Research in
ISSN : P-2409-0603, E-2409-9325
AGRICULTURE, LIVESTOCK and FISHERIES
An Open Access Peer-Reviewed International Journal

Article Code: 541/2026/RALF
Article Type: Review Article

Res. Agric. Livest. Fish.
Vol. 13, No. 2, August 2026: 309-340.

Bovine Mastitis in Bangladesh: Epidemiology, Etiology, Diagnosis, Antimicrobial Resistance and Sustainable Management Strategies

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ARTICLE INFO

Received
20 July 2026

Revised
18 August 2026

Accepted
31 August 2026

Key words:

Bovine mastitis
Dairy cattle
Dairy farming
Udder health
Milk quality
Somatic cell count
AMR
Bangladesh

ABSTRACT

Bovine mastitis is a major health, welfare, milk-quality, and economic constraint on dairy production in Bangladesh. It occurs as clinical mastitis, characterized by visible udder or milk abnormalities, and as subclinical mastitis (SCM), which causes inflammation and loss of production without obvious signs. Bangladesh studies report widely varying cow-level SCM prevalence, generally 20-60%, reflecting differences in production systems, regions, breeds, seasons, management, sampling, diagnostic tests, somatic cell count thresholds, and case definitions. Recent large-herd evidence found similarly high SCM prevalence in extensive and intensive systems, while yield and economic losses were greater during non-bathan confinement. Frequently reported risk factors include crossbreeding or high milk yield, increasing parity, late lactation, previous mastitis, poor body condition, udder or teat lesions, contaminated floors, inadequate drainage, unhygienic hand milking, common towels, failure to dry teats, absence of post-milking teat disinfection, and limited farmer awareness. Major pathogens include *Staphylococcus aureus*, non-aureus staphylococci, *Streptococcus* spp., *Escherichia coli*, and *Klebsiella* spp. Molecular studies have also identified multidrug resistance, methicillin resistance, beta-lactamases, virulence and biofilm genes, and mobile genetic elements in established and emerging mastitis pathogens, emphasizing their One Health importance. Sustainable control requires integrated udder health management rather than repeated empirical antimicrobial treatments. Priorities include routine screening, quantitative somatic cell monitoring, aseptic culture of persistent or recurrent cases, hygienic milking, individual teat drying, post-milking teat disinfection, clean and well-drained housing, appropriate nutrition, selective dry-period management, treatment records, and antimicrobial stewardship. Bangladesh also needs standardized case definitions, regional diagnostic services, competency-based farmer training, quality-based milk payments, residue monitoring, and coordinated surveillance of pathogens and antimicrobial resistance. This review synthesizes evidence from Bangladesh and proposes a phased, smallholder-compatible strategy to improve udder health, milk safety, animal welfare, and the sustainability of the dairy sector.

To cite this article: Islam M. A., 2026. Bovine Mastitis in Bangladesh: Epidemiology, Etiology, Diagnosis, Antimicrobial Resistance and Sustainable Management Strategies. Res. Agric. Livest. Fish. 13(2): 309-340.

DOI: https://doi.org/10.3329/ralf.v13i2.93307

www.agroaid-bd.org/ralf, E-mail: editor.ralf@gmail.com

1. Introduction

Dairy cattle contribute to household nutrition, income generation, employment, and agricultural intensification in Bangladesh. The sector includes backyard households, smallholder farms, cooperative milkshed systems, and an expanding number of commercial dairy units. Hand milking remains common, and cows are frequently maintained on concrete, brick, or earthen floors without dedicated bedding. Water supply, drainage, manure removal, fodder availability, veterinary access, milk cooling, and record keeping vary markedly among farms. These structural features create conditions in which udder infection can persist unnoticed, and control measures must be practical, low-cost, and compatible with smallholder labor and resources (Rahman et al., 2018; Shanta et al., 2020; Samad, 2022).

Mastitis is inflammation of the mammary gland and is most commonly associated with intramammary infection. Clinical mastitis is recognized by clots, flakes, watery milk, udder swelling, heat, pain, or systemic illness. Subclinical mastitis is more difficult to identify because the udder and milk appear normal despite increased somatic cells, microbial shedding, reduced milk synthesis, and altered milk composition. A cow with SCM may therefore remain in the milking group for weeks or months and act as a reservoir of contagious pathogens (Bradley, 2002; Ruegg, 2017; Sordillo, 2018). The consequences extend beyond visible treatment costs. Mastitis reduces saleable milk, compromises fat, protein, and lactose content, and processing quality, increases discarded milk and labor, contributes to premature culling, and may impair fertility. Persistent mammary inflammation is also a welfare issue. Resistant organisms and antimicrobial residues in the milk chain connect udder health with food safety and One Health (Kader et al., 2003; Khokon et al., 2017; Mia et al., 2025; Morales-Ubaldo et al., 2023).

Bangladesh research has progressed from early prevalence and economic surveys to comparisons of field screening tests, somatic cell thresholds, prospective clinical-mastitis cohorts, metagenomics, resistome analysis, whole-genome sequencing, and studies of pathogen virulence and antimicrobial resistance (Prodhan et al., 1996; Kader et al., 2002, 2003; Badiuzzaman et al., 2015; Hoque et al., 2018, 2019; Singha et al., 2021; Siddique et al., 2025). Nevertheless, the findings remain fragmented across districts and journals, and a coordinated national udder-health program has not yet emerged. The objectives of this article are to synthesize the available evidence on bovine mastitis in Bangladesh; describe its epidemiology, pathogens, diagnostic approaches, risk factors, and consequences; evaluate the antimicrobial-resistance evidence; and propose a sustainable, measurable, and nationally scalable management strategy.

2. Review methodology

A structured narrative review and focused bibliographic update were conducted using PubMed/MEDLINE, PubMed Central, BanglaJOL, journal and publisher websites, DOI and exact-title searches, and reference lists of Bangladesh and South Asian mastitis publications. Search combinations included “mastitis Bangladesh”, “subclinical mastitis dairy cow Bangladesh”, “clinical mastitis Bangladesh”, “somatic cell count Bangladesh”, “California Mastitis Test Bangladesh”, “*Staphylococcus aureus* mastitis Bangladesh”, “Escherichia coli mastitis Bangladesh”, “Streptococcus mastitis Bangladesh”, “Klebsiella mastitis Bangladesh”, “antimicrobial resistance mastitis Bangladesh”, “mastitis microbiome Bangladesh”, “mastitis genome Bangladesh”, and “farmer knowledge mastitis Bangladesh”. The focused update covered publications issued from 1 January 2015 through 31 December 2025. Foundational Bangladesh studies published before 2015 and selected international guidance were retained for context. Searches were last checked on 11 July 2026.

Primary studies involving dairy cattle in Bangladesh were prioritized. Clinical mastitis studies were included because pathogen ecology, antimicrobial susceptibility, treatment practices, and prevention overlap with SCM. Studies were eligible when they reported Bangladesh-specific epidemiology, diagnosis, risk factors, milk quality or economic effects, farmer practices, pathogens, antimicrobial resistance, molecular or genomic findings, or control interventions. Buffalo studies and milk-derived probiotic studies were retained only as complementary evidence where they informed national laboratory capacity, resistance ecology, or alternative-control research; they were not combined with cattle prevalence estimates. Reviews and preprints were identified and clearly distinguished from peer-reviewed primary evidence. Two recent preprints were additionally included because they provide unusually large, herd-clustered datasets on SCM severity, cow-level determinants, and economic loss. Their findings are classified as pre-peer-review evidence and interpreted with caution (Aktaruzzaman et al., 2025, 2026).

A formal meta-analysis was not performed. The Bangladesh studies differed in farm selection, sample size, unit of analysis, breed composition, season, test method, and definition of positivity. Direct pooling would therefore create a misleading summary without access to compatible denominators and study-level variance. Instead, the evidence was organized chronologically and thematically, and repeated findings were used to identify robust priorities for control.

3. Biological basis and classification of bovine mastitis

The teat canal, keratin lining, teat sphincter, resident microbiota, and local immune system form the first barriers against intramammary infection. Pathogens colonize the teat end, penetrate the canal, and multiply in mammary tissue or milk. Recognition of microbial components initiates recruitment of neutrophils and other leukocytes, thereby increasing the milk somatic cell count (SCC). Inflammatory mediators and bacterial toxins disrupt epithelial integrity, reduce lactose and casein synthesis, alter mineral balance, and increase permeability between blood and milk (Bradley, 2002; Sordillo, 2018).

Mastitis can be categorized by clinical expression, duration, and epidemiological source. Clinical cases may be mild (abnormal milk only), moderate (abnormal milk plus udder inflammation), or severe (systemic illness). Subclinical infection is detected through CMT, SCC, bacteriology, or other indicators. Persistent infection is especially important when the same pathogen is repeatedly recovered, or SCC remains elevated over time (National Mastitis Council, 2017; Ruegg, 2017).

