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REVIEW ON MASTITIS IN DAIRY LACTATING ANIMALS AND THEIR PUBLIC HEALTH IMPORTANCE: THE 56 YEARS BANGLADESH PERSPECTIVE

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ABSTRACT

Background: Mastitis is one of the most prevalent multi-etiological very complex production diseases affecting dairy animals. The occurrence of mastitis is not only reduces milk productivity of dairy animals and losses to the dairy farmers but also associated with post-partum reproductive performance of affected animals and public health importance of mastitis causing pathogens. Mastitis is primarily categorized in two forms, subclinical mastitis (SCM) and clinical mastitis (CM), associated with decreased milk yield, impaired quality of milk and safety for consumers.

Objective: The objective of this paper was to review for the assessment of the update status of mastitis in lactating dairy ruminant animals with their causal bacterial pathogens and antibiogram aspects, physiopathology, epidemiology including risk factors associated with mastitis, diagnosis, treatment and control measures suggested by different reports from Bangladesh and elsewhere.

Materials and Methods: The SCM and CM of domestic dairy ruminant animals of Bangladesh were calculated by using online and offline databases. The SCM and CM prevalence inland studies reported from 1967 to 2022 supported with some important international reports were collected, reviewed and analyzed. The SCM was diagnosed by using both direct (bacterial pathogens & SCC) and indirect tests (CMT, WST, SFMT etc.), whereas CM was diagnosed by clinical examination of the affected udder.

Results: The prevalence of SCM and CM of cows, buffaloes and goats based on analysis of 229 reports published during 1967 to 2022 from Bangladesh and elsewhere. The pooled prevalence of SCM and CM were 39.05% and 11.18% in cows, 42.53% and 23.68% in buffaloes and 43.70% and 4.16% in goats, respectively. Species-wise prevalence of SCM and CM were found higher in buffaloes in comparison to cattle and goats. The major bacterial pathogens associated with mastitis (SCM & CM) were non-staphylococcus aureus, *Staphylococcus aureus*, *Escherichia coli* and others. The prevalence of SCM of all species of animals was found higher than CM which indicates the more importance of SCM than CM in dairy animals. The host and management risk factors and antibiogram studies on the isolated bacteria associated with mastitis in lactating animals have been evaluated and discussed.

Conclusions: Mastitis is caused by a multi-causal agents and the bacterial agents are associated with multi-drug resistant (MDR) worldwide. These mastitis causing agents that affect the animal health, human health and environment that justify the 'One Health' approach. Adequate Antibiotic sensitivity testing facilities, scientific udder health control program (UHCP) along with veterinary medical extension services to provide good feeding practices and timely therapeutic management of mastitis affected dairy animals that would be required for the control of mastitis and benefits from dairy farming to the farmers in Bangladesh.

Keywords: Sub-clinical mastitis, Clinical mastitis, Cattle, Buffaloes, Goats, Bacteria, Risk factors, Antibiogram

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INTRODUCTION

Bangladesh has an estimated 2022 population of 168.64 million with a population density of 1,265 people per square of kilometer that makes Bangladesh the 8th most populous country in the world.[1] Approximately 24.3% of the population lives below the national poverty line.[2] Approximately 28% of children under five years are stunted (have low height-for-age) and 10% are acutely malnourished or wasted (have low weight-for-height) in Bangladesh.[3] The livestock population in Bangladesh during 2021-2022 has been estimated to comprise 24.7 million cattle, 1.508 million buffaloes, 3.751 million sheep and 26.774 million goats[4] which are the main source of animal protein food for humans. An adult person requires at least 250 ml milk every day (demand 156.68 lakh MT) but the availability of milk is only about 208.61 ml / head / day (total production 130.74 Lakh MT/annum) with a deficit of 25.94 Lakh MT/annum in Bangladesh.[4] However, the dairy farmers and concerned authority should focus on milk quality over quantity because milk that contains unsuitable components and /or antibiotic residues, or has a high somatic cell count (SCC), cannot be used in dairy food production and thereby results in reduced milk nutrients and yield.[5] Mastitis is the one of the most serious widespread diseases affecting dairy animals and associated with heavy economic losses and public health problem. The high rate of prevalence of mastitis in dairy animals is associated with reduces the milk yield (approximately 70% of the total losses[6]), degrades milk quality, shortens the productive life affected lactating animals, causes animal welfare problem, threat to nutrition, food safety, security and diminishing the dairy industry's ability to compete in national and international markets.[7] The word 'mastitis' is derived from the Greek word 'mastos' means 'breasts' (mammary gland), while the suffix -'itis' denotes inflammation (i.e. mastitis) and Greek word 'mammae' means breast in humans, inflammation of the mammary glands (breast) is called mammitis. Both the terms mammitis and mastitis are used in humans whereas it is usually named as mastitis in animals. Mastitis is an inflammation of the milk secreting tissues of the udder, caused by infectious and non-infectious etiological agents in one or more quarters of the dairy animals. It is characterized by physical, chemical and bacteriological changes in the milk and pathological changes in the glandular tissues of the udder and affect the quality and quantity of milk.[5-7] Intra-mammary infection (IMI) occurs when bacteria enter the teat orifice, multiply within the mammary gland and elicit an inflammatory response (high somatic cell count = SCC). It results decreased milk quality and yield and adversely affect animal health. Historical evidence suggests that cows have been milked since at least 3100 BC[8] and it is likely that bovine mastitis has existed since that time and it remains one of the most economically devastating diseases in dairy industry in the world. It is estimated that the total losses caused by mastitis amount of 2.11 million US $ in 2003 in Bangladesh.[9] Mastitis mainly occurs in two forms: (a) Clinical mastitis (CM) and (b) Sub-clinical mastitis (SCM). The CM is characterized by sudden onset with signs of inflammation (swelling, hot, pain and redness) of the udder and reduced and altered milk secretion from the affected quarters. The milk may have clots, flakes or of watery in consistency and accompanied by systemic reactions (fever, depression and anorexia). The SCM is characterized by having no visible signs either in the udder or in the milk but the milk production decreases and the SCC in milk increases. The SCM is more important than CM because it is 15 to 40 times more prevalent than the CM and it usually precedes the clinical form, is of long duration, difficult to detect, adversely affects milk quality and production and constitutes a reservoir of pathogens that lead to infection of other animals within the herd.[10] Losses of mastitis may even be higher in developing countries including Bangladesh than developed countries because udder health control programs (UHCP) has not yet been practiced in low-income countries like Bangladesh. Moreover, dairy animals are maintained in stall feeding due to limited grazing land and hand milking is practiced mainly due to rearing of dairy animals by smallholder farmers. Recently, a systemic meta-analysis of mastitis prevalence in dairy cattle and goats based on limited 33 articles published during January 2005 to November 2020 with an overall 43.0% and 31.0% prevalence of SCM in cattle and goats, respectively from Bangladesh have been reported.[11] More recently, the prevalence of SCM in cows has been estimated to be range from 20 to 80 with an average of 50% in south-Asian countries including Bangladesh.[12] There are numerous reports on the prevalence of SCM and CM in dairy animals from Bangladesh and elsewhere. However, the prevalence rates of mastitis reported in farm lactating animals is variable. The main objectives of the review of inland reports on mastitis in animals to: (a) characterize the mastitis causing bacteria, (b) estimate the prevalence of SCM and CM, (c) determine the risk factors of mastitis, (d) evaluate the antibiotic resistance status of mastitis causing bacterial agents, and (e) assess the treatment and control measures of mastitis in animals. Therefore, the available all inland reports on mastitis in lactating animals published during the period from 1967 to 2022 supported with some related international reports have been reviewed and analyzed which would provide useful management information to the dairy farmers, researchers, veterinarian and concerned mastitis control authorities.

RATIONALITY OF THE REVIEW

Review of inland research reports on mastitis in lactating farm animals and their zoonotic importance appear to be often conducted in unplanned and indiscriminately and suffer from statistical interpretations. Many related articles have been published in the different inland journals especially during the then East Pakistan and early Bangladesh period before the establishment of the journal websites, moreover, publication of some of these journals are either discontinued or highly irregular not in online and even library are not maintaining these journals probably due to old issues whereas most of the recent issues of the journals are easily available in the online like Banglajol and others. In addition, some articles are being published in international commercial journals which have not an open-access that are costly to purchase for individual users. It appears from the review that most of the recently published articles in both the national and international journals by using the cross references of the published articles due to limitation of the availability of the old inland journal issues either hard or soft copies caused error in cited references. Recognizing these limitations, the references of the present review on mastitis in ruminant farm animals are presented in original status. Therefore, this review would certainly stimulate future research workers to get the original accurate references and act as a valuable source of information.

MATERIALS AND METHODS

A systematic literature search on mastitis was performed by using different keywords mastitis in ruminant dairy animals in Bangladesh, Bovine mastitis, Caprine mastitis, Prevalence of mastitis in buffaloes, Review on mastitis in dairy animals by Google Scholar. Research reports on mastitis in lactating farm animals published at national and international journals have been reviewed from journal websites. In addition, the local journals especially the old issues which are not available online but available of the hard copies as personal collection during last 50 years have also been reviewed. It appears from the review of literature that the first research article on bovine mastitis has been published in 1967 from the then East Pakistan (now Bangladesh) and accordingly the retrieval dates for this study included from 1967 to 2022 and the retrieval language was limited to English only. A total of 229 research articles reviewed, of which 121 published from Bangladesh and 108 related articles published from elsewhere were reviewed for analysis.

ETIOLOGY OF MASTITIS

Mastitis is a complex and multi-factorial disease, the occurrence of which depends on variables related to the animal, environment and pathogen. Mastitis is caused by physical, chemical and biological agents especially microorganisms but bacterial infections are the main causes of mastitis. The initial research efforts were directed mainly on the isolation and identification of bacterial pathogens associated with bovine mastitis with some antibiogram of bacterial isolates. Similar research efforts were also directed to the buffaloes and goats in Bangladesh. There are more than 140 species of microorganisms include bacteria, mycoplasma, fungi, yeasts, algae and viruses have been reported as mastitic pathogens,[13] whereas only 17 species of bacteria from bovine mastitis (Table 1), eight from buffalo mastitis (Table 2) and six from goat mastitis (Table 3) have so far been isolated from lactating animals in Bangladesh up to 2022.

Table 1. Bacteria isolated in mastitis milk samples of lactating cows in Bangladesh

S/N Bacterial species	Sub-clinical mastitis No. tested	Sub-clinical mastitis Positive No. (%)	Clinical mastitis No. tested	Clinical mastitis Positive No. (%)	Ref. No.	District
01. *Staphylococcus aureus*	-	-	150	47 (31.33)	14	Manikganj & Mymensingh
	-	-	060	21 (35.0)	15	Mymensingh
	81	37 (45.68)	-	-	16	Sirajganj & Pabna
	60	11 (18.33)	-	-	17	Mymensingh
	-	-	153	04 (02.60)	18	Chattogram
Overall:	**141**	**48 (34.04)**	**363**	**72 (19.83)**		
02. *Staphylococcus* spp.	118	29 (24.58)	-	-	19	Dhaka & Mymensingh
	-	-	048	17 (35.45)	20	Nilphamari
	100	23 (23.00)	-	-	21	Sylhet
	19	14 (73.68)	-	-	22	Satkhira
	-	-	35	16 (45.71)	23	Rajshahi & Mymensingh
Overall:	**237**	**66 (27.85)**	**83**	**33 (39.76)**		
Total *Staphylococcus* spp.	**378**	**114 (30.16)**	**446**	**105 (23.54)**	-	10 districts

Table 1. Bacteria isolated in mastitis milk samples of lactating cows in Bangladesh (Contd.)

S/N Bacterial species	Sub-clinical mastitis No. tested	Positive No. (%)	Clinical mastitis No. tested	Positive No. (%)	Ref. No.	District
03. Non-aureus Staph. Spp.	19	01(5.26)	-	-	22	Satkhira
	-	-	153	31 (20.3)	18	Chattogram
04. Coagulase +ve *S. aureus*	52	27 (49.09)	-	-	24	Satkhira
Coagulase -ve *S. aureus*	52	10 (18.18)	-	-	24	Satkhira
05. *Staph.epidermidis*	-	-	150	27 (18.00)	14	Manikganj & Mymensingh
06. *Streptococcus* spp.	-	-	150	21 (14.00)	14	Manikganj & Mymensingh
	081	02 (02.47)	-	-	19	Dhaka & Mymensingh
	-	-	048	09 (18.75)	20	Nilphamari
	100	05 (05.00)	-	-	21	Sylhet
	-	-	153	35 (22.9)	18	Chattogram
	-	-	035	04 (11.43)	23	Rajshahi & Mymensingh
Sub-total:	**181**	**07(03.87)**	**386**	**69 (17.88)**		
07. Coagulase-negative Strep.	060	06 (10.00)	-	-	17	Mymensingh
08. *Streptococcus pyogenes*	200	06 (03.00)	20	0	25	Mymensingh
09. *Streptococcus agalactiae*	200	24 (12.00)	20	06 (30.0)	25	Mymensingh
	019	03 (15.79)	-	-	22	Satkhira
Sub-total:	**219**	**27 (22.33)**	**20**	**06 (30.0)**		
10. *Strep. dysgalactiae*	200	10 (05.00)	20	0	25	Mymensingh
11. *Streptococcus uberis*	200	20 (10.00)	20	03 (15.00)	25	Mymensingh
	81	12 (14.81)	-	-	16	Sirajganj & Pabna
Sub-total	**281**	**32 (11.39)**	**20**	**03 (15.00)**		
Overall	**681**	**66(09.69)**	**426**	**78 (18.31)**		
12. *Escherichia coli* /	-	-	150	09 (04.67)	25	Mymensingh
Coliform	081	09 (11.11)	-	-	19	Dhaka & Mymensingh
	-	-	48	07 (14.54)	20	Nilphamari
	100	03 (03.00)	-	-	21	Sylhet
	081	08 (09.88)	-	-	16	Sirajgonj & Pabna
	060	03 (05.00)	-	-	17	Mymensingh
	-	-	153	11 (07.20)	18	Chattogram
	-		035	06 (17.14)	23	Rajshahi & Mymensingh
Sub-total	**322**	**23 (07.14)**	**386**	**33 (08.55)**		
13. *Corynebacterium*	200	48 (24.00)	20	02 (10.00)	25	Mymensingh
pyogenes	-	-	150	12 (08.00)	14	Manikganj + Mymensingh
Sub-total	**200**	**48 (24.00)**	**170**	**14 (08.24)**		
14. *Bacillus* spp.	-	-	150	07 (04.67)	14	Manikganj & Mymensingh
	081	03 (03.70)	-	-	19	Dhaka & Mymensingh
	-	-	048	05 (10.41)	20	Nilphamari
	060	03 (05.00)	-	-	17	Mymensingh
	052	03 (5.45)	-	-	24	Satkhira
	-	-	153	29 (19.0)	18	Chattogram
	-	-	035	02 (05.71)	23	Rajshahi & Mymensingh
Sub-total:	**193**	**09 (04.66)**	**386**	**43 (11.14)**		
15. *Proteus* spp.	081	16 (19.75)	-	-	16	Sirajgonj & Pabna
16. *Acinebacter* spp.	081	06 (7.41)	-	-	16	Sirajgonj & Pabna
17. *Enterobacter* spp.	060	04 (06.67)	-	-	17	Mymensingh

Table 1. Bacteria isolated in mastitis milk samples of lactating cows in Bangladesh (Contd.)

S/N Bacterial species	Sub-clinical mastitis No. tested	Sub-clinical mastitis Positive No. (%)	Clinical mastitis No. tested	Clinical mastitis Positive No. (%)	Ref. No.	District
18. *Pseudomonas*	060	03 (05.00)	-	-	17	Mymensingh
aeruginosa	019	01	-	-	22	Satkhira
Overall	**079**	**04 (05.06)**	**-**	**-**		
19. *Actinomyces pyogenes*	019	01 (05.26)	-	-	22	Satkhira
20. *Klebsiella* spp.	-	-	048	30 (62.5)	26	Rangpur
A. Single infection	**2677**	**351 (13.11)**	**2165**	**361 (16.67)**		
21. Staph + Strep.	081	04 (04.94)	-	-	19	Dhaka & Mymensingh
	-	-	048	03 (06.25)	20	Nilphamari
	100	05 (05.00)	-	-	21	Sylhet
	-	-	035	01 (02.86)	23	Rajshahi & Mymensingh
Overall	**181**	**09 (04.97)**	**083**	**04 (04.82)**		
22. *E. coli* + Staph.	081	02 (02.47)	-	-	19	Dhaka & Mymensingh
	100	03 (03.00)	-	-	21	Sylhet
	060	03 (05.00)	-	-	17	Mymensingh
	444	261 (58.78)	035	02 (05.71)	23	Rajshahi & Mymensingh
Overall	**685**	**269 (39.72)**	**035**	**02 (05.71)**		
23. Staph. + Enterobacter	060	02 (03.33)	-	-	17	Mymensingh
24. Staph. + P. aeruginosa	060	02 (03.33)	-	-	17	Mymensingh
25. Staph. + Bacillus	037	05 (13.51)	-	-	19	Dhaka & Mymensingh
Staph. + Bacillus	-	-	035	01 (02.86)	23	Rajshahi & Mymensingh
26. Cory + Staph.	081	01 (01.23)	-	-	19	Dhaka & Mymensingh
27. *E. coli* + Strep spp.	-	-	48	02 (4.17)	20	Nilphamari
28. *E. coli* + Strep spp.	100	03 (03.00)	-	-	21	Sylhet
29. E. coli + CN strep.	060	03 (05.00)	-	-	17	Mymensingh
30. E. coli + Bacillus	060	02 (03.33)	-	-	17	Mymensingh
E. coli + Bacillus	-	-	35	02 (05.71)	23	Rajshahi & Mymensingh
31. Bacillus + *P. aeruginosa*	060	03 (05.00)	-	-	17	Mymensingh
Bacillus + Streptococcus	-	-	35	01 (02.86)	23	Rajshahi & Mymensingh
32. E. coli + Unidentified	060	02 (03.33)	-	-	17	Mymensingh
33. Enterobacter + UI	060	02 (03.33)	-	-	17	Mymensingh
B. Mixed infection	**638**	**25 (02.92)**	**153**	**06 (03.92)**		
34. Unidentified (UI)	-	-	153	13 (08.50)	18	Chattogram
	200	92 (46.00)	020	09 (45.00)	25	Mymensingh
	-	-	150	27 (18.00)	25	Mymensingh
	-	-	048	05 (10.41)	20	Nilphamari
	060	06 (10.00)	-	-	17	Mymensingh
Overall	**260**	**98 (37.69)**	**371**	**54 (14.56)**		

Analysis of the available 13 reports on the isolation and identification of bacteria in milk samples found higher single (16.67%; n = 361/2165) species (approximately 15 species) of bacterial infection in udder affected with clinical mastitis than the apparently healthy udder (13.11%; n = 351/2677) detected as SCM in lactating cows (Table 1). Similarly, mixed bacterial infection was also found comparatively higher in clinical mastitis (3.92%; n = 6/153) than SCM (2.92%; n = 25/ 638) cases (Table 1). The overall single bacterial infection was found higher than mixed bacterial infection in both the CM and SCM in lactating cows (Table 1). These analyzed results are in support of the individual reports used for analysis (Table 1). The most commonly encountered bacteria associated with both the CM and SCM in lactating cows was associated with both the contagious like *Staphylococcus* spp. (CM 23.54% & SCM 30.16%) and *Streptococcus* spp. (CM 18.31% & SCM 13.44%) and/or environmental pathogens like *E. coli* (CM 8.55% & SCM 7.14%) and *Bacillus* spp. (CM 11.14% & SCM 4.66%) in Bangladesh (Table 1).

Analysis of the available five reports on the findings of the bacteriological examination of the milk samples of lactating buffalo cows reveals that all the milk samples collected from apparently healthy udder and quarters and none was affected with clinical mastitis (Table 2). It appears from Table 2 that *Staphylococcus aureus* (42.45%) was found highest, followed by *Escherichia coli* (22.30%), *Streptococcus* spp. (21.15%) and *Bacillus* spp. (15.71%) which are associated with SCM in buffaloes in Bangladesh (Table 2).

Table 2. Bacteria isolated in mastitis milk samples of lactating buffalo cows in Bangladesh

S/N	Bacterial species	Sub-clinical mastitis No. tested	Sub-clinical mastitis Positive No. (%)	Sub-clinical mastitis PCR	Clinical mastitis No. tested	Clinical mastitis Positive No. (%)	Ref No.	District
1.	*Staphalococcus aureus*	42	21 (50.00)	-	-	-	27	Dhaka
		39	12 (30.77)	-	-	-	28	Bagerhat
		45	13 (28.89)	-	-	-	30	Mymensingh
		13	13 (100)	8 (61.54)	-	-	31	Bhola
	Overall	**139**	**59 (42.45)**	**-**	**-**	**-**		
2.	NAS	48	12 (24.70)*	-	-	-	29	Bagerhat & Noakhali
3.	*Streptococcus* spp.	39	08 (20.52)	-	-	-	28	Bagerhat
		13	03 (23.08)	-	-	-	31	Bhola
	Overall	**52**	**11 (21.15)**	**-**	**-**	**-**		
4.	*Escherichia coli*	42	12 (28.57)	-	-	-	27	Dhaka
		39	05 (12.82)	-	-	-	28	Bagerhat
		45	05 (11.11)	-	-	-	30	Mymensingh
		13	09 (69.23)	8 (61.54)	-	-	31	Bhola
	Overall	**139**	**31 (22.30)**	-	-	-		
5.	*Enterobacter* spp.	42	06 (14.29)	-	-	-	27	Dhaka
6.	*Bacillus* spp.	42	02 (04.76)	-	-	-	27	Dhaka
		39	06 (15.39)	-	-	-	28	Bagerhat
		45	10 (22.22)	-	-	-	30	Mymensingh
		14	04 (30.77)	-	-	-	31	Bhola
	Overall	**140**	**22 (15.71)**	-	-	-		
7.	*Proteus* spp.	42	01 (02.78)	-	-	-	27	Dhaka
8	*Lactobacillus* spp.	45	10 (22.22)	-	-	-	30	Mymensingh
9.	Mixed infection	39	05 (12.82)	-	-	-	28	Bagerhat
10.	Unclassified	45	02 (04.44)	-	-	-	30	Mymensingh

NAS = Non-aureus Staphylococcus   *Data not available in the abstract due to commercial article

Analysis of the available four reports on bacteriological isolation and identification of milk samples of lactating goats shows that all the four major species of bacteria (*Staphylococcus* sp., *Streptococcus* spp., *Escherichia coli* & *Bacillus* spp.) are associated with both SCM and CM in goats (Table 3).

Table- 3. Bacteria isolated in mastitis milk samples of lactating goats in Bangladesh

SN Bacterial species	Sub-clinical mastitis No. tested	Sub-clinical mastitis Positive No. (%)	Clinical mastitis No. tested	Clinical mastitis Positive No. (%)	Ref No.	District
01. *Streptococcus* spp.	11	01 (09.09)	90	04 (4.44)	32	Mymensingh
	49	17 (34.69)	59	23 (38.98)	33	Joypurhat & Mymensingh
Overall	**60**	**18 (30.00)**	**149**	**27 (18.12)**		
02. Coagulase -ve staph (CNS)	186	57 (28.8)	-	-	34	Rajshahi & Rangpur
	11	3 (27.27)	90	53 (58.89)	32	Mymensingh
Overall	**197**	**60 (30.46)**				
03. *Staphylococcus aureus*	106	+	-	-	35	BD (not in Abstract)*
	011	4 (36.36)	90	4 (4.44)	32	Mymensingh
Overall	117	-	-	-		
04. Non-aureus Staph. spp (NAS)	106	+	-	-	35	BD (not in Abstract)*
05. *Escherichia coli*	49	12 (24.49)	59	16 (27.12)	33	Joypurhat + Mymensingh
	11	02 (18.18)	90	05 (5.55)	32	Mymensingh
Overall	**60**	**14 (23.33)**	**149**	**21 (14.09)**		
06. *Bacillus* spp.	49	06 (12.25)	59	06 (10.17)	33	Joypurhat + Mymensingh
	11	0	90	03 (3.33)	32	Mymensingh
Overall	**60**	**06 (10.00)**	**149**	**09 (6.04)**		
07. Staph + *E. coli*	49	02 (04.08)	59	05 (8.48)	33	Joypurhat & Mymensingh
08. Staph + *Bacillus* spp.	49	03 (06.12)	59	01 (1.69)	33	Joypurhat & Mymensingh
09. *Bacillus* spp + *E. coli*	49	07 (14.29)	59	06 (6.78)	33	Joypurhat & Mymensingh
Mixed infection	**147**	**12 (08.16)**	**177**	**12 (6.78)**		
10. Unidentified	11	1 (9.09)	90	14 (15.55)	29	Mymensingh

+ = Population not mentioned   *Commercial articles no access without purchase   BD = Bangladesh   - = No data

Review of research reports reveal that mastitis in dairy animals is associated with more than 138 different species of microorganisms[36] including some mechanical and physical trauma and chemical insult that predisposes the gland to intra-mammary infection (IMI). The IMI in dairy animals is associated with ① Bacterial (~70%), ② Mycoplasmal, ③ Mycotic (fungi / yeast) (~2%), ④ Algal and ⑤ Viral infections.[37,38] It appears that approximately 70% mastitis cases are caused by bacteria with a few species of bacteria accounting for most cases.[37,38]

Mastitis causing agents can be divided into contagious and environmental pathogens, and the contagious pathogens are further classified as major and minor pathogens (Fig. 1). The major contagious pathogens include *Staphylococcus aureus*, *Streptococcus agalactiae* and *Mycoplasma* spp. whereas minor contagious pathogens include *Corynebacterium bovis* and others. Contagious pathogens are those whose main reservoir is the infected udder and these pathogens are mainly spread among animals during milking process usually by milker's hands, cleaning towels and even flies and milking machines.[38]

Major environmental pathogens include coliform bacteria (*Escherichia coli*, *Klebsiella* spp., *Enterobacter* spp. and *Citrobacter* spp.), environmental streptococci (*Streptococcus uberis*, *Streptococcus disgalactiae*). The source of environmental pathogens is the surrounding environment of the animals and usually spread from environment to udder at any time including milking process.[39,40] However, the majority of IMI in animals are caused by Staphylococci, Streptococci and *Enterobacteriaceae* but the St*aph. aureus* has been designated as the chief causal pathogen of mastitis in both cattle and buffaloes in Asian countries including Bangladesh and also the causative agent of both CM and SCM.[39,40] However, the epidemiological field study of mastitis concluded that bacteria such as *Staph. aureus, Strep. agalactiae* and *E. coli* account for over 75% of mastitis cases and *Staph. aureus* is the most prevalent, resistant and challenging candidate among them.[38]

