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REVIEW ARTICLE

Subclinical mastitis in dairy cows in south-Asian countries: a review of risk factors and etiology to prioritize control measures

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Abstract

Mastitis is a major production disease, causing significant economic losses for dairy farmers in South-Asian countries, as well as other parts of the world. Udder health control programs (UHCP) have been established in developed countries as an effective strategy for mastitis control but have not yet been introduced in South-Asian low-income countries like Bangladesh, India, Pakistan, and Sri Lanka. To launch UHCP successfully in dairy herds in South-Asia, it is important to know the current prevalence and risk factors for subclinical mastitis (SCM). Therefore, a narrative literature review was conducted with the aim to describe the dairy sector, the prevalence of SCM and its causal agents, risk factors for mastitis occurrence and the control measures suggested by different studies conducted in the selected countries. The literature revealed that India had the highest cattle population. Milking was mainly done by hand in all of the studied countries. Stall feeding was done in Bangladesh and Sri Lanka and limited access to grazing was also reported in some farms in India and Pakistan. There was substantial variation in the prevalence of SCM between studies in all 4 countries, ranging from about 20% to about 80%, but the average prevalence across all studies was high (50%). The most common causal agents for SCM were non-aureus staphylococci (NAS), *Staphylococcus (S.) aureus*, *Streptococcus* spp. and *Escherichia (E.) coli*. The management related risk factors reported for SCM were stall feeding of cows, a higher stock density, cracked floors, open drains, the presence of flies, poor drainage, peri-parturient diseases, infrequent dung removal and earth floors. The control measures suggested in these studies were to improve the hygiene and sanitation of cows, to improve the cleanliness of farms and milker's hands, to apply dry cow therapy, supplementing micronutrients and routine screening for SCM combined with taking intervention measures like isolation of cows or milking infected cows last, and proper treatment. Also, full hand milking, complete milking, machine milking, and providing feed and water immediately after milking have been recommended. Finally, we show that current literature often studies the same set of (non-manageable) risk factors, so more research is needed to obtain a comprehensive picture of the determinants of SCM. Randomized controlled trials are needed to truly quantify the effect of intervention under field conditions. Altogether, our work gives an overview of the udder health situation in South-Asia and provides the basis for the design of UHCP in this region.

Keywords Intramammary infection · Udder health · Prevalence · Incidence · Causal agent

Introduction

Throughout the world, mastitis is one of the major production diseases affecting the health, welfare, and productivity of dairy cows (Kee 2012; Zigo et al. 2021). Because of this, mastitis has been the subject of a vast amount of research for many years. However, much of this research has only focused on mastitis in developed countries, where cows have a high milk yield, are kept in large herds and are machine milked (Kumar et al. 2013). Substantially less research effort has been invested in mastitis in low-income countries, where herd sizes are generally small and hand milking is much more common. However, the effect of mastitis in these settings can be much more devastating (Islam et al. 2019) as smallholder farmers' livelihoods are directly dependent on

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their cows and production losses, culling or death have a relatively big economic impact.

To control mastitis, knowledge of the most important causative agents, their transmission routes, and the risk factors for subclinical mastitis (SCM) or clinical mastitis (CM) is essential (Cobirka et al. 2020). Based on such information, relevant interventions can be identified, which can be translated into an Udder Health Control Program (UHCP). Furthermore, it is important to tailor such control programs to the husbandry situation concerned, as risk factors, and therefore preventive strategies, can differ based on housing, feeding, and other dairy cow management practices (De Vliegher et al. 2012). Udder health control programs have successfully been implemented in developed world settings, but in order to devise such programs for low-income countries, it is important to first summarize the knowledge concerning udder health in each specific setting.

In this review, we focus on udder health in dairy cows in South Asia, in particular Bangladesh, India, Pakistan, and Sri Lanka. These countries are classified as lower-middle income countries by the World Bank and have comparable climatic conditions and animal husbandry. Despite the fact that milk production is mainly an activity of smallholder farms, these countries, particularly India, produce large quantities of milk and are together responsible for about 22% of the world's cow milk production (FAO 2016), making milk production an important tool for alleviating poverty (FAO 2018). Still, a clear description of the dairy sector in these countries and summary estimates of the incidence and prevalence of SCM, as well as its determinants, is lacking, hampering the development of UHCP tailored to the varied situations in South Asia. Therefore, this study aims to describe (1) the prevalence, (2) the etiology and (3) the risk factors for SCM in South Asia by reviewing the existing literature. We first describe the dairy industries in the countries of interest and then characterize the SCM prevalence, etiology, and risk factors in these countries. Finally, we discuss the most important control measures and identify knowledge gaps that need to be filled to guide the preparation of appropriate and individualised UHCP in these regions.

Methodology

The 4 South Asian developing countries (Bangladesh, India, Pakistan, and Sri - Lanka) were considered based on climatic similarity. Articles were collected from "Scopus" and "CAB Abstracts (veterinary sciences)" databases and also from Google Scholar and PubMed databases. The search key words were – primarily "Bovine" AND "mastitis" AND ("Bangladesh" OR "India" OR "Pakistan" OR "Sri AND Lanka"). The same search was done in all search engines (Google Scholar, PubMed, Scopus and CAB abstracts). We set the following criteria to exclude irrelevant papers:

1. The studies had to be published in English. Only research articles (full length/ short communication) were included, but not the reviews/ research project reports.
2. The studies should include at least total number of animals and affected animals.
3. Articles had to describe the prevalence of subclinical bovine mastitis with or without associated risk factors in Bangladesh, India, Pakistan, or Sri-Lanka.
4. The diagnostic methods for subclinical mastitis had to be CMT/ SCC. Papers were excluded if the titles and abstracts did not fulfill the set criteria.

The dairy cattle industry in South Asia

The general descriptive information on the dairy sectors in Bangladesh, India, Pakistan, and Sri Lanka, is depicted in Table 1. In Bangladesh, the average milk production per cow per year varied from 600 L to 1800 L depending on the farming system and breed type (Uddin et al. 2011). Both the crossbreed (mostly Holstein Friesian and indigenous cross, 88%) and indigenous (12%) cows are present on these farms. The average herd size varies greatly based on the farming systems; for household farms n = 1–6 and for semi-intensive farms n = 2–30. Most cows are inseminated artificially (87% of farms). The high figure of artificial insemination (AI) is due to the Bangladesh government's policy to increase milk production through upgrading cows by AI to meet the high milk demand of the population (Shamsuddoha and Edwards 2000; Hamid and Hossain 2002). In addition, private companies are also involved with providing AI services in Bangladesh (Hamid and Hossain 2002). There are regular training programs, run by several companies and the government to produce efficient AI technicians to work in remote areas in Bangladesh (personal communication, M.M. Rahman, Bangladesh, 2021).

India also uses both crossbreed and indigenous cows on their farms. Crossbreed cows have a higher milk yield than the indigenous cows. The milk production ranges from 400 to 1150 L/cow/year (Muhammad et al. 2020). More than half of the cow milk produced in India comes from rural farms where milking is mainly done by hand. India has the largest cattle population and the highest total cow milk production among the countries studied. Mostly stall feeding of cows is practiced in India although limited access to grazing has also been reported.