4. Development and current extent of mastitis research in Bangladesh

The national evidence base is larger than is often acknowledged. Early studies in Bangladesh milkshed areas established that SCM was common and associated with parity, breed, udder characteristics, and economic loss (Prodhan et al., 1996; Rahman et al., 1997; Kader et al., 2002, 2003; Uddin et al., 2009; Rahman et al., 2009). Later work expanded into district-level risk-factor surveys, test comparisons, pathogen isolation, molecular characterization, farmer knowledge, milk quality, and antimicrobial resistance. Table 2 summarizes major cattle mastitis studies and related works identified for this review. Estimates should be interpreted within each study, as a positive cow was defined differently by CMT, WST, SFMT, electrical conductivity, SCC, or bacteriological culture.

Table 1. Operational categories relevant to Bangladesh dairy farms

Category	Typical finding	Primary detection	Management implication
Clinical mastitis	Visible abnormal milk and/or swollen, painful udder; severe cases may be systemic	Foremilk examination and clinical assessment	Grade severity; sample before treatment when possible; provide supportive care and targeted therapy
Subclinical mastitis	No visible change, but inflammation and often intramammary infection	CMT, SCC, repeated testing, and culture	Identify reservoirs; correct herd-level risk factors; do not automatically treat every positive cow
Contagious pattern	Cow-to-cow spread, usually during milking	Repeated isolation of S. aureus, S. agalactiae or related organisms; high-SCC clusters	Milking hygiene, gloves/handwashing, individual towels, post-dip, infected cows milked last, culling of chronic reservoirs
Environmental pattern	Exposure to manure, water, bedding, or wet floors	Coliforms, environmental streptococci, or mixed farm pattern	Dry resting areas, drainage, manure removal, clean water, and pre-milking teat cleanliness
Chronic/recurrent case	Repeated high SCC or recurring clinical episodes	Cow history, repeat culture, and quarter examination	Assess cure probability, segregation, dry-period plan, or culling

Table 2. Major studies on bovine mastitis and related work were conducted in Bangladesh

Study/year	Area and population	Approach	Principal contribution
Prodhan et al., 1996	Bangladesh milkshed area	Field screening for SCM	Early evidence from Bangladesh that SCM was prevalent and varied with parity.
Rahman et al., 1997	Crossbred and exotic dairy cows	Prevalence/distribution study	Documented mastitis occurrence in improved dairy cattle.
Kader et al., 2002	Milch cows in Bangladesh	SCM screening, culture, and antibiogram	Early integrated evidence on prevalence, etiology, and antimicrobial susceptibility.
Kader et al., 2003	Dairy cows in Bangladesh	Host factors and economic assessment	Linked host determinants with SCM and estimated economic consequences.
Uddin et al., 2009	Bangladesh dairy cows	Udder/teat epidemiology	Associated mastitis with breed, poor condition, teat shape, wounds, and lesions.

Table 2. Major studies on bovine mastitis in Bangladesh (Contd.)

Study/year	Area and population	Approach	Principal contribution
Rahman et al., 2009	Selected dairy farms	CMT-based prevalence and risk factors	Reported substantial mastitis burden and cow-level determinants.
Jha et al., 2010	Bangladesh dairy cows	Prevalence and clinical treatment regimens	Evaluated clinical mastitis and treatment outcomes under field conditions.
Rabbani & Samad, 2010	Holstein-Friesian cross and Red Chittagong cows	CMT and host-factor comparison	Demonstrated breed and host differences in SCM.
Islam et al., 2010	Baghabari milk-shed, Sirajganj; 330 cows	Clinical examination and indirect SCM tests	Reported clinical mastitis around 2% and SCM around one-third; evaluated age, parity, yield, stage, and herd size.
Rahman et al., 2010	Sylhet district	SCM prevalence survey	Added regional evidence from northeastern Bangladesh.
Islam et al., 2011	BAU Dairy Farm and Tangail; 200 cows	CMT, WST, and SFMT	Overall, SCM 29%; test-specific positivity and breed/lactation differences.
Sinha et al., 2011	Selected Bangladesh areas: 389 cows	CMT severity scoring	Reported 42.7% mastitis positivity and differences by breed, age, and parity.
Sarker et al., 2013	212 smallholder farms in Rangpur, Mymensingh, and Satkhira	Random cross-sectional survey and CMT	Cow-level SCM 20.2%; previous mastitis, udder type, body condition, and feeding were important.
Siddiquee et al., 2013	High-yielding crossbred cows	Dramiński mastitis detector	Evaluated electrical-conductivity-based field screening.
Rahman et al., 2013	Mymensingh clinical cases	Bacterial isolation and antibiogram	Characterized bacterial agents from clinical mastitis and susceptibility patterns.
Bari et al., 2016	Patiya, Chattogram	Clinical mastitis prevalence and risks	Provided local clinical-mastitis risk-factor evidence.
Tripura et al., 2014	Mymensingh and Lakshmipur; 139 cows	SCM screening and intramammary therapy	Reported high SCM prevalence and field treatment efficacy.
Kayesh et al., 2014	Barishal district	SCM, bacteria, and risk factors	Linked the SCM occurrence with isolates and management conditions.
Hoque et al., 2015	Chattogram, Sirajganj, Mymensingh, and Gazipur; 228 cows	CMT, WST, SFMT, and SCC	Showed major variation among screening methods and districts.

Table 2. Major studies on bovine mastitis in Bangladesh (Contd.)

Study/year	Area and population	Approach	Principal contribution
Badiuzzaman et al., 2015	111 cows; 444 quarters	Four screening tests compared with culture	SCC had the greatest diagnostic accuracy; CMT was practical for field use.
Hasan et al., 2016	Farm-condition study	SCM screening, culture, and antibiogram	Reported bacterial causes and antimicrobial patterns under farm conditions.
Mia et al., 2016	Nilphamari district	Clinical-mastitis isolates and antibiogram	Identified bacterial species and susceptibility in northern Bangladesh.
Hossain et al., 2016	Keshabpur, Jashore	Farm-level clinical mastitis impact	Examined production and economic impact in small-scale dairy farming.
Biswas & Sarker, 2017	Banaripara, Barishal	Farm survey and CMT	SCM 51.56%; higher in crossbred and third-parity cows.
Kabir et al., 2017	BLRI Regional Station, Sirajganj	CMT and bacterial identification	Characterized SCM and associated bacteria in an institutional herd.
Sumon et al., 2017	Mymensingh; 240 quarter samples	SCC and culture	Quarter SCM about 25%; linked bacterial groups to SCC.
Khokon et al., 2017	Chattogram; 100 cows	CMT/WST and reproductive records	Associated mastitis positivity with delayed heat, calving interval, and services per conception.
Hasan et al., 2018	BAU-adjacent smallholder areas; 365 cows	SCM and socioeconomic survey	Connected farm socioeconomic context, milk production, and udder health.
Rahman et al., 2018	Gazipur and Mymensingh farmers	Knowledge, attitude, and practice survey	Documented limited screening, common towel use, and poor milking hygiene.
Hoque et al., 2018	Multiple Bangladesh dairy areas	Molecular S. aureus characterization	Found extensive resistance, mecA and enterotoxin-associated determinants.
Islam et al., 2019	Urban/peri-urban Chattogram	SCM epidemiology	Added evidence on prevalence and urban dairy risk factors.
Salauddin et al., 2019	Rangpur	Klebsiella isolation and molecular confirmation	Detected multidrug-resistant Klebsiella from bovine mastitis milk.
Arman et al., 2017	Selected Friesian-cross farms; 287 cows	CMT and cow-level risk factors	SCM 41.1%; parity, BCS, milk yield, and lactation stage were associated.

Table 2. Major studies on bovine mastitis in Bangladesh (Contd.)