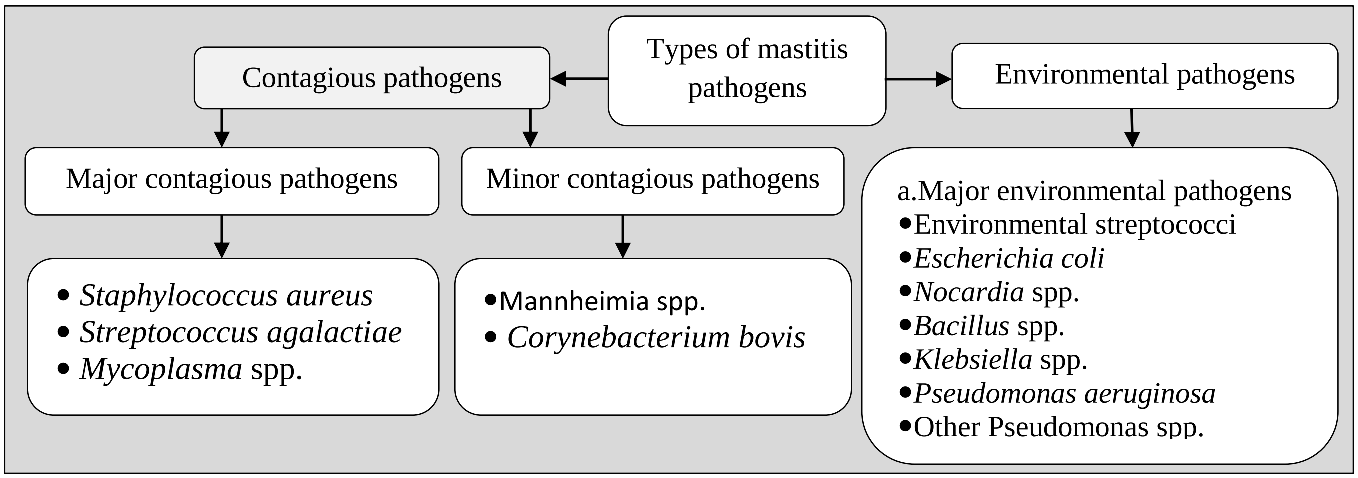

Fig.1. Classification of mastitis causing bacterial agents[38]

The *Staphylococcus* spp., *Streptococcus* spp., *Escherichia coli* and *Bacillus* spp. have been isolated and identified as the major bacterial agents associated with the sub-clinical and clinical mastitis in dairy lactating animals in Bangladesh (Table 1-3). A comparison on the occurrence of bacteria associated with mastitis in ruminant farm animals between Bangladesh and some developed countries are compared (Table 4). The bacterial pathogens isolated from mastitis

Table 4. Comparison of bacterial pathogens isolated from clinical mastitis in some developed countries with Bangladesh (%)

S/N	Country	No. of herds	Milk samples	Staph. aureus	Other Staph.	Strep. spp.	E. coli / Coliform	Other	No Growth	Ref. No.
①	Holland	274	2,737	18.0	06.0	25.0	28.0	NR	22.0	41
②	UK	090	0,480	03.0	13.0	25.0	21.0	11.0	27.0	42
③	NZ	028	1,332	19.0	07.0	45.0	NR	04.0	27.0	43
④	Canada	106	2,850	11.0	06.0	16.0	15.0	05.0	47.0	44
⑤	USA	050	0,741	03.0	07.0	11.0	36.0	16.0	27.0	45
⑥	BD	-	-	23.54	19.15	18.31	08.55	11.14	-	Table 1

NR = Not reported - = Data available in the Table 1 BD = Bangladesh

cases are in support the reports on bacterial pathogens of mastitis in dairy cattle of the developed countries (Table 4). Highest prevalence of *Staphylococcus aureus* (61.64%), followed by *E. coli* (10.96%), *Streptococcus* spp. (9.59%), *Pseudomonas* spp. (6.85%), *Bacillus* spp. (6.85%) and *Corynebacterium* spp. (4.11%) have been reported to be associated with SCM in dairy goats in Pakistan.[46] However, the *Bacillus* spp. isolated from mastitis cases in lactating animals in Bangladesh but not reported in dairy animals of developed nations might be due to application of high sanitary hygienic measures in dairy environment. The *Staphylococcus* spp. (*Staphylococcus aureus*) has been recorded as the major bacterial pathogen associated with both the sub-clinical and clinical mastitis (Table 1-3). The *Staph aureus* has been recognized as the major cause of mastitis in dairy animals in Bangladesh which are conformity of the reports of 66.66% in India,[47] 53.7% in Jordan,[48] 61% in Switzerland,[49] 47% in Canada[50] and 42.6% in Ethiopia.[51] The high prevalence of mastitis caused by *Staph. aureus* in lactating dairy animals could be due to its ability to evade and influence the host immune system by production of various enzymes and toxins that cause damage to mammary tissue and allow tissue invasion. Furthermore, *Staph. aureus* is capable to survive in the keratin of the teat canal of healthy cows and to confront phagocytosis. In addition, many *Staph. aureus* have the ability to resist antibiotic therapy by production of beta-lactamase an enzyme that inactivates penicillin and closely related antibiotics. Probably around 50% of mastitis *Staph. aureus* strains produce beta-lactamase and there is evidence that these strains are more difficult to cure with all antibiotics. Strains of *S. aureus* exhibiting either beta-lactamase or penicillin-binding protein 2a (PBP 2a) directed resistance (or both) have established, and then emergence and subsequent spread of bacterial strains designated as methicillin-resistant *S. aureus* (MRSA) and more recent variants of MRSA that are resistant to glycopeptide antibiotics like vancomycin.[52]

Relatively lower rate of *Streptococcus* spp. are associated with mastitis might be due to their readily response to antibiotic treatment.[48] The high prevalence of environmental bacterial pathogens in mastitis cases in Bangladesh indicates poor management system of dairy animals including cleanliness and sanitation. In addition to major bacterial pathogens, *Micrococcus* spp., *Pseudomonas aeruginosa*, *Proteus* spp., *Enterobacter* spp. and *Corynebacterium pyogenes* have also been recorded as mastitic pathogens in dairy lactating animals in Bangladesh (Table 1). The *S. aureus*, Streptococci, *E. coli*, *Corynebacterium* spp. and *Klebsiella* spp. have been reported as major mastitis causing pathogens in cattle and buffaloes in Asia but more recent reports indicating the changing trends from *S. aureus* to coagulase negative staphylococci (CNS) as major mastitis causing organism.[53] However, a review report showed non-aureus staphylococci (NAS), *S. aureus*, *Streptococcus* spp. and *E. coli* most common causal bacteria for SCM in south-Asian countries including Bangladesh.[12]

The SCM affected all the three host species of lactating cows (2.92%), buffaloes (12.82%) and goats (8.16%) had mixed bacterial infection, whereas CM has also been reported with mixed infection in cows (3.92%) and goats (6.78%) but no CM reported in buffaloes (Table 1-3).

Among the tested CM quarter milk samples, higher infection with Streptococci (22.9%) was recorded than non-aureus staphylococci (20.3%) which are the most frequently isolated pathogens and *S. aureus* and NAS reported resistance against penicillin and oxacillin in the district in Chottogram.[18]

Types of mastitis

There are many way to classify mastitis. These are as follows:

① Mastitis can be classified on the basis of origin (source) of bacterial pathogens into three types as: (a) Contagious mastitis, (b) Environmental mastitis (c) Summer mastitis (Fig. 2).

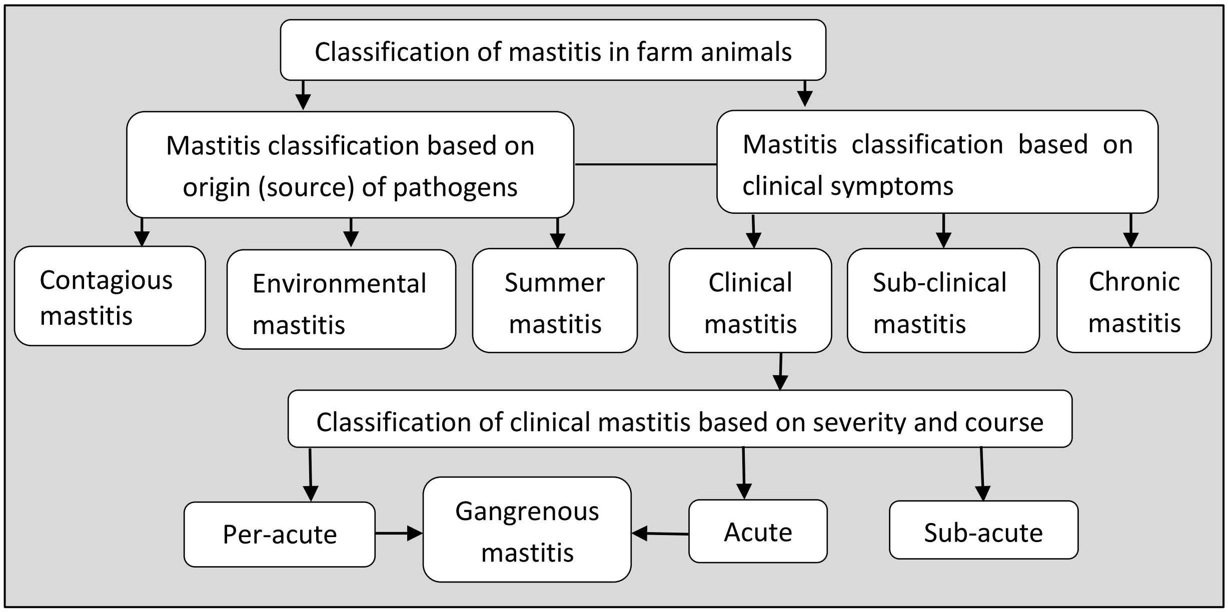

Fig. 2. Classification of bovine mastitis

(a) Contagious mastitis- caused by bacterial pathogens which are live on the skin of the teat and inside the udder. This type of mastitis pathogens can be transmitted from one cow to another during mainly milking.

(b) Environmental mastitis- caused by bacterial pathogens like *Escherichia coli* which do not live on the skin or in the udder but which enter the teat canal when the cow comes in contact with a contaminated environment like manure. Dairy animals may lie down in an enclosed area with a lot of manure present therefore the *E. coli* can get easy access to the teal canal and enter to the udder. The environmental bacterial pathogens normally found in feces bedding materials and contaminated feed and cases of environmental mastitis rarely exceed 10% of the total mastitis cases in the herd.[54]

(c) Summer mastitis, often known as ‘August bag’ is defined as intra-mammary infection of the non-lactating udder (dry cows and heifers), usually occurs in the summer months from July to September when increasing the population of biting fly. Bacterial causes include *Canobacterium pyogenes*, *Peptostreptococcus indolicus*, *Streptococcus dysgalactiae*, *Corynebacterium pyogenes* which act synergistically to cause summer mastitis. Flies are implicated in transmission of the infectious agents and infection often results in the quarter being unproductive in following lactations. Diagnosis of summer mastitis is based upon finding of a swollen and edematous quarter(s) with a characteristic foul discharge.

② Mastitis can also be classified into (A) Clinical mastitis (CM), (B) Sub-clinical mastitis (SCM) and (C) Chronic mastitis based on inflammatory inflammation of the udder and clinical findings.[55]

A. **Clinical mastitis** (CM)- is characterized by the presence of gross inflammation signs (swelling udder, reddish udder, increased udder temperature, pain in the udder), impaired udder function, and abnormalities in milk (discoloration) conditions in affected quarter of lactating animals. CM is defined as the production of abnormal milk with or without secondary symptoms such as swollen quarters, elevated body temperature and/or other systemic signs. CM can be recognized in pre- and post-calving secretions, colostrum or milk by the presence of clots and flakes, abnormal texture or discoloration. CM is observed in less than 5% of animals in a well-managed dairy herd. CM may further be classified based on severity of the inflammatory response and duration of illness into following four types.[54]

a. **Per-acute mastitis**- characterized by (i) marked systemic reactions and toxemia (rectal temperature 42^0 C), (ii) severe udder inflammation (e.g. coliform mastitis after parturition) and (iii) abnormal milk secretion with systemic signs of fever, depression, shivering and loss of appetite.

b. **Acute mastitis**- characterized by similar to per-acute mastitis but with lesser systemic signs like (i) mild systemic reaction (rectal temperature 41 ^{0}C), (ii) Severe inflammation of the udder and (iii) abnormal milk secretion and mild depression (Photo 1-5).

c. **Sub-acute mastitis**- characterized by (i) no visible systemic signs, (ii) mild inflammation of the udder and (iii) minor changes in the milk.

B. Sub-clinical mastitis (SCM)- characterized by change in milk composition with no signs of gross inflammation or milk abnormalities. The non-observable form of mastitis, such as no visible abnormalities of either the milk or the udder, is known as SCM. SCM refers to inflammation of the mammary gland in the absence of visible gross lesions in the udder or its secretion with the presence of pathogenic micro-organisms and unusual number of somatic cells in the milk.[56]

Generally more than 50% animals in a herd can have SCM at any given time. A high milk SCC in apparently healthy cows with decreased milk production and bacterial pathogens can usually be detected in milk sample may indicate the presence of SCM.

The SCM in dairy animals is important because (a) SCM is 15 to 40 times more prevalent than the CM, (b) It usually precedes the clinical form, (c) It is of long duration, (d) It is difficult to detect, (e) It reduces milk production, (f) It adversely affects milk quality, (g) Constitutes a reservoir of pathogens for susceptible animals. Moreover, when a cow is in heat or there is a climate change, SCM is converted into CM.[57] The SCM accounts for 60-70% of the total economic losses by all mastitis types and thus causes three times more production losses than CM.[58,59]

C. Chronic mastitis- characterized by an inflammatory process that exists for months and may continue from one lactation to another. It exists as sub-clinical but may exhibit periodical flare-ups sub-acute or acute form at irregular intervals, which last for a short period of time. Clinically characterized by (i) changes in milk as the presence of clots or flakes and (ii) fibrosis and atrophy of the gland, so one quarter becomes smaller than another one (Photo 6,7.9).

Cows with chronic mastitis are unlikely to recover and should be culled because they're likely to pass bacteria onto other cows. Culling them prevents the infection from spreading and thus protects healthy young cows. Persistent high SCCs in two consecutive lactations, despite treatment with antibiotic in the dry period between should be considered culling chronically infected cows. In addition, type of infection like treatment of *Streptococcus agalactiae* is likely to be successful while treatment of *Staphylococcus aureus* infection probably won't in chronic cases considered for culling. However, surgical method of treatment of bovine chronic mastitis has been described.[60]

Grading of mastitis in cattle

Clinical disease (mastitis) can be identified and graded based on visual signs. Any alteration in the color (off white/yellow/red) or consistency (clotted/ thickened) of the milk and/or changes to the udder (hot, hard, swollen, painful, and sloughing) can be indicative of clinical mastitis. The severity of the disease can be graded on clinical grounds using a simple three point scale. The CM is categorized into three grades (grade 1 to 3) based on severity on the extent of tissue involvement.[61]

Grade 1 (Mild 50%): Changes to the milk only (color/consistency) i.e. describes an infection limited to clinically abnormal milk e.g. clotting of milk.

Grade 2 (Moderate 40%): Changes to the udder (heat, swelling, pain) i.e. changes in milk and visible signs of inflammation of the udder'

Grade 3 (Severe 10%): Changes to the cow (sick cow). Changes in milk and udder and systemic signs of disease.[61,62]

Cows affected with different grade of CM with severity, receive different treatment and therefore have different economic impact.

Epidemiology of mastitis

Mastitis is one of the first observed diseases of farm animals when cattle were domesticated over 5000 years ago. Since then it will have been an ever present problem for all those who kept and milked dairy animals. Prevalence of mastitis is increased in parallel with the development of high milk producing breeds. Mastitis is world-wide distributed in mammals, especially importance in dairy industry. There are about 80% cattle are reared in smallholder farming system and only 13% cattle farmers have an intensive or semi-intensive housing system. Approximately, 60% of cattle farms have concrete floor without using bedding materials and usually milked by hands. The dairy cattle are mostly fed rice straw as a source of roughage and only 40% of the farmers have land to grow fodder for their dairy cattle.[18] This scarcity of feed combined with insufficient knowledge of dairy cattle management hygiene are important determinants and major constraints in the dairy industry in Bangladesh.[18]

Source and spread of infection

There are three main sources of mastitis pathogens in dairy animals, (a) Infected udder e.g. *Str. agalactiae*, *Staph. aureus*, (b) Environment e.g. *E. coli*, Pseudomonas and (c) Infected milk e.g. *Str. pyogenes.* The dairy animals can be infected by mastitis causing pathogens through routes including, (a) teat canal especially *Str. agalactiae*, after milking, the teat sphincter still opened facilitating the direct invasion of pathogens into the udder, (b) hematogenous as a systemic form of tuberculosis and (c) the skin covering the gland especially staphylococcus.[63] The mastitis causing pathogens are usually transmitted to the susceptible dairy animals through (a) milker's hands, (b) teat cup of the milking machine, (c) teat wiping towel, (d) teat siphon and (e) flies (Fig. 3). Udder pathogens are often categorized into contagious and environmental on the basis of their main reservoirs. Contagious pathogens are well adapted to the udder and spread primarily from infected to healthy udders during the milking process through contaminated milking equipment and milker's hands and contaminated wash cloths (towels) used to wash or dry udder of more than one animal and possibly by flies. The contaminated environment is the main source of environmental pathogens mostly in the animal surroundings like bedding, flooring, manure which are generally transmitted during milking and dry period. Housed cows are at great risk for environmental mastitis than cows at pasture. Reviewing the bacterial pathogens associated with the incidence of mastitis in domestic lactating animals in Bangladesh that the contagious pathogen, *Staphylococcus aureus* is at the top of the list of the etiology of mastitis in all species of animals (Table 1). The *Streptococcus* spp. and *E. coli* are mostly associated with mastitis as environmental pathogens (Table 1).

Prevalence of mastitis in dairy lactating animals

Bangladesh is divided into 64 administrative districts, of which the studies on the bovine mastitis have so far been conducted in 24 districts (SCM from 23 districts and CM from 15 districts), buffalo mastitis in six districts and goat mastitis in 13 districts (Table 5-7). Bangladesh has a 3.53 million lactating dairy cows[64] and the analysis of the published reports on bovine mastitis reveals that 11.18 % (n = 3,94,654) cows are affected with CM and 39.05% (n = 1.378465 million) with SCM (Table 5). However, highest prevalence of SCM in lactating cows has been reported from Chattogram district which varied from 28.75 to 74.49% and also Jhenaidah district at both the dairy farm (71.9%) and smallholder farm (67.9%) levels[65] in comparison to other reports published from different districts in Bangladesh (Table 5). These variations of the prevalence of SCM in lactating cows in different districts and elsewhere might be period of study, geographical location, breed of animals, lactation stage, number of sample tested, sample methodology used and dairy farm and lactating animal management practices.[7] In lactating buffalo cows, 42.53% had SCM and 23.68% had CM (Table 7). Recent analysis of Indian reports on SCM and CM reported 45% SCM and 18% CM in dairy cows.[7] In India and Pakistan, prevalence of SCM is ranged from 17 to 93% in cows and 4 to 48% in buffaloes.[66] These findings can also be compared with the earlier report[67] who reported overall prevalence of 27.0% and 36.0% SCM and 4.0% and 5.5% CM in buffaloes and cows, respectively. Prevalence of SCM has been reported as 46.35% on cow basis and 23.25% on quarter basis in India.[68] However, the higher prevalence of CM has been reported in buffaloes (24.60%) than cattle (18.21%) and SCM in buffaloes (36.38%) and in cattle (33.67%) in Pakistan.[69]

The prevalence of mastitis varies from district to district and host species. The overall prevalence rate of SCM than CM mastitis was recorded in the investigated lactating cattle (SCM: CM 39.32 : 8.57), buffaloes (SCM : CM 42.53 : 23.68) and goats (SCM : CM 44.16 : 3.85) in Bangladesh. Quarter-wise prevalence of mastitis shows more in single and

Table 5. Prevalence of subclinical and clinical mastitis in dairy lactating cows in Bangladesh

S/N	District	Sub-clinical mastitis Test used	No. of cows tested	Cow positive No. (%)	Ref. No.	Clinical mastitis Test used	No. of cows tested	Cow positive No. (%)	Ref. No.
01	Barishal	CMT	200	057 (28.50)	70	-	-	-	-
02	Barishal	CMT	064	033 (51.56)	71	-	-	-	-
03	Barishal	WST, SFMT	152	054 (35.53)	72	-	-	-	-
04	Barishal	4 testsD	40	017 (42.50)	73	-	-	-	-
05	Brahmanbaria	CMT	400	115 (28.75)	74	-	-	-	-
06	Chittagong (CTG)	CMT	306	215 (70.26)	75	CE	634	053 (08.36)	76
07	Chittagong	3 tests	444	144 (32.43)	77	CE	300	007 (02.33)	21
08	Chittagong	CMT	153	100 (65.36)	78	CE	334	028 (08.36)	76
09	Chittagong	CMT, WST	100	069 (69.00)	79	-	-	-	-
10	Chittagong	CMT	114	039 (34.21)	80	-	-	-	-
11	Chittagong	CMT	196	146 (74.49)	81	-	-	-	-
12	Chittagong	CMT	042	013 (30.95)	82	-	-	-	-
13	Chittagong	CMT	262	128 (48.85)	83	CE	262	014 (05.34)	83
14.	Chittagong	-	-		-	CE	602	124 (20.6)	84
14	Chattogram	CMT	445	253 (56.85)	85	-	-	-	-
15	Dhaka (D) + CTG	CMT	287	118 (41.11)	86	-	-	-	-
16	Dhaka (CCBSDF)	-	-	-	-	CE	1082	229 (21.20)	87
17	Dinajpur	-	-	-	-	CE	100	058 (58.0)	88
18	Gopalgonj	-	-	-	-	CE	561	035 (06.24)	89
19	Jessore	-	-	-	-	CE	307	052 (12.04)	90
20	Jhenaidah	SFMT	078	053 (67.95)	65	-	-	-	-
21	Magura	-	-	-	-	CE	327	006 (02.10)	91
22	Mymensingh (M)	DMT	158	087 (55.06)	92	CE	16	016 (100)	93
23	Mymen + Rajbari	CMT	116	051 (43.97)	94	CE	060	021 (35.00)	15
24	M + Dhaka (D)	CMT	560	380 (67.86)	95	-	-	-	-
25	M + Dhaka (D)	CMT, WST	305	044 (14.43)	96	-	-	-	-
26	M + Lakshmipur	CMT	139	072 (51.80)	97	-	-	-	-
27	M + Tangail (T)	3 tests	200	058 (29.00)	98	-	-	-	-
28	M + NTC + KRG	CMT	460	085 (18.48)	99	CE	460	061 (13.30)	98
29	Naogaon	CFT	103	053 (51.46)	100	-	-	-	-
30	Rajshahi	4 tests	111	073 (65.77)	101	-	-	-	-
31	M+Rang+Satkhira	CMT	480	097 (20.21)	102	-	-	-	-
32	Rajshahi + Rangpur	CMT	261	114 (43.68)	103	-	-	-	-
33	Satkhira (STK)	CMT	150	052 (34.67)	24	-	-	-	-
34	Satkhira	CMT	250	066 (26.40)	22	-	-	-	-
35	Sirajganj (SRJ)	3 tests	330	120 (36.36)	104	CE	832	046 (05.53)	105
36.	Sirajgonj	WST, CMT	805	133 (16.52)	106	-	-	-	-
37	Sirajganj + Pabna	3 tests	300	153 (51.00)	16	-	-	-	-
38	Sirajganj + Pabna	CMT	735	243 (33.06)	107	CE	735	025 (03.40)	107
39	Sirajganj	CMT	1124	409 (36.39)	108	-	-	-	-
40	Sylhet	CMT	100	042 (42.00)	21	-	-	-	-
41	Sylhet (SLT)	WST	225	122 (54.22)	109	-	-	-	-
42	Sylhet	WST	158	081 (51.27)	110	-	-	-	-
43	CTG + SRJ +M+GP	4 tests	228	148 (64.91)	111	-	-	-	-
44	R+M+D+S	WST	581	122 (21.00)	112	CE	581	029 (05.00)	112
	Overall	**39**	**11,162**	**4,359 (39.05)**		**16**	**7,193**	**804 (11.18)**	

CMT= California Mastitis Test
WST = White side test
SFMT = Surf Field Mastitis Test
2 tests = CMT & WST
3 tests = WST, SFMT & CMT
4 tests = 3 tests + Somatic cell count (SCC)
4 testsD = = 3 tests + Dye test
SCT = Strip cup test
DMT = Draminski Mastitis Detector

M = Mymensingh SRJ- = Sirajgonj L= Lakshmipur R + R = Rajshahi + Rangpur
Ran + My + Sat = Rangpur + Mymensingh + Satkira RMDS = Rajshahi + Mymensingh + Dhaka + Sylhet
C+S+M+G=Chittagong+Sirajgonj+Mymensingh+ Gazipur R+M+D+S = Rajshahi + Mymensingh + Dhaka + Sylhet
M+ NTC + KRG = Mymensingh + Netrokona + Kishorganj
CTG + D + SRJ +M+ GP = Chittagong + Dhaka +Sirajgonj + Mymensingh + Gazipur
GM= Gangrenous mastitis caused by *Staph. aureus* & E. coli (n=7) ^ = *Staph. aureus*

Quarter-wise prevalence of SCN in lactating cows

Highest prevalence of SCM was recorded in the left hind quarter (30.02%) in comparison to left front quarter (28.69%), right front quarter (27.82%) and right hind quarter (26.15%) in lactating cows (Table 6).