Pakistan, the 4th largest cow milk producing country in the world, produced 63,684,000 Tons of milk in 2020–21 (Economic Survey of Pakistan 2020-21 2021). The average milk yield per cow per year is 1236 L (Table 1). The main

Table 1 General descriptive information on the dairy sectors in Bangladesh, India, Pakistan, and Sri Lanka

Variables	Bangladesh	India	Pakistan	Sri Lanka	References
Number of cattle head (reporting years)	24,200,000 (2018–2019)	192,490,000 (2019)	51,500,000 (2020–2021)	1,399,815 (2017)	Bulletin (2017), GOP (2017), MoFL 2018-19 (2019), Census (2019), Economic Survey of Pakistan 2020-21 (2021)
Cow milk production per year (tons)	930,000 (2018–2019)	176,400,000 (2017–2018)	63,684,000 (2017)	287,586 (2008)	DAPH (2008); GOP (2017); MoFAD 2017-18 (2018); MoFL 2018-19 (2019)
Milk yield (L/cattle/year)	Traditional: 600–700 Intensive: 1000–1400 Bathan: 1200–1800	400–1150	1236 (Calculated)	730 (Calculated)	Census (2006), Uddin et al. (2011), Muhammad et al. (2020), Economic Survey of Pakistan 2020-21 (2021)
Average herd size	Traditional: 1–6 Intensive: 2–10 Bathan: 2–30	–	Smallholder: 1–3 Rural commercial: >50 Per-urban: 100–200	–	FAO (2011), Uddin et al. (2011)
Farms applying hand milking (%)	–	–	–	100%	Vairamuthu et al. 2010
Main breeds (proportion of all cattle) (reporting years)	87.95% crossbred	Exotic/cross breed: 51,360,000 Indigenous: 142,110,000 (2019)	Sahiwal, Red Sindhi (2006)	Indian cross: 25% (2017) European cross: 49% Local: 26%	Bulletin (2017), Census (2019), Census (2006)
Husbandry systems (stall feeding)	63%	–	–	Intensive farms: 15% Semi-intensive farms: 51% Extensive farms: 34%	Bulletin (2017)
Location (urban/rural)	Rural: (Animal heads) 25,351,506 Urban: 3,344,257	Rural: 185,270,000 Urban: 8,190,000 Rural: 91% Milk	30–40% rural milk		BBS (2017), Census (2019)
Breeding (AI) (reporting years)	Cows under AI 4,300,000 (2018–2019)			15% (1996–1997)	MoFL 2018-19 2019; Abeygunawardena et al. 2001

'-' indicates no information available

breeds available are Sahiwal and Red Sindhi. Rural farms contribute 30–40% of the total milk production of the country, with Urban farms producing 60–70%. Limited access to grazing is also common in Pakistan.

In Sri Lanka, the average production per cow per year is 730 L. Hand milking is the most common milking method used in Sri Lanka. They use both indigenous (26%) and crossbreed cows (74%). Stall feeding is practiced in most of the farms (63%) with limited grazing practice (37%).

In summary, the South Asian countries described in this paper increasingly use crossbreeds to improve milk yield, and a substantial proportion of the milk is produced in urban settings. Hand milking is still the most common technique and herd size is generally small.

Prevalence of subclinical mastitis

An overview of the prevalence of SCM in the four South Asian countries is presented in Table 2. Subclinical mastitis was generally diagnosed using a California Mastitis Test (CMT) or a derivative, and somatic cell count (SCC) was rarely used (Bansod et al. 2021). In Bangladesh, the reported prevalence of SCM in cows ranged from 20 to 75%. Sarker et al. (2013) reported the lowest prevalence (20%) of SCM in Bangladesh, however, this study was conducted in a specific period, from October to January, and the samples were taken from 3 districts of Bangladesh that might not represent the total population. Variation in the prevalence of SCM might have occurred between the cows as the management systems

Table 2 Overview of the occurrence of subclinical mastitis (SCM) in the South Asian countries

Country	No (cows tested)	Cow level prevalence of SCM (%)	Definition of SCM	Threshold	References
Bangladesh	196	75	CMT	Coagulation of milk	Islam et al. 2014
Bangladesh	228	65	CMT, WST, SFMT	CMT + ve score > 1, flakes, viscid mass in WST, Gel in SFMT	Hoque et al. 2015
Bangladesh	200	29	CMT	Coagulation of milk	Kayesh et al. 2014
Bangladesh	330	37	CMT, WST, SFMT	CMT + ve score > 1 Flakes, viscid mass in WST, Gel in SFMT	Islam et al. 2010
Bangladesh	139	52	CMT	Coagulation of milk	Tripura et al. 2014
Bangladesh	212	20	CMT	Coagulation of milk	Sarker et al. 2013
Bangladesh	116	44	CMT	Coagulation of milk	Rabbani and Samad 2010
India	100	80	CMT	Coagulation of milk	Pachauri et al. 2013
India	1022	38	–	–	Sahu et al. 2014
India	3[6]	67	[3]WST, CMT	Coagulation of milk	Bandyopadhyay et al. 2015
India	20	18	CMT	Coagulation of milk	Sharma and Brinty 2014
India	352	74	–	–	Bhattacharyya et al. 2016
India	422	83	On spot BTB[4], SCC[5]	–	Banerjee et al. 2017
India	94	87	CMT, SCC	Coagulation of milk	Prebavathy et al. 2015
India	316	19	Modified WST	Flakes, viscid mass	Mishra et al. 2018
Pakistan	300	44	[1]SFMT	Gel formation	Bachaya et al. 2005
Pakistan	500	36	SFMT	Gel formation	Bachaya et al. 2011
Pakistan	100	17	SFMT	Gel formation	Khan et al. 2013
Pakistan	1947	81	SFMT	Gel formation	Khan et al. 2017
Pakistan	100	25	[2]CMT	Coagulation of milk	Azeez et al. 2012
Sri Lanka	696	71	CMT	Coagulation of milk	Gunawardana et al. 2014
Sri Lanka	152	43	CMT	Coagulation of milk	Sanotharan et al. 2016
Sri Lanka	745	43	CMT	Coagulation of milk	Samarakoon et al. 2014

[1]Surf Field Mastitis Test, [2]California Mastitis Test, [3]White Side Test, [4]Bromomethyl Blue Test, [5]Somatic Cell Count[6]Number of farms instead of samples/ animal

used can be expected to vary from farm to farm (Mekonnen et al. 2017). For example, risk factors such as milking practices, bedding materials, and feeding systems might be very different between farms.

In India, the prevalence of SCM in cows ranged from 18 to 87%. Subclinical mastitis was mostly detected using CMT but sometimes through direct measurements of SCC or a modified White Side Test (WST). A different method was also applied for diagnosing SCM, namely the cow side Bromomethyl Blue Test (BBT) (Banerjee et al. 2017), followed by SCC enumeration. The lowest prevalence (18%) of SCM was reported (Sharma et al. 2011) in a study conducted together in a group of farms (n = 20 farms). The variation in prevalence might be due to the differences in the individual herd management practices (Abebe et al. 2016), particularly milking hygiene and farm biosecurity measures (Balaji and Senthilkumar 2017).

In Pakistan, the prevalence of SCM in cows ranged from 17 to 81%. The most used diagnostic method for SCM was the Surf Field Mastitis Test (SFMT), which is a derivative of the CMT, a reasonable diagnostic method (Senthilkumar et al. 2020). The large variation between studies could be due to the differences in the risk factors present in the farms or could be caused by selection bias. For example, in a study by Prebavathy et al. (2015), 87% SCM prevalence was recorded where the samples were collected from cows that were exposed to several risk factors for mastitis.

In Sri Lanka, Gunawardana et al. (2014) and Sanotharan et al. (2016) documented a 43 to 71% prevalence of SCM in cows. In this case, the SCM was identified by CMT. This variation might be related to the differences in the housing systems and hygienic management practices (Sanotharan et al. 2016).

In general, the prevalence was within roughly the same range in all the countries under study (ranging from 17 to 87%) although most of the studies in India reported a higher prevalence (>38%) of SCM, with a few exceptions (18% prevalence was recorded in a study by Sharma and

Brinty (2014)). Overall, there were wide variations in the prevalence of SCM between individual studies within and between countries. This variation might have occurred due to variations in sampling strategy between studies, differences in farm hygiene, biosecurity, and herd management practices.

Etiology of subclinical mastitis

In Bangladesh, only two studies were found which reported the causative agents of SCM. Islam et al. (2014) detected *Staphylococcus (S.) aureus* and non-aureus *Staphylococcus* (NAS) from the SCM positive samples. Kayesh et al. (2014) found NAS*, Streptococcus* spp. and *Escherichia (E.) coli* from SCM positive samples (Table 3).