Study/year	Area and population	Approach	Principal contribution
Bhuiyan et al., 2020	Bijoynagar, Brahmanbaria	CMT-based survey	Provided district-level prevalence and host-factor evidence.
Sayeed et al., 2020	Jhenaidah; 100 cows from 32 farms	SFMT and management questionnaire	Estimated cow-level SCM and identified management-related risks.
Salauddin et al., 2020	Rangpur division; mastitis milk samples	Culture, PCR, and antibiogram	Confirmed multidrug-resistant S. aureus in bovine mastitis milk.
Sumon et al., 2020a	Bangladesh dairy cows	SCC threshold evaluation	Assessed the diagnostic performance of SCC thresholds for SCM.
Sumon et al., 2020b	Bangladesh dairy cows	SCC dynamics and intramammary infection	Quantified effects of infection, bacterial group, and cow factors on SCC.
Bag et al., 2021	Selected Bangladesh dairy farms	Clinical-mastitis E. coli molecular study	Demonstrated virulence genes and antimicrobial resistance in E. coli.
Singha et al., 2021	24 commercial farms, Chattogram; 1,383 cows	Six-month prospective cohort	First major prospective clinical-mastitis incidence study; pathogens, risks, and staphylococcal susceptibility.
Bari et al., 2022	South Asian evidence, including Bangladesh	Structured review	Identified Bangladesh control gaps and prioritized risk-factor and pathogen-based udder-health programs.
Sohidullah et al., 2024	Khulna: 100 cows, 400 quarters	CMT, risk-factor survey, and antibiogram	Cow-level SCM 28%; *E. coli* and Staphylococcus spp. prominent; hygiene and dry-cow practices associated.
Al Emon et al., 2024	Sylhet: 325 cows from 52 herds	Screening, culture, PCR, and resistance genes	High animal- and herd-level SCM; S. aureus, E. coli, and K. pneumoniae with important resistance determinants.
Tanvi et al., 2024	Sylhet: 114 cows from 22 farms	CMT and risk-factor analysis	Cow-level SCM 25.43% and farm-level 31.81%; milk yield and farmer education were associated.
Ara et al., 2024	Chattogram dairy farms	CMT, bacterial isolation, and antibiogram	Reported SCM, *S. aureus/E. coli* isolation and resistance patterns.
Sajib et al., 2024	Selected Bangladesh area	CMT and risk-factor study	Added recent evidence on animal and management determinants.

Table 2. Major studies on bovine mastitis in Bangladesh (Contd.)

Study/year	Area and population	Approach	Principal contribution
Mia et al., 2025	Chattogram and Cox's Bazar; 1,012 cows, 4,048 quarters	CMT, milk quality, and economic assessment	SCM 41.3% at the animal level and 32.3% at the quarter level; documented production, quality, and economic consequences.
Al Farabi et al., 2025	Bangladesh composite milk samples	Molecular Staphylococcus/Streptococcus study	Characterized prevalence, risk factors, and AMR in major Gram-positive mastitis pathogens.
Faruk et al., 2025	Northern Bangladesh; 122 cows from 43 herds	Clinical examination, CMT, culture, and antibiogram	Overall mastitis 35.24%; SCM 27.86%, clinical 7.37%; Staphylococcus spp. predominated.
Anika et al., 2025	Bangladesh dairy cows	SCM screening, E. coli antibiogram, and genomics	Reported resistant E. coli and multiple resistance genes.
Aktaruzzaman et al., 2025, preprint	Sirajganj; 3,174 cows from 76 herds	SCC-based economic modeling	Large economic assessment; should be interpreted as pre-peer-review evidence.
Aktaruzzaman et al., 2026, preprint	Sirajganj; 3,173 lactating cows from 76 herds	SCC classification and Bayesian hierarchical multinomial regression	SCM prevalence was similar in extensive (64.5%) and intensive (63.3%) systems; late lactation and a history of clinical mastitis predicted severity.

The accumulated evidence demonstrates that SCM occurrence is neither uniformly low nor uniformly high. Rather, Bangladesh faces a heterogeneous mastitis problem influenced by production systems, geography, herd selection, and diagnostic approaches. Studies based on a single sensitive cow-side test can classify more cows as positive than studies requiring culture or repeated SCC, and herd-level prevalence is expected to exceed cow-level prevalence because one affected cow makes the herd positive (Badiuzzaman et al., 2015; Hoque et al., 2015; Sumon et al., 2020).

4.1 Bangladesh publication landscape, 2015–2025

The focused search identified a large and increasingly diverse Bangladesh literature published from 2015 through 2025. Studies in the first half of the period were dominated by prevalence surveys, comparisons of CMT, SCC, WST, and SFMT, conventional culture, and antibiograms. From 2018 onward, investigations increasingly addressed mecA, toxin genes, beta-lactamases, multidrug resistance, and farmer hygiene. Between 2019 and 2025, metagenomics, resistome analysis, whole-genome sequencing, experimental microbiota-transfer models, and genomic evaluation of probiotics and bacteriocins substantially broadened the national evidence base.

The bibliography includes Bangladesh-specific peer-reviewed articles and closely related works located and bibliographically verified through the structured search. Cattle studies form the principal evidence base. Complementary buffalo and milk-derived probiotic studies are retained only where they materially inform mastitis ecology, antimicrobial resistance, laboratory development, or sustainable control, and preprints are separated from peer-reviewed publications. Absolute completeness cannot be guaranteed because some local journals, proceedings, theses, and institutional records are incompletely indexed.

Diagnostic comparisons and prevalence studies highlighted the practical value and limitations of on-farm tests and SCC, while regional surveys documented animal- and management-related risks (Badiuzzaman et al., 2015; Hoque et al., 2015; Begum et al., 2015).

Farm and district investigations reported clinical and subclinical mastitis, bacterial etiology, antibiograms, production impact, risk factors, and an adjunct vitamin E-selenium intervention (Hasan et al., 2016; Mia et al., 2016; Hossain et al., 2016; Bari et al., 2016; Hoque et al., 2016).

Research expanded to institutional and milk-shed herds, molecular detection, SCC-bacteria relationships, reproductive consequences, treatment guided by susceptibility, and risk factors in crossbred cows (Kabir et al., 2017a, 2017b; Sumon et al., 2017; Biswas and Sarker, 2017; Khokon et al., 2017; Hossain et al., 2017; Arman et al., 2017).

Studies linked udder health with farm socioeconomic conditions and farmer practices and strengthened molecular evidence for resistant and virulent S. aureus, while additional surveys extended regional coverage to Barishal and Satkhira (Hasan et al., 2018; Rahman et al., 2018; Hoque et al., 2018; Meher et al., 2018; Nahian et al., 2018).

Urban epidemiology, multidrug-resistant Klebsiella, local test-kit development, metagenomic profiling, comparative pathogen resistance, inflammatory responses, and field-test assessment marked a transition from descriptive surveys toward mechanistic and laboratory-focused research (Islam, Barua et al., 2019; Salauddin et al., 2019; Kabir et al., 2019; Hoque et al., 2019; Siddiki et al., 2019; Hossain et al., 2019; Islam, Rume et al., 2019).

District prevalence and risk-factor studies continued, while molecular confirmation of multidrug-resistant S. aureus, SCC-threshold analysis, SCC dynamics, resistome and microbiome studies, and milking-hygiene assessment deepened the evidence base (Bhuiyan et al., 2020; Sayeed et al., 2020; Salauddin et al., 2020; Sumon et al., 2020a, 2020b; Hoque, Istiaq, Clement et al., 2020; Hoque, Istiaq, Rahman et al., 2020; Shanta et al., 2020).

The first major prospective clinical-mastitis cohort in Chattogram quantified incidence, etiology, and risk factors; parallel studies characterized virulent and resistant E. coli, E. coli O157, national prevalence patterns, and complementary buffalo pathogen ecology (Singha, Koop et al., 2021; Bag et al., 2021; Farhad et al., 2021; Hasan, 2021; Singha, Ericsson et al., 2021).

Research addressed peri-urban prevalence, udder lesions, South Asian control priorities, experimental microbiota transfer, treatment trends, buffalo S. aureus resistance, and a long-term Bangladesh perspective (Al-Noman et al., 2022; Hasan et al., 2022; Bari et al., 2022; Hoque, Rahman et al., 2022; Kabir et al., 2022; Hoque, Talukder et al., 2022; Samad, 2022).

Molecular work resolved Staphylococcus and Streptococcus species, virulence genes, resistance profiles, and genome sequences of mastitis-associated E. coli and K. pneumoniae (Fazal et al., 2023; Hassan et al., 2023; Farzana et al., 2023; Hoque, Fazal et al., 2023; Rahman et al., 2023; Hoque, Faisal et al., 2023).

Large regional surveys and hygiene studies were accompanied by extensive pathogen, resistance, environmental, experimental, and draft-genome investigations involving S. aureus, E. coli, K. pneumoniae, streptococci, enterococci, Staphylococcus warneri, Pseudomonas putida, P. asiatica, Pediococcus, and candidate probiotic strains (Al Emon et al., 2024; Sohidullah et al., 2024; Islam et al., 2024; Sajib et al., 2024; Tanvi et al., 2024; Ara et al., 2024; Hoque, Rahman et al., 2024; Anika et al., 2024; Akter et al., 2024; Hoque, Faisal, Jerin et al., 2024; Hoque, Faisal, Das et al., 2024; Rahaman et al., 2024; Mallick et al., 2024; Sultana et al., 2024; Rahman, El Zowalaty et al., 2024; Rahman, Siddique, Akter et al., 2024; Rahman, Siddique, Rahman et al., 2024; Siddique et al., 2024).