Table 6. Quarter-wise prevalence of sub-clinical mastitis in lactating cows

S/N	District	Left front quarter		Left hind quarter		Right front quarter		Right hind quarter		Total		Ref. No.
		No. tested	Positive No (%)	No. tested	Positive No. (%)	No. tested	Positive No. (%)	No. tested	Positive No. (%)	No. tested	Positive No. (%)	
01	M	158	51 (32.28)	158	38 (24.05)	158	40 (25.32)	158	31 (19.62)	632	160 (25.32)	91
02	M + D	-	-	-	-	-	-	-	-	2059	1167 (56.68)	94
03	M + RAJB	116	18(15.52)	116	18 (52.52)	116	24 (20.69)	116	28 (24.14)	464	89 (19.18)	93
04	Barihsal	-	-	-	-	-	-	-	-	800	209 (26.13)	70
05	M+ L	139	39 (28.06)	139	46 (33.09)	139	34 (24.46)	139	24 (17.27)	556	143 (25.72)	96
06	Rajshahi	111	50 (45,05)	111	75(67.57)	111	60 (54.05)	111	80 (72.07)	444	265 (59.68)	101
07	Naogaon	103	29 (28.1)	103	34 (33.1)	103	25 (24.3)	103	16 (15.5)	412	104 (25.24)	100
08	CTG	-	-	-	-	-	-	-	-	1224	556 (45.42)	75
09	Jhenaidah	-	- -	-	-	-	-	-	-	100	30 (30.00)	65
10	Satkhira	-	- -	-	-	-	-	-	-	1000	214 (21.4)	22
11	SRJ+PBN	-	- -	-	-	-	-	-	-	2936	385 (13.11)	106
12	Sirajgonj	389	55 (14.1)	389	63 (16.2)	389	55 (14.1)	389	55 (14.1)	1556	228 (14.65)	18
13	SRJ+CTG + M+GP	225	114(50.7)	220	97 (44.0)	224	107 (47.8)	223	90 (40.3)	692	408 (58.96)	110
	Overall	1241	356 (28.69)	1236	371 (30.02)	1240	345 (27.82)	1239	324 (26.15)	10627	3958 (37.24)	

M = Mymensingh D = Dhaka RAJB = Rajbari M+L = Mymensingh + Lakshmipur
SRJ + PBN = Sirajgonj + Pabna GP = Gazipur SCM = Sub-clinical mastitis CM = Clinical mastitis

Table 7. Prevalence of subclinical and clinical mastitis in dairy lactating buffaloes in Bangladesh

S/N	District	Sub-clinical mastitis			Ref. No.	Clinical mastitis			Ref. No.
		Test used	No. of buffaloes tested	Positive No. (%)		Test used	No. of buffaloes tested	Positive No. (%)	
1	Barishal	4 tests+D	040	013 (32.50)	80	-	-	-	-
2	Mymensingh	Culture	050	035 (70.00)	30	-	-	-	-
3	Coastal area	CMT	114	036 (31.58)	112	CE	114	027 (23.68)	112
4	Bhola	CMT	070	014 (20.00)	31				
5	Dhaka	CMT	030	021 (70.00)	27	-	-	-	-
6	Bagerhat	3 tests	030	017 (56.67)	28	-	-	-	-
7	Bagerhat + Noakhali	CMT + SCC	076 299 quarters	062 (81.80) 127 (42.50)	29	-	-	-	-
8	Bhola	CMT	200	021 (10.50)	113	-	-	-	-
	Overall	-	610	219 (42.53)	-	Overall	114	027 (23.68)	-

CMT= California Mastitis Test 3 tests = White Side Test (WST), Surf Field Mastitis Test (SFMT) & CMT
4 tests = 3 tests + Dye test

Table 8. Prevalence of subclinical and clinical mastitis in dairy lactating goats in Bangladesh

S/N	District	Host	Sub-clinical mastitis			Ref. No.	Clinical mastitis			Ref. No.
			Test used	No. of animals tested	Animal positive No. (%)		Test used	No. of animals tested	Animal +ve No. (%)	
01	District*	Goats	3 tests	231	103 (44.59)	114	-	-	-	-
02	Barishal	Goats	4 testsD	20	007 (35.00)	80	-	-	-	-
03	Chittagong	Goats	CMT	106	054 (50.94)	35	CE	300	07 (02.33)	115
04	Dhaka	Goats	CMT	050	018 (36.00)	116	CE	50	03 (06.00)	116**
05	Dinajpur	Goats	CMT	120	052 (43.33)	117	CE	120	17 (14.17)	117
06	Gazipur	Goats	-	-	-	-	CE	488	07 (01.43)	118
07	Gopalganj	Goats	-	-	-	-	CE	1428	47 (03.29)	88
08	Jessore	Goats	-	-	-	-	CE	112	13 (03.01)	89
09	Jhalakati	Goats	-	-	-	-	CE	39	03 (07.69)	119
10	Magura	Goats	-	-	-	-	CE	209	05 (02.6)	90
11	Mymensingh	Goats	CMT	242	090 (37.19)	32	CE	242	11 (4.55)	32
12	Mymensingh	Goats	CMT	059	011 (18.64)	120	-	-	-	-
13	M+ Joypurhat	Goats	-	-	-	-	CE	1025	54 (05.27)	33
14	Raj + Rang	Goats	CMT	292	164 (56.16)	34	-	-	-	-
15	Rajshahi	Goat	4 tests	070	021 (30.00)	121	-	-	-	-
	Overall	Goats	-	1190	520 (43.70)	-	CE	4,013	167 (04.16)	-

*Three goat farms but name of farms or district not mentioned CMT = California Mastitis Test - = Not available
**Only one available report on mastitis in sheep from Bangladesh 3 tests = CMT, WST, SFNT 4 tests = 3 tests + dye test

occasionally two quarter but rarely more than two in large ruminants. The prevalence of SCM mastitis was found to be directly associated with age, parity, lactation period and management, whereas CM is more associated with breed of animals and environmental conditions.

Analysis of the findings of the available inland reports on mastitis of small ruminant animals reveal that overall 43.70% goats had SCM and 4.16% had CM mastitis, whereas a single report shows that 4.0% ewes were affected with SCM as well CM (Table 8). Comparatively lower and higher prevalence rates of SCM have been reported in does from India as 19.89%,[120] 35.55%[121] and 66.6%.[122] However, comparatively lower prevalence rate of SCM (11.41% with SFMT and 13.0% with CMT) in does have also been reported in Pakistan.[123] The overall 3.85% prevalence of CM recorded in does in Bangladesh may be compared with 6.4% prevalence of CM in does in India.[122]

Continent-wise analysis showed highest SCM prevalence in North America (46%), followed by Africa (44%), Asia (42%), Europe (37%), Oceania (36%) and Latin America (34%) and species-wise analysis showed highest in buffaloes (46%) in comparison to cattle (42%).[7] The prevalence of mastitis in Asia especially in south-east Asia is increasing in parallel with the development of new, high-milk producing breeds of cows, buffaloes and goats without any udder health control program (UHCP). Other factors have been identified that contribute to increase spread of the mastitis pathogens including lack of awareness, delay in disease detection in the absence of visible signs of abnormal milk, unhygienic milking practices and delayed and incomplete treatment of mastitis.[53]

The diagnostic method SCC reported highest prevalence of SCM (46%) in comparison to some indirect methods like CMT (43%), SFMT (41%) and WST (37%) whereas an overall prevalence of 15% CM reported with highest in buffaloes (28%) than cattle (14%) species.[7] These variations of prevalence rates of mastitis might be due to variation of breeds of animals and hygienic management practice. However, the variation in prevalence rates of SCM in different reports might be due to animal species, management of animals and sensitivity of tests used for the detection of mastitis.

Mastitis in dairy animals has received little attention in Bangladesh, especially SCM which is mainly caused by bacterial pathogens. Efforts have only been concentrated on the treatment of clinical cases in lactating animals. Several studies on mastitis have been conducted in the lactating farms animals managed in farms and community levels in different districts in Bangladesh and reported the prevalence rates of SCM and CM (Table 1-3).

Predisposing risk factors

Mastitis is a complex disease problem in dairy industry which is an interaction of main three predisposing risk factors: ① Host risk factors, ② Management risk factors, and ③ Agent / pathogen risk factors (Fig.3). These risk factors increase the chance of incidence of mastitis in dairy animals.

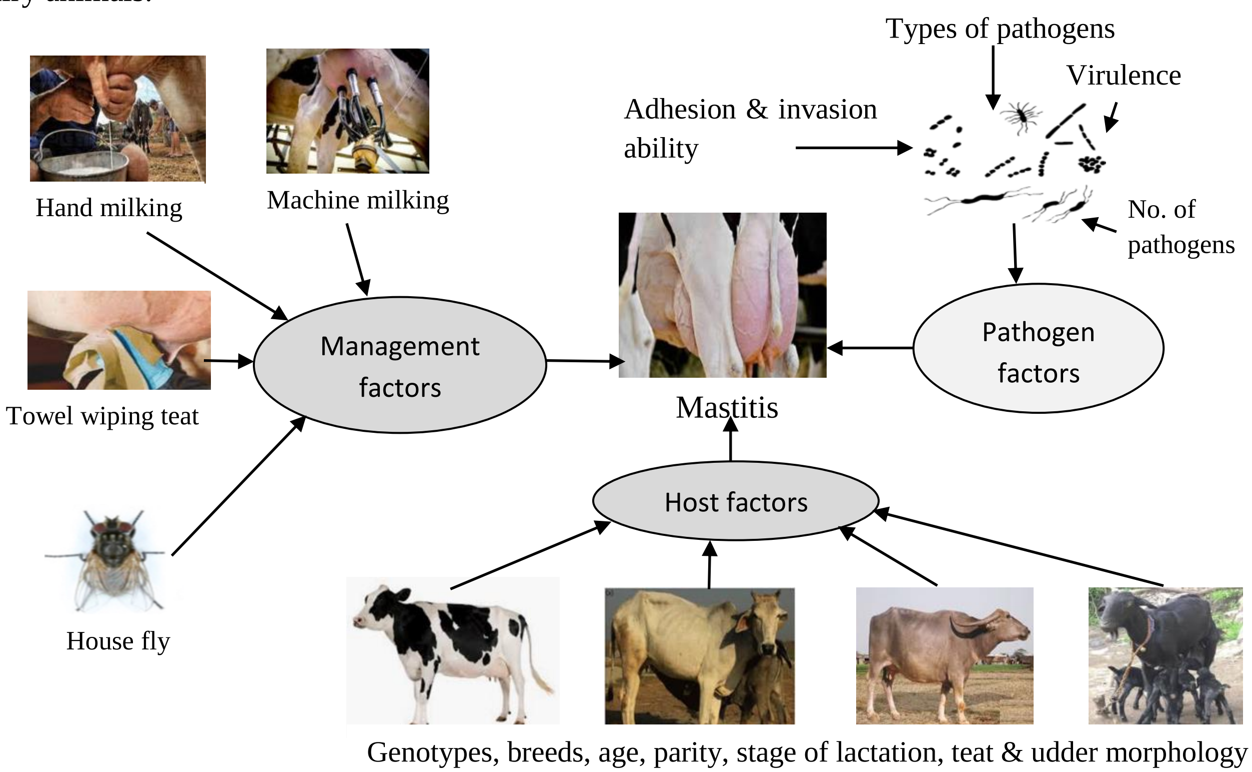

Fig. 3. Risk factors of mastitis in ruminant farm animals

① Host risk factors

The host factor consists of breed, age, stage of lactation, milking interval, parity, milk yield capacity, udder and teat conformation, somatic cell count, udder defense, dry period, teat injuries and genetic resistance.[124]

a. Breed-wise prevalence

Breed-wise analysis showed higher prevalence rates of SCM in cross-bred (45.83%) and Sahiwal (50.75) breeds in comparison to Red Chittagong (34.67%) and local zebu (28.55%) dairy lactating cows (Table 9). These analyzed results are in conformity with the findings[106] who reported significantly highest prevalence of mastitis in HF × Local cross (74.42%) in comparison to Sahiwal × Local cross (10.20%), Jersey × Local cross (2.18%) and local zebu (13.20%) lactating cows. Similarly highest prevalence of SCM in HF (56.5%) compared to local zebu (30.9%) and Jersey (28.9%) breeds have been reported from Ethiopia.[125] Significantly higher prevalence of SCM has also been reported in cross-bred (64.28%) than local zebu (27.27%) cows.[71]

The milk yield has been reported to be higher in cross-bred cows than indigenous cows in Bangladesh. In addition to larger udder size and genetic factors, the prevalent climatic conditions of tropical countries (high temperature and humidity) and intensive dairy farming systems could impose heat stress on the higher-yielding cross-bred cows more than indigenous cows,[126] possibly impairing the immune function of the cows and resulting in bacterial invasion and multiplication.[127]

Breed-wise comparative susceptibility of goats to mastitis showed higher prevalence rates in Jamunapari breed (SCM 71.60% & CM 7.14%) in comparison to Black Bengal (SCM 43.33% & CM 4.52%) goats (Table 12). The differences on the prevalence of mastitis in different breeds of dairy lactating cows and goats may be due to the inheritance character of milk production, immunity of the individual breeds and habituation of breeds of animals to the environmental conditions. However, the difference between the breeds may be in part associated with udder conformation, genetic traits and with metabolic, endocrine and immunological differences.[131]

b. Age

Approximately 17 articles have been published on age-wise prevalence of mastitis in lactating cows but the groupings of cows based on age varied greatly in different articles (Table 9). Accordingly, statistical analysis could not be applied to detect the influence of age on the prevalence of mastitis in cows. However the higher prevalence of SCM was recorded in dairy lactating cows aged between 7 to 10 years (50.0%) and > 10 years (52.0%) in comparison to between 3 to 6 years (31.60%) animals (Table 9). Similarly, the CM was recorded in cows aged between 7 to 10 years (3.28%) and > 10 years (3.75%), whereas it was absent at aged between 3 to 6 years old cows (Table 9). The older cows are reported at more risk (44.6%) for mastitis than younger cows (23.6%).[125] The higher prevalence of SCM and increase in milk production during the age group between 7 to 10 years indicate that the increased production of milk is directly proportional to prevalence of SCM and higher prevalence of CM at the aged cows (7 to 10 years and >10 years) may be due to increased potency of teat and udder, decreased immunity, increased degree and frequency of previous exposure in multiparous old cows, and resistance of bacteria to antibiotics that were indiscriminately used for the treatment of mastitis during previous infections.[39,132] A higher intra-mammary infection (IMI) rates have been reported in adult cows (93.1%) in comparison to heifer cows (65.0%) which have explained that older cows have largest teats and more relaxed sphincter muscles, which increase the accessibility of infectious agent in the cow's udder.[37]

Table 9. Risk factors associated with the prevalence of subclinical mastitis in dairy lactating cows

S/N	Risk factors	Test used	No. tested	Positive No. (%)	Ref. No.
A. Host factors					
1.	**Breed**				
	Indigenous	CMT	147	33 (22.45)	70
	Indigenous	CMT	62	28 (45.2)	99
	Indigenous	2 tests	84	22 (26.19)	72
	Indigenous	CMT	186	52 (27.95)	74
	Indigenous	3 tests	130	32 (24.61)	97
	Indigenous	CMT	179	39 (21.79)	22
	Indigenous	CMT	147	53 (36.10)	102
	Indigenous	CMT	097	26 (26.80)	106
	Indigenous	CMT	134	41 (30.60)	94
	Indigenous	CMT	93	35 (37.60)	107
	Indigenous	4 tests	71	19 (26.80)	110
	Indigenous	CMT	22	06 (27.27)	71
	Total (n = 12)	-	**1352**	**386 (28.55)**	
	Cross-bred	2 tests1	68	032 (47.06)	72
	Cross-bred	CMT	53	024 (45.28)	70
	Cross-bred	CMT	214	063 (29.43)	74
	Cross-bred	CMT	306	215 (70.26)	75
	Cross-bred	3 tests1	111	052 (46.85)	77
	Cross-bred	CMT	96	042 (43.75)	93
	Cross-bred	3 tests	70	026 (36.36)	97
	Cross-bred	CMT	71	025 (35.31)	22
	Cross-bred	3 tests	330	116 (35.15)	103
	Cross-bred	CMT	114	061 (53.51)	102
	Cross-bred	CMT	638	217 (34.01)	106
	Cross-bred	CMT	390	323 (82.82)	94
	Cross-bred	CMT	296	131 (44.26)	107
	Cross-bred	4 tests	62	035 (56.40)	110
	Cross-bred	CMT	42	027 (64.28)	71
	Cross-bred	CMT	287	118 (41.10)	85
	Cross-bred	CMT	309	071 (22.98)	98
	Cross-bred	CMT	41	025 (61.00)	99
	Total (n = 18)	-	**3498**	**1603 (45.83)**	
	Sahiwal	CMT	09	9 (100)	94
	Sahiwal	4 tests	58	25 (43.1)	110
	Total (n = 2)	-	**67**	**34 (50.75)**	
	Red CTG	CMT	018	5 (27.8)	94
	Red CTG	CMT	020	9 (45.00)	93
	Red CTG	4 tests	037	12 (32.4)	110
	Total (n = 3)	-	**075**	**26 (34.67)**	
	Holstein	CMT	150	14 (9.3)	98
	ASF	CMT	009	8 (88.9)	94
	ASF = Australian Sahiwal Friesian				
2.	**Age of cows**				
	3-4 years	CMT	072	24 (33.3)	107
	3-4 years	CMT	-	- (71.00)	75
	5-6 years	CMT	153	65 (42.5)	107
	5-6 years	CMT	-	- (78.00)	75
	7-8 years	CMT	128	58 (45.30)	107
	7-8 year	CMT	-	- (77.00)	75
	9-10 years	CMT	036	19 (52.8)	107
	9-10 years	CMT	-	- (75.00)	75
	11-12 years	CMT	-	- (72.00)	75
	3-5 years	CMT	74	21 (28.38)	70
	5-7 years	CMT	77	20 (25.97)	70
	7-9 years	CMT	38	12 (31.58)	70
	9-12 years	CMT	08	03 (37.50)	70
	>12 years	CMT	03	01 (33.33)	70
	3-7 years	CMT	71	24 (33.80)	70
	>7 years	CMT	32	29 (90.60)	70
	2-3 years	2 tests1	32	10 (31.25)	72
	>3-5 years	2 tests1	44	16 (36.36)	72
	>5-7 years	2 tests1	54	24 (44.44)	72
	>7-≥ 8 years	2 tests1	22	04 (18.18)	72
	3-5 years	CMT	195	52 (26.67)	74
	>5 years	CMT	205	63 (30.73)	74
	3-8 years	3 tests	65	24 (36.92)	77
	9-18 years	3 tests	46	29 (63.04)	77
	Up to 3 years	CMT	07	0	73
	>3-6 years	CMT	58	22 (38.00)	73
	>6-<8 years	CMT	31	08 (26.00)	73
	>8 years	CMT	18	09 (50.00)	73
	24-36 months	CMT	60	27 (39.1)	85
	37-72 months	CMT	126	54 (42.9)	85
	73-141 months	CMT	92	37 (40.2)	85
	3-5 years	3 tests	36	10 (27.78)	97
	>5-8 years	3 tests	112	37 (33.04)	97
	>8-12 years	3 tests	40	09 (22.50)	97
	>12 years	3 tests	12	02 (16.67)	97
	3.5-7 years	CMT	83	33 (39.8)	96
	> 7 years	CMT	56	39 (69.9)	96
	2-5 years	CMT	89	23 (25.84)	22
	5-7 years	CMT	94	24 (25.53)	22
	7-9 years	CMT	56	15 (26.79)	22
	9-12 years	CMT	08	03 (37.50)	22
	>12 years	CMT	03	01 (33.33)	22
	< 5 years	3 tests	19	07 (36.84)	103
	5- < 7 years	3 tests	109	46 (42.22)	103

Table 9. Risk factors associated with the prevalence of subclinical mastitis in dairy lactating cows (Contd.)

>7 - <10 years	3 tests	122	52 (42.62)	103
10-13 years	3 tests	59	27 (45.76)	103
>13 years	3 tests	21	10 (47.61)	103
>3-6 years	CMT	208	26 (24.10)	102
>7-10 years	CMT	66	27 (41.00)	102
> 10 years	CMT	87	61 (70.10)	102
2-4 years	CMT	97	26 (26.80)	101
>4-8 years	CMT	97	48 (49.50)	101
>8 years	CMT	97	23 (23.70)	101
3-6 years	CMT	735	295 (40.14)	106
7-8 years	CMT	735	267 (36.33)	106
9-19 years	CMT	735	173 (23.54)	106
3-5 years	4 tests	85	031 (36.40)	110
6-8 years	4 tests	91	46 (50.50)	110
9-10 years	4 tests	52	18 (34.60)	110
1-3 years	CMT	17	10 (58.82)	71
4-6 years	CMT	42	24 (57.14)	71
>6 years	CMT	05	03 (60.00)	71
2-4 years	CMT	97	26 (26.80)	71
>4-8 years	CMT	97	48 (49.48)	101
>8 years	CMT	97	23 (23.71)	101
3. Parity				
1-3	CMT	58	15 (25.90)	99
1-3	3 tests	62	26 (41.94)	77
Total (Parity 1-3)		**120**	**41 (34.17)**	
≥ 4	CMT	45	38 (84.40)	99
≥ 4	3 tests	49	26 (53.06)	77
Total (Parity ≥ 4)		**94**	**64 (68.09)**	
1	2 tests1	35	11 (31.43)	77
1	CMT	11	02 (18.18)	74
1	CMT	51	30 (58.82)	75
1	CMT	52	21 (40.90)	85
1	CMT	43	08 (18.60)	93
1	CMT	79	19 (24.05)	22
1	CMT	16	07 (43.75)	101
1	CMT	122	26 (21.31)	106
1	CMT	69	17 (24.64)	70
1	CMT	21	08 (38.08)	71
1	2 tests	162	11 (06.80)	105
Total (Parity 1)	-	**661**	**160 (24.21)**	
2	2 tests	38	15 (39.47)	77
2	2 tests	234	67 (28.63)	74
2	CMT	54	41 (75.93)	75
2	CMT	45	23 (51.11)	93
2	CMT	57	13 (22.81)	22
2	CMT	17	10 (58.82)	101
2	CMT	193	44 (22.80)	106
2	CMT	50	14 (28.00)	70
2	CMT	24	11 (45.83)	71

2	2 tests	192	32 (16.66)	105
Total (Parity 2)		**904**	**270 (29.87)**	
3	2 tests	41	17 (41.46)	77
3	2 tests	95	32 (33.68)	74
3	CMT	56	44 (78.57)	75
3	CMT	09	06 (66.67)	93
3	CMT	39	17 (43.58)	22
3	CMT	30	24 (80.00)	101
3	CMT	186	64 (34.41)	106
3	CMT	40	14 (35.00)	70
3	CMT	10	08 (80.00)	71
3	2 tests	205	41 (20.00)	105
Total (Parity 3)	-	**711**	**267 (37.55)**	
4	2 tests	38	11 (28.94)	77
4	2 tests	31	10 (32.26)	74
4	CMT	49	36 (73.47)	75
4	CMT	08	06 (75.00)	93
4	CMT	05	0	22
4	CMT	28	23 (82.14)	101
4	CMT	96	39 (40.63)	106
4	CMT	21	07 (33.33)	70
4	CMT	09	06 (66.67)	71
4	2 tests	246	47 (19.91)	10
Total (Parity 4)	-	**531**	**185 (34.84)**	
5	2 tests	15	02 (13.33)	74
5	CMT	23	16 (69.56)	75
5	CMT	11	08 (72.73)	93
5	CMT	45	12 (26.67)	22
5	CMT	20	16 (80.00)	101
5	CMT	63	32 (50.79)	106
5	CMT	05	0	70
Total (Parity 5)	-	**182**	**86 (47.25)**	
6	CMT	09	02 (22.22)	74
6	CMT	27	18 (66.67)	75
6	CMT	18	02 (11.11)	22
6	CMT	08	02 (25.00)	70
Total (Parity 6)	-	**62**	**24 (38.71)**	
7	CMT	05	01 (20.00)	74
7	CMT	31	21 (67.75)	75
7	CMT	07	03 (42.86)	22
7	CMT	07	03 (42.86)	70
Total (Parity 7)	-	**50**	**28 (56.00)**	
8 (Parity 8)	**CMT**	**15**	**09 (60.00)**	75
<2	CMT	16	03 (19.0)	73
>2	CMT	98	36 (37.0)	73
2-4	CMT	159	74 (46.50)	85
5-10	CMT	76	23 (30.30)	85
1-2	CMT	69	26 (37.70)	96
>2	CMT	70	46 (65.70)	96
1-3	3 tests	164	55 (33.54)	103
1-3	4 tests	97	37 (38.10)	110
Total (n = 2)	-	**261**	**92 (35.25)**	

Table 9. Risk factors associated with the prevalence of subclinical mastitis in dairy lactating cows (Contd.)

4-7	3 tests	121	43 (35.56)	103
8-11	3 tests	038	15 (39.47)	103
>11	3 tests	006	03 (50.00)	103
≤ 3	CMT	163	36 (22.10)	102
4-7	CMT	83	63 (75.90)	102
>7	CMT	15	15 (100)	102
1-2	CMT	97	51 (52.6)	101
1-2	CMT	197	65 (32.9)	107
Overall (n = 2)	-	**294**	**116 (39.46)**	
3-4	CMT	97	29 (29.9)	101
3-4	CMT	160	81 (50.6)	107
Overall (n = 2)	-	**257**	**110 (42.80)**	
≥ 5	CMT	97	17 (17.5)	101
≥ 5	CMT	32	20 (62.5)	107
Overall (n = 2)	-	**129**	**37 (28.68)**	
6-13	CMT	75	35 (46.67)	106
4-6	4 tests	82	43 (52.40)	110
7-9	4 tests	49	11 (22.40)	110
4. Lactation stage				
Early (15-90d)	-	45	25 (55.60)	99
Early (15-90d)	CMT	98	26 (26.53)	22
Early (15-90d)	CMT	49	11 (22.45)	70
Early (6-90d)	CMT	51	40 (78.43)	101
Early (60-90d)	CMT	46	14 (30.43)	93
Early (60-90d)	3 tests	64	23 (04.69)	97
Early (?)	CMT	205	70 (34.14)	74
<100 days	CMT	306	254 (83.00)	75
7-30 days	CMT	37	16 (43.20)	85
Early (<3 m)	3 tests	25	10 (40.00)	103
Overall (Early stage)		**926**	**489 (50.81)**	
Mid (90-180d)	-	38	19 (50.00)	99
Mid (90-180d)	CMT	71	22 (30.99)	22
Mid (90-180 d)	CMT	80	26 (32.50)	70
Mid (91-180d)	CMT	31	10 (32.26)	93
Mid (91-180d)	3 tests	54	12 (22.22)	97
Mid (91-180 d)	CMT	103	43 (41.70)	85
Mid (91-180d)	CMT	28	19 (67.86)	101
Mid (?)	CMT	175	40 (22.85)	74
100-200 days	CMT	306	245 (80.00)	75
31-90 days	CMT	61	27 (44.30)	85
Mid (3-6 m)	3 tests	127	35 (27.56)	103
Overall (Mid stage)		**1074**	**498 (46.37)**	
Late (>180d)	-	20	09 (45.00)	99
Late (> 180d)	CMT	81	18 (22.22)	22
Late (>180 d)	CMT	71	20 (28.17)	70
Late (>180d)	CMT	39	27 (69.23)	93
Late (>180d)	3 tests	82	23 (28.05)	97
Late (> 180d)	CMT	32	21 (65.63)	101
Late ?)	CMT	020	05 (25.00)	74
>200 days	CMT	306	226(74.00)	75
181-285 days	CMT	86	32 (37.20)	85
Late (>6 m)	3 tests	98	71 (72.45)	103
Overall (Late stage)		**835**	**452 (54.13)**	
Four stages:				
2 months	CMT	30	11 (37.00)	73
1-2 months	CMT	162	51 (31.50)	107
Sub-total (1st stage)		**192**	**62 (32.29)**	
>2-5 months	CMT	36	10 (28.00)	73
3-4 months	CMT	153	72 (43.70)	107
Sub-total (2nd stage)		**189**	**82 (43.39)**	
>5-7 months	CMT	29	06 (21,00)	73
5-6 months	CMT	53	31 (59.70)	107
Sub-total (3rd stage)		**82**	**37 (45.12)**	
>7 months	CMT	19	12 (63.00)	73
≥ 7 months	CMT	21	12 (57.90)	107
Sub-total (4th stage)		**40**	**24 (60.00)**	
Five lactation stages				
1-4 months	4 tests	71	34 (47.90)	110
1 month	-	102	12 (11.60)	98
Sub-total (1st stage)		**173**	**46 (26.59)**	
5-8 months	4 tests	34	22 (64.70)	110
2 months	-	102	17 (16.70)	98
Sub-total (2nd stage)		**136**	**39 (28.68)**	
9-12 months	4 tests	26	07 (26.90)	110
3 months	-	161	34 (21.10)	98
Sub-total (3rd stage)		**187**	**41 (21.93)**	
13-16 months	4 tests	43	11 (25.60)	110
4 months	-	75	20 (26.70)	98
Sub-total (4th stage)		**118**	**31 (26.27)**	
17-20 months	4 tests	49	15 (30.60)	110
≥ 5 months	-	19	02 (10.50)	98
Sub-total (5th stage)		**68**	**17 (25.00)**	
5. Milk yield (liter / day)				
1-5	CMT	204	50 (24.50)	74
1-5	CMT	57	22 (38.60)	85
1-5	2 test2	31	09 (17.31)	77
<5	CMT	-	- (71.00)	75
1-5	CMT	34	24 (70.59)	93
1-5	CMT	15	06 (40.00)	96
1-5	3 tests	24	07 (29.92)	103
1-5	CMT	77	42 (54.50)	107
1-5	4 tests	53	15 (28.30)	110
1-5	CMT	94	15 (15.90)	98
1-5	CMT	36	12 (33.33)	71
Overall (1-5 L)	-	**625**	**192 (30.72)**	
6-10	CMT	135	42 (31.11)	74
6-10	CMT	151	61 (40.4)	85
6-10	SFMT	35	15 (42.85)	77
6-10	3 tests	115	38 (33.04)	103
6-10	CMT	109	53 (48.60)	107
6-10	4 tests	59	26 (44.00)	110
6-10	CMT	20	14 (70.00)	71
Overall (6-10 L)	-	**624**	**249 (39.90)**	

Table 9. Risk factors associated with the prevalence of subclinical mastitis in dairy lactating cows (Contd.)