In India, a total of 15 studies have reported the causal agents for SCM positive cases based on bacterial culture. The most identified causal agents were NAS, *S. aureus*, S*treptococcus* spp. (particularly *Streptococcus agalactiae*, *Streptococcus dysgalactiae*, and *Streptococcus uberis* (Prabhu et al. 2013; Shome et al. 2012), *Bacillus* spp. and *E. coli,* along with fungi such as *Candida albicans* and *Aspergillus* spp. (Table 3). Bhattacharyya et al. (2016) reported 61.4% *S. aureus* infection in SCM positive cows. This higher prevalence might have occurred from these cows being in pasture or possibly through human contact or environment (Bhattacharyya et al. 2016). Koovapra et al. (2016) reported 68.5% *Klebsiella* spp. in the SCM positive samples, which might have occurred as it is one of the pathogens responsible for environmental mastitis, and it readily colonizes in the udder (Timofte et al. 2014).

In Pakistan, four studies identified the causal agents of SCM. The most common pathogens identified were *S. aureus*, NAS, *Streptococcus* spp. and *E. coli* (Table 3).

In Sri Lanka, the major causal agents for SCM were reported to be *Staphylococcus* spp., *Klebsiella* spp., *E. coli*, *Streptococcus* spp., *Pasteurella* spp., *Corynebacterium* spp., and *Proteus* spp. (Table 3).

Non-aureus staphylococci were reported most frequently in Pakistan (>75%). The prevalence of *E. coli* infections was also higher in Pakistan compared to Bangladesh and India. This variation might be associated with the hygiene and sanitation of the farms, farming system, milking and udder hygiene, type of floor and bedding materials used (Sanotharan et al. 2016; Hussain et al. 2016; Sarker et al. 2013). Only 4 studies from Pakistan, 2 from Bangladesh and 2 from Sri Lanka reported the causal agents of SCM in those countries. Therefore, more research in those countries could contribute to revealing the most important and frequent causal agents of SCM. Overall, staphylococci were generally most frequently found, but the etiology of mastitis differed largely between studies. Therefore, local studies are still needed to determine the dominant species in a particular region or farm.

Risk factors for SCM

Out of 37 studies identified in our literature review, 11 investigated risk factors. The following risk factors at cow level were reported in one or more studies: age, parity, breed, body condition score (BCS), milk yield, stage of lactation, and, at quarter level: teat lesions and teat or udder conformation. Although India is a major milk producing country, no studies describing risk factors for SCM were available. However, a total of 4 papers reported on risk factors at the herd level. All risk factors are discussed below.

Age and parity

Although various studies used different categorizations for age or parity, we could identify that, in general, older cows, which are generally also of higher parity, had a higher likelihood of having SCM than younger cows (Table 4). This is in line with the fact that *Staphylococcus* spp. was a common cause of SCM as revealed in this study. Staphylococci generally cause chronic infections (Sağlam et al. 2017) and, even during a dry period, a substantial proportion of these cases are never cured (Smith et al. 2005). Therefore, the older cows likely accumulate more intramammary infections (IMI) than younger animals, resulting in a higher prevalence of SCM. This stresses the importance of infection prevention for controlling mastitis in older cows as once an infection occurs, the animal may stay infected for a long time, even the entire milk producing lifetime. These old cows should receive selective dry cow therapy through a thorough examination of milk, as the older cows are less likely to recover from IMI than younger cows (Barkema et al. 2006). Unlike in developed countries, cows are kept in the herds for longer in developing countries. Thus, the management of older cows to prevent IMI in South Asian countries should be a major concern (personal communication, Dr. Rahman 2021, Bangladesh and Dr. S. Sivaraman, India, 2021). Management strategy such as regular check-ups of older cows with CMT is logical as it is a cheap and fast cow side test.

Breed and milk yield

Exotic breeds were crossed with indigenous breeds in different studies, and the crossbred and, in some cases, pure exotic breeds were more susceptible to SCM than indigenous breeds (Table 5). Indigenous cows might be more resistant

Table 3 Reported etiology of subclinical mastitis (SCM) in South Asian countries

Country	N	Samples positive (%)	NAS (+ve)	*S. aureus*	*Strep.* spp.	*Bacillus* spp.	*E. coli*	*Klebsiella* spp.	*Pseudomonas* spp.	*Micrococcus* spp.	*Pasteurella* spp.	*Proteus* spp.	*Salmonella* spp.	Fungal spp.	References
Bangladesh	196	74.5	15.1	5.5	–	–	–	–	–	–	–	–	–	–	Islam et al. 2014[3]
	200	28.5	73.3	–	33.3	–	6.67	–	–	–	–	–	–	–	Kayesh et al. 2014[4]
India	–	35.8	–	83.7	–	–	–	–	–	–	–	–	–	–	Sharma and Brinty 2014[2]
	392	56.4	–	–	–	56.4	–	–	–	–	–	–	–	–	Sadashiv and Kaliwal 2014
	100	83	33.8	–	11.8	10.3	14.2	8.8	5.9	5.9	–	–	1.5	–	Kumar et al. 2010[2]
	167	37.1	37.1	–	–	–	–	–	–	–	–	–	–	–	Mahato et al. 2017
	422	94.8	–	–	–	–	–	–	6.5	–	–	–	–	–	Banerjee et al. 2017[2]
	352	61.4	–	61.4	–	–	–	–	–	–	–	–	–	–	Bhattacharyya et al. 2016
	340	85.6	–	–	–	–	–	85.6	–	–	–	–	–	–	Koovapra et al. 2016
	167	23.4	–	23.4	–	–	–	–	–	–	–	–	–	–	Mistry et al. 2016
	92	32.6	–	–	–	–	32.6	–	–	–	–	–	–	–	Balakrishnan et al. 2016
	1022	73.8	–	22	–	–	–	–	–	–	–	–	–	–	Sahu et al. 2014[2]
	158	–	46.8	–	–	–	–	–	–	–	–	–	–	–	Vishnupriya et al. 2014[2]
	131	30.5	–	–	30.5	–	–	–	–	–	–	–	–	–	Prabhu et al. 2013[2]
	100	64	–	–	–	–	–	–	–	–	–	–	–	64	Pachauri et al. 2013
	209	–	55.2	23.8	6.3	–	14.7	–	–	–	–	–	–	–	Shome et al. 2012[2]
	316	18.9	–	–	–	–	–	–	–	–	–	–	–	55.5	Mishra et al. 2018[2]

Table 3 (continued)

Country	N	Samples positive (%)	NAS (+ve)	*S. aureus*	*Strep.* spp.	*Bacillus* spp.	*E. coli*	*Klebsiella* spp.	*Pseudomonas* spp.	*Micrococcus* spp.	*Pasteurella* spp.	*Proteus* spp.	*Salmonella* spp.	Fungal spp.	References
Pakistan	100	32	–	90	–	–	–	–	–	–	–	–	–	–	Khan et al. 2013[2]
	435	–	72–76.3	–	12–14.5[1]	–	–	–	–	–	–	–	–	–	Tarfarosh et al. 2007
	2791	81	7.5	–	1.5	–	54.5	6	2.25	–	3	12	1.49	0.75	Rafiullah et al. 2017[2]
	100	68	23.5	76.5	–	–	–	–	–	–	–	–	–	–	Azeez et al. 2012[2]
Sri Lanka	152	66	90.5	–	3.5	–	6.0	–	–	–	–	–	–	–	Sanotharan et al. 2016[2]
	745	43	–	52	5.9	–	8.1	12.7	–	–	4.5	2.7	–	–	Samarakoon et al. 2014[2]

[1]6 years' prevalence in range. [2]Prevalence of organisms of CMT positive samples. [3]Specific organisms are only detected from CMT positive samples. [4]More than 1 causal agent detected in a single sample

to infections than the crossbreed cows and thus might have a lower risk of SCM (Siddiquee et al. 2013; Kurjogi and Kaliwal 2014). The risk of IMI increases with increased milk production (Taponen et al. 2017) and usually local breeds produced less milk in comparison to crossbreed cows (Islam et al. 2016; Curone et al. 2018), which might explain the higher susceptibility for SCM in crossbred cows. Some studies (Kayesh et al. 2014) reported that SCM was more prevalent among high yielding cows, but others found no connection between prevalence and yield. Rabbani and Samad (2010) and Sanotharan et al. (2016) found the highest prevalence among the low milk-producing cows (Table 5). This low production might be related to infection or due to the cows being in late lactation, as production is usually reduced in late production (Rabbani and Samad 2010; Sanotharan et al. 2016). Cows that yield more milk are more susceptible to mastitis (Haile-Mariam et al. 2001) as the teat canal remains open for a comparatively longer period in high yielding cows (Klaas et al. 2005).