Recent work quantified production and economic consequences, updated prevalence and resistance patterns, reviewed national control, and delivered genomic or functional evidence for multidrug-resistant S. aureus, E. coli, Klebsiella, Pseudomonas, Enterobacter, streptococci, and potential probiotic or bacteriocin-based alternatives (Mia et al., 2025; Faruk et al., 2025; Al Farabi et al., 2025; Anika et al., 2025; Ara et al., 2025; Chowdhury et al., 2025; Ali et al., 2025; Islam, Hossain et al., 2025; Siddique, Arafat et al., 2025; Mallick et al., 2025; Hasnat et al., 2025; Sultana et al., 2025; Rahman, Siddique, Arafat, Homa et al., 2025; Rahman, Siddique, Arafat, Das et al., 2025; Islam, Rahman et al., 2025; Rahman, Siddique, Gilman et al., 2025; Siddique, Rahman et al., 2025). A large Sirajganj preprint separated SCC-defined SCM into mild and severe categories and used Bayesian hierarchical multinomial regression to compare intensive and extensive systems while accounting for herd clustering. It extended the Bangladesh evidence base from binary SCM classification toward severity-specific, cow-level risk estimation (Aktaruzzaman et al., 2026).

5. Epidemiology of bovine mastitis in Bangladesh

5.1 Reported prevalence and heterogeneity

Published cow-level estimates of SCM commonly range from approximately 20% to more than 60%. Islam et al. (2011) reported an overall prevalence of 29% using three indirect tests, whereas Sarker et al. (2013) reported a prevalence of 20.2% across randomly selected smallholder farms in three geographically separated districts. Higher estimates were reported in Banaripara, selected farms in Chattogram, Rajshahi-Rangpur, and some Sylhet populations (Begum et al., 2015; Biswas and Sarker, 2017; Arman et al., 2017; Al Emon et al., 2024). Recent studies reported cow-level SCM near 25-28% in Sylhet, Khulna, and northern Bangladesh, whereas the Chattogram hill-tract investigation reported 41.3% (Tanvi et al., 2024; Sohidullah et al., 2024; Faruk et al., 2025; Mia et al., 2025). This range should not be presented as a single national prevalence. Many studies used convenience or purposive farm selection, and test characteristics varied. CMT detects inflammation rather than a specific pathogen; WST and SFMT have variable interpretation; electrical-conductivity devices are influenced by milk and cow factors; SCC thresholds ranged across studies; and culture may be negative when pathogen shedding is intermittent or antimicrobial treatment preceded sampling (Badiuzzaman et al., 2015; Hoque et al., 2015; Sumon et al., 2020a, 2020b).

In a two-stage cross-sectional survey conducted during 2023-2024, Aktaruzzaman et al. (2026) enrolled 3,173 lactating cows from 76 herds and classified SCC-defined SCM by severity. Cow-level prevalence was high but did not differ significantly between extensive (64.5%) and intensive (63.3%) systems. This near-equivalence indicates that the broad production-system label alone may obscure the effects of individual cow history and within-herd management; the estimate should nevertheless be interpreted as preprint evidence from a high-density dairy setting rather than as a national prevalence. The sampling unit is equally important. Quarter-level prevalence is usually lower than cow-level prevalence because a cow is often classified as positive when any one quarter reacts. Composite milk can dilute a high-SCC quarter or combine contamination from several teats. Future Bangladesh studies should always report farm-, cow-, and quarter-level results separately and specify whether prevalence is based on test positivity, intramammary infection, or a combined case definition.

5.2 Clinical mastitis

Clinical mastitis has received less epidemiological attention than SCM. Earlier surveys were mainly cross-sectional or retrospective. The prospective Chattogram cohort of Singha et al. (2021) was therefore an important advance: 1,383 cows on 24 commercial farms were monitored for six months, enabling estimation of incidence rather than prevalence and providing pathogen and antimicrobial-susceptibility data. Clinical cases in Bangladesh range from mild milk abnormalities to severe systemic disease. Their occurrence is epidemiologically linked to the hidden SCM reservoir, environmental contamination, teat-end damage, and inadequate case follow-up.

5.3 Geographic, seasonal, and production-system differences

The dairy zones represented in the literature- Sirajganj-Pabna, Mymensingh, Gazipur, Rangpur-Dinajpur, Rajshahi, Khulna-Jashore, Barishal-Barguna, Chattogram-Cox's Bazar, Brahmanbaria, Jhenaidah, Dhaka, and Sylhet- differ in rainfall, heat load, farm size, flooring, drainage, breed composition, fodder systems, and market access. Wet-season and monsoon conditions have repeatedly been associated with greater floor contamination and mastitis risk in some studies, although seasonal findings are not fully consistent (Rahman et al., 2009; Islam et al., 2010; Sayeed et al., 2020; Faruk et al., 2025). A practical national program should therefore treat hot-humid and monsoon periods as high-risk windows for drainage maintenance, udder cleanliness monitoring, and intensified screening. The recent Sirajganj comparison also cautions against assuming that extensive management is inherently protective: SCM prevalence was comparable under extensive and intensive management, although the economic analysis of the same milkshed population showed greater SCC-associated loss during non-bathan confinement. Production system may therefore modify the consequences of SCM even when the proportion of affected cows is similar (Aktaruzzaman et al., 2025, 2026).

6. Etiology and pathogen ecology

The evidence from Bangladesh supports a mixed contagious-environmental epidemiology. Staphylococcus aureus and some Streptococcus species can spread during hand- or machine-milking, especially through contaminated hands, common towels, liners, or milk. Non-aureus staphylococci may be cow-associated, teat-skin-associated, or environmental. Escherichia coli, Klebsiella, Enterobacter, Bacillus, Pseudomonas, and environmental streptococci reflect exposure to feces, soil, water, wet bedding, and dirty floors (Kader et al., 2002; Sumon et al., 2017; Hassan et al., 2023; Al Emon et al., 2024; Faruk et al., 2025). A sustainable program must therefore address both transmission during milking and exposure between milkings.

Table 3. Pathogen and antimicrobial-resistance evidence most relevant to bovine mastitis in Bangladesh

Evidence source	Organism(s)	Laboratory focus	Implication
Kader et al., 2002	Mixed bacterial flora	Culture and antibiogram	Established early evidence that SCM pathogens in Bangladesh had variable susceptibility.
Rahman et al., 2013; Mia et al., 2016	Clinical-mastitis bacteria	Isolation and antibiogram	Demonstrated regional differences and the need for sample-based therapy.
Sumon et al., 2017/2020	S. aureus, NAS, coliforms and other bacteria	Culture linked with SCC	Showed that bacterial group and intramammary infection strongly affect SCC.
Hoque et al., 2018	S. aureus	PCR, resistance and virulence markers	Reported widespread resistance, mecA and enterotoxin-associated genes.
Salauddin et al., 2019	Klebsiella spp.	Molecular confirmation and antibiogram	Documented multidrug-resistant environmental mastitis organisms.

Table 3. Pathogen and antimicrobial-resistance evidence of bovine mastitis (Contd.)

Evidence source	Organism(s)	Laboratory focus	Implication
Salauddin et al., 2020	*S. aureus*	PCR and multidrug-resistance profiling	Confirmed MDR S. aureus in mastitis milk from Rangpur division.
Bag et al., 2021	*E. coli*	Virulence genes and AMR	Demonstrated resistant and virulent *E. coli* from clinical mastitis.
Singha et al., 2021	*S. aureus* and non-aureus staphylococci	Prospective clinical cases and susceptibility	Found concerning penicillin/oxacillin resistance and generated treatment-policy evidence.
Fazal et al., 2023	Staphylococcus spp.	Species identification, AMR and virulence genes	Expanded molecular evidence from bovine SCM.
Al Emon et al., 2024	*S. aureus, E. coli, K. pneumoniae*	PCR and resistance genes	Detected important beta-lactamase-associated genes and high resistance.
Al Farabi et al., 2025	*Staphylococcus* and *Streptococcus spp.*	Molecular detection, risks and AMR	Provided updated Gram-positive pathogen evidence from SCM cattle.
Faruk et al., 2025	*Staphylococcus, Streptococcus, E. coli, Klebsiella* and *Bacillus spp.*	Culture and antibiogram	Showed predominance of staphylococci and high resistance to commonly used agents.
Anika et al., 2025	*E. coli*	Antibiogram, PCR and whole-genome sequencing	Identified multiple resistance genes and emphasized genomic surveillance.

6.1 Staphylococcus aureus

S. aureus is a central Bangladesh mastitis pathogen because it can persist within the udder, form micro-abscesses and biofilms, shed intermittently, and spread from cow to cow during milking. Chronic infections often have lower bacteriological cure rates than new infections, particularly in older cows, multiple quarters, or high-SCC cases. Bangladesh investigations have documented multidrug resistance, mecA, enterotoxin-associated genes, and other virulence determinants (Hoque et al., 2018; Salauddin et al., 2020; Fazal et al., 2023; Islam, Hossain et al., 2025). These findings support early identification, strict milking hygiene, culture-based decision-making, and the removal of chronic reservoirs when economically and ethically justified.