	> 10	CMT	08	07 (87.50)	71
	>10	CMT	61	23 (37.70)	74
	>10	CMT	44	29 (65.91)	77
	>10	CMT	-	- (73.00)	75
	>10	CMT	85	46 (54.10)	96
	>10	3 tests	191	71 (37.12)	103
	≥10	CMT	14	02 (14.29)	93
	>10	-	09	06 (66.70)	99
	Overall (>10 L)	**-**	**412**	**184 (44.66)**	
	5-10	CMT	-	- (90.00)	75
	5-10	CMT	39	20 (51.30)	96
	11-15	4 tests	42	22 (52.30)	110
	11-15	CMT	125	47 (37.60)	107
	Overall (n = 4)	**-**	**167**	**69 (41.32)**	
	11-27	CMT	79	35 (44.30)	85
	16-20	CMT	63	20 (31.20)	107
	16-20	4 tests	26	17 (65.30)	110
	Overall (n = 3)	**-**	**89**	**37 (41.57)**	
	21-25	CMT	15	04 (26.60)	107
	21-25	4 tests	43	09 (20.90)	110
	Overall (n = 2)	**-**	**58**	**13 (22.41)**	
	6-9	CMT	48	16 (33.33)	93
	6-9	CMT	189	46 (24.30)	98
	Overall (n = 2)	**-**	**197**	**62 (31.47)**	
	1-2	-	37	16 (43.20)	99
	2-5	-	32	17 (53.10)	99
	5-10	-	25	14 (56.00)	99
	5-10	-	39	20 (51.28)	65
	11-20	-	39	20 (50.00)	65
	>20	-	8	01 (10.30)	65
	13	CMT	58	22 (38.00)	73
	>13	CMT	56	17 (30.00)	73
	0.5-1.5	CMT	67	22 (32.83)	22
	0.5-1.5	4 testsD	12	05 (41.67)	103
	0.5- 1.5	CMT	59	11 (18.64)	70
	Overall (n = 3)	**-**	**138**	**38 (27.54)**	
	1.5-3.0	CMT	98	23 (23.47)	22
	1.5-3.0	CMT	20	09 (45.00)	103
	1.5-3.0	CMT	93	23 (24.73)	70
	Overall (n = 3)	**-**	**211**	**55 (26.07)**	
	3-5	CMT	75	15 (20.00)	22
	3-5	CMT	08	03 (37.50)	103
	3-5	CMT	39	17 (43.59)	70
	Overall (n = 3)	**-**	**122**	**35 (28.69)**	
	5-7	CMT	08	05 (62.50)	22
	5-7	CMT	07	05 (71.43)	70
	Overall (n = 2)	**-**	**15**	**10 (66.67)**	
	7-10	CMT	02	01 (50.00)	22
	7-10	CMT	02	01 (50.00)	70
	Overall (n = 2)	**-**	**04**	**02 (50.0)**	
	1-4	CMT	97	37 (38.10)	102
	5-8	CMT	74	31 (41.90)	102
	≥ 9	CMT	90	46 (51.10)	102
	0.5-3	CMT	97T	21 (21.60)	101
	>3-5	CMT	97	08 (08.20)	101
	>5	CMT	97	68 (70.10)	101
	9-13	CMT	047	11 (23.40)	98
	13-17	CMT	129	13 (10.10)	98
6.	**Udder type**				
	Round	-	61	27 (44.30)	99
	Round	CMT	82	37 (45.10)	96
	Overall (n = 2)	**-**	**143**	**64 (44.76)**	
	Pendulous	-	42	26 (61.90)	99
	Pendulous	CMT	57	35 (61.40)	96
	Pendulous	DFMT	78	10 (12.18)	65
	Overall (n = 3)	**-**	**177**	**71 (40.11)**	
	Sac-shaped	-	221	124 (56.00)	128
	Tough-shaped	-	221	27 (12.00)	128
	Bowl	SFMT	78	10 (12.80)	65
	Cup	SFMT	78	01 (01.30)	65
	Tight	SFMT	78	57 (73.10)	65
7.	**Teat type**				
	Conical	-	58	25 (43.10)	96
	Conical	CMT	77	36 (46.80)	96
	Overall (n = 2)	**-**	**135**	**61 (45.19)**	
	Cylindrical	-	45	28 (62.20)	96
	Cylindrical	CMT	62	36 (58.10)	96
	Cylindrical	SFMT	78	12(15.40)	65
	Overall (n = 3)	**-**	**185**	**76 (41.08)**	
	Rounded	DSFMT	78	02 (02.60)	65
	Rounded teat tips	-	221	29 (13.00)	128
	Overall (n = 2)	**-**	**299**	**31 (10.37)**	
	Flat	SFMT	78	03 (03.90)	65
	Pointed	SFMT	78	61 (78.20)	65
	Platform teat tips	-	221	77 (35.00)	128
8.	**History of peri-parturient diseases**				
	Absent	2 tests2	56	19 (33.92)	77
	Absent	CMT	343	135 (39.4)	106
	Overall (n = 2)	**-**	**399**	**154 (38.60)**	
	Present	SFMT	55	34 (61.82)	77
	Present	CMT	45	39 (86.70)	106
	Overall (n = 2)	**-**	**100**	**73 (73.00)**	
	Retained placenta	CMT	21	17 (80.90)	106
	Vaginal prolapse	CMT	09	09 (100)	106
	Uterine prolapse	CMT	08	07 (87.50)	106
	Milk fever	CMT	07	06 (85.70)	106

Table 9. Risk factors associated with the prevalence of sub-clinical mastitis in dairy lactating cows (Contd.)

9. Dry cow therapy				
Used	2 tests2	19	11 (57.89)	77
Not used	SFMT	92	41 (44.57)	77
10. Body condition score (BCS)				
Good	CMT	91	17 (18.70)	102
>3.5	4 tests	71	22 (30.90)	110
Overall (n = 2)	-	**162**	**39 (24.04)**	
Medium	CMT	62	27 (43.50)	102
3.0-3.5	4 tests	65	29 (44.50)	110
Overall (n = 2)	-	**127**	**56 (44.09)**	
Poor	CMT	108	70 (64.80)	102
2.0-2.5	4 tests	92	51 (55.40)	110
Overall (n = 2)	-	**200**	**121 (60.50)**	
B. Management factors				
01. Dairy farm size				
Large	2 tests2	286	53 (18.58)	105
Medium	2 tests2	222	33 (14.86)	105
Backyard	2 tests2	297	41 (13.80)	105
02. Udder hygiene				
Washing	CMT	83	30 (36.10)	102
Not washing	CMT	178	84 (47.20)	102
03. Management system				
Intensive	-	76	14 (18.40)	102
Semi-intensive	-	97	43 (44.30)	102
Extensive	-	88	57 (64.80)	102
04. Floor type				
Brick block	CMT	18	02 (11.00)	73
Brick block	CMT	53	30 (56.60)	71
Overall (n = 3)	-	**71**	**32 (45.07)**	
Cemented	CMT	96	37 (39.00)	73
Concrete	CMT	98	23 (23.47)	22
Concrete	CMT	82	19 (23.17)	70
Overall (n = 3)	-	**276**	**79 (28.62)**	
Earthen	CMT	104	33 (31.73)	22
Earthen	CMT	104	34 (32.69)	70
Soiled floor	CMT	11	03 (27.27)	71
Overall (n = 3)	-	**219**	**70 (31.96)**	
Slatted	CMT	48	08 (16.66)	22
Slatted	CMT	14	04 (28.57)	70
Overall (n = 2)	-	**62**	**12 (19.35)**	
05. Cleanliness of floor				
Good	CMT	45	10 (22.00)	73
Poor	CMT	69	29 (42.00)	73
06. Application of floor disinfectant				
Yes	CMT	?67	13 (19.40)	102
No	CMT	194	101 (52.10)	102
07. Milkers' hand washing				
Yes	CMT	98	31 (31.60)	102
No	CMT	163	83 (50.90)	102

Table 10. Risk factors associated with the prevalence of clinical mastitis in dairy lactating cows

S/N	Risk factors	Test used	No. tested	Positive No. (%)	Ref. (No.)
01.	**Body condition score (BCS)**				
	≤ 3.0	CE	427	(34.9)	18
	3.25	CE	488	(45.7)	18
	≥ 3.5	CE	468	(51.0)	18
02.	**Breed**				
	Indigenous	CE	188	08 (04.26)	76
	Indigenous	CE	-	13 (04.23)	89
	Indigenous	CE	20575	1105 (5.37)	104
	Local	CE	322	19 (05.90)	86
	Overall (n = 4)	**CE**	**21085**	**1145 (05.43)**	
	Sahiwal	CE	138	37 (26.80)	86
	Fresian	CE	050	12 (24.00)	86
	Holstein	CE	150	06 (04.00)	98
	Overall (n = 3)	**CE**	**200**	**18 (09.00)**	
	Cross	CE	309	55 (17.80)	98
	Cross	CE	572	161 (28.15)	86
	Cross	CE	446	45 (10.09)	76
	Cross	CE	-	39 (12.70)	89
	Cross	CE	330	07 (2.12)	103
	Cross	CE	14750	1295 (8.78)	104
	Overall (n = 6)	-	**16407**	**1563 (9.53)**	
03.	**Age (yrs)**				
	3.5-5	CE	190	09 (04.74)	76
	5-6.5	CE	242	24 (09.52)	76
	6.5-8	CE	162	15 (09.26)	76
	≥ 8	CE	040	05 (12.50)	76
	<5 yrs	CE	19	0	103
	5-<7 yrs	CE	109	0	103
	7- <10 yrs	CE	122	4 (3.28)	103
	10-13 yrs	CE	59	3 (5.08)	103
	>13 yrs	CE	21	0	103
04.	**Parity**				
	1	CE	085	04 (04.71)	76
	1	CE	364	153 (42.1)	18
	1	CE	1082	59 (5.5)	86
	Overall (n = 3)	-	**1531**	**216 (14.11)**	
	2	CE	183	09 (04.92)	76
	2	CE	354	152 (42.9)	18
	2	CE	944	45 (04.80)	86
	Overall (n = 3)	**CE**	**1481**	**206 (13.91)**	
	3		235	32 (13.65)	76
	3	CE	279	105 (37.5)	18
	3	CE	680	35 (05.0)	86
	Overall (n = 3)	-	**1194**	**172 (14.41)**	

Table 10. Risk factors associated with the prevalence of clinical mastitis in dairy lactating cows (Contd.)

4		098	05 (05.10)	76
4	CE	214	111(51.80)	18
4	CE	502	40 (8.0)	86
Overall (n = 3)	-	**814**	**156 (19.16)**	
5	CE	033	03 (09.09)	76
5	CE	059	40 (11.1)	86
Overall (n = 2)	-	**092**	**43 (46.74)**	
≥ 5	CE	172	(51.4)	18
6	CE	0237	27 (11.4)	86
7	CE	0176	16 (09.1)	86
8	CE	0125	13 (10.4)	86
9	CE	0082	06 (07.3)	86
≥ 10	CE	0078	07 (09.0)	86
1-3	-	164	0	103
4-7	-	121	5 (4.13)	103
8-11	-	38	2 (5.26)	103
>11	-	6	0	103
1-2	CE	124	60 (48.38)	84
3-4	CE	124	57 (45.97)	84
>5	CE	124	07 (05.6)	84
05. Stage of lactation				
1 month	CE	097	17 (17.53)	76
1 month	-	102	16 (17.0)	98
Overall (n = 2)	-	**199**	**33 (16.58)**	
2 month		103	09 (08.74)	76
2 month	-	102	10 (09.8)	98
Overall (n = 2)	-	**205**	**19 (09.27)**	
3 months		127	07 (05.51)	76
3 months	-	161	31 (19.3)	98
Overall (n = 2)	-	**288**	**38 (13.19)**	
4 months	-	119	09 (07.56)	76
4 months	-	075	12 (16.0	98
Overall (n = 2)	-	**194**	**21 (10.82)**	
5 months	-	112	06 (05.36)	76
≥ 5 months	-	019	02 (10.5)	98
≥ 6 months	-	076	05 (06.58)	76
Early (<3 months)	-	25	0	103
Mid (3-6 months)	-	127	4 (3.15)	103
Late (> 6 months)	-	98	3 (3.06)	103
≤ 27 days	-	354	182 (51.4)	18
28-90 days	-	392	220 (56.2)	18
91-185 days	-	292	111 (38.3)	18
>185 days	-	345	96 (29.7)	18
1-4 months	-	124	68 (54.8)	84
5-8 months	-	124	41 (33.0)	84
>8 months	-	124	17 (13.7)	84
06. Milk yield (liter / day)				
1-5	-	24	0	103
6-10	-	115	1 (0.87)	103
>10	-	191	6 (3.14)	103
≤ 10.0	-	462	(30.8)	18
10.1-13	-	266	(38.6)	18
13.1-17	-	328	(38.8)	18
>17	-	327	(73.0)	18
1-5	-	094	16 (17.0)	98
5-9	-	189	35 (18.5)	98
9-13	-	047	05 (10.6)	98
13-17	-	129	05 (03.9)	98
6-10	-	124	34 (27.4)	84
11-15	-	124	59 (47.6)	84
> 15	-	124	31 (25.0)	84
07. Affected quarters				
1	CE	-	33 (62.26)	76
2	-	-	13 (24.53)	76
3	-	-	04 (07.55)	76
4	-	-	03 (05.66)	76
Overall (n = 4)	-	**634**	**53 (08.36)**	**76**
1	-	-	28 (09.12)	89
>1	-	-	24 (07.81)	89
08. Physical condition				
Poor	CE	230	35 (15.22)	76
Good	-	404	18 (04.46)	76
09. Frequency of cleaning /day				
1	-	385	35 (09.09)	76
2	-	226	16 (07.08)	76
3	-	023	02 (08.70)	76
10. Floor drainage quality				
Poor	-	290	35 (12.07)	76
Acceptable	-	238	15 (06.30)	76
Proper	-	106	03 (02.83)	76
11. Floor type				
Concrete	-	238	13 (05.46)	76
Bare floor	-	296	40 (10.10)	76
Brick block floor	-	561	32 (10.42)	89
Soiled floor	-	561	20 (6.51)	89
12. History of peri-parturient diseases				
Absent	-	536	20 (03.73)	76
Absent	-	561	02 (0.65)	89
Overall (n = 2)	-	**597**	**22 (3.69)**	
Present	-	098	33 (33.67)	76
Present	-	561	50 (16.28)	89
Overall (n = 2)	-	**659**	**83 (12.59)**	

Table 11. Risk factors associated with the prevalence of sub-clinical mastitis in dairy lactating buffalo cows

S/N	Risk factors	Test used	No. tested	Positive No. (%)	Ref No.
A.	**Host factors**				
1.	**Breed**				
	Local	CMT	192	20 (10.42)	113
	Cross	CMT	008	01 (12.50)	113
2.	**Age (years)**				
	3-6	CMT	96	07 (07.29)	113
	7-18	CMT	104	14 (13.46)	113
	1-5	CMT	21	06 (28.57)	31
	>5-7	CMT	25	05 (20.00)	31
	>7	CMT	24	03 (12.50)	31
3.	**Parity**				
	1-3	CMT	79	08 (10.13)	113
	≥ 4	CMT	121	13 (10.74)	113
	1-2	CMT	24	07 29.17)	31
	3-4	CMT	31	05 (16.13)	31
	>4	CMT	15	02 (13.33)	31
4.	Lactation period				
	Early 15-90 d	CMT	017	01 (05.88)	113
	Mid 90-180 d	CMT	144	15 (10.42)	113
	Late > 180 d	CMT	039	05 (12.82)	113
	Early ≤ 2 M	CMT	23	05 (21.74)	31
	Mid >2-5 M	CMT	22	04 18.18)	31
	Late >5 M	CMT	25	05 (20.00)	31
5.	**Peri-parturient disease history**				
	Present	CMT	139	16 (11.51)	113
	Present	CMT	13	3 (23.08)	31
	Overall (n = 2)	-	**269**	**19 (7.06)**	
	Absent	CMT	57	11 (19.30)	31
	Absent	CMT	061	05 (08.20)	113
	Overall (n = 2)	-	**118**	**16 (13.56)**	
6.	**Health status**				
	Poor	CMT	127	14 (11.02)	113
	Medium	CMT	068	07 (10.29)	113
	Good	CMT	005	0	113
7.	**Reproductive disorders**				
	Abortion	CMT	04	02 (50.0)	31
	Uterine prolapse	CMT	02	-	31
	No other disease	CMT	64	12 (18.75)	31
B.	**Management factors**				
1.	Feeding system				
	Free range	CMT	182	20 (10.99)	113
	Stall feeding	CMT	018	01 (05.56)	113
2.	**Farm size**				
	Large (>50)	CMT	103	10 (9.71)	113
	Medium (11-50)	CMT	085	10 (11.76)	113
	Small (1-10)	CMT	012	01 (08.33)	113
3.	**Seasons**				
	Summer	CMT	64	07 (10.94)	113
	Winter	CMT	100	10 (10.00)	113
	Rainy	CMT	36	04 (11.11)	113

Table 12. Risk factors associated with the prevalence of mastitis in lactating goats

S/N	Risk factors	Sub-clinical mastitis: Goat level infection		Udder halves level		Clinical mastitis: Goat level infection		Ref. No.
		Total goats	Positive No. (%)	Total halves	Positive No. (%)	Total goats	No. + ve (%)	No.
A.	**Host risk factors**							
1.	**Breed**							
a.	Black Bengal goats	270	117 (43.33)	535	142 (26.54)	112	04 (03.57)	
	Black Bengal goats	-	-	-	-	300	07 (02.33)	115
	Black Bengal goats	211	106 (50.2)	422	125 (29.6)	-	-	34
	Black Bengal goats	-	-	-	-	-	05 (4.46)	89
	Black Bengal goats	59	11 (18.64)	113	17 (15.04)	-	-	129
	Black Bengal goats	-	-	-	-	1025	54 (5,27)	33
	Overall (n = 3)	**540**	**234 (43.33)**	**1070**	**284 (26.54)**	**1437**	**65 (4.52)**	
b.	Jamunapari goats	081	058 (71.60)	162	073 (45.06)	-	-	34
	Jamunapari goats	-	-	-	-	-	08 (7.14)	89
2.	**Age (years)** 2-3	37	13 (35.14)	-	-	37	2 (05.41)	117
	2-3	34	4 (12.50)	-	-	-	-	129
	Sub-total (n = 2)	**71**	**5 (7.04)**	-	-	**37**	**2 (05.41)**	

Table 12. Risk factors associated with the prevalence of mastitis in lactating goats (Contd.)

	3-4	57	24 (42.11)	-	-	57	9 (15.79)	117
	3-4	20	05 (25.00)	-	-	-	-	129
Sub-total (n = 2)		**77**	**29 (37.66)**	**-**	**-**	**57**	9 (15.79)	
	4-5	26	15 (57.69)	-	-	26	6 (23.08)	117
	4-5	05	4 (80.00)	-	-	-	-	129
Sub-total (n = 2)		**31**	**19 (61.29)**	**-**	**-**	26	6 (23.08)	
	2	21	0	-	-	21	0	32
	3	72	16 (22.22)	-	-	72	1 (1.39)	32
	4	124	61 (49.190	-	-	124	5 (4.03)	32
	5	25	13 (52.0)	-	-	25	5 (20.0)	32
Sub-total (2-5) Overall		**242**	**90 (37.19)**	-	-	**242**	**11 (4.55)**	
3. Litter size								
a. Litter size -	1	116	75 (64.66)	232	92 (39.66)	-	-	34
	1	15	02 (13.33)	-	-	15	0	117
	1	12	02 (16.67)	-	-	12	0	32
Sub-total (n = 3)		**143**	**79 (12.08)**	**-**	**-**	**27**	**0**	
b. Litter size -	2	137	73 (53.28)	274	88 (32.12)	-	-	34
	2	74	30 (40.54)	-	-	74	09 (12.16)	117
	2	196	68 (34.69)	-	-	196	07 (03.57)	32
Sub-total (n = 3)		**407**	**171 (25.15)**	**-**	**-**	**270**	**16 (05.93)**	
c. Litter size -	3	39	16 (41.03)	078	18 (23.08)	-	-	34
	3	31	20 (64.52)	-	-	31	08 (25.81)	117
	3	26	15 (57.69)	-	-	26	03 (11.54)	32
Sub-total (n = 3)		**96**	**51 (07.80)**	**-**	**-**	**57**	**11 (19.30)**	
d. Litter size	**4**	**8**	**05 (00.76)**	**-**	**-**	**08**	**01 (12.50)**	**32**
Overall		**654**	**306 (46.79)**	**-**	**-**	**362**	**28 (07.73)**	
4. Parity								
a. Few	≤ 3	182	97 (53.30)	364	117 (32.14)	-	-	34
b. Moderate	4-7	082	46 (56.10)	164	058 (35.37)	-	-	34
c. Late	≥ 7	028	21 (75.00)	056	023 (41.07)	-	-	34
	1	11	0	-	-	11	0	117
	1	20	0	-	-	20	0	32
	1	09	01 (11.11)	-	-	-	-	129
Overall (n = 3)		**40**	**01 (02.50)**	**-**	**-**	**31**	**0**	
	2	22	05 (22.73)	-	-	22	02 (9.09)	117
	2	36	02 (5.56)	-	-	36	0	32
	2	21	01 (4.76)	-	-	-	-	129
Overall (n = 3)		**79**	**08 (10.13)**	**-**	**-**	**58**	**02 (3.45)**	
	3	19	10 (52.63)	-	-	19	02 (1053)	117
	3	47	17 (36.17)	-	-	47	1 (2.13)	32
	3	16	01 (6.25)	-	-	-	-	129
Overall (n = 3)		**82**	**28 (34.15)**	**-**	**-**	**66**	**03 (4.55)**	
	4	35	17 (48.57)	-	-	35	05 (14.29)	117
	4	62	33 (53.22)	-	-	62	3 (4.84)	32
	4	07	04 (57.14)	-	-	-	-	129
Overall (n = 3)		**104**	**54 (51.92)**	**-**	**-**	**97**	**08 (8.25)**	
	5	33	20 (60.61)	-	-	33	08 (24.24)	117
	5	61	33 (54.09)	-	-	61	4 (6.56)	32

Table 12. Risk factors associated with the prevalence of mastitis in lactating goats (Contd.)

5	03	02 (66.66)	-	-	-	-	129
Overall (n = 3)	**97**	**55 (56.70)**	**-**	**-**	**94**	**12 (12.77)**	
6	11	09 (81.82)	-	-	11	3 (27.27)	32
6	03	02 (66.66)	-	-	-	-	129
Overall (n = 2)	**14**	**11 (78.57)**	**-**	**-**	**11**	**03 (27.27)**	
5. Lactation stage							
a. Early (≤ 1 months)	117	56 (47.86)	234	65 (27.78)	-	-	34
b. Mid (2-3 months)	101	64 (63.37)	202	79 (39.11)	-	-	34
c. Late (≥ 4 months)	074	44 (59.46)	148	54 (36.49)	-	-	34
Early (?)	071	32 (45.07)	-	-	071	12 (16.90)	117
Mid (?)	027	12 (44.44)	-	-	027	03 (11.11)	117
Late (?)	022	08 (36.36)	-	-	022	02 (9.09)	117
Early (< 2 months)	153	71 (46.41)	-	-	153	8 (5.23)	32
Mid (2-3 months)	050	14 (28.00)	-	-	050	2 (4.00)	32
Late (>3 months)	039	05 (12.82)	-	-	039	1 (2.56)	32
0-1 Month	17	0	-	-	-	-	129
1-2 month	38	9 (23.68)	-	-	-	-	129
2-3 month	03	1 (33.33)	-	-	-	-	129
3-4 month	01	1 (100)	-	-	-	-	129
Early (< 3 M)	09	1 (11.10)	-	-	-	-	130
Mid (3-4 M)	32	09 (28.10)	-	-	-	-	130
Late (> 4M)	29	11 (37.90)	-	-	-	-	130
6. Body condition							
a. Good	124	49 (39.52)	248	64 (25.81)	-	-	34
b. Medium	029	19 (65.52)	058	20 (34.48)	-	-	34
c. Poor	139	96 (69.06)	278	114 (41.01)	-	-	34
7. Udder halve affected							
1	-	-	-	-	-	08 (7.14)	89
2	-	-	-	-	-	05 (4.46)	89
SCM Left	-	-	120	46 (38.33)	-	-	117
SCM Right	-	-	120	47 (39.17)	-	-	117
CM Left	-	-	120	13 (10.83)	-	-	117
CM Right	-	-	120	15 (12.5)	-	-	117
8. **Teat** Present	38	18 (47.39)	-	-	38	17 (44.74)	117
lesions Present	78	66 (84.62)	-	-	78	11 (14.10)	32
Total	116	84 (72.41)	-	-	116	28 (24.14)	
Absent	164	24 (14.63)	-	-	164	0	32
Absent	82	34 (41.46)	-	-	82	0	117
Total	246	58 (23.58)	-	-	246	0	
B. Management and environmental risk factors							
1. Rearing system							
Farming	216	83 (38.43)	-	-	216	10 (4.60)	32
Farming	20	05 (25.00)	-	-	-	-	130
Overall (n = 2)	**236**	**88 (37.29)**	**-**	**-**	**216**	**10 (4.60)**	
Subsistence	26	07 (26.92)	-	-	026	01 (3.85)	32
Rural	50	16 (32.00)	-	-	-	-	130
Overall (n = 2)	**76**	**23 (30.26)**	**-**	**-**	**026**	**01 (3.85)**	

Table 12. Risk factors associated with the prevalence of mastitis in lactating goats (Contd.)