Lactation stage, BCS and body weight

Some studies reported higher SCM prevalence in early lactation (Islam et al. 2010; Hossain et al. 2012; Qayyum et al. 2016), but others reported the highest risk in late lactation (Rabbani and Samad 2010; Sanotharan et al. 2016) (Table 6). In early lactation, the cows are often stressed due to post-parturition conditions, like compromised hygiene and immunity immediately after calving, and colostrum production (Oliver and Sordillo 1988; Sharma et al. 2011). At a later lactation stage, there might be more damage to the teat canal, thus facilitating pathogen entry and causing a higher risk of SCM (Qayyum et al. 2016). The latter might be associated with chronic infections in cows.

The body condition score is associated with the health and nutritional status of the dairy cows, which influences production. Maintaining an optimal BCS of around 3 is ideal, as cows with a low BCS (<3) had SCM more often than cows with a higher BCS (>3) (Sarker et al. 2013). On the other hand, cows with a higher BCS may suffer from different metabolic diseases, such as milk fever or ketosis (Roche et al. 2013), which in turn increases the chances of infectious diseases like mastitis (Chagunda et al. 2006; Moyes et al. 2009). A BCS of 2.5 to 3.0 is recommended (Chagas et al. 2007), with an acceptable variation of 0.5 between cows (Roche et al. 2013). Also, cows with a higher body weight in relation to breed characteristics were more likely to have SCM (Table 6). Being overweight might be related to a lower lymphocyte function (Banos et al. 2013), which increases the risk of infection. Also, cows with a higher BCS produced more milk, and thus were more prone to have SCM (Sarker et al. 2013). Cows at a higher or extremely low level of BCS

Table 4 Reported association between age and parity and subclinical mastitis in 4 South Asian countries

Country	N (cows)	Variables	Categories	Odds ratio[1]	95% CI	Reference
Bangladesh	212	Age of cow (years)	2–4	**Ref**	–	Sarker et al. 2013
			> 4–8	1.17	0.69–1.97	
			> 8	3.20	1.64–6.25	
Bangladesh	139	Age of cow (years)	3.5–7	**Ref**	–	Tripura et al. 2014
			> 7	3.48	1.69–7.14	
Pakistan	1457	Age of cow (years)	3–6	**Ref**	–	Qayyum et al. 2016
			6.1–9	1.23	0.84–1.79	
			9.1–12	0.89	0.61–1.30	
			> 12	1.98	1.44–2.72	
Sri Lanka	152	Age of cow (years)	< 5	**Ref**	–	Sanotharan et al. 2016
			5–8	2.92	1.59–12.97	
			> 8	4.55	1.35–6.32	
Bangladesh	212	Parity	1–2	**Ref**	–	Sarker et al. 2013
			3–4	1.48	0.89–2.46	
			≥ 5	3.17	1.61–6.25	
Bangladesh	139	Parity	1–2	**Ref**	–	Tripura et al. 2014
			> 2	3.17	1.58–6.34	
Bangladesh	96	Parity	1	**Ref**	–	Rabbani and Samad 2010
			2	4.57	1.74–12.01	
			3	8.75	1.79–42.67	
			4	13.13	2.22–77.45	
			5	3.18	0.97–10.47	
Pakistan	1457	Parity	1–3	**Ref**	–	Qayyum et al. 2016
			4–6	1.04	0.76–1.41	
			7–9	3.50	2.36–5.19	
			> 10	1.62	0.74–3.56	
Pakistan	493	Parity	1	2.0	0.87–4.59	Hossain et al. 2012
			2–3	1.86	0.85–4.08	
			4–5	**Ref**	–	
			6–7	7.24	3.35–15.67	
Sri Lanka	152	Parity	< 2	**Ref**	–	Sanotharan et al. 2016
			3–5	2.81	1.39–46.45	
			> 5	8.84	1.68–15.63	

[1]Odds ratios from multivariable analyses, Ref = Reference category

have been demonstrated to be more affected by lameness in association with later parity and an early lactation stage (Kranepuhl et al. 2021). To ensure lower susceptibility to concurrent diseases, as well as optimal production level, the farmers should be aware of the ideal BCS and standard body weight of their cows (Paul et al. 2020). To ensure this, farmers should receive training on feeding their cows as well as estimating BCS.

Udder and teat conformation

The prevalence of SCM significantly varied with udder shape, teat shape, the presence of lesions on the udder and teats, and the depth of the udder (distance from the base of the teats to the junction of the abdomen/pelvis) (Hossain et al. 2012; Qayyum et al. 2016). Any pathological lesion on the teat could harbor pathogens that may enter the udder more easily, causing a higher risk of SCM (Qayyum et al. 2016). Overall, rounded and flat teats were more susceptible than cylindrical or pointed teats. Teats with laceration, necrosis, skin abrasion and inflammation had a higher SCM prevalence than the teats without such lesions or conditions (Qayyum et al. 2016). Subclinical mastitis was more prevalent among the cows with bowl shaped or pendulous udders than in cows with cup shaped or rounded udders (Hussain et al. 2016) (Table 7).

Table 5 Reported animal level risk factors (breed and milk yield) of subclinical mastitis in 4 South Asian countries

Country	N (cows)	Variables	Categories	Odds ratio[1]	95% CI	References
Bangladesh	200	Breed	Local	**Ref**	–	Kayesh et al. 2014
			Cross	2.86	1.47–5.56	
Sri Lanka	152	Breed	Local	**Ref**	**–**	Sanotharan et al. 2016
			Shahiwal	9.41	5.85–32.23	
			European cross	21.34	3.13–27.05	
Bangladesh	200	Milk yield (L)	0.5 - < 1.5	**Ref**	–	Kayesh et al. 2014
			1.5 - < 3.0	1.43	0.64–3.21	
			3 - < 5	3.37	1.36–8.39	
			5 - < 7	10.91	1.87–63.78	
			7–10	4.36	0.25–75.3	
Bangladesh	96	Milk yield (L)	High	**Ref**	–	Rabbani and Samad 2010
			Medium	3.26	0.85–12.49	
			Low	14.50	3.59–58.52	
Sri Lanka	152	Milk yield (L)	9–12	**Ref**	–	Sanotharan et al. 2016
			< 3	0.93	0.83–5.61	
			3–6	6.94	1.24–39.02	
			6–9	1.25	1.01–9.62	

[1]Odds ratios from multivariable analyses, Ref = Reference category

Table 6 Reported animal level risk factors (stage of lactation and physical condition) of subclinical mastitis in 4 South Asian countries

Country	N (cows)	Variables	Categories	Odds ratio[1]	95% CI	References
Bangladesh	330	Stage of lactation	Early (< 3 months)	1.64	0.67–3.99	Islam et al. 2010
			Mid (3–6 months)	**Ref**	–	
			Late (> 6 months)	7.27	3.96–13.34	
Bangladesh	96	Stage of lactation	Early (6–90 days)	**Ref**	–	Rabbani and Samad 2010
			Mid (91–180 days)	1.09	0.41–2.9	
			Late (> 180 days)	5.14	2.04–12.98	
India	200	Stage of lactation	Early (6–90 days)	1.96	0.86–4.46	Kathiriya et al. 2014
			Mid (91–180 days)	**Ref**	–	
			Late (> 180 days)	1.36	0.61–3.04	
Pakistan	1457	Stage of lactation	> 0.9–3 months	1.42	1.01–2.0	Qayyum et al. 2016
			> 3–6 months	**Ref**	–	
			> 6 months	3.37	2.48–4.57	
Pakistan	453	Stage of lactation	1–4 months	1.07	0.54–2.12	Hossain et al. 2012
			4.1–8 months	**Ref**	–	
			8.1–12 months	4.76	2.64–8.6	
Sri Lanka	152	Stage of lactation	Early (6–90 days)	**Ref**	–	Sanotharan et al. 2016
			Mid (91–180 days)	1.61	1.41–5.23	
			Late (> 180 days)	6.44	2.60–15.96	
Bangladesh	212	BCS	2–2.5	16.26	2.21–119.44	Sarker et al. 2013
			> 2.5–3	21.91	2.89–166.38	
			> 3	**Ref**	–	
Pakistan	453	Body weight	≤ 300	2.48	0.88–6.99	Hossain et al. 2012
			301–350	**Ref**	–	
			351–400	5.88	2.98–11.58	
			> 400	7.66	3.75–15.61	

