microbiol [Internet], 2011, 77(17): 5908-15. Available from:
https://www.ncbi.nlm.nih.gov/pubmed/21742927

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