2. Housing							
a. Earthen	225	140 (62.22)	450	168 (37.33)	-	-	34
b. Raised	067	024 (35.82)	134	030 (22.39)	-	-	34
3. Season							
a. Summer	178	093 (52.25)	356	116 (32.58)	300	0	34
b. Rainy	114	071 (62.28)	228	132 (57.89)	0	85.7 (6)	34
c. Winter	-	-	-	-	300	14.3 (1)	
4. Floor condition							
Brick block	-	-	-	-	-	9 (8.04)	89
Soiled floor	-	-	-	-	-	4 (3.57)	89
5. Hygienic condition							
Hygienic	-	-	-	-	-	02 (1.79)	89
Unhygienic	-	-	-	-	-	11 (9.82)	89

? = Not mentioned - = Not done

c. Parity

Out of 20 articles published to detect the influence of parity on the prevalence of mastitis, of which 12 articles based on individual parity data whereas the rest eight articles based on varied range of parities (Table 9). Accordingly, the parity influenced prevalence of mastitis reported in 12 articles is analyzed for significance whereas data of the rest eight articles remain unutilized. Table 9 shows comparatively lower prevalence of mastitis at first parity (24.21%) and then progressively increased to 2nd (29.87%), 3rd (37.55%), 4th (34.84%), 5th (47.25%), 6th (38.71%) with significantly highest prevalence at 7th (56.00%) and 8th (60.00%) parities.

Out of four available published articles on parity based prevalence of SCM in goats, only one has reported as ranged values and other three as individual parity values (Table 12). The prevalence of SCM in goats was found lowest at first parity (2.50%) and then increased steadily at 2nd (10.13%), 3rd (34.15%), 4th (51.52%), 5th (56.70%) and 6th (78.57%) parity (Table 12).

The parity-wise prevalence of bovine CM was found more or less similar at first (14.11%) and second (13.91%) parities, and then increased steadily from 3rd (14.41%) to 4th (19.16%) and highest at 5th (46.74%) parity (Table 10). These findings are in support of the reported highest prevalence of mastitis at 5th lactation (73.3%) in dairy cows.[132]

The clinical prevalence of caprine mastitis based on parity are found negative at first parity and lowest prevalence at 2nd parity (3.45%), which progressively increased at 3rd (4.55%), 4th (8.25%), 5th (12.27%) and 6th (27.27%) parities (Table 12). These findings are in supports that goats in their 5 to 6th parity more likely to be infected by mastitis than goats in their 1 to 2nd parities.[129,133]

d. Affected udder quarter number and position

Investigation of number of quarter affected with clinical mastitis showed comparatively highest incidence of CM in one quarter (33/62.26%), followed by two quarters (13/24.53%), three quarters (4/7.55%) and lowest in four quarters (3/ 5.66%) in lactating cows.[76]

Out of 10,627 quarter milk samples tested, of which 37.24% (n = 3958) affected with SCM in dairy lactating cows (Table 6). Comparatively higher prevalence of SCM was recorded in left hind-quarters (30.02%) than left front-quarters (28.69%), right front quarter (27.89%) and right hind quarter (26.15%) of dairy lactating cows (Table 6). These findings support the earlier report of higher prevalence of SCM in hindquarters (32.0%) of cross-bred cows than those of buffaloes (29.0%), and left hind quarter reported to be most susceptible.[67] A higher prevalence of CM in hindquarter (49.39%) in comparison to front (33.04%) and in 17.55% cases affected with both the hind and front quarters in dairy cows have also been reported elsewhere.[134] The reasons for higher prevalence of mastitis in hind quarter might be due to more frequent exposure to dung and urine, larger capacity and mass, greater vulnerability to direct trauma and relatively more closeness to the floor as compared to front quarters.

e. Lactation stage

Six stages of reproductive cycle in cows have been described for better nutritional and higher milk production such as Stage-1: Pre-calving- three weeks before calving (transition), Stage-2: Post-calving days 1 to 30 (Fresh cows), Stage-3: **Early lactation-** days 31-130 (Peak milk production), Stage-4: **Mid lactation**- days 131 to 230 (Settled period after mating for churning out milk solids, Stage-5: **Late lactation**- days 231 to 300 (Lengthen lactation before doing off) and Stage-6: Dry (cow) period days 301 to -30 (Rest and recovery to maintain body condition).[a] Often a cow's lactation cycle is referred to in stage and it is common to group cows according to their stage of lactation such as (a) early lactation (14 to 100 days), mid lactation (>100 to 200 days), late lactation (>200 to 305 days) and the dry period (45 to 60 days).[b] The lactation stages have also been divided into four phases, the early, mid and late lactation, each of about 120 days and the dry period of 65 days.[c] Table 9 shows that the split of lactating cows based on lactation stages varied widely, some authors used days,[22,70,75,85,93,97,99,101] some authors used months,[73,98,103,107,110] some authors classified the lactation stages in three stages,[22,70,74,75,85,93,97,99,101,103] some authors classified into four stsages[73,107]and some authors classified into five stages [98,110] with varied duration of lactations stages.

No significant differences was recorded on the prevalence of SCM based on lactation stages in lactating dairy cows, which was found as 50.81%, 46.47% and 54.13% in early, mid and late stages of lactation, respectively (Table 9). However, the higher IMI rates have reported at early (87.2%) as compared to mid (65.9%) and late (73.1%) lactation stages in cows.[135] Similarly the prevalence of SCM in goats has also found comparatively higher at mid (2-3 months; 63.4%) in comparison to late (≥ 4 months; 59.5%) and early (≤ 2 months; 47.9%) lactation (Table 12). However, goats with lactation period of 3 to 4 months have the highest prevalence rate of mastitis.[129]([a]https://dairynutritionspecialists.co.nz [b]www.holsteinfoundation.org [c]thecattlesite.com)

f. Milk yield

Breed (genetic), age, stage of lactation, parity, feeding, diseases and milking frequencies has been reported to affect milk production. Mastitis is considered the most common disease leading to economic loss in dairy industries due to reduced yield and poor quality milk.[55] This study has reviewed a total of 27 articles associated with influence of milk yield caused by mastitis in lactating cows. Out of 27 articles on milk yield of SCM cases, 12 articles have been presented milk yield data systematically[71,74,75,77,85,93,96,98,99,103,107,110] and 15 articles presented such data on milk yield indiscriminately.[22,65,70,73,75,85,93,96,98,99,101,102,103,107,110] Accordingly, only the systematically presented data are analyzed and it appears from Table 9 that the lactating cows with lower milk yield (1-5 liter/day) had lower prevalence of SCM (30.72%) and then the prevalence of SCM progressively increased with the increased of milk yield 6 to 10 liter (39.90%) and >10 liter (44.66%).

Some influence on the higher prevalence of SCM with increased of milk production has been recorded in dairy lactating cows but the values did not differ significantly (Table 9). However, high milk yielding animals are more prone to mastitis when compared to low milk yielding animals. The teat canal diameter and stretch ability are correlated with milk yield and thus are greater in high- yielding cows. The teat canal usually remains open for a comparatively longer period in cows yielding larger volumes of milk, which may lead to an increased risk of mastitis.[135]

g. Litter size in goats

Prevalence of SCM in lactating goats based on litter size shows highest prevalence in twin births (25.15%), followed by single birth (12.08%), and then triplets (7.80%) and quadruplet (0.76) births (Table 12).[32,34,117] The highest percentage of CM was recorded in lactating goats with triplets (19.30%), followed by quadruplet (7.73%) and 5.93% with twin births but with a single birth found negative for CM (Table 12).[32,34,117]

These observations on the prevalence of mastitis in goats associated with litter size could not be explained due to lack of similar reports.

h. Body condition

Analysis of reports on the prevalence of SCM based on body conditions showed that the highest prevalence of SCM is associated with poor body condition (60.50%) in comparison to medium (44.09%) and good (24.04%) condition (Table 9).[102,110] Similarly, a higher prevalence of SCM has been reported with poor body condition (69.1%) in comparison to medium (65.5%) and good (39.5%) body conditions in goats.[34] The lower immune status and poor body condition of dairy animals due to inadequate nutritional status, metabolic and infectious diseases can also lead to increased incidence of mastitis. However, no association between cow body condition score and incidence of CM in cows.[136]

i. Udder and teat morphology

The prevalence of bovine SCM based on different udder types varied widely such as round (44.76%), pendulous (40.11%), sac-shaped (56.0%), tough-shaped (12.00%), bowl-shaped (12.80%), cup-shaped (1.30%) and tight (73.10%) structure (Table 9).[65,96,99,128] Similarly, the prevalence of bovine SCM based on different teat types also varied widely such as conical (45.19%), cylindrical (41.08), rounded teat tips (10.37%), flat (3.90%), pointed (78.20%) and platform teat tips (35.0%).[65,96,128]

Cows with teats and teat tips with undesirable conformation are more susceptible to injury and infection by pathogens. The teat canal is the first line of defense against intra-mammary infection because it prevents entry of pathogens into the udder between milking. Different types of morphology of teat shape (desirable, short, funnel, bottle, cone, pencil and plump) and teat tips (rounded, flat, crater, disk, pointed) have been reported elsewhere.[137] The probability of mastitis occurring varies considerably between different teat shapes, sizes, teat placement and morphology of teat tip.[138] The incidence of bovine mastitis associated with poor body condition

(44.74%), bottle shaped teat (36.8%), teat with round end of rear teat (33.78%), injuries and other lesions to the udder, and skin and diseases of teats have been reported.[111]

Cows with pendulous quarter appear to be most susceptible to IMI because the pendulous quarter exposes the teat and quarter to injury and pathogens easily adhere to the teat and gain access to the udder. Higher prevalence of mastitis has been reported in animals with funnel shaped teat tip which might be due to retention of some milk which facilitates the microbial growth to establish mastitis. Smaller teats have been reported to be more prone to mastitis (53.66%) than medium (35.29) and larger (18.33%) teats. It has explained that the shorter teat canal enabling the microbes to move upward without much hindrance in comparison to large teat canal. However, some workers explained as the long teats increase the risk of accidental trauma and such lesions constitute potential sources of pathogens, which increases the probability of quarter infection. However, long teats have more keratin that prevents the occurrence of mastitis.[138] However, there is no consensus in literature data about the influence of teat morphology on the occurrence of mastitis.[134,139] The teat injury may cause damage the teat and udder and expose the gland to secondary bacterial infection.[37,140] Udder and teat morphology is very heritable and could serve as a marker trait for selection to reduce mastitis in dairy animals. Therefore, the conformation udder traits could be used for the genetic selection of dairy cows for mastitis resistance.

j. Udder lesions

Bacterial cultures of swab samples of udder lesions collected from lactating cows revealed *Staphylococcus* spp. 77.4% (120/445), *Streptococcus* spp. 72.2% (112/445), *E. coli* 71.0% (110/445) and *Bacillus* spp. 30.3% (47/445), whereas the CMT positive milk samples of the these cows with udder lesions had *Staphylococcus* spp. 70.4% (186/445), *Streptococcus* spp. 55.3% (146/445), *E. coli* 7.6% (20/445) and *Bacillus* spp. 23.5% (62/445) infections. These findings indicate that udder lesions are associated with the occurrence of SCM in lactating cows in Bangladesh.[84]

Table 12 shows significantly higher prevalence of SCM recorded in lactating goats with teat lesions (72.41%) in comparison to lactating goats without any teat lesions (23.58%).[32,117] Similarly, the prevalence of CM was recorded in lactating goats with teat lesions (24.14%) but none of 246 lactating goats without any teat lesions reported negative to CM (Table 12).[32,117]

② Management risk factors

The environmental (management) risk factors that can increase exposure of the IMI include: overcrowding (inadequate floor space/animal), poor ventilation, unhygienic maintenance of animals, delayed and inadequate manure removal, poorly maintained animal housing, faulty milking techniques, dirty maternity stalls and calving areas, and general inadequate farm cleanliness and sanitation. Bedding materials are a significant source of teat end exposure to environmental pathogens.[40,141] Physical injury to teat skin, teat canal and mammary cistern are also important risk factors for entry of microbial pathogens in the udder to cause mastitis.

a. Dairy animal management practices

The effects of different dairy animal management practices on the prevalence of SCM especially the effects of (a) farm size such as large (18.58%), medium (14.86%) and backyard (13.80%), (b) udder hygiene such as washing udder (36.10%) and non-washing udder (47.20%), (c) rearing systems such as intensive (18.40%), semi-intensive (44.30%) and extensive (4.80%) have been evaluated in lactating cows (Table 9).[102,105]

Floor of housing of dairy lactating cows have been evaluated on the prevalence of SCM in Bangladesh and the higher prevalence of SCM was recorded in cows reared in earthen floor (31.96%) in comparison to concrete (28.62%), brick block (45.07%) and slatted (19.35%) floor (Table 9).[22,70,71,73] These observations support the earlier findings[132] who reported higher prevalence of mastitis (59.5%) in unorganized farm where floor was wet and soiled.

Significantly higher prevalence of SCM was recorded in goats housed in earthen (62.22%) than housed in raised / slatted (35.82%) floor (Table 12). These observations are in conformity with earlier reports[129,142] who reported that goats raised in earthen floors have a higher incidence of mastitis than goats kept in raised slatted floors. Poorly designed housing facilities and management practices on farms contribute to the contamination of environment and the exposure of teats to the environmental pathogens. High stocking density, dirty bedding or ground, infected dairy equipment, poor ventilation and high humidity are important risk factors. Housing increases the risk factors of mastitis mainly due to confinement of the animals and the multiplication of micro-organisms in the various litters elevate test challenge and consequently mastitis.

b. Seasons

The higher prevalence of SCM has been reported in the rainy season (45.09%) compared to dry summer (25.79%) and winter seasons (Table 7). However, the high prevalence of mastitis during monsoon season has been reported elasewhere.[125,132] Moisture, mud and manure present in the environment of the animals are primary sources of exposure of environmental pathogens. Incorrect ventilation, with high temperature and relative humidity, encourages the multiplication of various bacteria.[39]

Similarly, significantly higher prevalence of CM was recorded during rainy season (85.7%) in comparison to winter season (14.3%) in goats, whereas SCM did not differ significantly between the rainy (62.3%) and summer (52.2%) seasons (Table 12).

c. Milking management

Faulty milking practice, either milker’s hands (knuckling) or machine milking (higher or lower vacuum pressure) and calf suckling injury are associated risk factors of mastitis.[39] Inadequate sanitation of dairy environment, poor animal health service and lack of proper attention to health of the mammary glands are the important factors contributing to high prevalence of mastitis.[125] The incompleteness of milking- if the milk is left in the udder, it will serve as admirable media for bacterial growth and multiplication

d. Nutrition

Heavy protein feeding may be a predisposing factor. Vitamin E, Vitamin A and selenium may be involved in resistance to certain types of mastitis.[143]

③ Agent / Pathogen risk factors

Two distinct patterns in the epidemiology of mastitis can be recognized which include contagious disease pattern and environmental (opportunistic) disease patterns. The pathogen factors include the species, virulence and strain of bacteria and the size of inoculum of infectious agent in the host. Bacteria require virulence factors to colonize, multiply and survive in the udder. These include toxins, adhesions, invasions, capsule production and the ability to resist serum complement.[101] Virulence factors may be divided into three functional categories: Factors that mediate adhesion of bacteria to host cells, those that produce tissue damage and those that protect the bacteria against the host's immune system and antibiotics.[40]

The predominant species of bacteria causing CM have been reported to be Streptococcus spp. and non-aureus staphylococcus (NAS) and both S. aureus and NAS had high level of resistance against penicillin and oxacillin in Chottogram.[29]

The presence of immunosuppressive diseases like brucellosis and bovine leucosis that decreases the power of phagocytic cells of the udder to engulf an invading agent. Other infectious diseases cause lesions on the teat and udder like FMD, malignant head cattrah and pox facilitate the weakly invasive microorganism to invade the udder.

Economic impact of mastitis

Mastitis is often regarded as the ultimate threat to the dairy industry, resulting in both financial losses and harmful impacts on public health. Mastitis related financial losses are difficult to quantify, however, financial losses are attributed to the milk production losses (31%), veterinary services and drugs (24%), discarded milk (18%), laboratory fees and additional labor for the farmer (4.0%), and 23% pre-mature culling / death of dairy animals.[144] In addition, each infected animal's lactation period is reduced by about 57 days[10] and reduction of milk output to be 375 kg for each lactation.[145]

Lactating cows suffering from mastitis have decreased milk production by 30% per quarter which can have impact on decreasing milk production by 15% per cow/ lactation, making mastitis as one of the most important disease problem in dairy industry in the world.[146]

Treatment cost, involuntary culling, death, increased risk of anti-microbial resistance (AMR) and reduced animal welfare.[29]

Intra-mammary infection has been reported to affect milk production negatively, which is largely due to physical damage to the mammary parenchyma of the affected mammary gland. Mastitis can cause decreased appetite and lowered food intake due to pain and decreased movement which will have a negative impact on milk production.[39] Mastitis milk is low quality may contains abnormal constituents like clots and flakes. In addition, milk has to be discarded during the treatment days and waiting time at least for 6 days.[39] There are two elements of the treatment costs which include veterinarians' fees and the cost of drugs. The highest economic loss is caused by premature culling and replacement of animals due to mastitis.

Mastitis reduces the quality and quantity of milk and is one of the important and expensive diseases of dairy industry worldwide. The associated costs of mastitis can be categorized as: (a) milk production loss, (b) drugs, (c) discarded milk, (d) veterinary services, (e) labor, (f) product quality, (g) materials and investments, (h) diagnostics, (i) other diseases and (j) culling.[147]

A study has estimated the economic impact of the average case of CM during the first 30 days of lactation in a total economic cost of US $ 444, including $ 128 in direct costs (diagnostics $10, therapeutics $36, non-saleable milk $25, veterinary service $4, labor $ 21 & death loss $ 32) and $ 316 in indirect (future milk production loss $125, premature culling & replacement loss $182 and future reproductive loss $9) costs.[62]

The estimated annual economic losses due to mastitis has been reported to be US$ 2 billion in USA in 2009[146] and US$ 98,228 million in India due to both SCM and CM.[148] Mastitis is predicted to cost the global dairy industry between US$ 19.7 and 30 billion every year.[144]

Udder infection causes immune responses, resulting in the abnormal secretion of cytokines and hormones and abnormal function of the reproductive system such as ovary, corpus luteum, uterus and embryo. Cows with mastitis have delayed estrus, decreased pregnancy rate and increased risk of abortion. The adverse effects of mastitis on reproductive performance are affected by many factors like occurrence time, pathogen and cow factors.[149]

Mastitis has reported to have significant negative effect on post-partum estrus (75 days) and conception rate and calving interval (380-400 days) affect reproductive performance by preventing ovulation and resumption of post-calving estrus by reducing fertilization rates and embryogenesis.[79]

SCM has a significant impact on production, nearly 10-20% decrease in milk production, causes an desirable effect on the milk constituents which affects its nutritional value and renders it unfit for processing and consumption.[150]

The major economic risk factors of mastitis in dairy cows include: ① Low quality milk, ②Milk of infected animals is not suitable for human consumption, ③ Losses in affected cows, ④ Reduce milk production, ⑤ Premature culling of affected cows from the herd and ⑥ Public health risk due to the bacteria that are shed in milk such as (a) Streptococcus pyogenes can cause septic sore throat, (b) Staphylococcus aureus produces enterotoxin which is responsible for food poisoning, (c) Tuberculosis and (d) Brucellosis shed in milk of affected animals.

The economic loss due to SCM range from Rs 21627-88,340 / cow for a lactation period.[151] SCM causes three-fold more production losses as compared to CM leading to substantial economic losses of 60-70% all due to mastitis. [58,59]

Globally, the losses caused by mastitis in goats is about US $ 10 billion while in cattle, it amounts to about US $ 53 billion annually[123] and USA itself suffers from US $ 1.5 to 2 billion loss.[152,153] The magnitude of the economic losses to dairy industry in the USA due to mastitis was around $ 1.3 billion in 1979 and around $ 2 billion in 1988.[154] In India, the losses caused by mastitis in dairy industry in 1962 was Rupes 52.9 crores, then increased to Rupes 2809 crores in 1994 per annum[155] and in 2001 Rupes 6053.21 crores[156] and in 2015 as Rs 7165.51 crores, of which 57.93% (Rs 4151.16 crores) due to subclinical mastitis.[157] In Bangladesh, it is estimated approximately Taka 122.6 (US $ 2.11) million per year.[9]

Effect of mastitis on milk composition

The milk composition is subjected to change in response of genetics, breeding, feeding, number and stage of lactation and health status of the animals. Mastitis causes disruption of the normal function of the mammary gland that changes the composition of milk and reduces milk yield. Effects of mastitis on milk composition are determined by severity and extent of infection.

There is a reduction of synthesis of the main components of milk which include fat, lactose and protein which may lead to a change in the relative proportions of these components in the milk. There are also increased concentrations of blood plasma components due to the inflammatory reaction, e.g. proteins (blood albumen and immunoglobulin), chloride and sodium.[158] These have effects on properties of milk, often decreasing yield, quality and shelf-life of end product.

Casein, the major milk protein of high nutritional quality declines and lower quality whey protein increase which adversely affects the quality of dairy products such as cheese. Plasma albumin, immunoglobulin, transferrin and other serum proteins pass into milk because of increased vascular permeability. The lactoferrin concentrations are increased during intra-mammary infection possibly related to the immune function of this protein (Table 13).

Table 13. Comparison of mastitis milk with normal milk[56,159]

S/N	Constituent	Unit	Normal milk	Mastitis milk	S/N	Constituent	Unit	Normal milk	Mastitis milk
01	Milk nonfat solid	%	8.9	8.8	12	Fat	%	3.5	3.2
03	Lactose	%	4.9	4.4	13	Total protein	%	3.61	3.56
04	Total casein	%	2.8	2.3	14	Whey protein	%	0.8	1.3
05	Serum protein	%	0.02	0.07	15	Lactoferrin	%	0.02	0.1
06	Immunoglobulin	%	0.1	0.60	16	Sodium	%	0.057	0.105
07	Chloride	%	0.091	0.147	17	Potassium	%	0.173	0.157
08	Calcium	%	0.12	0.04	18	Phosphorus	mg /dl	30.50	24.40
09	Calcium	mg/ dl	126.29	90.45	19	Potassium	mg /dl	167.74	151.56
10	Sodium	mg/dl	52.93	91.97	20	Albumin	g/dl	2.65	5.62
11	Chloride	g/dl	< 0.14	> 0.14	21	pH	-	6.59	6.69

It is well established that mastitis causes a decrease in the concentration of milk lactose, probably due to the damage to the alveolar epithelial cells. The reduced lactose concentration is one important factor impaired acidification properties of milk with elevated SCC. There is a decrease in calcium absorption from blood into milk, resulting in impaired coagulation characteristics of mastitis milk. Most of the calcium in milk is associated with casein, the disruption of casein contributes to lowered in milk is absorbed with casein and the disruption of casein contributes to lowered calcium in milk.

Plasmin and enzymes derived from somatic cells can cause extensive damage to casein in the udder before milk removal. Potassium leaks out of milk through the para-cellular pathway, consequently its concentration decreases. High level of sodium in blood, leaks into the milk increasing concentrations above normal. The concentrations of chloride in milk from cows with SCM are elevated probably due to the influx of blood constituents into the milk during infection.

Host defense mechanism and pathogenesis of mastitis

The pathogenesis of mastitis in dairy animals, especially the inflammatory infection which occurs via the teat can be explained in three stages, including (a) invasion- in which pathogens pass from the exterior of the teat to the milk inside the teat canal, (b) Infection- in which organism multiply and invade the mammary tissue and (c) Inflammation- at which clinical mastitis appears or greatly increased leukocyte content in the milk.

The smooth muscles sphincter covers the mammilla of the milk duct and works to ensure that it is closed from the outside. It prevents the milk from escaping from the udder and also prevents pathogens from entering the teat canal. The stratified squamous epithelium secretes keratin which lines the mammillary duct from the inside and this keratin suppress the bacteria in the teat canal and prevent their proliferation.[160] Keratin is a waxy substance made up of phospholipids and fibrous protein. Keratin fiber proteins are able to bind electrostatically to mastitis pathogens in the teat canal, thus altering the bacterial cell wall and making it more vulnerable to osmotic pressure. Invading pathogens are inhibited and killed when osmotic pressure is not maintained.[161] During the milking process, pathogens near the teat's canal opening find a way into the teat canal, causing shock and damage to the keratin and mucous membranes surrounding the teat sinus.[162] The teat canal may remain partially open for 1 to 2 hours after milking, allowing infections to freely enter the teat canal.

Invading pathogens penetrate the irritated udder through the teat canal, which is located at the anterior margin of the cow mammilla. In addition to physical stress and chemical irritants, bacterial pathogens grow and produce toxins that cause harm to the milk-producing tissue. The quantity of leukocytes in the milk increases as an effect of these factors. The initial line of defense is presented by the bovine mammary epithelial cells (bMECs). Thus, the bMECs play a significant role in that they provide broad and unique protection against resistant pathogenic microorganisms. The udder may be contaminated by a number of microbial pathogens which kill these cells and result in mastitis.

Diagnosis

It is essential to diagnose mastitis at the initial stage of infection to initiate the treatment as early as possible before the bacterial pathogens are anchored in the mammary glands. Early diagnosis of mastitis is vital because changes in the udder tissue take place much earlier before they become apparent. Mastitis can be categorized mainly two forms, clinical mastitis (CM) and sub-clinical mastitis (SCM).

Clinical mastitis (CM)

- Diagnosis of CM is based on inspection and palpation of the individual udder quarters for abnormal type of size, consistency, symmetry, fibrosis and inflammatory signs (redness, swelling, heat & pain), empty affected quarter, differences in firmness and unbalanced quarters.
- Milk is examined for the detection of abnormalities like discoloration, blood ting, wateriness, flakes, clots and pus. However, the CM can be categorized into per-acute, acute, sub-acute and chronic forms.

a. Per-acute mastitis is characterized by a sudden onset, severe inflammation of the udder, serous milk and systemic reactions. The systemic reaction is due to toxemia and septicemia, results in fever, anorexia, depression, decreased rumen motility, dehydration and sometimes death of affected animals.

b. **Acute mastitis** is characterized by a sudden onset, moderate to severe inflammation of udder, decreased milk production and serous milk / fibrin clots. Systemic signs are similar to per-acute form but less severe.
c. **Sub-acute mastitis** is characterized by mild inflammation of the udder without any visible changes of the udder and systemic reaction but there are generally small flakes or clots in the milk and the milk may have an off-color.
d. **Chronic mastitis** may persist in subclinical form for months-years with occasional flare-up.

Strip-cup test

The strip-cup or strip plate is for determining the presence of CM for which few streams of the foremilk are squirted onto the strip cup and are visually examined for milk abnormalities.