[1]Odds ratios from multivariable analyses, Ref = Reference category

Table 7 Reported animal level risk factors (udder and teat condition) of subclinical mastitis in 4 South Asian countries

Country	N (cows)	Variables	Categories	Odds ratio[1]	95% CI	References
Pakistan	1457	Teat shape	Cylindrical	**Ref**	–	Qayyum et al. 2016
			Pointed	2.71	2.0–3.67	
			Flat	1.10	0.73–1.65	
			Round	1.53	1.05–2.22	
Pakistan	453	Teat shape	Pointed	**Ref**	–	Hossain et al. 2012
			Cylindrical	21.16	7.97–56.19	
			Round	12.28	4.36–34.55	
			Flat	20.90	7.71–56.63	
Pakistan	1457	Teat lesions	None	**Ref**	–	Qayyum et al. 2016
			Laceration	2.92	2.10–4.20	
			Abrasion	4.49	2.88–7.0	
			Inflammation	0.59	0.18–1.97	
			Cord formation	3.07	0.99–9.49	
			Hemorrhages	2.30	1.37–3.88	
			Necrosis	1.64	0.79–3.41	
			Edema	0.76	0.17–3.38	
Pakistan	453	Teat lesions	None	1.51	0.34–6.78	Hossain et al. 2012
			Teat apex	2.67	0.53–13.42	
			Skin abrasion	3.78	0.75–19.0	
			Inflammation	3.72	0.67–20.63	
			[2]Cord formation	2.04	0.37–11.33	
			Hemorrhages	**Ref**	–	
			Necrosis	2.32	0.33–16.19	
			Udder edema	17.0	2.26–127.75	
Pakistan	1457	Udder depth (cm)	10–12	**Ref**	–	Qayyum et al. 2016
			13–15	2.27	1.46–3.54	
			16–18	2.87	1.73–4.69	
Pakistan	453	Udder shape	Cup	**Ref**	–	Hossain et al. 2012
			Round	5.18	2.71–9.93	
			Bowl	7.36	3.81–14.24	
Bangladesh	212	Udder type	Others	**Ref**	–	Sarker et al. 2013
			Pendulous	2.39	1.43–4.01	
Pakistan	453	Tail length (inches)	20–30	1.76	0.87–3.54	Hossain et al. 2012
			30–40	1.19	0.67–2.12	
			> 40	**Ref**	–	
Pakistan	453	Milk leakage	Yes	2.81	1.38–5.72	Hossain et al. 2012
			No	**Ref**	–	

[1]Odds ratios from multivariable analyses, Ref = Reference category, [2]Cord formation = hard mass formation inside the udder due to inflammation

In general, pendulous and bowl-shaped udders with flat teats seemed to have the highest risk potentially due to the greater surface for pathogen contact (Sharma et al. 2017) if unhygienic udder management persists. Pendulous udders are also more prone to accidental self-inflicted injury by the cows (Sarker et al. 2013). Cows with shorter tail were more prone to IMI than the cows with longer tails, albeit non-significantly. Cows with having milk leakage had higher SCM prevalence than the cows with no such milk leakage (Hossain et al. 2012) (Table 7).

Housing and herd size

Three studies (Islam et al. 2010; Sarker et al. 2013; Sanotharan et al. 2016) reported herd level risk factors for SCM in dairy cows. An extensive/open housing system was associated with a lower prevalence of SCM than semi-intensive or intensive/closed housing (Sanotharan et al. 2016). An intensive housing system may contribute to more frequent infections as the cow stays longer within a small area that may be less clean and, in addition, cows may be more stressed because of overcrowding (Barker et al. 2001). Cows from larger herds had a higher SCM prevalence than those in small/medium scale farms (Islam et al. 2010). The larger herds are usually managed under an intensive management system to be commercially viable and, therefore, are likely to have increased pathogen exposure due to high stocking density, dirty condition of the sheds or equipment, and high humidity. Herds with cows with milk leakage were more susceptible to SCM (Sarker et al. 2013) (Table 8) probably because the teat canal remains open if there is milk leakage. Also, leaked milk from the udder might act as a transmission route (Steeneveld et al. 2008). Herds with cows with a history of IMI also had more SCM (Sarker et al. 2013) (Table 8), possibly because infections may persist in cows with a previous history of mastitis (Steeneveld et al. 2008).

Feeding

Various feeding systems have been investigated. Hossain et al. (2012) compared stall feeding in combination with grazing to stall feeding alone. Sarker et al. (2013) compared farms that only used concentrates and straw for feeding to farms feeding concentrates and grass to their cows. Stall feeding together with the grazing of cows was associated with a higher risk of SCM than cows under complete stall

Table 8 Reported herd level risk factors of subclinical mastitis in 4 South Asian countries

Country	N (Herd size)	Variables	Categories	Odds ratio[1]	95% CI	References
Bangladesh	330	No. of milking cows	Small (1–5)	**Ref**		Islam et al. 2010
			Medium (6–15)	12.5	0.84–186.31	
			Large (16 - ≥ 60)	35	1.74–703.03	
Sri Lanka	152	Farming system	Extensive	**Ref**		Sanotharan et al. 2016
			Semi intensive	4.08	1.57–10.61	
			Intensive	10.29	3.76–28.18	
Sri Lanka	152	Housing system	Open housing	**Ref**		Sanotharan et al. 2016
			Housing night only	5.32	1.55–18.21	
			Closed housing	9.21	3.53–24.04	
Bangladesh	212	History of previous IMI	No	**Ref**		Sarker et al. 2013
			Yes	12.63	7.56–21.11	

[1]Odds ratios from multivariable analyses, Ref = Reference category

Table 9 Reported management level risk factors of subclinical mastitis in 4 South Asian countries

Country	**Herd size**	**Variables**	**Categories**	**Odds ratio[1]**	**95% CI**	**References**
Pakistan	453	Feed system	Stall	**Ref**	–	Hossain et al. 2012
			Stall & Grazing	2.04	1.25–3.34	
Bangladesh	212	Grass feeding	Yes	**Ref**	–	Sarker et al. 2013
			No	2.28	1.41–3.69	
Sri Lanka	152	Separation of infected cow	Separated	**Ref**	–	Sanotharan et al. 2016
			All together	7.04	2.48–20.02	
Sri Lanka	152	Hygienic practice	Good	**Ref**	–	Sanotharan et al. 2016
			Poor	12.61	5.81–27.35	
Bangladesh	212	Teat dipping	Yes	**Ref**	–	Sarker et al. 2013
			No	2.77	1.51–5.08	
Sri Lanka	152	Calf suckling practice	Yes	**Ref**	–	Sanotharan et al. 2016
			No	17.98	5.14–62.97	
Pakistan	453	[2]Oxytocin use	Rare	**Ref**	–	Hossain et al. 2012
			Frequent	2.57	1.51–4.38	
Bangladesh	212	Training received	Yes	**Ref**	–	Sarker et al. 2013
			No	1.81	1.12–2.93	

[1]Odds ratios from multivariable analyses, Ref = Reference category

[2]Some farmers use oxytocin in lactating cows to increase milk let down

feeding. However, cows with no grass-feeding (concentrate and straw-based farms) also had a higher risk of SCM than the partly grass-fed cows (Table 9). Previous studies have suggested that regular access to pasture reduces the risk of SCM (Firth et al. 2019). This might be related to the lower stock density and better hygienic conditions on pasture than in sheds (Aljoe 2019). Also, grazed grasses may provide substances that enhance immunomodulatory function (Di Grigoli et al. 2019), which can provide some level of protection against SCM causing pathogens.