6.2 Non-aureus staphylococci and streptococci

Non-aureus staphylococci are commonly recovered from subclinical infections, although their clinical importance varies by species and persistence. Streptococcus species include contagious and environmental organisms, and Bangladesh studies have identified *S. agalactiae*, *S. dysgalactiae*, *S. uberis*, and other *Streptococci* with differing resistance and virulence profiles (Sumon et al., 2017; Fazal et al., 2023; Hassan et al., 2023; Farzana et al., 2023; Al Farabi et al., 2025). Future surveillance should identify isolates to the species level because control priorities and expected treatment responses differ among species.

6.3 Coliforms and other environmental organisms

E. coli and Klebsiella spp. are strongly associated with manure, organic material, contaminated water, and wet resting areas. They can cause severe clinical disease, but subclinical shedding also occurs. Bangladesh studies have identified virulence and resistance determinants in *E. coli* and multidrug-resistant *Klebsiella*, while *Pseudomonas*, *Enterobacter*, and *Bacillus* have also been reported (Salauddin et al., 2019; Bag et al., 2021; Al Emon et al., 2024; Chowdhury et al., 2025; Siddique, Arafat et al., 2025; Mallick et al., 2025; Islam, Rahman et al., 2025). Their presence emphasizes drainage, water quality, clean sampling, and avoidance of contaminated intramammary preparations.

6.4 Microbiome, resistome, and genomic evidence

Research on mastitis in Bangladesh has moved beyond conventional culture-based lists of pathogens. Metagenomic deep sequencing identified disease-associated microbiome signatures and functional biases, followed by studies that mapped the clinical-mastitis resistome and integrated microbiome dynamics with genomic determinants (Hoque et al., 2019; Hoque, Istiaq, Clement et al., 2020; Hoque, Istiaq, Rahman et al., 2020). A cow-to-mouse fecal and milk microbiota-transplantation model then provided experimental evidence that mastitis-associated microbial communities can induce dysbiosis and functional perturbation (Hoque, Rahman et al., 2022).

Species-focused genomic work has described *Streptococcus uberis*, *S. agalactiae*, *S. dysgalactiae*, sequence-defined *E. coli*, *Klebsiella pneumoniae*, *Enterococcus avium*, *E. faecalis*, *E. faecium*, *Staphylococcus warneri*, *Pseudomonas putida*, *P. asiatica*, and *Enterobacter roggenkampii* from mastitis-associated cattle, milk, feces, or farm environments (Rahman et al., 2023; Hassan et al., 2023; Farzana et al., 2023; Hoque, Faisal et al., 2023; Rahaman et al., 2024; Rahman, El Zowalaty et al., 2024; Hoque, Faisal, Das et al., 2024; Mallick et al., 2024, 2025; Sultana et al., 2024, 2025; Siddique, Arafat et al., 2025; Rahman, Siddique, Arafat, Homa et al., 2025; Rahman, Siddique, Arafat, Das et al., 2025; Islam, Rahman et al., 2025). These studies document extensive resistomes, virulence repertoires, mobile genetic elements, biofilm-related traits, and possible links among mammary, intestinal, and environmental reservoirs.

Omics evidence is valuable for surveillance, source attribution, and recognition of emerging pathogens, but it does not replace aseptic quarter-level sampling, culture, and cow-level clinical interpretation. Detection of microbial DNA does not always establish a viable intramammary infection. A tiered diagnostic model is therefore appropriate for Bangladesh: CMT and SCC at the farm level, culture and susceptibility testing for individual decisions, and molecular or genomic investigation at regional and reference laboratories.

7. Risk factors under Bangladesh conditions

7.1 Breed, milk yield, and genetic background

Crossbred cows, especially those with greater Holstein-Friesian inheritance, are more often affected than indigenous cattle in studies from Bangladesh. This association may reflect greater milk yield, larger udders, metabolic demand, and more intensive housing rather than breed alone. Indigenous and Red Chittagong cattle are not resistant under all conditions, but their lower production and local adaptation may reduce risk in some systems (Rabbani and Samad, 2010; Islam et al., 2011; Biswas and Sarker, 2017; Sajib et al., 2024). Breed should therefore be interpreted together with milk yield, parity, housing, and management.

7.2 Age, parity, and lactation stage

Advanced parity increases cumulative exposure to pathogens and teat injury and is repeatedly associated with SCM. Some Bangladesh studies reported the greatest positivity in the second to fourth parities, whereas others reported an increasing prevalence through later parities. Early lactation is a period of negative energy balance and impaired immune function, whereas late lactation is associated with longer cumulative exposure. Both phases have been reported to be high risk, indicating that the locally important pattern depends on nutrition, pathogen pressure, and management (Prodhan et al., 1996; Badiuzzaman et al., 2015; Arman et al., 2017; Al Emon et al., 2024; Faruk et al., 2025). Severity-specific modeling refined these relationships. Relative to the reference stage, late lactation increased the relative risk of mild SCM (RRR 2.03; 95% credible interval [CrI] 1.55-2.69) and severe SCM (RRR 1.92; 95% CrI 1.36-2.72). Lower-parity and higher-producing cows had lower modeled SCM risk, supporting targeted surveillance of later-parity and late-lactation animals while recognizing that cross-sectional associations do not establish causality (Aktaruzzaman et al., 2026).

7.3 Previous mastitis, udder anatomy, and teat condition

A previous clinical episode is one of the strongest practical predictors of future mastitis. Persistent infection, residual tissue damage, and failure to confirm bacteriological cure can explain recurrence. Pendulous udders, large or bottle-shaped teats, wounds, cracks, lesions, and teat-end hyperkeratosis have been associated with mastitis in Bangladesh (Uddin et al., 2009; Sarker et al., 2013; Hasan et al., 2022; Singha, Koop et al., 2021). Routine teat-end and udder scoring should therefore form part of herd visits, not only clinical case examinations. Consistent with this biological interpretation, cows with a previous clinical mastitis episode had a markedly higher relative risk of severe SCM (RRR 4.26; 95% CrI 2.20-8.54) in the Bayesian hierarchical analysis. Mastitis-history records can therefore support risk-based SCC surveillance even where routine whole-herd testing is financially difficult (Aktaruzzaman et al., 2026).

7.4 Body condition, feeding, and transition-cow health

Poor body condition can indicate inadequate energy, protein, or micronutrient supply, whereas overconditioned cows may experience transition disorders and depressed feed intake. Studies in Bangladesh have linked BCS and feeding patterns to SCM, although the directionality remains inconsistent (Sarker et al., 2013; Arman et al., 2017; Sayeed et al., 2020; Faruk et al., 2025). Nutritional interventions should be based on ration evaluation rather than indiscriminate supplementation. Adequate, effective fiber, energy, protein, clean water, and appropriate mineral-vitamin supply support immunity but cannot compensate for contaminated teats and poor milking hygiene.

7.5 Milking hygiene and technique

Hand milking dominates much of Bangladesh. Transmission risks include unwashed hands, long fingernails, shared towels, wet teats, incomplete bucket cleaning, milking infected cows before healthy ones, rough stripping, knuckling, cross-suckling, and failure to separate treated milk. Surveys have documented limited routine mastitis screening, widespread use of common towels, and inconsistent udder and hand hygiene (Rahman et al., 2018; Shanta et al., 2020; Anika et al., 2024). Washing without thorough drying can increase bacterial movement toward the teat end; the control objective is a visibly clean and completely dry teat.

7.6 Housing, drainage, and environmental contamination

Wet, muddy, or manure-contaminated floors increase bacterial load on teats and udders. Concrete is not inherently safe: poorly sloped concrete can retain urine and wash water, while rough surfaces may damage hocks and teats. Earthen floors may be comfortable when dry, but become heavily contaminated during the monsoon. Studies on Bangladesh repeatedly associate muddy floors, poor cleaning, drainage limitations, and inadequate hygiene with mastitis (Sarker et al., 2013; Sayeed et al., 2020; Sohidullah et al., 2024; Faruk et al., 2025). Sustainable design requires adequate slope, rapid drainage, frequent manure removal, dry resting space, ventilation, and control of roof leakage and waterlogging.

7.7 Farm size, purchased animals, and biosecurity

Larger herds may experience more pathogen introductions, greater cow-to-cow contact, more milkers, and less consistent routines. Purchased cows can introduce chronic S. aureus or high-SCC infection. New cows should be examined, CMT-tested, and preferably cultured or SCC-tested before joining the main milking group. Separate equipment for clinically affected cows, visitor control and clean sampling procedures are practical biosecurity components.