Sub-clinical mastitis (SCM)

The SCM is always asymptomatic with no visible changes observed on the udder but only milk production decreases and milk quality degraded. It is a multi-etiological complex that includes nutritional deficiency, number of lactations and unhygienic management practices. The diagnosis of SCM in suspected quarters can be made using either direct detection of bacteriological status of the affected quarters and estimation of abnormal increased of the somatic cell count (SCC) due to inflammatory process or indirectly by using different indirect tests like California Mastitis Test (CMT), Modified White side test (WST), Surface field mastitis test (SFMT), Electrical conductivity (EC) and others. Analysis of the 39 reports on the diagnosis of SCM in lactating cows reveals that the most of the studies were carried out by using CMT (58.97%), followed by WST (7.69%), SFMT (2.56%) and DMT (2.56%) as single test used, whereas multiple indirect tests like two tests (10.26%), three tests (10.26%) and four tests (7.69%) were also used to compare the sensitivity and specificity of the tests. The SCM can also be diagnosed based on physical and chemical changes of milk and isolation of the causative organism in the milk samples. The changes of the sub-clinical and clinical mastitis with grade are presented in Table 14 to determine the severity of mastitis.[163]

Table 14. Clinical scale to determine the severity of mastitis[163]

S/N	Parameters	Non-infected	Sub-clinical mastitis	Clinical mastitis Mild (Grade 1)	Moderate (Grade 2)	Severe (Grade 3)
①	Cow	Normal	Normal	Normal	Normal	+
②	Udder	Normal	Normal	Normal	+	+
③	Milk	Normal	Normal	+	+	+
④	SCC	Normal	+	+	+	+
⑤	Bacteria	Normal	+	+	+	+

Somatic cell count (SCC)

The majority of the somatic cells in milk are 75% leukocytes (neutrophils, monocytes, macrophages) and 25% mammary epithelial cells, which become present in increasing numbers due to immune response to a mastitis causing pathogens. The SCC is used to detect the SCM and as indicator of the quality of milk. An individual cow SCC of ≤ 100,000 indicates an uninfected cow and cows with SCC ≥ 200,000 are considered infected with mastitis, whereas ≥ 300,000 infected with significant pathogens. For detection of quality of milk within the EU, the limit is 400,000 cells / ml whereas in the USA the limit is 750,000 cells /ml.[164,165] However, the optimal SCC threshold for identification of SCM has been reported to be 150,000 cell/ml of milk and this threshold led to higher specificity than 100,000 cells / ml of milk.[166]

The SCC of uninfected quarters may be varied from 170,000 to 214,000 cells / ml with an average of 106,000 cells/ ml of milk. The somatic cell responses of infected cows depend on the type of pathogens. Infections with minor pathogens (*Corynebacterium bovis* and coagulase-negative Staphylococcus) result average SCC 227,000 cells / ml. Quarters infected with major pathogens (*Str. agalactiae*, *Staph. aureus*, environmental Streptococci) produce 600,000 cells/ ml of milk.

A NucleoCounter SCC-100™ (Counter Electronic ChemoMetec A/S, Denmark) has been used to detect the SCC in milk samples of dairy cows in Bangladesh.[110] Approximately 25.0% quarters affected with SCM in lactating cows (n=240 quarters) diagnosed by using SCC (NucleoCounter SCC-100™, Denmark) considering SCC > 100×10^3 cells / ml milk) in Mymensingh, Bangladesh.[17] In addition, the effect of SCC on dairy products without the support of any inland reports has been reported.[167]

SCCs are indicators of both resistance and susceptibility of cows to mastitis and it can be used to monitor the level or occurrence of SCM in herds or individual cows. SCC is a useful predictor of IMI and therefore, an important component of milk in assessment of aspects of quality, hygiene and mastitis control.[168] The contagious pathogens generally cause comparatively more SCC increased than environmental pathogens. Udder infection is usually assumed when SCC is exceeds 200,000 cells / ml of milk.

California Mastitis Test (CMT), Wisconsin Mastitis Test (WMT), Microscopic Somatic Cell Count (MSSC) and Electronic Somatic Cell Counting (ESCC) methods can be used to estimates the number of somatic cells in milk.

California Mastitis Test (CMT)

The CMT has been the only reliable cow-side screening test for SCM in lactating animals used since 1957.[169] Commercial CMT kit (Leukocytest®, Synbiotic Corporation, France) is readily available in the local market used for the diagnosis of SCM research works in Bangladesh. The CMT works on the principle that the mixing of equal volume of reagent and milk causes the somatic cells in the milk to rupture. When the DNA is released from these cells, it coagulates and forms slime or gels in proportion to the number of leukocytes present and indicates the severity of the inflammation.

CMT is useful in identifying quarters that have high SCC to detect the SCM. This test is CMT is the first choice of diagnosis of SCM because it is more perfect, efficient and reliable than other field and chemical tests.

Photo 1. A lactating goat affected with acute mastitis in both the halves and treated by a quack by open wound

Photo 2. A lactating cow affected with acute mastitis in both the hind quarters showing red, swollen & hard quarters

Photo 3. A cow affected with acute mastitis in the left front quarter showing hemorrhagic discharge through teat syphon

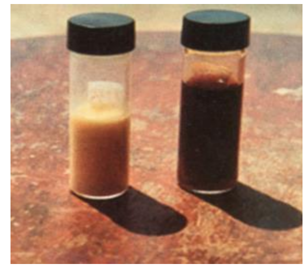

Photo 4. Light and deep red color of milk collected from two different lactating cows affected with acute mastitis.

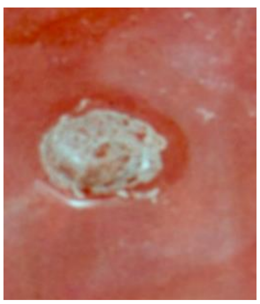

Photo- 5. White flake collected from milk of cow affected with acute mastitis

Photo- 6. Udder of a cow affected with chronic mastitis showing atrophy of the front quarter

Photo-7. A Black Bengal goats affected with chronic mastitis showing enlarged udder haves

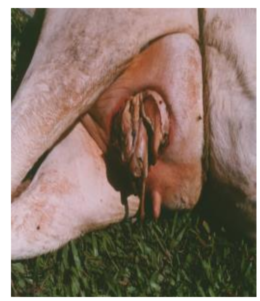

Photo-8. A cow affected with gangrenous mastitis showing gangrenous tissues in the quarters

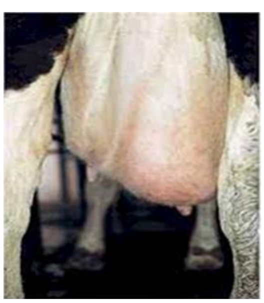

Photo 9. A lactating cow affected with chronic mastitis showing atrophy of the quarters

Photo- 10. Positive California Mastitis Test (CMT) results showing visible gel formation of milk samples within 20 seconds

Photo- 11. Positive Whiteside Test (WST) showing large masses of coagulated milk samples

Modified photo 10-12: Source 10.14202/vetworld

Photo-12. Positive Surf Field Mastitis Test (SFMT) showing whey-like background with clumps of coagulated milk samples

White Side test (WST)

There are two types of WST which include Modified Whiteside test (MWT) and Field Whiteside test. The White side test is an indirect test to detect SCM in farm animals[108] and the method is described as: 50 µl (five drop) of milk is placed on a glass slide using a dark background. Then 20 µl of WST reagent (4% NaOH) are added to the milk sample, and the mixture is rapidly stirred with a toothpick for 20-25 seconds. A positive reaction is indicated by the formation of precipitation, whereas the negative reaction is indicated by opaque precipitant-free milk. Leucocyte nuclei are mainly responsible for the formation of the precipitate in the Whiteside reaction and CaCl2 dispersed the precipitate formed by the leucocyte nuclei into small clumps. Leucocyte protein and fibrinogen increased the amount of precipitate, probably by being trapped in the precipitate.[170]

Surf Field Mastitis Test (SFMT

The SFMT has been used to evaluate the comparative sensitivity and specificity of the different indirect tests to detect SCM in lactating dairy animals in Bangladesh (Table 3 & 5). Equal volumes of 3% solution of Surface Excel detergent and milk are mixed together that causes rupture of somatic cells and release DNA and other cell components. The DNA and detergent unite to form a gel and the consistency of gel depends upon the number of somatic cells. The mastitis (reaction of the mixture) is graded into four categories based on the severity of disease from lower to higher intensity as, + = moderate, ++ = severe, +++ = more severe and ++++ = very severe. However, the use of single indirect test has not been suggested for diagnosis of SCM in dairy lactating animals.[110,114]

The comparative efficacy of CMT, WST, SFMT and SCC has been reported to be 65.8, 57.9, 51.0 and 82.5% sensitivity, and 76.2, 72.4, 69.5 and 89.4% specificity with 70.0, 64.8, 59.9 and 85.2% accuracy in lactating cows in Bangladesh.[110] However, they concluded that the use of any single test may not be reliable in diagnosis SCM in dairy cows.[110]

Electrical conductivity test (ECT)

Inflammatory infections change the composition of milk and increase electrical conductivity of milk and decrease milk electrical resistance. Electrical conductivity of milk increases during mastitis due to increases in Na^+ and Cl^- and decreases in K^+ and lactose. An increase in conductivity of milk from lactating cows suffering from mastitis is due to an increase in the salt concentration, which can be measured by an ECT. Mastitis led to changes in ion concentrations which impacts on the electrical conductivity of milk. The EC can be measured and the EC rises with the increase in the concentration of sodium chloride in milk.[171] Therefore, the measurement of electrical conductivity meter is used to determine the EC.

The EC of milk is expressed in the unit of milliSiemens (mS). This test has the following advantages: (a) One-time marginal investment is enough, (b) no special training is needed and (c) easy to do and results are readily available. However, electrical conductivity of milk can give useful information about udder health status, but hand-held EC meters, such as Draminski mastitis detector, cannot be used alone in diagnosis of subclinical mastitis.[172]

Bacteriological examination

The main bacteria associated with mastitis in lactating animals are grouped into two categories: contagious (spreading from cow to cow) and environmental (animal's surrounding-bedding, manure, soil) pathogens. The bacteriological examination of mastitis milk samples is performed by culture followed by biochemical tests on the cultured bacteria to allow identification of the causative pathogens.

Bacterial culture and isolate identification is considered the gold standard in mastitis diagnosis but is time consuming and results in many culture-negative samples. Identification of mastitis pathogens by PCR have been proposed as a fast and sensitive alternative to bacterial culture. A mastitis pathogen could not be recovered from approximately 30% of samples by bacterial culture, however, the etiological agents have been identified by PCR in 79% of these samples. In addition, mixed infection of two or more mastitis pathogens could also be detected more commonly by PCR. The use of PCR technology may assist in rapid mastitis diagnosis however, accurate interpretation of PCR results in the absence of bacterial culture remains problematic.[173] However, the molecular diagnostic tools became the gold standard of mastitis diagnosis that identify pathogens at the subspecies level which is necessary for the epidemiological studies, vaccine production and control.[174,175] Milk samples of 76 lactating buffaloes and their 299 quarter samples tested with CMT and SCC, of which 42.5% at quarter level and 81.6% at animal level SCM have been reported but 40.4% milk samples reported positive with bacteriological culture method. Non-aureus staphylococcus (NAS) recoded as the most common pathogens (24.7%) with highly resistant to penicillin.[18]

Treatment and outcome of mastitis

There are two main aims of mastitis treatment: (a) Returning milk to normal with an acceptable cell count and (b) getting rid of the pathogenic bacteria. Approximately 60-70% of all antimicrobials administered on dairy farms are for preventing and treating mastitis.[176] The principles of mastitis treatment are based on the basis of bacteriological culture and antimicrobial susceptibility testing (AST) when applicable, which is usually not practiced in Bangladesh (Fig. 4). The choice of treatment is made on the clinical manifestations and availability of antibiotics, especially intra-mammary infusion (IMI) products and parenteral antibiotics. Cows treated with intra-mammary antibiotics and NSAIDs has lower SCCs, better cure rates and better fertility than cows treated with antibiotics alone.[177]

Intra-mammary antibiotics target the infectious cause without penetrating other body systems. Prior to intra-mammary infusion (IMI), the teat is cleaned well and the tip of the teat is swabbed with an alcohol swab and allowed to dry for 30 seconds. Currently the antibiotics for IMI are available in plastic tubes with a shorter plastic infusion cannula on the end for partial insertion into the teat canal and the antibiotic is pushed from the tube into the teat cistern. After emptying the antibiotic from the tube and then the antibiotic are massaged into the udder (Table 15).

The target site of pathogens in the udder infection may depend on the causative agent: Streptococci are known to remain in the milk compartment, but *Staph. aureus* penetrates udder tissue and causes deep infection. The most common route of administration of antimicrobials in

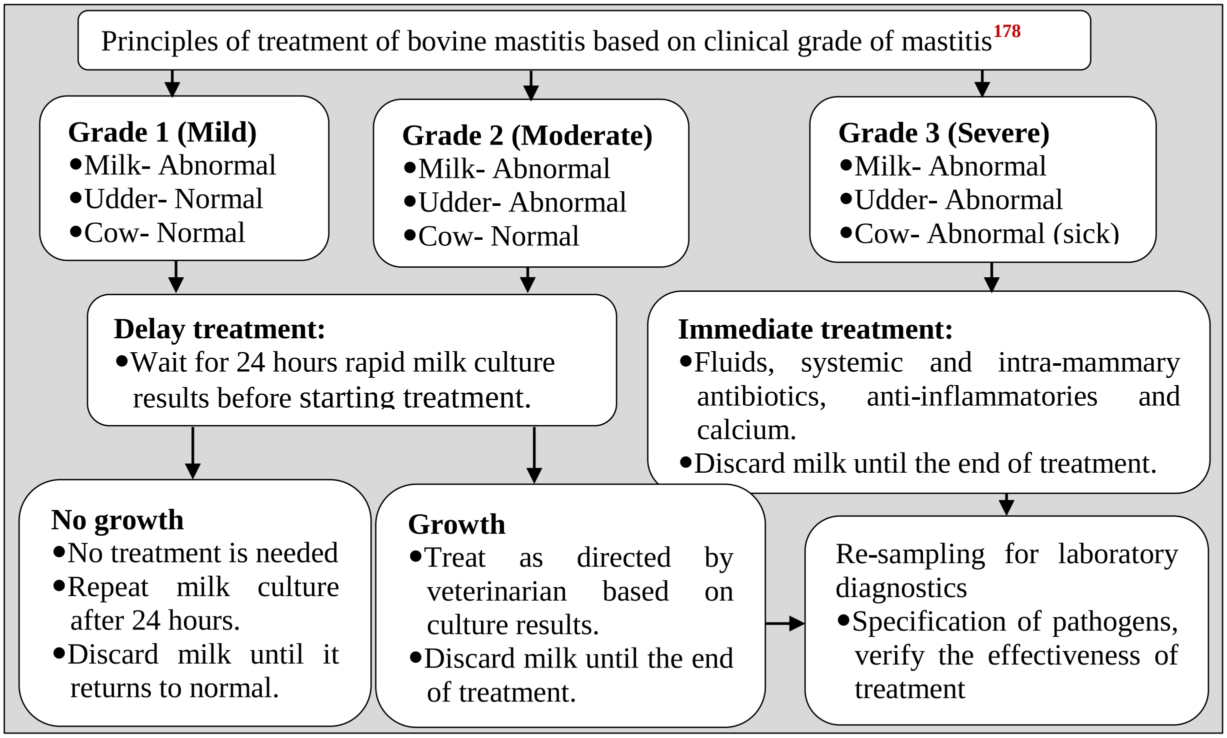

Fig. 4. Principles of treatment of bovine mastitis based on clinical grade of mastitis[178]

Table 15. Results of treatment of clinical mastitis in cross-bred cows[122]

SN	Types of mastitis	Diagnostic criteria	Treated with intramammary infusion infusion	Total No. treated	Cured cases No. (%)
1.	Mild	Udder reaction	Gentamast® (Bremar Pharma, Germany)	44	35 (79.5)
2.	Moderate	Udder reaction	Gentamast® (Bremar Pharma, Germany) Keto-aid Vet® (Popular Pharmaceuticals)	40	33 (82.5)
3.	Severe	Udder + Systemic reaction	Gentamast® (Bremar Pharma, Germany) Keto-aid Vet® (Popular Pharmaceuticals) Systemic parenteral antibiotics*		

Keto-aid Vet® - anti-inflammatory drugs
*Gentaren® (Renata Animal Health), Amoxyvet® (Techno Drugs), Streptopen® (Renata Animal Health), Cipro-A-Vet® (ACME Lab.) and Ceftron® (Square Pharmaceuticals).

mastitis is the IMI route, but both the IMI and parenteral routes are used in case of mastitis with systemic reactions. The IMI treatment with gentamycin has cured 85.71% (30/35) clinical cases of mastitis in cows, 10 clinical cases and 5 not cured with gentamycin IMI have cured with ceftriaxone, two mastitis cases treated with amoxicillin and five cases of mastitis cases treated with streptomycin-penicillin combination cured 100% cases.[89] Approximately, 66.7% cure rate of CM in cows with Neomastipra-JRS (Hipra, Spain) has been reported from Bangladesh.[96] However, antibiotic treatment during lactation is not recommended for SCM in lactating dairy animals.

Although SCC and CMT data are an excellent tool to evaluate herds, monitor progress and select cows for culture, it is not a good tool to select cows for treatment. However, selecting subclinical infection based on culture results will help target cows for treatment and improvement treatment success.

The decision to treat SCM is dependent upon the type of pathogens that are prevalent and diagnostic efforts (milk culturing) must be undertaken before developing a treatment protocol. When *Staph. aureus* is prevalent, treatment of subclinical cases of mastitis is only advised for animals.

During 50 years periods from 1967 when the first report on bovine mastitis published from this country,[179] a large number of clinical mastitis cases in animals have been occurred in this country but very limited reports are published on clinical mastitis in lactating animals.[89,180] However, gentamicin, ceftriaxone, amoxicillin, streptomycin and penicillin have been used for treatment of clinical mastitis cases in lactating cows with 85.71 to 100% efficacy in Bangladesh.[89] Neomastipra-JR5 (Hipra, Spain) intra-mammary infusion @ 1 tube /cow daily for 3 days in 72 lactating cows with SCM recovered 48 (66.7%) cases detected with CMT.[96]
In the treatment of CM in small ruminants, intra-mammary and/or parenteral antibiotics i.e. lactam, macrolid, fluouroquinolines, penicillin, nafcillin and dihydro-streptomycin have been reported to be effective in reducing the load of mastitic pathogens.[181]

Current treatment of mastitis during lactation is not very successful and cure rates are poorer, especially in case of *Staph. aureus* usually between 25 to 50%.[182] Poor contact of the antimicrobial with micro-organisms at the site of infection is a major cause of mastitis treatment failure.[183] There are four major group of factors associated with bovine mastitis treatment failure[184]

a. Management and iatrogenic factors

- Inadequate supportive therapy, partial or full insertion of teat cannula, re-infection, delayed initial treatment, duration of treatment, super infection and improper route of administration.

b. Drug factors

- Improper antimicrobial selection, short half-life of the drug, inadequate local tissue concentration, side effects of the drug, high degree of milk and serum protein binding, combined used of bactericidal and bacteriostatic antimicrobials, low bio-availability and weak passage of drug across the blood-milk barrier.

c. Mastitis-causing organism factors

- Tissue invaders or intracellular location, microbial dormancy and metabolic state, microbial mechanisms that overcome anti-microbial effects in milk, mastitis causing organisms that are short lived in mammary gland, such as coliforms and drug tolerance and resistance.

d. Mammary gland factors

- Poorer and uneven distribution and physical obstruction, trauma, udder tissue necrosis, adverse effects of drugs, teat canal infection and irritation

Antibiogram of bacteria isolated from milk samples of lactating cows

There are different types of antibacterial drugs and each type is only effective against certain bacteria. Antibiotic sensitivity (susceptibility) testing (AST) is a laboratory method performed to identify which antibacterial drug is specifically effective for individual patients. The main goals of AST are to detect possible drug resistance in common bacterial pathogens and to assure susceptibility to drugs of choice for particular bacterial infections. Globally approximately 50% of antibiotic treatments are started with wrong antibiotics without a proper identification and AST of the pathogens. In Bangladesh, clinical treatment is usually based on clinical diagnosis without any AST especially in mastitis cases. In addition, there is no national surveillance programs for monitoring the prevalence of mastitis in farm lactating animals and AST and antibacterial resistance status are lacking at national level. However, only some discrete research studies on the AST of bacterial pathogens isolated from milk samples of mastitis associated lactating dairy animals have been carried out in different districts in Bangladesh (Table 16-18).

Analysis of the research reports of antibiogram studies on the isolated bacteria from milk samples of lactating dairy cows published during the period from 1967 to 2022 in Bangladesh reveals that an overall 5014 bacterial isolates have been tested for AST, of which 62.15% (n = 3116) found sensitive and 37.85% (n = 1898) resistant to different antibacterial drugs (Table 16). It appears that the antibiotic therapy used for the treatment of mastitis in lactating cows has misused 37.85% antibacterial drugs due resistant to mastitis causal bacteria. Out of 26 antibacterial drugs tested for AST, of which 25 anti-bacterial drugs have developed resistant to bacteria isolated from milk samples associated with mastitis in lactating cows. Whereas, only one drug such as amikacin has been used for AST against *E. coli* isolated from milk samples showed 100% susceptible (Table 1). However, overall highest resistant to bacterial isolates was recorded with oxicillin (68.25%) and streptomycin (65.87), followed by penicillin (61.05%), ampicillin (55.50%), STX (50.63%), amoxicillin (49.65%), doxycycline (44.94%), tetracycline (40.65%), oxytetracycline (28.85%) and others (Table 16). The bacteria species-wise antibacterial sensitivity and resistant status are presented in Table 16.

The highest number of bacterial isolates had multi-drug resistant (MDR) and this high rate of MDR status probably due to indiscriminate use of antibiotics without AST in clinical cases of bovine mastitis in Bangladesh.

Antibiotic resistance bacteria are a concern for the health and well-being of both humans and farm animals world-wide. Antibiotic resistance is the genetic ability of bacteria to encode the resistance gene that counterfeit the inhibitory effect of potential antibiotics for survival Antibiotic resistance may occur through a mutation or through exposure to exogenous DNA such as transposons or plasmids, containing the gene(s) coding for resistance. The presence of antibacterial resistant pathogenic bacteria in milk is considered a food safety issue through consumption contaminated milk and close contact with infected dairy cows increases infection risk to animal farmers and workers.

The high prevalence of MDR bacterial isolates of milk samples in Bangladesh requires AST based mastitis treatment for considering both health and productivity of animals but also prevent the transmission of zoonotic bacteria from milk to humans.

Table 16. Antibiotic sensitivity and resistance to bacteria isolated from bovine mastitis milk samples

SN	Antibiotics	Bacteria isolated	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
1.	Penicillin	*Str. pyogenes*	15	12 (80.00)	03 (20.00)	185
	Penicillin	*Str. agalactiae*	30	26 (86.67)	04 (13.33)	185
	Penicillin	*Str. uberis*	10	08 (80.00)	02 (20.00)	185
	Penicillin	*Str. dysgalactiae*	15	11 (73.33)	04 (26.67)	185
	Penicillin	*Staph. aureus*/spp.	20	16 (80.00)	04 (20.00)	185
	Penicillin G	*Staph. aureus*/spp.	21	12 (57.14)	09 (42.86)	15
	Penicillin	*Staph. aureus*/spp.	30	02 (06.67)	28 (93.33)	19
	Penicillin	*Staph. aureus*	92	48 (52.17)	44 (47.83)	186
	Penicillin	*Cory. pyogenes*	35	31(88.57)	04 (11.43)	185
	Penicillin	*Cory. pyogenes*	03	02 (66.67)	01 (33.33)	18
	Penicillin	NAS	39	27 (69.23)	12 (30.77)	18
	Penicillin	*Escherichia coli*	34	15 (44.12)	19 (55.88)	186
	Sub-total	**-**	**344**	**210 (61.05)**	**134 (38.95)**	
2.	Streptomycin	*Str. pyogenes*	15	13 (86.67)	02 (13.33)	185
	Streptomycin	*Str. agalactiae*	30	30 (100)	0	185
	Streptomycin	*Str. uberis*	10	08 (80.00)	02 (20.00)	185
	Streptomycin	*Str. dysgalactiae*	15	14 (93.33)	01 (06.67)	185
	Streptomycin	*Streptococcus* spp.	09	08 (88.89)	01 (11.11)	20
	Streptomycin	*Streptococcus* spp.	30	21 (70.00)	09 (30.00)	23
	Streptomycin	*Escherichia coli*	07	05 (71.43)	02 (58.57)	20
	Streptomycin	*Escherichia coli*	30	21 (70.00)	09 (30.00)	23
	Streptomycin	*Escherichia coli*	34	11 (32.35)	23 (67.65)	186
	Streptomycin	*Bacillus* spp.	05	04 (80.00)	01 (20.00)	20
	Streptomycin	*Bacillus* spp.	30	24 (80.00)	06 (20.00)	23
	Streptomycin	*Stap. aureus*/spp.	20	18 (90.00)	02 (10.00)	185
	Streptomycin	*Stap. aureus*/spp.	21	06 (28.57)	15 (71.43)	15
	Streptomycin	*Staph. aureus*/spp.	30	0	30 (100)	19
	Streptomycin	*Staph. aureus*/spp.	17	13 (76.47)	04 (23.53)	20
	Streptomycin	*Staph. aureus*/spp.	30	21 (70.00)	09 (30.00)	23
	Streptomycin	*Staph. aureus*	92	54 (58.70)	38 (41.30)	186
	Streptomycin	*Cory. pyogenes*	35	32 (91.43)	03 (08.57)	185
	Sub-total		**460**	**303 (65.87)**	**157 (34.13)**	
3.	Terramycin	*Str. pyogenes*	15	05 (33.33)	10 (66.67)	185
	Terramycin	*Str. agalactiae*	30	08 (03.33)	22 (73.33)	185
	Terramycin	*Str. uberis*	10	01 (10.00)	09 (90.00)	185
	Terramycin	*Str. dysgalactiae*	15	03 (20.00)	12 (80.00)	185
	Tetracycline	*Cory. pyogenes*	03	01 (33.33)	02 (66.67)	18
	Terramycin	*Cory. pyogenes*	35	10 (28.57)	25 (71.43)	185
	Terramycin/	*Staph. aureus*/spp.	20	02 (10.00)	18 (90.00)	185
	Tetracycline	*Staph. aureus*/spp.	21	09 (42.86)	12 (57.14)	15
	Tetracycline	*Staph. aureus*/spp.	30	0	30 (100)	19
	Tetracycline	*Staph. aureus*	92	70 (76.09)	22 (23.91)	186
	Tetracycline	NAS	39	17 (43.59)	22 (56.41)	18
	Sub-total		**310**	**126 (40.65)**	**184 (59.35)**	

Table 16. Antibiotic sensitivity and resistance to bacteria isolated from bovine mastitis milk samples (Contd.)