Hygiene, sanitation, and biosecurity

Different studies have reported hygienic measurements in different ways and thus have identified different risk factors. Lack of separation of infected cows, poor hygienic practices, and absence of teat dipping were identified as risk factors for SCM (Table 9). Good hygiene, teat dipping and motivating and training farmers to practice these are important measures to prevent infections (Omore et al. 1999).

Keeping newly purchased cows in quarantine for 3–4 weeks is an important biosecurity measure to prevent the spread of infections, particularly contagious mastitis, in the existing dairy cows (Barkema et al. 2009). Keeping the dairy herd closed (avoiding buying live animals) is good practice. But, if farmers do buy live animals, quarantine (Shortall et al. 2017) should be mandatory, along with inspection and examination of newly acquired stock. Also, the handling of isolated animals should be done by trained personnel within the facility to protect the herd from carriers of pathogens.

Calf suckling

Mechanical stimulation using lukewarm water or soaking cloths in warm water or with hands rather than calf suckling to prepare the cow for milking was also associated with SCM in cows (Table 9). A milking machine might injure the teat canal or teat surface, thus calf suckling might reduce the risk of SCM (Mekonnen et al. 2017). The risk of a new infection is increased by machine induced changes in the condition of the teat-end, such as congestion and edema on the teat surface (Hamann et al. 1994a, b). In addition, calf suckling removes pathogens from the teat skin and the mixture of milk and saliva prevents colonization of bacteria on the teats (Kälber and Barth 2014; Rigby et al. 1976; Rasmussen and Larsen 1998). Suckling also contributes to udder emptying, which might be useful in reducing the chance of infections or may help cure existing infections.

Overall, the risk factor studies of South Asia revealed older age, higher parity, high milk yield, late lactation, a bowl shaped or pendulous udder, stall feeding, intensive housing, machine milking, and poor hygiene and sanitation to be associated with a higher probability of SCM.

Controlling SCM in South Asia

Based on the risk factors identified for SCM in South Asian countries, optimization of those factors through management is of importance. Risk factors may vary from farm to farm. Therefore, although recommendations may be generalizable for the dairy industry, a specific control plan for every dairy farm should be created. This requires an individualized approach, in which local veterinarians can play a key role (Bangar et al. 2015). Based on the risk factors and the strength of the measures of association described earlier, we have summarized and prioritized the interventions that should be taken (Table 10). We have averaged the odds of the same risk factors from different papers, and then ranked the risk factors accordingly. We have prioritized

Table 10 Prioritization of interventions to control SCM in dairy cows in South Asia

Risk factor	Intervention	Strength of association with SCM[1]
Poor hygiene of floor, milking, milkers' hands	Improve hygiene and sanitation	++++
No calf suckling	Use a calf for stimulating the milk let down and let the calf suckle after milking	++++
Too high or too low BCS	Adjust the feeding to obtain BCS 2.5–3.0	+++
Stall feeding	Explore options for grazing	+++
Intensive housing system	Explore options for extensification	+++
Bowl-shaped/ Pendulous udder shape	Breed for cup shaped and non-pendulous udders	++
No facility for quarantine	Make a quarantine shed	++
Not practising teat dipping	Practice teat dipping	++
Too high non-indigenous breed blood level	Breed with local cows	+

[1]Strength of association with SCM is based on the measures of association observed in the literature: +: average odds ratio > 0–3, ++: average odds ratio 3–5, +++: average odds ratio 5–10, and ++++: average odds ratio > 10

them based on their average odds. Of course, the veterinarians interacting with the farmers should identify which risk factors are present on a particular farm and, based on that farm's specific risk factors, prioritize interventions. The full set of possible interventions is discussed in more detail below.

Hygiene, and biosecurity

Disposal of excreta (urine and manure), cleaning and disinfection of the barns, cleaning the udder of the cows before milking, teat dipping before and after milking, sanitizing milker's hands, proper management of the milking machine (where available), and fly control have been proven to be effective in controlling environmental mastitis caused by coliforms and contagious mastitis caused by *S. aureus* in India (Bachaya et al. 2011). Frequent removal of cow manure from the sheds, preventing contact with other livestock and animals, using footbaths at the entrance, and access to handwashing facilities might also be good biosecurity measures to prevent SCM (Sarrazin et al. 2014).

For better hygienic practice and to control pathogen entry, a particular milking strategy might be recommended. The cows should be provided with feed during milking, especially concentrates which increase milk flow and reduce the duration of milking (Prieto Jimenez 2014), which might work as a conditional reflex in cows when done regularly. Bachaya et al. (2011) also recommended providing feed and water immediately after milking to keep the cow standing, as the teat canals remain open for up to 2–3 hours after milking (Bhakat et al. 2020; Neijenhuis 2004).

Isolation

Isolation of infected cows is important to prevent new instances of SCM, as many pathogens for SCM are contagious. To control SCM in a herd, infected cows should be isolated immediately and provided with proper care and treatment (Abebe et al. 2016; Dego 2020). Where space is limited, the affected cows should at least be placed to one side of the animal shed. Milking primiparous cows (usually healthier) before multiparous cows (at higher risk of having SCM) is suggested to control mastitis in dairy herds (Bachaya et al. 2011).

Feeding system, feeding, and nutrition

As stall feeding is associated with more SCM, grazing is recommended where possible. In addition, providing adequate space around the feeding and water troughs is also important for the movement of the dairy cows (Singha et al. 2021). The stock density should be decreased to prevent and reduce contamination and transmission of infections.

Feeding high quality feed to the cows is important but providing green grass to the cows is a challenge in South Asia. To feed good quality roughage, fodder cultivation should be encouraged. Required quantities of concentrates along with good quality roughage should be supplied to the cows on a routine basis to ensure balanced nutrition (Krishnamoorthy et al. 2021), which can enhance the functioning of the immune system (Di Grigoli et al. 2019). The roughage to concentrate ratio should be 60:40 on a fresh product weight basis (Sirohi and Oberoi 2018; Phesatcha et al. 2020).

Supplementing micro-nutrients like zinc, copper, cobalt, iron, manganese, chromium, and selenium for the dairy cows to optimize udder immunity is important (Chamberlain and Wilkinson 1996) as the cows are often deficient in micronutrients, which should be prevented. Beta-carotene, vitamin A, C, E, lactoferrin and L-histidine contribute to effective immunity, have an anti-oxidative effect (Spears and Weiss 2008), and prevent udder tissue degeneration (Mustacich and Powis 2000; Spears and Weiss 2008; Warren 2018).

Housing system

Intensive housing systems are reported to be associated with SCM in cows in South Asia and other parts of the world (Bihon et al. 2019; Tedla et al. 2018; Pugliese et al. 2021; Shum et al. 2009). Therefore, where possible, semi-intensive housing for cows is recommended. Providing suitable bedding materials like sand can ensure cow comfort and reduce the prevalence of SCM (Singha et al. 2021). Cows should be kept untied (if possible) to enable movement.

Udder and teat conformation

Udder and teat conformation is important for maintaining udder health in dairy cows. Bowl-shaped and pendulous udders are identified as risk factors for SCM (Bhutto et al. 2010; Bharti et al. 2015). Selective breeding for suitable udder and teat shape is important for long-term control of mastitis. Tightly attached shallow udders and narrowly placed rear teats are less prone to mastitis (Dube et al. 2009; Fernandes et al. 2019).

Age and parity

Age and parity are important parameters to be considered while taking control measures against SCM infection. The literature shows that cows aged >7 years and parity >4–5 are more susceptible to IMI (Zhang et al. 2016; Taponen et al. 2017). Of course, the age or parity of a cow cannot be managed, but by taking these factors into account, transmission to younger cows can be reduced. For instance, lactating cows might be housed in age/parity groups rather than mixing cows of different ages in the same barn. Older cows could be housed separately in case of a large herd or be placed on one side of the same shed far from the young cows in smaller herds. Grouping in this way also facilitates milking the cows in the preferred order (from young to old).