7.8 Farmer knowledge, incentives, and veterinary access

Many farmers recognize swollen udders and abnormal milk but do not understand SCM. A healthy-looking cow is unlikely to be tested unless training, milk-quality feedback, or financial incentives are in place. Empirical advice from informal providers and drug sellers can lead to repeated broad-spectrum treatment. Bangladesh knowledge and hygiene surveys show a persistent need for practical, competency-based education and accessible diagnostic support (Rahman et al., 2018; Shanta et al., 2020; Anika et al., 2024).

8. Diagnosis and herd monitoring

Diagnosis serves different purposes: identifying clinical cases, screening apparently healthy cows, confirming intramammary infection, selecting treatment, and monitoring herd progress. No single test achieves all of these goals. A tiered Bangladesh algorithm should combine low-cost cow-side screening with targeted quantitative and bacteriological confirmation (Badiuzzaman et al., 2015; National Mastitis Council, 2017; Ruegg, 2017).

8.1 Foremilk examination and clinical grading

The first streams of milk should be examined at every milking. A strip cup or a dark surface improves the detection of flakes, clots, or watery secretions. Udder swelling, pain, temperature, appetite, hydration, and systemic signs should be assessed. Severe cases require immediate veterinary attention, fluid and anti-inflammatory support, and milk sampling before initiating antimicrobial therapy, provided this does not delay life-saving treatment.

8.2 California Mastitis Test

CMT is the most suitable routine quarter-level screening test for most farms in Bangladesh. Equal volumes of milk and reagent are mixed in a four-well paddle and interpreted from negative or trace to strong gel formation. CMT is inexpensive, rapid, and useful for identifying the affected quarter, but scoring is subjective and reflects somatic cells rather than a specific pathogen. Bangladesh comparisons consistently support CMT as a practical field tool when results are interpreted with SCC, repeated testing, or culture (Islam et al., 2011; Badiuzzaman et al., 2015; Hoque et al., 2015; Kabir et al., 2019).

8.3 Somatic cell count

SCC provides a quantitative measure of mammary inflammation. A value around 200,000 cells/mL is widely used as an operational threshold for probable intramammary infection in an individual cow or quarter, but repeated results and sample type matter. Bangladesh work has shown that threshold choice changes sensitivity and specificity, and that bacterial group and infection status strongly influence SCC (Sumon et al., 2017, 2020a, 2020b). A practical interpretation is: below 100,000 cells/mL, low probability; 100,000-199,999 cells/mL, suspect and repeat; and 200,000 cells/mL or more, probable infection when persistent. Colostrum, late lactation, stress, and sampling errors must be considered (National Mastitis Council, 2017; Ruegg, 2017).

8.4 Electrical conductivity and pH

Inflammation increases the movement of sodium and chloride into milk and may increase electrical conductivity. Portable detectors have been evaluated in Bangladesh, including the Dramiński device and locally developed test systems (Siddiquee et al., 2013; Kabir et al., 2019). Conductivity is rapid but affected by milk temperature, parity, stage of lactation, yield, and normal quarter differences. Milk pH also tends to rise during inflammation, but neither pH nor conductivity should be used alone to prescribe antimicrobials; their best role is as an adjunct to CMT and SCC.

8.5 Bacteriological culture and susceptibility testing

Aseptic quarter milk culture is the key confirmatory test for persistent, recurrent, high-SCC, or herd-level problems. Samples should be collected before treatment, after cleaning and alcohol disinfection of the teat end, using sterile tubes and cold transport. Mixed growth of several unrelated organisms often indicates contamination. Repeated culture may be needed because S. aureus shedding can be intermittent. Susceptibility results should inform therapy but must be interpreted alongside pathogen, cow, and quarter factors; in vitro susceptibility does not guarantee cure of a chronic infection (National Mastitis Council, 2017; Ruegg, 2017).

8.6 Molecular and emerging diagnostics

PCR, resistance-gene detection, MALDI-TOF, metagenomics, and whole-genome sequencing are valuable for surveillance, source attribution, and outbreak investigation (Hoque et al., 2018, 2019; Fazal et al., 2023; Siddique, Arafat et al., 2025). Infrared thermography, automated conductivity, on-farm SCC devices, biosensors, and machine-learning tools are promising but require validation in Bangladesh against repeated SCC and culture. New tools should be evaluated for diagnostic accuracy, cost per cow, robustness in tropical farms, and whether their results change management decisions.

9. Production, economic, reproductive, welfare, and public-health consequences

9.1 Milk yield and composition

Inflammation damages secretory tissue and reduces milk synthesis. Lactose and casein decline, while sodium, chloride, enzymes, and inflammatory proteins increase. Fat and total solids may vary with severity and dilution. The hill-tract study by Mia et al. (2025) directly linked SCM to poorer production, poorer physicochemical milk quality, and market consequences under Bangladesh conditions. In the 76-herd Sirajganj study, SCC was negatively associated with milk yield after adjustment for cow-level factors and herd clustering. Mean SCC was approximately 429,000 cells/mL during the bathan period and 454,383 cells/mL during the non-bathan period, reinforcing the biological and production relevance of persistent inflammatory burden (Aktaruzzaman et al., 2025).

9.2 Farm economics

Economic loss consists of hidden production loss, rejected or discarded milk, veterinary visits, diagnostics, drugs, labor, reduced milk price, recurrence, reproductive delay, premature culling, and replacement. The earliest economic study in Bangladesh estimated major national losses from SCM, while recent large-scale modeling and hill-tract data confirm substantial production and quality consequences (Kader et al., 2003; Mia et al., 2025; Aktaruzzaman et al., 2025). Robust national estimates require longitudinal milk records and current input and milk prices. Prevention is generally more economical than repeated treatment because it reduces both infection and antimicrobial use. Aktaruzzaman et al. (2025) analyzed 3,174 lactating cows from 76 herds in Sirajganj using a mixed-effects linear model centered at 200,000 cells/mL. During the bathan period, the estimated SCC-associated loss averaged 0.10 L/cow/day, valued at BDT 6.03; standardized to 1,000 cows, this equaled 100.5 L/day and BDT 6,028.90 (USD 49.42). During non-bathan confinement, loss approximately doubled to 0.20 L/cow/day and BDT 11.98/cow/day, or 200 L/day and BDT 11,976.20 (USD 98.17) per 1,000 cows, using BDT 60/L and USD 1 = BDT 122. These estimates cover SCC-associated milk loss rather than the full cost of disease, and are pre-peer-review findings; however, the strong herd variation and seasonal housing contrasts support investment in cow comfort, forage continuity, and farm-specific SCC control.

9.3 Reproduction and longevity

Mastitis-associated inflammation can disrupt ovarian function and fertility. Bangladesh studies have associated mastitis with delayed postpartum heat, longer calving interval, more services per conception, and poorer reproductive performance (Khokon et al., 2017; Akter et al., 2024). Causal inference is limited by cross-sectional designs and confounding, but the biological relationship is plausible and deserves longitudinal study.

9.4 Animal welfare

Clinical mastitis is painful, and severe cases may cause systemic illness or death. SCM is less visible but represents persistent inflammation and may progress to clinical disease. Welfare-oriented management means preventing infection, detecting cases early, providing analgesia and supportive care, avoiding traumatic milking, and making timely culling decisions for chronic painful disease.

9.5 Food safety, residues, and One Health

Mastitic milk can contain foodborne pathogens, resistant bacteria, resistance genes, and antimicrobial residues. Risks are greatest in informal chains with delayed cooling, consumption of raw milk, or failure to observe withdrawal periods. Resistant *S. aureus*, *E. coli*, *Klebsiella*, *Streptococci*, *Enterococci*, and *Pseudomonas* documented in Bangladesh reinforce the need to integrate udder-health surveillance with national AMR, food-safety, and laboratory programs (Hoque et al., 2018; Bag et al., 2021; Al Emon et al., 2024; Chowdhury et al., 2025; Siddique, Arafat et al., 2025). Pasteurization reduces viable bacterial hazards but does not address farm losses, residues, or animal welfare problems.

10. Treatment principles and antimicrobial stewardship

Treatment must distinguish clinical severity from subclinical test positivity. A positive CMT is not, by itself, an indication for antimicrobial treatment. Many subclinical infections are culture-negative, caused by organisms with low cure benefit during lactation, or better addressed at drying off. Conversely, severe clinical mastitis requires rapid supportive treatment even when bacteriological results are pending (Ruegg, 2017; Tomanić et al., 2023).

10.1 Clinical mastitis

Before therapy, collect an aseptic milk sample whenever feasible. Grade the case, assess hydration and systemic illness, and provide fluids, anti-inflammatory treatment, and nursing care as indicated. Antimicrobials should be selected based on the likely pathogen, local susceptibility patterns, approved veterinary products, and withdrawal requirements. Culture-based selective therapy can reduce unnecessary treatment of mild cases of Gram-negative or culture-negative infections, but protocols must be supervised by veterinarians and adapted to local diagnostic turnaround times (National Mastitis Council, 2017; Ruegg, 2017).