SN	Antibiotics	Bacteria isolated	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
4.	Chloromycetin	*Str. pyogenes*	15	0	15 (100)	185
	Chloromycetin	*Str. agalactiae*	30	2 (06.67)	28 (93.33)	185
	Chloromycetin	*Str. uberis*	10	0	10 (100)	185
	Chloromycetin	*Str. dysgalactiae*	15	0	15 (100)	185
	Chloromycetin	*Staph. aureus*/spp.	20	0	20 (100)	185
	Chloromycetin	*Cory. pyogenes*	35	01 (02.86)	34 (97.14)	185
	Sub-total		**125**	**3 (2.40)**	**122 (97.60)**	
5.	Ampicillin	*Streptococcus* spp.	09	04 (44.44)	05 (55.56)	20
	Ampicillin	*Streptococcus* spp.	10	10 (100)	0	21
	Ampicillin	*Streptococcus* spp.	30	21 (70.00)	09 (30.00)	23
	Ampicillin	*Escherichia coli*	07	07 (100)	0	20
	Ampicillin	*Escherichia coli*	30	13 (43.33)	17 (56.67)	23
	Ampicillin	*Escherichia coli*	34	20 (58.82)	14 (41.18)	186
	Ampicillin	*Bacillus* spp.	30	24 (80.00)	06 (20.00)	23
	Ampicillin	*Bacillus* spp.	05	02 (40.00)	03 (60.00)	20
	Ampicillin	*Staph. aureus*	92	65 (70.65)	27 (29.35)	186
	Ampicillin	*Staph. aureus*/spp.	21	07 (33.33)	14 (66.67)	15
	Ampicillin	*Staph. aureus*/spp.	30	01(03.33)	29 (96.67)	19
	Ampicillin	*Staph. aureus*/spp.	36	04 (11.11)	32 (88.89)	81
	Ampicillin	*Staph. aureus*/spp.	17	08 (47.06)	09 (52.94)	20
	Ampicillin	*Staph. aureus*/spp.	10	10 (100)	0	21
	Ampicillin	*Staph. aureus*/spp.	30	21 (70.00)	09 (30.00)	23
	Sub-total		**391**	**217 (55.50)**	**174 (44.50)**	
6.	Amoxicillin	*Streptococcus* spp.	09	04 (44.44)	05 (56.56)	20
	Amoxicillin	*Streptococcus* spp.	10	10 (100)	0	21
	Amoxicillin	*Streptococcus* spp.	30	27 (90.00)	03 (10.00)	23
	Amoxicillin	*Escherichia coli*	07	07 (100)	0	20
	Amoxicillin	*Escherichia coli*	32	16 (50.00)	16 (50.00)	187
	Amoxicillin	*Escherichia coli*	10	03 (30.00)	07 (70.00)	21
	Amoxicillin	*Escherichia coli*	30	13 (43.33)	17 (56.67)	23
	AUG	*Escherichia coli*	34	16 (47.06)	18 (52.94)	186
	Amoxicillin	*Bacillus* spp.	05	03 (60.00)	02 (40.00)	20
	Amoxicillin	*Bacillus* spp.	30	06 (20.00)	24 (80.00)	23
	Amoxycillin	*Staph. aureus*/spp.	21	05 (23.81)	16 (76.19)	15
	Amoxycillin	*Staph. aureus*/spp.	30	01 (03.33)	29 (96.67)	19
	Amoxicillin	*Staph. aureus*/spp.	36	04 (11.11)	32 (88.89)	81
	Amoxicillin	*Staph. aureus*/spp.	17	09 (52.94)	08 (47.06)	20
	Amoxicillin	*Staph. aureus*/spp.	10	10 (100)	0	21
	Amoxicillin	*Staph. aureus*/spp.	30	27 (90.00)	03 (10.00)	23
	AUG	*Staph. aureus*	92	54 (58.70)	38 (41.30)	186
	Sub-total		**433**	**215 (49.65)**	**218 (50.35)**	
07.	Enrofloxacin	*Streptococcus* spp.	09	03 (33.33)	06 (66.67)	20
	Enrofloxacin	*Escherichia coli*	30	0	30 (100)	23
	Enrofloxacin	*Bacillus* spp.	05	01 (20.00)	04 (80.00)	20
	Enrofloxacin	*Bacillus* spp.	30	0	30 (100)	23
	Enrofloxacin	*Staph. aureus*/spp.	17	05 (29.41)	12 (70.59)	20

Table 16. Antibiotic sensitivity and resistance to bacteria isolated from bovine mastitis milk samples (Contd.)

SN	Antibiotics	Bacteria isolated	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
	Enrofloxacin	*Cory. pyogenes*	03	0	03 (100)	18
	Enrofloxacin	NAS	39	10 (25.64)	29 (74.76)	18
	Sub-total		**133**	**19 (14.29)**	**114 (85.71)**	
08.	Erythromycin	*Streptococcus* spp.	09	02 (22.22)	07 (77.78)	20
	Erythromycin	*Streptococcus* spp.	30	0	30 (100)	23
	Erythromycin	*Escherichia coli*	30	0	30 (100)	23
	Erythromycin	*Escherichia coli*	07	05 (71.43)	02 (28.57)	20
	Erythromycin	*Escherichia coli*	10	07 (70.00)	03 (30.00)	21
	Erythromycin	*Escherichia coli*	32	13 (40.63)	19 (59.38)	187
	Erythromycin	*Escherichia coli*	34	08 (23.53)	26 (76.47)	186
	Erythromycin	*Bacillus* spp.	05	01 (20.00)	04 (80.00)	20
	Erythromycin	*Bacillus* spp.	30	13 (43.33)	17 (56.67)	23
	Erythromycin	*Staph. aureus*/spp.	30	0	30 (100)	23
	Erythromycin	*Staph. aureus*/spp.	21	0	21 (100)	15
	Erythromycin	*Staph. aureus*/spp.	36	07 (19.44)	29 (80.56)	81
	Erythromycin	*Staph. aureus*/spp.	17	03 (17.65)	14 (82.35)	20
	Erythromycin	*Staph. aureus*/spp.	10	0	10 (100)	21
	Erythromycin	*Staph. aureus*	92	54 (58.70)	38 (41.30)	186
	Erythromycin	*Cory. pyogenes*	03	0	03 (100)	18
	Erythromycin	NAS	39	26 (66.67)	13 (33.33)	18
	Sub-total		**435**	**139 (31.95)**	**296 (68.05)**	
09.	Ceftriaxone	*Streptococcus* spp.	10	0	10 (100)	21
	Ceftriaxone	*Escherichia coli*	10	0	10 (100)	21
	Ceftriaxone	*Escherichia coli*	34	09 (26.47)	25 (73.53)	186
	Ceftriaxone	*Staph. aureus*/spp	10	0	10 (100)	21
	Ceftriaxone	*Staph. aureus*	92	27 (29.35)	65 (70.65)	186
	Sub-total	**-**	**156**	**36 (23.08)**	**120 (76.92)**	
10.	Chloramphenicol	*Streptococcus* spp.	30	0	30 (100)	23
	Chloramphenicol	*Escherichia coli*	30	0	30 (100)	23
	Chloramphenicol	*Bacillus* spp.	30	10 (33.33)	20 (66.67)	23
	Chloramphenicol	*Staph. aureus*/spp.	30	0	30 (100)	23
	Chloramphenicol	*Staph. aureus*/spp.	21	0	21 (100)	15
	Sub-total		**141**	**10 (07.09)**	**131(92.91)**	
11.	Ciprofloxacin	*Streptococcus* spp.	09	01 (11.11)	08 (88.89)	20
	Ciprofloxacin	*Streptococcus* spp.	10	0	10 (100)	21
	Ciprifloxacin	*Streptococcus* spp	30	0	30 (100)	23
	Ciprofloxacin	*Escherichia coli*	07	0	07 (100)	20
	Ciprofloxacin	*Escherichia coli*	10	0	10 (100)	21
	Ciprifloxacin	*Escherichia coli*	30	0	30 (100)	23
	Ciprifloxacin	*Escherichia coli*	32	05 (15.63)	27 (84.38)	187
	Ciprifloxacin	*Escherichia coli*	34	09 (26.47)	25 (73.53)	186
	Ciprofloxacin	*Bacillus* spp.	05	0	05 (100)	20
	Ciprifloxacin	*Bacillus* spp.	30	0	30 (100)	23
	Ciprofloxacin	*Staph. aureus*/spp	36	02 (05.56)	34 (94.44)	81
	Ciprofloxacin	*Staph. aureus*/spp	17	01 (05.88)	16 (94.12)	20
	Ciprofloxacin	*Staph. aureus*/spp	10	0	10 (100)	21

Table 16. Antibiotic sensitivity and resistance to bacteria isolated from bovine mastitis milk samples (Contd.)

SN	Antibiotics	Bacteria isolated	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
	Ciprifloxacin	*Staph. aureus*/spp	30	0	30 (100)	23
	Ciprifloxacin	*Staph. aureus*	92	32 (34.78)	60 (65.22)	186
	Sub-total		**382**	**50 (13.09)**	**332 (86.91)**	
12.	Gentamicin	*Streptococcus* spp	09	0	09 (100)	20
	Gentamicin	*Streptococcus* spp	10	0	10 (100)	21
	Gentamicin	*Streptococcus* spp	30	0	30 (100)	23
	Gentamicin	*Escherichia coli*	07	1 (14.29)	06 (85.71)	20
	Gentamicin	*Escherichia coli*	10	0	10 (100)	21
	Gentamicin	*Escherichia coli*	30	0	30 (100)	23
	Gentamicin	*Escherichia coli*	32	0	32 (100)	187
	Gentamicin	*Escherichia coli*	34	11 (32.35)	23 (67.65)	186
	Gentamicin	*Bacillus* spp.	05	0	05 (100)	20
	Gentamicin	*Bacillus* spp.	30	0	30 (100)	23
	Gentamicin	*Staph. aureus*/spp.	21	0	21 (100)	15
	Gentamicin	*Staph. aureus*/spp.	30	0	30 (100)	19
	Gentamicin	*Staph. aureus*/spp.	36	02 (05.56)	34 (94.44)	81
	Gentamicin	*Staph. aureus*/spp.	17	17 (100)	0	20
	Gentamicin	*Staph. aureus*/spp.	10	0	10 (100)	21
	Gentamicin	*Staph. aureus*/spp.	30	0	30 (100)	23
	Gentamicin	*Staph. aureus*	92	59 (64.13)	33 (35.87)	186
	Gentamycin	*Cory. pyogenes*	03	02 (66.67)	01 (33.33)	18
	Gentamycin	NAS	39	12 (30.77)	27 (69.23)	18
	Sub-total		**475**	**104 (21.89)**	**371 (78.11)**	
13.	Doxycycline	*Streptococcus* spp	30	13 (43.33)	17 (56.67)	23
	Doxycycline	*Escherichia coli*	30	07 (23.33)	23 (76.67)	23
	Doxycycline	*Escherichia coli*	32	14 (43.75)	18 (56.25)	187
	Doxycycline	*Bacillus* spp.	30	07 (23.33)	23 (76.67)	23
	Doxycycline	*Staph. aureus*/spp.	36	30 (83.33)	06 (16.67)	81
	Sub-total		**158**	**71 (44.94)**	**87 (55.06)**	
14.	Oxytetracycline	*Streptococcus* spp	30	0	30 (100)	23
	Oxytetracycline	*Escherichia coli*	30	0	30 (100)	23
	Oxytetracycline	*Escherichia coli*	15	05 (33.33)	10 (66.67)	187
	Oxytetracycline	*Bacillus* spp.	30	0	30 (100)	23
	Oxytetracycline	*Staph. aureus*/spp.	30	13 (43.33)	17 (56.67)	23
	Oxytetracycline	*Staph. aureus*/spp.	36	32 (88.89)	04 (11.11)	81
	Sub-total		**171**	**45 (28.85)**	**126 (73.68)**	
15.	Clindamycin	*Cory. pyogenes*	03	0	03 (100)	18
	Clindamycin	NAS	39	12 (30.77)	27 (69.23)	18
	Sub-total	**-**	**42**	**12 (28.57)**	**30 (71.43)**	
16.	Azithromycin	*E. coli*	32	09 (28.13)	23 (71.88)	187
17.	Neomycin	*Staph. aureus*/spp	21	04 (19.05)	17 (80.95)	15
	Neomycin	*E. coli*	32	02 (06.25)	30 (93.75)	187
	Sub-total		**53**	**06 (11.32)**	**47 (88.68)**	
18.	Cephalexin	*Staph. aureus*/spp	36	20 (55.56)	16 (44.44)	81

Table 16. Antibiotic sensitivity and resistance to bacteria isolated from bovine mastitis milk samples (Contd.)

SN	Antibiotics	Bacteria isolated	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
19.	Cefalotin	*Cory. pyogenes*	03	0	03 (100)	18
	Cefalotin	NAS	39	0	39 (100)	18
	Cefoxitin	*Cory. pyogenes*	03	01 (33.33)	02 (66.67)	18
	Cefoxitin	*Staph. aureus*	92	25 (27.17)	67 (72.83)	186
	Cefoxitin	*Escherichia coli*	34	11 (32.35)	23 (67.65)	186
	Sub-total		**171**	**37 (21.64)**	**134 (78.36)**	
20.	Oxacillin	*Staph. aureus*/spp	21	02 (09.52)	19 (90.48)	15
	Oxacillin	*Staph. aureus*	92	65 (70.65)	27 (29.35)	186
	Oxacillin	*Escherichia coli*	34	22 (64.71)	12 (35.29)	186
	Oxacillin+	*Cory. pyogenes*	03	02 (66.67)	01 (33.33)	18
	Oxacillin+	NAS	39	38 (97.44)	01 (02.56)	18
	Sub-total	**-**	**189**	**129 (68.25)**	**60 (31.75)**	
21.	Nitrofurantoin	*Cory. pyogenes*	03	0	03 (100)	18
	Nitrofurantoin	NAS	39	02 (05.13)	37 (94.87)	18
	Sub-total		**42**	**02 (04.76)**	**40 (95.24)**	
22.	Cefaclor	*Staph. aureus*	92	44 (47.83)	48 (52.17)	186
	Cefaclor	*Escherichia coli*	34	10 (29.41)	24 (70.59)	186
	Sub-total		**126**	**54 (42.86)**	**72 (57.14)**	
23.	Sefalotin	*Cory. pyogenes*	03	0	03 (100)	18
24.	Fusidic acid	*Cory. pyogenes*	03	01 (33.33)	02 (66.67)	18
	Fusidic acid	NAS	39	0	39 (100)	18
	Sub-total		**42**	**01 (02.38)**	**41 (97.62)**	
25.	SXT	*Escherichia coli*	32	15 (46.88)	17 (53.13)	187
		Escherichia coli	34	21 (61.76)	13 (38.24)	186
		Staph. aureus	92	44 (47.83)	48 (52.17)	186
	Sub-total	**-**	**158**	**80 (50.63)**	**78 (49.37)**	
26.	Amikacin	*Escherichia coli*	06	0	06 (100)	187
	Overall	**-**	**5014**	**1898 (37.85)**	**3116 (62.15)**	

+2% NaCl
SXT = Sulfonamide/sulfamethoxazole-trimetoprim
NAS = Non-aureus Staphylococcus
ACA = Amoxicillin-clavulanic acid

Antibiogram of bacteria isolated from milk samples of buffalo cows

A study on the isolation of bacteria form milk samples of lactating buffaloes (n = 50) showed higher rate of infection with *Staphylococcus* spp. (32.5%), followed by *Lactobacillus* spp. (25.0%) and *Bacillus* spp. (25.0%) and lowest with *E. coli* (12.5%) infection.[30] The antibiotic sensitivity and resistant status of different isolated bacteria are presented in Table 17.

All four quarter milk samples (n = 500) of 125 lactating buffaloes tested with CMT showed 37.6% (n = 188) quarters affected with SCM.[188] Among the bacteria isolated from milk samples, *Staph. aureus* reported as the single most causal agent of SCM (37.4%) in lactating buffalo cows, followed by *E. coli* (7.6%), *Str. agalactiae* (6.2%), *Klebsiella* spp. (4.5%), coagulase-negative staphylococci (4.1%), *Str. uberis* (3.8%), *Str. dysagalactiae* (3.1%), *Bacillus* spp. (2.4%) and *Enterobacter* spp. (1.4%).[188] It indicates that the *Staph. aureus* is the major causal agent of mastitis not only in buffaloes but also in other ruminant farm lactating

Table 17. Antibiotic sensitivity and resistance to bacteria isolated from buffalo mastitis milk samples

SN	Antibiotics	Bacterial pathogens	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
1.	Metronidazole	*Staphylococcus* spp.	10	10 (100)	0	30
		Bacillus spp.	10	10 (100)	0	30
		Escherichia coli	05	0	5 (100)	30
		Lactobacillus spp.	10	10 (100)	0	30
		Overall	**35**	**30 (85.71)**	**5 (14.29)**	
2.	Azithromycin	*Staphylococcus* spp.	10	05 (50.00)	05 (50.00)	30
		Staph. aureus	109	0	109 (100)	188
		Bacillus spp.	10	06 (60.00)	04 (40.00)	30
		Escherichia coli	05	01 (20.00)	04 (80.00)	30
		Lactobacillus spp.	10	0	10 (100)	30
		Overall	**144**	**12 (08.33)**	**132 (91.67)**	
3.	Amoxycillin	*Staphylococcus* spp.	10	06 (60.00)	04 (40.00)	30
		Bacillus spp.	10	10 (100)	0	30
		Escherichia coli	05	02 (40.00)	03 (60.00)	30
		Lactobacillus spp.	10	10 (100)	0	30
		Overall	**35**	**28 (80.00)**	**07 (20.00)**	
4.	Nalidixic acid	*Staphylococcus* spp.	10	05 (50.00)	05 (50.00)	30
		Bacillus spp.	10	03 (30.00)	07 (70.00)	30
		Escherichia coli	05	01 (20.00)	04 (80.00)	30
		Lactobacillus spp.	10	03 (30.00)	07 (70.00)	30
		Overall	**35**	**12 (34.29)**	**23 (65.71)**	
05.	Ampicillin	*Staphylococcus* spp.	10	07 (70.00)	03 (30.00)	30
		Staph. aureus	109	101 (92.7)	08 (07.3)	188
		Bacillus spp.	10	10 (100)	0	30
		Escherichia coli	05	0	05 (100)	30
		Lactobacillus spp.	10	10 (100)	0	30
		Overall	**144**	**128 (88.89)**	**16 (11.11)**	
06.	Trimethoprim	*Staphylococcus* spp.	10	10 (100)	0	30
		Bacillus spp.	10	10 (100)	0	30
		Escherichia coli	05	05 (100)	0	30
		Lactobacillus spp.	10	02 (20.00)	08 (80.00)	30
		Overall	**35**	**27 (77.14)**	**08 (22.86)**	
07.	Erythromycin	*Staphylococcus* spp.	10	03 (30.00)	07 (70.00)	30
		Staph. aureus	109	10 (09.2)	99 (90.83)	188
		Bacillus spp.	10	07 (70.00)	03 (30.00)	30
		Escherichia coli	05	02 (40.00)	03 (60.00)	30
		Lactobacillus spp.	10	02 (20.00)	08 (80.00)	30
		Overall	**144**	**24 (16.67)**	**120 (83.33)**	
08.	Penicillin	*Staphylococcus* spp.	10	06 (60.00)	04 (40.00)	30
		Bacillus spp.	10	10 (100)	0	30
		Escherichia coli	05	02 (40.00)	3 (60.00)	30
		Lactobacillus spp.	10	10 (100)	0	30
		Overall	**35**	**28 (80.00)**	**07 (20.00)**	
09.	Doxycycline	*Staph. aureus*	109	99 (90.80)	10 (09.20)	188
10.	Cefoxitin	*Staph. aureus*	109	53 (48.62)	56 (51.38)	188
11.	Tetracycline	*Staph. aureus*	109	83 (76.15)	26 (23.85)	188

Table 17. Antibiotic sensitivity and resistance to bacteria isolated from buffalo mastitis milk samples (Contd.)

SN	Antibiotics	Bacterial pathogens	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
12.	Chloramphenicol	*Staph. aureus*	109	77 (70.64)	32 (29.36)	188
13.	Ciprofloxacin	*Staph. aureus*	109	65 (59.63)	54 (49.54)	188
14.	Imipenem	*Staph. aureus*	109	23 (21.10)	86 (78.90)	188
15.	Nitrofurantoin	*Staph. aureus*	109	61 (55.96)	48 (44.04)	188
16.	Gentamicin	*Staph. aureus*	109	46 (42.20)	63 (57.80)	188
17.	Cefoxitin	*Staph. aureus*	109	12 (11.01)	87 (79.82)	188
18.	Nalidixic acid	*Staph. aureus*	109	17 (15.60)	92 (84.40)	188
19.	Cefazoline	*Staph. aureus*	109	18 (16.51)	91 (83.49)	188

animals. The antibiogram profiling showed that approximately 96.0% *Staph aureus* isolates found multi-drug resistant pathogen carrying both mecA and pvl genes along with nine different Staphylococcal enterotoxins.[188]

Moderate to high antibiotic sensitivity of *Staphylococcus* spp., *Streotococcus* spp., *Bacillus* spp. and *Escherichia coli* has been reported with gentamicin, ciprofloxacin, enrofloxacin and chloramphenicol but these bacteria reported mostly resistant or less sensitive to ampicillin, amoxicillin and streptomycin.[28] However, 42 bacterial pathogens (bacterial species even genus not mentioned in the article) isolated from milk samples from lactating buffaloes have been tested against 10 anti-bacterial drugs (amoxicillin, azithromycin, chloramphenicol, ciprofloxacin, ceftriaxone, erythromycin, gentamicin, levofloxacin, nitrofurantoine, trimethoprim) with 4.76 to 21.43% resistance status.[27]

Antibiogram of bacteria isolated from milk samples of goats

Correct diagnosis and identification of the causal agent associated with mastitis are required for effective treatment but the treatment of clinical mastitis in ruminant animals are usually practiced with knowing the causal agent and as a result increase the risk of antibiotic resistance. Accordingly, identification of mastitis causing pathogens, and their antibacterial susceptibility profile would be required for the appropriate antibiotic selection for the treatment of mastitis affected animals. Table 18 shows the antibiotic sensitivity and resistance status of bacteria isolated from milk samples of mastitis affected goats.

Table 18. Antibiotic sensitivity and resistance status of bacteria isolated from milk samples of mastitis affected goats

SN	Antibiotics	Bacterial pathogens	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
01.	Penicillin	Coagulase +ve Staph aureus	38	38 (100)	0	189
02.	Streptomycin	*Staphylococcus* spp.	10	R	1+	33
	Streptomycin	*Escherichia coli*	78	59 (75.64)	19 (24.36)	190
	Streptomycin	*Escherichia coli*	10	R	1+	33
	Streptomycin	*Bacillus* spp.	10	R	1+	33
	Sub-total		**108**	**-**	**-**	**-**

Table 18. Antibiotic sensitivity and resistance status of bacteria isolated from milk samples of mastitis affected goats (Contd.)

SN	Antibiotics	Bacterial pathogens	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
03.	Ampicillin	*Escherichia coli*	10	R	1+	33
	Ampicillin	*Staphylococcus* spp.	10	R	1+	33
	Ampicillin	*Escherichia coli*	78	71 (91.03)	07 (08.97)	190
	Ampicillin	*Bacillus* spp.	10	R	-	33
	Sub-total	**-**	**108**	**-**	**-**	**-**
04.	Amoxicillin	*Staphylococcus* spp.	10	R	1+	33
	Amoxicillin	*Escherichia coli*	10	-	1-2+	33
	Amoxicillin	*Escherichia coli*	08	08 (100)	0	191
	Amoxicillin	*Bacillus* spp.	10	R	-	33
	ACA	*Escherichia coli*	78	68 (87.18)	10 (12.82)	190
	Sub-total	**-**	**116**	**-**	**-**	**-**
05.	Gentamicin	*Staphylococcus* spp.	10	-	2-3+	33
	Gentamicin	*Bacillus* spp.	10	-	2-3+	33
	Gentamicin	*Escherichia coli*	10	-	2-3+	33
	Gentamicin	*Escherichia coli*	78	42 (53.85)	36 (46.15)	190
	Gentamicin	*Escherichia coli*	08	02 (25.00)	06 (75.00)	191
	Gentamycin	Coagulase +ve *Staph aureus*	38	0	38 (100)	189
	Sub-total	**-**	**154**	**-**	**-**	**-**
06.	Ciprofloxacin	*Staphylococcus* spp.	10	-	2-3+	33
	Ciprofloxacin	*Escherichia coli*	10	-	2-3+	33
	Ciprofloxacin	*Escherichia coli*	08	08 (100)	0	191
	Ciprofloxacin	*Bacillus* spp.	10	-	2-3+	33
	Sub-total	**-**	**38**	**08**	**-**	**-**
07.	Norfloxacin	Coagulase +ve *Staph aureus*	38	0	38 (100)	189
08.	Erythromycin	*Staphylococcus* spp.	10	-	1-2+	33
	Erythromycin	*Escherichia coli*	10	-	2-3+	33
	Erythromycin	*Bacillus* spp.	10	R	1+	33
	Sub-total	**-**	**30**	**-**	**-**	-
09.	Vancomycin	Coagulase +ve *Staph aureus*	38	08 (21.05)	30 (78.94)	189
10.	Oxacillin	Coagulase +ve *Staph aureus*	38	38 (100)	0	189
11.	Chloramphenicol	*Staphylococcus* spp.	10	-	1-2+	33
	Chloramphenicol	*Bacillus* spp.	10	-	2-3+	33
	Sub-total	**-**	**20**	**-**	**-**	**-**
12.	Enrofloxacin	*Staphylococcus* spp.	10	-	2-3+	33
	Endrofloxacin	*Escherichia coli*	10	-	1-2+	33
	Enrofloxacin	*Bacillus* spp.	10	-	2-3+	33
	Sub-total	**-**	**30**	**-**	**-**	-
13.	Levofloxacin	Coagulase +ve *Staph aureus*	38	0	38 (100)	189
14.	Tetracycline	*Escherichia coli*	78	50 (64.10)	28 (35.90)	190
	Tetracycline	Coagulase +ve *Staph aureus*	38	0	38 (100)	189
	Sub-total	**-**	**116**	**50 (43.10)**	**66 (56.90)**	**-**
15.	Oxytracycline	*Staphylococcus* spp.	10	-	2-3+	33
	Oxytracycline	*Escherichia coli*	10	-	2-3+	33
	Oxytracycline	*Bacillus* spp.	10	-	1-2+	33
	Sub-total	**-**	**30**	**-**	**-**	**-**

Table 18. Antibiotic sensitivity and resistance status of bacteria isolated from milk samples of mastitis affected goats (Contd.)