Breed and milk yield

Crossbreed cows are more susceptible to SCM compared to the local cows (Abebe et al. 2016). As native cows are less productive, dairy farming in South Asia depends on crossbreeding and, therefore, returning to local breeds for milk production is not a viable option. In contrast, to control mastitis, practical measures can be taken that address the underlying causes of the higher prevalence of SCM in crossbreed cows. It is not completely known why crossbreed cows are more susceptible to mastitis, but it is likely linked to the following factors: (1) A higher milk yield increasing the chances of pathogen entry through a longer opening of teat ends during milking, as well as before and after milking. (2) Crossbreed cows possibly experiencing more stress from environmental factors such as a high temperature-humidity index which suppresses the functioning of the immune system. (3) Crossbreed cows possibly being less capable of digesting and utilizing the fodder available. These factors can be addressed to reduce the susceptibility of crossbreed cows to mastitis. For example, increasing the frequency of milking might be a good alternative to prevent the accumulation of milk in the udder. Usually milking twice daily is common in South Asia, but, for the high yield cows, milking three times daily could be recommended and is probably economically attractive considering the low costs of labor and processing of milk. Providing good quality roughage and concentrates (Di Grigoli et al. 2019) or sufficient space for free movement inside the sheds (Gustafson 1993) may contribute to a better functioning immune system. Maintaining a BCS of around 2.5 to 3.0 is important for a well-functioning immune system (Roche et al. 2009) and cows having a BCS >3.5 have a greater chance of developing milk fever and ketosis (Roche and Berry 2006; Gillund et al. 2001). Thus, cows should be inspected regularly to assess their BCS.

Stage of lactation

The literature shows that cows in both early (0 to 90 days) and late lactation (> 180 days) stages are more susceptible to mastitis (Moosavi et al. 2014; Abebe et al. 2016; Zhang et al. 2016). Cows might be stressed immediately after parturition, compromising their immunity (Oliver and Sordillo 1988; Sharma et al. 2011). Some measures, including providing a straw-bedded maternity shed, vitamin-mineral supplements before parturition, and checking dehydration before and during parturition, might be helpful to reduce stress during parturition. In late lactation, more care for the cows could be taken, including increasing the frequency of SCC measurement and taking immediate measures if a cow tests positive for SCM by drying off the cows followed by dry cow therapy.

Further measures

Dry cow management and greater farmer awareness, training and monitoring are important factors for controlling mastitis. There are no systematic studies on these issues in South Asian countries and therefore it was not possible to include such information on these in this paper as they are only practiced to a limited extent in this region. However, these factors are very important to consider when attempting to control SCM in South Asia and thus have been discussed briefly.

For SCM, selective dry cow therapy is an effective option (Hogeveen et al. 2011) in the control plan and is a common practice in developed countries, although appropriate management of SCM during lactation is also of importance (Adkins and Middleton 2017). Using intramammary long-acting antibiotics in the cows' dry period has been reported to reduce mastitis occurrence following the freshening of the cows (Berry and Hillerton 2002; Rahman et al. 2009; Bachaya et al. 2011). It is also reported that dry cow therapy reduced mastitis occurrence significantly in the following lactation (Ismail et al. 2018). There is evidence that the SCC in milk is reduced in subsequent lactations after dry cow therapy (Cameron et al. 2015).

Although the present scenario revealed that dry cow therapy is being practiced sporadically in South Asia, there are no guidelines in this region for dry cow management. Selective dry cow therapy is recommended over blanket dry cow therapy as the latter contributes more to developing antibacterial resistance. To select cows for dry cow therapy, lactating cows ready to be dried off should be screened using CMT, and only cows with a CMT score of III-V should receive dry cow therapy (Zecconi et al. 2019).

To minimize the burden of SCM in dairy cows, some particular steps can be taken, such as monitoring for SCM (measured by CMT/ SCC) regularly along with immediate action to control SCM (Rahman et al. 2009). It is important to encourage and facilitate monitoring facilities, e.g., providing farmers with CMT reagents or motivating farmers to carry out regular CMT screening and start measuring SCC in bulk milk in milk collection centers. Monitoring might also be achieved by providing support in installing devices for milk testing and SCC at regional livestock offices or regional veterinary institutes. This would, however, be costly, as it requires equipment and manpower. Somatic Cell Count could be done at random by the milk collection centres. As it is related to quality, specially reducing drug residues, of milk, dairies should be encouraged to include SCC as a pricing factor and provide this facility at collection centres. Also, increasing farmers' awareness regarding the risk factors of SCM and how to deal with them might be helpful. For this, regular periodic farmer training by veterinary institutes or regional livestock offices is necessary (Raina et al. 2017).

Moreover, CMT is a very popular test for SCM diagnosis in South Asia although it has some drawbacks. A positive CMT result may be associated not only with mastitis, but also with other diseases, e.g. metabolic diseases in cows, or even with physiological conditions, e.g. lactation phase. However, SCC count is not available in South Asia except few places. Thus most of the cases the published papers used CMT as a threshold for SCM diagnosis in South Asia.

Conclusions

Mastitis is one of the most economically significant diseases of cattle in the world and is also highly prevalent in cows in South Asian countries. The prevalence of SCM varies from low to very high in various studies within the studied South Asian countries, supporting the notion that improvement is possible. A number of risk factor studies have been performed, but most have studied a similar set of risk factors that are easily measured but hard to manage such as parity, breed, and stage of lactation. Studies on risk factors of SCM that are manageable, such as those related to milking technique and hygiene, were limited in number in all four countries, and more extensive research into these factors is warranted. This should not only be undertaken using observational study designs but, preferably, intervention studies should also be performed to identify promising manageable interventions, to quantify the effect that farmers may expect from implementing such interventions. Various measures have been suggested for controlling SCM, including improved hygiene and sanitation of cows, cleanliness of milkers and farms, dry cow management, supplementing micronutrients, routine screening, and husbandry practices like full hand milking, complete milking, teat dipping, providing feed and water immediately after milking. However, evidence supporting the efficacy of these interventions in the given circumstances is poor. An individualized country specific UHCP should be established in South Asia to mitigate the incidence and severity of mastitis in this region. This would need to be supported by more research on the effectiveness of management interventions through randomized controlled trials and continuous monitoring of the mastitis situation, using farm monitoring, record keeping and data analysis.

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References

Abebe R, Hatiya H, Abera M, Megersa B, Asmare K (2016) Bovine mastitis: prevalence, risk factors and isolation of *Staphylococcus aureus* in dairy herds at Hawassa milk shed, South Ethiopia. BMC Vet Res 12(1):270. https://doi.org/10.1186/s12917-016-0905-3

Abeygunawardena H, Alexander PABD, Abeygunawardena IS (2001) Artificial insemination of cattle in Sri Lanka: status, performance and problems. (No IAEA-TECDOC-1220). https://inis.iaea.org/collection/NCLCollectionStore/_Public/32/032/32032357.pdf. Accessed 8 May 2021

Adkins PR, Middleton JR (2017) Laboratory handbook on bovine mastitis, 3rd edn. National Mastitis Council, New Prague, MN, USA

Aljoe H (2019) What is high stock density grazing. Noble Research Institute Available at: https://wwwnobleorg/news/publications/ag-news-and-views/2019/april/what-is-high-stock-density-grazing/ (accessed on November 13, 2020)

Azeez Q, Sajjad-ur-Rahman UW, Ismail M, Ali R, Ali T (2012) Application of nitrocefin test for the direct detection of methicillin resistant *Staphylococcus aureus* from bovine mastitis milk samples. Life 11(2):96–101

Bachaya H, Iqbal Z, Muhammad G, Yousaf A, Ali H (2005) Subclinical mastitis in buffaloes in Attock district of Punjab (Pakistan). Pak Vet J 25(3):134–136

Bachaya H, Raza M, Murtaza S, Akbar I (2011) Subclinical bovine mastitis in Muzaffar Garh district of Punjab (Pakistan). J Anim Plant Sci 21(1):16–19

Balaji N, Senthilkumar A (2017) Prevalence of subclinical mastitis in dairy cows of Theni district in Tamil Nadu. Int J Sci Environ Tech 6(6):3427–3432

Balakrishnan S, Antony PX, Mukhopadhyay HK, Pillai RM, Thanislass J, Padmanaban V, Srinivas MV (2016) Genetic characterization of fluoroquinolone-resistant Escherichia coli associated with bovine mastitis in India. Vet World 9(7):705