10.2 Subclinical mastitis

Lactation therapy may be considered for recent infections caused by organisms with a reasonable likelihood of cure, particularly *S. agalactiae*. Chronic *S. aureus* infections in older cows, multiple quarters, or high SCC often respond poorly. Decisions should consider pathogen, duration, quarter damage, parity, pregnancy status, milk yield, herd transmission risk, treatment cost, and withdrawal loss. Repeated empirical courses should be avoided, especially given the widespread resistance documented among Bangladesh isolates (Hoque et al., 2018; Salauddin et al., 2020; Singha, Koop et al., 2021; Al Farabi et al., 2025).

10.3 Dry-period management

The dry period offers an opportunity to cure existing infections and prevent new ones. Selective dry-cow therapy is preferable when reliable cow records, SCC or CMT history, aseptic technique, and veterinary oversight are available. Internal teat sealants may reduce new infections but require strict hygiene. Blanket antimicrobial dry-cow therapy should not be introduced as a default national recommendation without considering AMR, product approval, and the ability to maintain asepsis (Ruegg, 2017; Tomanić et al., 2023).

10.4 Stewardship safeguards

- Collect and label a pre-treatment milk sample whenever possible.
- Use only veterinary-approved products under professional direction.
- Follow the correct dose, route, treatment interval, and duration.
- Record cow, quarter, product, batch, date, administrator, and withdrawal end date.
- Clearly identify treated cows and exclude their milk for the full withdrawal period.
- Avoid mixing several antimicrobials or changing drugs without diagnostic justification.
- Review recurrent cases for chronic infection, teat damage, milking transmission, and culling.
- Never use prohibited substances in food-producing animals. Drug lists from older regional reviews should not be copied without current regulatory verification.

11. Sustainable management strategy for Bangladesh

Sustainable mastitis control is a continuous herd process rather than a single drug or disinfectant. It should reduce new infections, shorten infection duration, prevent transmission, improve milk quality, and minimize unnecessary antimicrobial exposure. The core interventions below are compatible with hand-milked smallholder and commercial farms, although the intensity of monitoring can be scaled to herd size (Food and Agriculture Organization of the United Nations and International Dairy Federation, 2011; Ruegg, 2017; Bari et al., 2022).

11.1 The Bangladesh Minimum Udder-Health Package

- Assign a permanent identification to every lactating cow.
- Observe foremilk and the udder at every milking.
- Screen all lactating cows with quarter-level CMT monthly and whenever yield falls unexpectedly.
- Wash the milker's hands with soap and clean water before milking; use clean gloves where practical.
- Clean only visibly dirty teats and dry each cow with an individual clean towel.
- Use calm, complete full-hand milking and avoid knuckling or traumatic stripping.
- Milk low-SCC/healthy cows first and suspected, treated, or chronically infected cows last.
- Apply an approved full-coverage post-milking teat disinfectant after every milking.
- Offer feed after milking so cows remain standing while the teat canal begins to close.
- Remove manure at least twice daily and maintain a dry floor and functional drains.
- Culture persistent, recurrent, high-SCC or treatment-failure cases.
- Maintain treatment, withdrawal, CMT/SCC, and outcome records.
- Conduct a veterinary udder-health review at least every three to six months.

11.2 Recommended milking routine

A standardized milking routine reduces variability among family members and hired milkers. Before milking, identify the cow, inspect the udder, examine foremilk, and clean the milker's hands. Remove visible dirt with minimal water, then dry each teat completely with an individual towel. During milking, use a gentle full-hand technique and prevent contaminated hands from moving between cows. After milking, dip the entire teat, clean the equipment, invert it to dry, record any abnormalities, and feed the cow.

11.3 Teat disinfection

Post-milking teat disinfection is central to controlling contagious pathogens. The product should be approved for dairy use, prepared at the labeled concentration, and stored safely. Dip cups must be cleaned, and contaminated solution must be discarded. The full teat surface should be covered. Pre-milking teat disinfection may reduce environmental infection where contamination is high, but teats must be wiped completely dry before milk collection.

11.4 Cow cleanliness, floors, and drainage

The objective is not simply to wash the shed but to keep the udder and teats clean and dry. Drains should be cleared before the monsoon, floors sloped toward channels, leaking roofs repaired, and resting areas protected from slurry. Repeated disinfection of a dirty, wet floor is ineffective. Physical removal of organic matter, drying, and separation of manure storage from the milking area are higher priorities.

Table 4. Proposed phased udder-health program for Bangladesh

Component	Smallholder minimum	Commercial/collection-center enhancement	Frequency	Indicator
Case detection	Foremilk inspection and monthly CMT	Individual SCC plus electronic records	Every milking/monthly	New clinical cases and CMT-positive quarters
Milker hygiene	Handwash with soap and clean nails	Disposable gloves and documented routine	Every milking	Observed compliance
Teat preparation	Individual clean towel; teats completely dry	Approved pre-dip plus individual drying	Every milking	Clean/dry teat score
Post-milking protection	Approved full-coverage teat dip	Automated or audited dipping	Every milking	Teat coverage and product concentration
Environment	Manure removal and functioning drain	Cow cleanliness and bedding audits	At least twice daily/monthly audit	Floor wetness and udder cleanliness
Diagnostics	Culture persistent/recurrent cases	Routine culture, SCC trend, and pathogen mapping	Risk-based	Proportion sampled before treatment
Treatment	Veterinary prescription and withdrawal record	Culture-guided protocols and outcome review	Each case	Clinical/bacteriological cure and residue compliance
Dry period	CMT/SCC history and clean dry-off	Selective dry-cow therapy and teat sealant protocol	At dry-off	New infection after calving
Milk-chain quality	Separate abnormal/treated milk	Bulk SCC, bacterial count, and residue test	Each collection/monthly	Milk rejection, SCC, and residue results
Training	Practical demonstration for all milkers	Competency certification and refresher audit	Twice yearly	Skills score and sustained adoption

11.5 Nutrition, heat stress, and transition management

Rations should match milk yield and lactation stage, maintain an appropriate BCS, and provide sufficient amounts of effective fiber, energy, protein, minerals, and vitamins. During hot-humid periods, shade, airflow, clean water, and feeding during cooler hours help maintain intake and immunity. Fresh cows require close monitoring for ketosis, hypocalcemia, retained placenta, and metritis because transition disorders may increase susceptibility to infection.

11.6 Managing infected and chronic cows

Cows with repeated high CMT or SCC should be visibly identified, sampled, milked last, and evaluated for chronic udder change. Post-treatment testing should assess response. A chronic high-SCC S. aureus cow that repeatedly infects herd mates may cost more than her apparent milk yield. Segregation or culling should be considered after evaluating pregnancy, production, replacement cost, and welfare.

11.7 Biosecurity and purchase policy

Purchased cows should have a mastitis history, an udder examination, and a CMT/SCC assessment before entry. When possible, culture milk from high-SCC or suspicious cows. New animals should not immediately share milking towels or equipment with the resident herd. Calves should not be allowed to cross-suckle infected cows, and waste milk containing residues should not be fed raw.

11.8 Emerging non-antibiotic and microbiome-informed approaches

Bangladesh studies published in 2024-2025 generated genomic resources for milk-derived *Pediococcus pentosaceus, P. acidilactici, Enterococcus faecalis,* and *E. faecium* and evaluated bacteriocin-based candidates against clinical-mastitis pathogens (Rahman, Siddique, Akter et al., 2024; Rahman, Siddique, Rahman et al., 2024; Siddique et al., 2024; Rahman, Siddique, Gilman et al., 2025; Siddique, Rahman et al., 2025; Hasnat et al., 2025). Genomic and in-vitro analyses suggest potential probiotic or antimicrobial functions, while computational bacteriocin studies provide a discovery pipeline for alternatives to conventional intramammary antimicrobials.

These approaches remain investigational. Before farm recommendation, they require strain-safety assessment, confirmation that transferable resistance or virulence determinants are absent, formulation and stability studies, mammary-tissue safety testing, residue and milk-quality evaluation, dose and delivery studies, randomized controlled field trials, and regulatory review (Tomanić et al., 2023; Hasnat et al., 2024, 2025). They should complement, not replace, clean milking, teat disinfection, environmental hygiene, and pathogen-based treatment decisions.

12. Farmer training, milk-quality incentives, and service delivery

12.1 Competency-based farmer and milker training

Training should require demonstration rather than attendance only. Each participant should correctly perform CMT, collect an aseptic milk sample, wash hands, dry teats individually, apply teat dip, identify a treated cow, calculate the withdrawal end date, and complete a simple record. Women and other household members who actually milk cows should be included even when the registered farm owner is male.