SN	Antibiotics	Bacterial pathogens	Total No. tested	Resistant No. (%)	Sensitive No. (%)	Ref. No.
16.	Doxycycline	*Escherichia coli*	10	-	1+	33
	Doxycycline	*Staphylococcus* spp.	10	R	1+	33
	Doxycycline	*Bacillus* spp.	10	-	1-2+	33
	Sub-total	**-**	**30**	**-**	**-**	**-**
17.	Cefotaxime	*Escherichia coli*	78	47 (60.26)	31 (39.74)	190
	Ceftriaxone	*Escherichia coli*	78	39 (50.00)	39 (50.00)	190
	Sub-total	**-**	**156**	**86 (55.13)**	**70 (44.87)**	
18.	Colistin	*Escherichia coli*	08	02 (25.00)	06 (75.00)	191
19.	SXT	*Escherichia coli*	78	41 + 21	16 (20.51)	190

ACA= Amoxicillin-clavulanic acid SXT = Trimethoprim-sulfamethoxazole R = Resistant - = Not mentioned

The AST of 10 isolates of *Staphylococcus* spp., 96 isolates of *E. coli*, 10 isolates of *Bacillus* spp. and 38 isolates of coagulase positive *Staphylococcus aureus* isolated from milk samples of mastitis affected goats have been tested *in vitro* with 19 different antibacterial drugs and their resistant and sensitivity status are presented (Table 18). However, the most of the AST results have been expressed as R (resistant) and sensitivity results as 1+ to 3+ and some have been expressed as percentage (Table 18).

The highest percentage of *Staphylococcus* spp. was found resistance to streptomycin, ampicillin and amoxicillin but sensitive to gentamicin, ciprofloxacin, norfloxacin, erythromycin, chloramphenicol, enrofloxacin and oxytetracycline (Table 18).[33] The coagulase positive *Staphylococcus aureus* has been reported to be highly resistant to penicillin (100%), oxacillin (100%) and vancomycin (21.05%) but highly sensitive to gentamicin, nonfloxacin, levofloxacin and tetracycline (Table 18).[189]

The antibiogram of the isolated *E. coli* from SCM affected goats showed highly resistant to streptomycin (75.64%),[33,190] ampicillin (91.03%),[190] amoxicillin (100%)[191] and ciprofloxacin (100%)[191] but varied with gentamicin (53.85%,[190] 25.0%[191] & 0.0%)[33] whereas sensitive to gentamicin (2-3+),[33] erythromycin (2-3+),[33] enrofloxacin (1-2+),[33] oxytetracycline (2-3+)[33] and colistin (75%).[191]

The AST of the isolates of *Bacillus* spp. showed resistant to streptomycin, ampicillin, amoxicillin, erythromycin but sensitive to gentamycin (2-3+), ciprofloxacin (2-3+), chloramphenicol (2-3+), enrofloxacin (2-3+), oxytetracycline (1-2+) and doxycycline (1-2+).[33] The antibiotic resistance of *Bacillus* spp. isolated from milk samples reported to be 100% resistance to methicillin, followed by penicillin G (91.40%), oxacillin (80.54%), cefixime (54.75%), ampicillin (50.67%), streptomycin (28.50%), erythromycin (20.36%), norfloxacin (13.12%), gentamicin (12.21%), tetracycline (7.69%), chloramphenicol (6.33%), ciprofloxacin (4.07%) but all isolates reported susceptible to vancomycin.[193]

Isolation and identification of mastitis bacterial pathogens and their antimicrobial susceptibility is required when selecting appropriate antibiotics for treatment. The antibiogram profile of different bacterial isolates indicates that enrofloxacin, norfloxacin, ciprofloxacin and gentamicin proved to be the most effective antibacterials against mastitis causing bacteria in different studies (Table 16-18).[20] Penicillin, streptomycin, others have been reported mostly resistant antibiotics against bacterial isolates, which might be due to indiscriminate and frequent use of these antibiotics in dairy animals leading to development of antibiotic resistance.

Knowledge of types and characteristics of pathogens, minimum inhibitory concentration (MIC) of antimicrobials and drug resistance are having paramount importance and having aided values in the treatment of mastitis. Beside the consideration of pharmacokinetic alone, the relationship of pharmacokinetic / pharmacodynamics of antimicrobial drugs resolve the solution of selection and application of antimicrobial agents used for rational treatment of mastitis on basis of pharmaco-therapeutic knowledge.

Many cases are bacteriologically negative when detected and will not benefit from antibiotic therapy. Other cases are caused by bacteria that cannot be expected to benefit from antibiotic therapy. Antibiotic treatments should be reserved for cases that will benefit. Research evidence is available to help guide mastitis treatment decisions and to better select animals that will benefit from specific treatment.[194]

Mastitis remains a disease causing the biggest economic losses to the dairy industry, and the success of mastitis therapy is dependent upon the selection of appropriate antimicrobial therapies. Therefore, periodic surveillance of the antibiotic susceptibilities of pathogenic bacteria isolated from milk of dairy animals with clinical mastitis as well as molecular characterization of resistance would be an important measure in detecting emergence and spreading resistance.

A number of bacteria isolated from milk samples of mastitis affected animals were found to be multi-drug resistant. Gentamicin and ciprofloxacin showed high efficacy against the tested organisms and were recommended for the treatment of mastitis while penicillin is of no value for the treatment of the disease.

The antibiogram reports on isolated bacteria from milk samples of mastitis affected goats are limited in comparison to bovine mastitis in Bangladesh (Table 16-18). However, the results on antibiogram findings of the bacteria isolated from milk samples of goats supports the 61.11% sensitivity to gentamicin, 55.55% enrofloxacin and 44.44% ampicillin against isolated bacteria from milk samples of goats in India.[47] The ciprofloxacin and ceftriaxone reported to be the first choice antibiotics, whereas cefotaxime and azithromycin suggested as the second choice of antibiotic based on in vitro antibiogram study.[195]

The resistance pattern of bacterial pathogens to penicillin, and others may be attributed to the extensive and often injudicious use in treating mastitis in farm animals. Antibiotic sensitivity patterns showed a relatively high level of resistance to ampicillin, amoxicillin and streptomycin, whereas gentamicin and ciprofloxacin have been reported as most effective antibiotics against the major prevalent mastitis pathogens of caprine mastitis.[33] The *Staphylococcus aureus* and *E. coli* isolated from milk samples of does affected with SCM showed highly sensitive to gentamicin both *in vitro* and *in vivo* treatment in Bangladesh.[114]

Widespread use of antibiotics is thought to have made evolutionary changes in bacteria that allow them to survive these powerful drugs. With many of the antibiotics already being used in bovine mastitis are also used in human medicine and with the way antibiotic resistant bacteria can easily transfer their resistance traits to unrelated bacteria once inside the human body, this can be major problem we have to face in the near future.[196]

There is an urgent need for rapid and decentralized diagnostics including microbial sensitivity testing facilities to reduce the misuse of antibiotics. It is important to identify the etiological pathogens of mastitis, to identify the antimicrobial resistances in bacteria and to find out which antimicrobial agent should be used for the cure. Thereby the unnecessary use of antibiotics could be minimized and the spread of antibiotic resistance better controlled.

Prevention and control of mastitis

Mastitis is a worldwide distributed multifactorial disease in animals, caused by ubiquity prevalent of wide range of microorganisms, make difficult to control and impossible to complete eradication. Therefore, optimum prevention and control lies in first understanding the causal agents and epidemiology of the disease and then implementing an integrated control strategy. The main principle of mastitis control is to prevent new IMI, for which management and control of risk factors associated with mastitis and their specific pathogens are required.

Mastitis caused by contagious pathogens are mainly prevented through improvements in milking hygiene, use of post-milking teat disinfection, dry-cow therapy (DCT), treatment, well-maintained milking equipment, isolation and persistently chronically infected cows should be culled. Cows with contagious mastitis should be milked last or a separate milking claw used for infected animals. The milker's hand should be properly washed, dried and cleaned so that chances of spread of infection can be minimized.

Environmental mastitic pathogens are primarily prevented by improvement in barn or pasture hygiene and general optimization of the cows' immune system.[197] However, the environmental pathogens are more difficult to control than contagious pathogens. Most of the environmental pathogens are resistant to germicides in teat dips and antibiotics in dry cow therapy.

New additions to the herd should be cultured for bacterial infection. The teat canal remains open up to 2 to 3 hours after milking to resume its normal confirmation. This is the reason for providing feed and water immediately after milking to encourage animals to remain standing and the reason for having freshly cleaned and bedded stall when the cows do lie down. However, proper ventilation and good sanitation at the farm building is necessary to decrease the exposure of pathogens to the mammary gland. Calf sucking practiced from the dam udder may cause the pathogens to get entry into the teat. Therefore, calf suckling must be avoided at all costs in dairy animals.

Dry cow therapy has shown effective results in eliminating the existing intramammary infections and preventing the occurrence of new intramammary infections; hence plays a vital role in the mastitis control program. This therapy includes udder infusion of intra-mammary antibiotics during the dry period.[198] The dung and urine should be removed immediately, as these are constant source of infection at the farm.

Recently, the National Mastitis Council[199] of USA and Canada suggested 10 points for mastitis control which include: ① Establishment of goals for udder health, ② Maintenance of a clean, dry and comfortable environment, ③ Proper milking procedures, ④ Proper maintenance and use of milking equipment, ⑤ Good record keeping, ⑥ Appropriate management of clinical mastitis during lactation, ⑦ Effective dry cow management, ⑧ Maintenance of biosecurity for contagious pathogens and culling of incurable and chronically infected cows, ⑨ Regular monitoring of udder health status, and ⑩ Periodic review of the mastitis control program.

A technology package of mastitis control in large ruminants has been adopted recently in Nepal consisting of (a) developing good husbandry practices, implementing mastitis detection and control technologies, (b) training technicians and farmers with feedback system. Six months after implementation, the prevalence of SCM decreased from 55% to 28% in cows and 78% to 18% in buffalo cows.[200]

Udder health control program (UHCP) have been established in developed countries as an effective strategy for mastitis control but have not yet been introduced in low-income countries like Bangladesh with hand milking and stall feeding due to lack of pasture land.[12]

A study has been conducted on farmers' knowledge, attitude and practices of mastitis in dairy cows in Bangladesh showed that 46.15% farmers had knowledge of microorganisms are the cause of mastitis, 20% farmers reported that mastitis is caused by injury and 27.69% farmers don't know the causes of mastitis. Most of the farmers considered unhygienic floor might be the cause of mastitis, whereas others have clear conception about the mastitis causes. Only 23.10% farmers wash the whole udder before milking and 58.5% farmers used single towel. About 76.9% farmers have no knowledge of screening mastitis and only 9.2% farmers practiced regular mastitis screening. Approximately, 55.4% farmers are used antiseptic solution during cleaning the floor whereas other farmers clean the floor of animal houses only by water.[201] The scarcity of feed combined with insufficient knowledge, attitude and practices in dairy industry are important determinants of animal health and mastitis are the major constraints in the dairy industry in Bangladesh.

The antibiotic resistance has been attributed to the overuse, misuse with inappropriate prescribing antibiotics and extensive agricultural uses, as well as a lack of new antibacterial drug development made the crisis in both the medical and veterinary medical field all over the world. Antibiotics are widely used as growth supplements in livestock in both the developed and developing world. An estimated 80% of antibiotics sold in the United States are used in animals, primarily to promote growth and to prevent infection.[202] The antibiotics used in livestock are ingested by humans when they consume protein food from animal sources.

Public health importance of milk borne diseases

Milk ranks among other foods and is considered as the most perfect food for human from birth to senility as it is not has good sensory properties and all nutrients required for the body for rapid growth but also could prevent or reduce risks of many nutritional deficiency diseases.

Milk and milk products can harbor a variety of microorganisms of food borne pathogens in milk may be due to direct contact with contaminated sources in the dairy farm environment, milkers and handlers and to excretion from the udder of an infected animal. The common sources include: (a) animal feces, (b) mastitis affected lactating animals, (c) animals affected with systemic diseases like tuberculosis, brucellosis, (d) bacteria source from animal skin and udder, (e) environment like feces, dirt, dairy equipment, (f) vectors includes insects, rodent,

(g) unhygienic conditions of milk processing plant and (h) contamination from dairy workers including dirty clothing, towel, boots and others.[203]

Raw milk should be considered as a vehicle for the transmission of potentially pathogenic bacteria. Milk may serve not only as a potential vehicle of transmission of pathogens but it can also allow these pathogens to grow, multiply and produce certain toxic metabolites (toxins) of public health importance.

Raw milk can carry human pathogens that are associated with the highest risk of foodborne disease. The most commonly encountered milk borne pathogens includes: (a) Infections of animals transmitted to humans- brucellosis, tuberculosis, streptococcal and staphylococcal infections, salmonellosis, Q fever, anthrax, leptospirosis and others, (b) Infection due to ingestion of milk contaminated with excreta of small mammals includes *Campylobacter jejuni*, *Yersinia entercolitica*, and (c) Infections primarily of humans transmitted through milk which include *Salmonella typhi*, Paratyphoid bacilli, *Cholera vibrio*, Shigella, *E. coli*, streptococcal and staphylococcal infections, tuberculosis, hepatitis virus and diphtheria bacilli. *Staph. aureus* can cause different infectious diseases in humans like skin and soft tissue infections, endocarditis, osteomyelitis, bacteremia and lethal pneumonia.[204] It is usually considered that the pasteurized milk and milk products are safe for human consumption but it is not always safe for human consumption due to contamination after pasteurization.[205]

Bacteriological evaluation of pasteurized milk samples in five commercial brands of marketed milk in Bangladesh showed that all the brands of pasteurized milk contained a high level of bacteria (SPC cfu / ml $\times$ 10^4) which include Milk vita (5.4), Tatka (5.3), Farm Fresh (6.3), Aarong (6.4) and RD Milk (6.8). The reasons for high bacterial count in pasteurized milk might be due to defective pasteurization machinery, surviving of organisms and post-pasteurized contamination due to poor processing and handling conditions and/or poor hygienic practices by the workers.[205]

People can get very sick or even causes death due to consumption of pathogen contaminated raw milk. Not only the contaminated raw milk but also raw milk products including soft cheese, ice cream and yogurt cause the milk borne disease in humans. However, the infants and young children, older adults, pregnant women and people with weakened immune system (e.g. cancer, AID, organ transplant etc.) are at high risk of these milk borne diseases.

Antibiotics have long been used as a first line of defense against mastitis, where antibiotic residues occur in the milk and there is a risk that microbial resistance will spread to the environment. The existence and multiplication of multiple antibiotic-resistance (MAR) bacteria, which is pressing public health concern for animal and human health, food security and development. The mastitis causing bacteria have broken through a number of hierarchical barriers, allowing for zoonotic transmission from animals to people via milk and meat and thus putting public health at risk.

The *E. coli* isolated from full cream powder milk showed resistant to nalidixic acid (85%), cefuroxime (79%), ceftriaxone (55%), ampicillin (83%) and erythromycin (88%), whereas *Staph. aureus* reported resistant to nalidixic acid (67%), cefuroxime (58%), cefixime (48%) ceftriazone (47%), ampicillin (72%) and erythromycin.[206] *E. coli* isolated from raw market milk showed resistant to amoxycillin 86.67%) and erythromycin (73.33%).[207] The methicillin-resistant Staphylococcus aureus in raw milk and cheese samples have been reported.[208]

The transfer of resistant bacteria to humans by farm animals was first noted more than 35 years ago, when high rates of antibiotic resistance were found in the intestinal flora of both farm animals and farmers.[202] Molecular detection methods have demonstrated that resistant bacteria in farm animals reach consumers through products of animal source of proteins. This occurs through the following sequence of events: (a) antibiotic use in food-producing animals kills or suppress susceptible bacteria, allowing antibiotic-resistant bacteria to thrive, (b) resistant bacteria are transmitted to humans through the food supply and (c) these bacteria can cause infections in humans that may lead to adverse health consequences.[202]

Staphylococcus aureus is a major opportunistic pathogen in humans and one of the most important pathogenic Staphylococcus species in veterinary medicine. *S. aureus* is dangerous because of its deleterious effects on animal health and its potential for transmission from animals to humans and vice-versa. It thus has a huge impact on animal health and welfare and causes major economic losses in livestock production. Presence of *E. coli* and *Staphylococcus* spp. in milk and milk products are of public health concern therefore, monitoring of the market milk both raw and pasteurized would be required to meet the minimum legal standards and overall hygienic condition of milk production and handling[209]

Prevention of milk borne diseases

It is essential to keep dairy lactating animals healthy and good hygienic management of the cow sheds, disposal of manure, health and hygiene of workers and pasteurization of milk are the methods used to prevent and control the milk borne diseases. Pasteurization largely eliminates the milk borne infections. However, contamination may also occur after pasteurization.[210] Veterinary medical extension services are required on the safety and health issues related to raw milk hazards, efforts to improve dairy farmer's awareness, risk factors associated with milk borne pathogens and efficient cleaning of all milk utensils and equipment.

DISCUSSION

Although a review report on the SCM in cattle and goats has recently been published from Bangladesh with limited period of studies from 2005 to 2020 with some incomplete references,[11] but this review reports has been compiled with all the aspects on mastitis (both SCM & CM) in domestic lactating ruminant species published in journals during the period from 1967 to 2022. This report will serve as compiled baseline information at one place for veterinary medical researchers and practitioners and appropriate stakeholders working in inland and elsewhere. The number of research reports on the prevalence of SCM is found comparatively more than the reports on the prevalence of CM and necessitates the importance of SCM in dairy industry. This might be due to fact that the SCM is not grossly detectable in milk and requires diagnostic test to detect early detection of SCM in lactating animals.

There is wide variations on the species-wise prevalence of SCM in literatures, higher prevalence in buffaloes (45%) than cattle in India,[7] whereas higher in cattle (36 & 33%) than buffaloes (27% & 8%) in Pakistan[67] and Bangladesh,[211] respectively. However, the variations of the prevalence of SCM might be due to differences in management practices, diagnostic methods, breeds of animals, immune response and climatic conditions.[212]

Mastitis has mainly been categorized into two forms, clinical mastitis (CM) and sub-clinical mastitis (SCM). The CM is usually diagnosed on clinical examination of inflamed udder (swollen, hot, red and pain) and abnormalities of milk secretions, whereas the SCM is diagnosed mainly based on indirect tests (CMT, WST, SFMT). The Somatic cell count (SCC) and Bulk Tank SCC (BTSCC) are used for early mastitis detection and detection of SCM or chronic mastitis, respectively. The indirect screening tests have been evaluated in all the species of dairy lactating animals. The sensitivity of the CMT, WST, SFMT and SCC have been report as 65.8, 57.9, 51.0 and 82.5%; specificity 76.2, 72.4, 69.5 and 89.4%; percentage accuracy 70.0, 64.8, 59.9 and 85.2%; positive predictive value 75.2, 69.8, 64.9 and 92.7%, respectively. The categories of CMT reactions are strongly correlated with SCC and kappa value of SCC reported higher than that of other tests.[110] The culture based isolation and identification based diagnosis require detecting the specific causal microbial agents. The PCR technology along with its various versions like multiplex and RT-PCR has improved the rapidity and sensitivity of specific diagnosis.[24]

Univariate analysis of the potential risk factors has depicted that mastitis was more prevalent in animals with increased party, poor body conditions, increased milk production, late lactation stage and long teat. Lactating cows with a history of peri-parturient disease reported comparatively higher prevalence of mastitis (86.7%) than cows affected with mastitis (39.4%) without any history of peri-parturient disorders and disease. Cows that are affected with peri-parturient disorders become more susceptible to udder infection due to lowered immunity.[106] Cows affected with milk fever during peri-parturient period causes decreased blood calcium levels which decreases the rigidity of the teat sphincter that perhaps allows the pathogens to pass into the udder. In addition, cows having infected uterine discharge and retained placenta risk the udder and teats being contaminated.[106]

Early diagnosis of mastitis is vital because changes in the udder tissue take place much earlier before they become apparent. If detected early, antibiotic therapy is very effective in curing and controlling the spread of contagious pathogens. However, the uses of antimicrobials have increased the number of antimicrobial resistant microbes globally including Bangladesh, mostly due indiscriminate use of antimicrobials with wrong dose, drug or duration without improving the outcome of treatment. Although the intra-mammary antibiotics are indiscriminately used in the treatment of CM cases in lactating dairy animals for therapeutics purposes but there is a scope to utilize it as a dry cow therapy for prophylaxis of mastitis in Bangladesh. The restriction of introduction of newly purchase animals, improvement of milking hygiene, implementation of pre- and post- teat dips, regular control and disinfection of milking equipment, implementation of milking order (healthy then infected), good housing management including bedding materials, culling of chronically-infected cows and effective dairy cattle nutrition to promote good cow health are the general measures to prevent new cases of mastitis. The possibilities of use the vaccines and disease resistant cattle could also help to prevent bovine mastitis. This review describes the progress on mastitis research especially on etiology, epidemiology and diagnosis during the period from 1967 to 2022, where there is changing the dairy herd structure, the research on the control aspect of mastitis remain an important subject focus of future research in Bangladesh and elsewhere.

This review on bovine and caprine mastitis in Bangladesh concluded that the SCM is associated with age, parity, lactation period and environmental factors of dairy animals whereas the CM is more associated with dairy breeds and environmental management factors.

Mastitis has been recognized as one of the most important complex multifactorial disease associated with more than 17 bacterial pathogens, some of which exhibited multidrug resistance in dairy industry in Bangladesh. Therefore, there is a need to provide veterinary medical extension services to the smallholder and commercial dairy farm owners on the risk factors of mastitis with the aim of reducing the incidence of mastitis in Bangladesh.

The host and management related factors reported in mastitis in dairy ruminant animals stall feeding, overcrowding, cracked floors, open drains, presence of flies, poor drainage, peri-parturient diseases, infrequent dung removal and earth floors. The control measures suggested in the reviewed reports were to improve the hygiene and sanitation of cows to improve the cleanliness of dairy farms and milker's hands, to apply dry cow therapy, supplementing micronutrients and routine screening for SCM and suggested for isolation of cows or milking infected cows last and proper treatment. In milking, machine milking and providing feed and water immediately after milking. It appears from this review that the associated risk factors have been assessed in dairy ruminant animals with some recommendations for control of mastitis in dairy animals in Bangladesh. However, research works on UHCP program with veterinary medical extension services would be required for the control of mastitis in dairy animals in Bangladesh.

Miscellaneous reports on mastitis in farm animals in Bangladesh

Prevalence of mastitis in dairy cows,[213,214] prevalence and associated risk factors of bovine mastitis,[215] bacterial population and their morphological identification in milk samples of cows,[216] isolation and characterization of *Staphylococcus aureus* from raw milk[217] and mastitic milk[218] molecular characterization of *Staphylococcus aureus* collected from milk of bovine mastitis,[219] epidemiology of SCM in dairy cows,[220] management condition of private dairy farms,[221] small scale dairy farming practice,[222] characterization of pathogenic bacteria from raw and pasteurized milk[223] incidence of clinical mastitis in Black Bengal goats,[224] detection of mastitis causing bacteria and their susceptibility to various antibiotics,[225] reverin in the treatment of mastitis in cows, buffaloes and goats,[226] mastitis in goats and its treatments with leukomycin,[227] microorganisms causing mastitis in dairy cows and their response to chemotherapeutic agents[228] and surgical management of unilateral gangrenous mastitis in a doe[229] have been reported from Bangladesh.

Conclusions and Recommendations

The findings of this review reveal that mastitis is widely prevalent in lactating dairy animals in both the smallholder managed and organized dairy farms animals in Bangladesh and several necessary and sufficient causes are identified with clinical and sub-clinical mastitis in animals of Bangladesh. The overall animal level and quarter/ halve level prevalence of mastitis signify the effect of mastitis in diary industry in Bangladesh.

This review recorded that the mastitis is one of the major constraint of dairy lactating animals in Bangladesh due to its high prevalence and economic impact. The SCM is the most prevalent in comparison to CM in dairy animals. It is necessary to detect all the mastitis infected animals rapidly and need to isolate from the non-infected animals and proper milking management and other preventive measures are used to minimize the spread of infection. Culling of the drug resistant chronically affected animals, screening of milk for mastitis, dry cow therapy, hygiene at milking and husbandry system should be considered for the prevention of mastitis. Moreover, veterinary medical extension services and training programs aiming at creation of awareness about the importance and prevention of SCM among small holder dairy farmers. For early detection of SCM any indirect screening test (e.g. CMT) can be used on a regular basis to control the disease.

This review indicates that a higher prevalence of mastitis linked with several factors. Thus, early diagnosis and regular screening of cows for SCM together with proper therapeutic management of clinical cases are of paramount importance. The first month of lactation, high SCC, rainy season and history of clinical mastitis cases have been reported as factors associated with CM for both primiparous and multiparous cows in elsewhere.

Treatment is an important aspect of mastitis control but implementation of management practices that reduce transmission of pathogens are always more cost effective. SCM is prevalent in lactating animals in Bangladesh, which is associated with animal, environmental and pathogen risk factors. Therefore, careful management of the identified risk factors with improved sanitation in implementing preventive programs to reduce the incidence of mastitis.

The high prevalence rate of mastitis (especially SCM) in dairy lactating cows and goats in Bangladesh is attributed to lack of implementation of the routine mastitis prevention and control practices. The findings of this review warrants the need for strategic approach including dairy extension that focus on enhancing dairy farmers' awareness and practice for SCM, dry-cow therapy and culling of chronically infected cows.

This review of inland published reports on mastitis recognized the unhygienic management and the environment are the main risk factors for high prevalence of mastitis in lactating animals in Bangladesh and therefore, it is recommended to maintain hygienic management of dairy lactating animals for the prevention and control of mastitis in Bangladesh. Therefore this review on inland literature on mastitis in dairy animals warrants the need for applying feasible mastitis intervention strategy which includes strong dairy veterinary extension service that focused on awareness creation and hygienic milking practice. Besides, the animal health service delivery need to focus on regular screening of dairy cows for SCM and treating of the cases both in lactation and dry period, and provision of advice to cull chronically infected animals. Based on the review of the published reports on mastitis in dairy lactating animals the following recommendations are forwarded: ① Adequate housing and general sanitary condition of farms should be improved and maintained, ② The farmers should ensure strict personal hygiene and that of animals and working equipment, ③ Regular screening for early detection of IMI and effective treatment should be implemented all across the country and ④ The government and stakeholders should have to give special emphasis and new strategy for the prevention and control of mastitis.

Control and prevention strategies should be designed and implemented with great emphasis given to risk factors to reduce mastitis and its impact on milk production and food security. The risk factors identified in this review can be used in intra-mammary infection control programs to reduce the frequency of SCM and CM in dairy lactating animals. Methicillin-resistant *Staphylococcus aureus* (MRSA) have created a huge clinical burden in the hospital as well as in the community in both human and veterinary medicine in Bangladesh. Raw milk and raw milk products, particularly those are unpasteurized are potentially hazardous, even pasteurized milk products, because contamination may occur after pasteurization. Therefore, unpasteurized milk and milk products should be avoided for consumption. Anti-microbial resistance (AMR) is a multi-dimensional problem involving different sectors, disciplines and stakeholders requiring a 'One Health' comprehensive approach for containment.

ETHICAL APPROVAL

This review does not contain any research studies with animals or human participants performed by the author and therefore, ethical approval is not required for this review article.

CONFLICT OF INTEREST

The author declares that the review work was conducted in the absence of any commercial or financial relationships that could be constructed as a potential conflict of interest.

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