12.2 Quality-based milk payment

Milk processors and cooperatives can sustain motivation by measuring bulk-milk SCC, total bacterial count, and residues, and by providing transparent feedback. Price premiums for consistently good quality are preferable to sudden punitive exclusion. High-SCC farms should receive advisory visits and a time-bound corrective plan. Collection-center testing can serve as a bridge between individual farm practices and national surveillance.

12.3 Veterinary and laboratory network

District and regional laboratories should offer SCC, culture, species identification, susceptibility testing, and residue screening. Field veterinarians need sterile sampling kits, cold-chain guidance, standard submission forms, and clear interpretation reports. A practical service target would be preliminary culture guidance within 24-48 hours for clinical cases and a complete report within a defined period.

13. National sustainable mastitis-control framework

Bangladesh requires coordinated action among the Department of Livestock Services, veterinary universities, the Bangladesh Livestock Research Institute, milk cooperatives, processors, laboratories, farmer organizations, food safety agencies, and professional bodies. The following staged framework is proposed.

13.1 Phase 1: standardization and baseline

- Adopt standard definitions for clinical severity, SCM, intramammary infection, new infection, recurrence, and bacteriological cure.
- Specify reporting at farm, cow, and quarter level and require exact diagnostic thresholds.
- Conduct a stratified baseline survey in major milk zones using harmonized CMT, SCC, and culture procedures.
- Map available laboratories, test costs, transport time, and antimicrobial-resistance capacity.

13.2 Phase 2: sentinel surveillance and extension

- Establish sentinel dairy farms and milk collection centers in Sirajganj-Pabna, Mymensingh, Gazipur, Rangpur-Dinajpur, Khulna-Jashore, Chattogram-Cox's Bazar, and Sylhet.
- Monitor clinical incidence, bulk SCC, major pathogens, resistance, and antimicrobial use.
- Deploy the Bangladesh Minimum Udder-Health Package with quarterly farm feedback.
- Train veterinarians, paraprofessionals, and milk collectors in sample collection and practical control.

13.3 Phase 3: quality incentives and stewardship

- Introduce transparent quality-based payment with farmer support and appeal procedures.
- Link antimicrobial prescription to standard mastitis protocols and withdrawal records.
- Screen milk for residues and provide corrective education before sanctions.
- Publish annual anonymized regional pathogen and resistance reports.

13.4 Phase 4: evaluation and scale-up

- Measure reduction in new infections, high-SCC cows, clinical recurrence, antimicrobial treatments, and rejected milk.
- Evaluate benefit-cost ratios for smallholder and commercial farms.
- Revise protocols according to pathogen shifts, adoption barriers, and resistance trends.
- Scale successful packages through dairy projects, cooperatives, and veterinary teaching hospitals.

14. Research gaps and priorities

Nationally representative epidemiology. Bangladesh still lacks a probability-based national estimate using standardized farm-, cow-, and quarter-level definitions.

Longitudinal incidence and persistence. Most studies are cross-sectional. Repeated sampling is needed to distinguish transient inflammation, persistent infection, cure, and recurrence.

Pathogen species resolution. Studies often group non-aureus staphylococci and streptococci together. Species-level identification is needed for targeted control.

Economic loss. Updated longitudinal estimates should incorporate milk yield, price, rejected milk, labor, fertility, culling, and prevention costs. Severity- and system-specific validation. The new mild/severe SCM estimates and bathan/non-bathan economic contrasts require independent, longitudinal validation across major milk zones, with repeated SCC, bacteriology, exact days at risk, and complete cost accounting.

Intervention trials. Controlled farm trials should test teat dipping, individual drying, milker hygiene, drainage improvement, post-milking standing, selective dry-cow therapy, and integrated packages.

AMR and antimicrobial use. Studies should connect prescriptions, doses, durations, withdrawal compliance, and treatment outcomes with isolate-level susceptibility and genomic data.

Milk-chain transmission. Research should track pathogens, resistance, and SCC from the farm to the collection center and the processor.

Climate adaptation. Rainfall, floor wetness, heat stress, and seasonal hygiene need to be evaluated prospectively.

Diagnostic validation. Dramiński conductivity, pH, infrared thermography, portable SCC, and biosensors should be validated against repeated culture and SCC.

Implementation science. Adoption studies should quantify the roles of labor, gender, water access, cost, trust, veterinary availability, and milk-price incentives.

15. Discussion

The Bangladesh literature consistently identifies mastitis as a substantial but heterogeneous burden. Its greatest strength is the repeated detection of SCM across diverse regions and production systems; its greatest limitation is methodological inconsistency. Test-positive prevalence cannot be equated with culture-confirmed infection, and cross-sectional associations cannot prove causation. Nevertheless, repeated associations with udder hygiene, milking practice, parity, milk yield, previous mastitis, teat lesions, and environmental cleanliness provide a rational basis for immediate control (Sarker et al., 2013; Badiuzzaman et al., 2015; Singha, Koop et al., 2021; Al Emon et al., 2024; Faruk et al., 2025). The two large Sirajganj analyses add a useful distinction between frequency and consequence. Similar SCM prevalence across intensive and extensive systems does not imply similar impact: SCC-associated yield and income loss were greater during confinement. At the same time, late lactation and prior clinical mastitis strongly predicted severity, indicating that effective programs should combine herd-level management improvements with cow-level risk-based surveillance (Aktaruzzaman et al., 2025, 2026).

Evidence of pathogen involvement has become increasingly concerning over time. Earlier culture studies described common bacteria and antibiograms; recent studies demonstrate mecA, beta-lactamase-associated genes, virulence factors, mobile genetic elements, and multidrug resistance in several major and emerging pathogens (Hoque et al., 2018; Salauddin et al., 2019, 2020; Bag et al., 2021; Fazal et al., 2023; Al Emon et al., 2024; Al Farabi et al., 2025; Siddique, Arafat et al., 2025). This progression does not prove that resistance is increasing nationally, given that sampling frames differ, but it establishes that resistant mastitis pathogens are entrenched in Bangladesh. Continued empirical antimicrobial use without culture, records, or withdrawal control is therefore unsustainable.

The most important policy shift is from case treatment to udder-health management. Treatment addresses an individual episode, whereas control reduces exposure and transmission in the whole herd. Many recommended measures, such as handwashing, individual drying, milking order, teat dipping, manure removal, and recording, are low technology, but their effectiveness depends on consistency, product quality, water availability, and farmer incentives (Rahman et al., 2018; Shanta et al., 2020; Bari et al., 2022). Extension programs should therefore monitor adoption and outcomes rather than distribute advice once.

Bangladesh should avoid importing a control program unchanged from high-income machine-milked systems. Smallholder herds may not have routine access to laboratories or electronic SCC testing. A tiered model is more realistic: monthly CMT and hygiene at farm level; SCC and culture for selected cows; bulk-milk monitoring at collection centers; and molecular surveillance at reference laboratories. This layered approach preserves scientific rigor while remaining financially feasible and is consistent with good dairy-farming principles and regional control priorities (Food and Agriculture Organization of the United Nations and International Dairy Federation, 2011; Bari et al., 2022).

Sustainability also requires attention to animal welfare and to climate change. Wet monsoon floors, heat stress, painful chronic infection, and traumatic milking are not separate problems. They interact with immunity, pathogen exposure, and farmer labor. A national program should integrate cow comfort, housing, welfare assessment, and milk quality rather than treat mastitis as only a drug-selection issue.

16. Conclusion

Bovine mastitis is a major challenge for production, welfare, food safety, and antimicrobial resistance in Bangladesh. The national evidence base now includes early prevalence and economic studies, district surveys, diagnostic comparisons, prospective clinical cohorts, and molecular pathogen investigations. Although reported prevalence varies widely, the conclusion is consistent: subclinical infection is common, clinical disease remains important, and both contagious and environmental transmission occur.

A sustainable response should not depend on repeated empirical antimicrobial treatment. The immediate priorities are routine quarter-level screening, quantitative SCC where available, culture of persistent and recurrent cases, clean and dry teat preparation, individual towels, hand hygiene, post-milking teat disinfection, correct milking order, dry floors and drains, balanced nutrition, selective dry-period management, cow-level records, and veterinary stewardship.

At the national level, Bangladesh needs harmonized definitions, sentinel surveillance, regional diagnostic services, annual reporting on pathogens and resistance, residue monitoring, and quality-based milk payments linked to farmer support. Coordinated implementation can reduce new infections, improve milk yield and quality, protect animal welfare and public health, and make dairy production more economically and environmentally sustainable.

17. Declarations

Author contributions: M.A.I. conceived the review, conducted the literature synthesis, interpreted the evidence, developed the proposed national control framework, and wrote and approved the final manuscript.

Funding: No external funding was received specifically for the preparation of this review.

Conflict of interest: The author declares no conflict of interest.

Data availability: No new primary dataset was generated. All information synthesized in this review is available in the cited publications.

Ethical approval: Ethical approval was not required because this article reviews previously published evidence and contains no new animal or human experimentation.

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