Bandyopadhyay S, Samanta I, Bhattacharyya D, Nanda PK, Kar D, Chowdhury J, Dandapat P, Das AK, Batul N, Mondal B (2015) Co-infection of methicillin-resistant *Staphylococcus epidermidis*, methicillin-resistant *Staphylococcus aureus* and extended spectrum β-lactamase producing *Escherichia coli* in bovine mastitis–three cases reported from India. Vet Q 35(1):56–61

Banerjee S, Batabyal K, Joardar S, Isore D, Dey S, Samanta I, Samanta T, Murmu S (2017) Detection and characterization of pathogenic *Pseudomonas aeruginosa* from bovine subclinical mastitis in West Bengal, India. Vet. World 10(7):738–742. https://doi.org/10.14202/vetworld.2017.738-742

Bangar YC, Singh B, Dohare AK, Verma MR (2015) A systematic review and meta-analysis of prevalence of subclinical mastitis in dairy cows in India. Trop Anim Health Prod 47(2):291–297

Banos G, Wall E, Coffey MP, Bagnall A, Gillespie S, Russell GC, McNeilly TN (2013) Identification of immune traits correlated with dairy cow health, reproduction and productivity. PLoS One 8(6):1–14. https://doi.org/10.1371/journal.pone.0065766

Bansod A, Masand R, Jadhao A, Bhardwaj A, Singh S, Gaikwad V (2021) An overview of subclinical mastitis in dairy cattle. Indian J Ani Health 1–9. https://doi.org/10.36062/ijah.2021.04521

Barkema H, Schukken Y, Zadoks R (2006) Invited review: the role of cow, pathogen, and treatment regimen in the therapeutic success of bovine *Staphylococcus aureus* mastitis. J Dairy Sci 89(6):1877–1895. https://doi.org/10.3168/jds.S0022-0302(06)72256-1

Barkema HW, Green MJ, Bradley AJ, Zadoks RN (2009) Invited review: the role of contagious disease in udder health. J Dairy Sci 92(10):4717–4729. https://doi.org/10.3168/jds.2009-2347

Barker J, Stevens D, Bloomfield S (2001) Spread and prevention of some common viral infections in community facilities and domestic homes. J Appl Microbiol 91(1):7–21. https://doi.org/10.1046/j.1365-2672.2001.01364.x

BBS (2017) Yearbook of agricultural statistics, Holding reporting herd and flock population of the cross bred classified by tenancy and farm type & size. 470. http://bbs.portal.gov.bd/sites/default/files/files/bbs.portal.gov.bd/page/1b1eb817_9325_4354_a756_3d18412203e2/Agriculture1%20Year%20Book%202017-18.pdf. Accessed 8 May 2021

Berry E, Hillerton J (2002) The effect of selective dry cow treatment on new intramammary infections. J Dairy Sci 85(1):112–121. https://doi.org/10.3168/jds.s0022-0302(02)74059-9

Bhakat CA, Mohammad DK, Mandal A, Mandal S, Rai A, Chatterjee MK, Ghosh TK, Dutta (2020) Readily usable strategies to control mastitis for production augmentation in dairy cattle: a review. Vet world 13(11):2364–2370

Bharti P, Bhakat C, Pankaj PK, Bhat SA, Prakash MA, Thul MR, Japheth KP (2015) Relationship of udder and teat conformation with intra-mammary infection in crossbred cows under hot-humid climate. Vet. World 8(7):898. https://doi.org/10.14202/vetworld.2015.898-901

Bhattacharyya D, Banerjee J, Bandyopadhyay S, Mondal B, Nanda PK, Samanta I, Mahanti A, Das AK, Das G, Dandapat P (2016) First report on vancomycin-resistant *Staphylococcus aureus* in bovine and caprine milk. Microb Drug Resist 22(8):675–681. https://doi.org/10.1089/mdr.2015.0330

Bhutto AL, Murray RD, Woldehiwet Z (2010) Udder shape and teat-end lesions as potential risk factors for high somatic cell counts and intra-mammary infections in dairy cows. Vet J 183(1):63–67. https://doi.org/10.1016/j.tvjl.2008.08.024

Bihon A, Syoum A, Assefa A (2019) Assessment of risk factors and isolation of *Staphylococcus aureus* and Escherichia coli from bovine subclinical mastitic milk in and around Gondar, Northwest Ethiopia. Trop Anim Health Prod 51(4):939–948. https://doi.org/10.1007/s11250-018-1777-2

Bulletin LS (2017) Cattle population-2017, Department of animal production and health, Peradeniya, Sri Lanka, 7. http://www.daph.gov.lk/web/images/content_image/publications/other_publications/2018/Livestock_bulletin_2017_com1.pdf. Accessed 8 May 2021

Cameron M, Keefe G, Roy J-P, Stryhn H, Dohoo I, McKenna S (2015) Evaluation of selective dry cow treatment following on-farm culture: Milk yield and somatic cell count in the subsequent lactation. J Dairy Sci 98(4):2427–2436. https://doi.org/10.3168/jds.2014-8876

Census L (2006) Average yield of milk per cow per day by age and by breed Ministry of Food Agriculture and Livestock, Government of Pakistan. https://www.pbs.gov.pk/content/special-report-data-milk-yield-and-its-parameters-animals-slaughtered-meat-and-commercial. Accessed 8 May 2021

Census L (2019) Livestock population in India- major species. Minister of Animal Husbandry, Dairying and Fisheries, Animal husbandry statistics division, New Delhi, India https://dahd.nic.in/documents/statistics/livestock-census

Chagas L, Bass J, Blache D, Burke C, Kay J, Lindsay D, Lucy M, Martin G, Meier S, Rhodes F (2007) Invited review: new perspectives on the roles of nutrition and metabolic priorities in the subfertility of high-producing dairy cows. J Dairy Sci 90(9):4022–4032. https://doi.org/10.3168/jds.2006-852

Chagunda MG, Larsen T, Bjerring M, Ingvartsen KL (2006) L-lactate dehydrogenase and N-acetyl-β-D-glucosaminidase activities in bovine milk as indicators of non-specific mastitis. J Dairy Res 73(4):431–440. https://doi.org/10.1017/s0022029906001956

Chamberlain A, Wilkinson J (1996) The ideal silage. Feeding the Dairy Cow Chamberlain Publication, Lincol, UK, pp 28–30

Cobirka M, Tancin V, Slama P (2020) Epidemiology and classification of mastitis. Animals 10(12):2212

Curone G, Filipe J, Cremonesi P, Trevisi E, Amadori M, Pollera C, Castiglioni B, Turin L, Tedde V, Vigo D (2018) What we have lost: mastitis resistance in Holstein Friesians and in a local cattle breed. Res Vet Sci:11688–11698. https://doi.org/10.1016/j.rvsc.2017.11.020

DAPH (2008) Average Milk production per cow/day (litre) by province and district in Sri Lanka. Department of Animal Production & Health, Farm Registration Programme-2008, Sri Lanka http://www.daph.gov.lk/web/index.php?option=com_content&view=article&id=63&Itemid=218&lang=en. Accessed 8 May 2021

De Vliegher S, Fox L, Piepers S, McDougall S, Barkema H (2012) Invited review: mastitis in dairy heifers: nature of the disease, potential impact, prevention, and control. J Dairy Sci 95(3):1025–1040. https://doi.org/10.3168/jds.2010-4074

Dego OK (2020) Control and prevention of mastitis: part two in animal reproduction in veterinary medicine. IntechOpen:171–181. https://doi.org/10.5772/intechopen.93484

Di Grigoli A, Di Trana A, Alabiso M, Maniaci G, Giorgio D, Bonanno A (2019) Effects of grazing on the behaviour, oxidative and immune status, and production of organic dairy cows. Animals 9(6):371. https://doi.org/10.3390/ani9060371

Dube B, Dzama K, Banga CB, Norris D (2009) An analysis of the genetic relationship between udder health and udder conformation traits in south African Jersey cows. Animal 3(4):494–500. https://doi.org/10.1017/s175173110800390x

Economic Survey in Pakistan 2020 - 2021 (2021) Economic survey in Pakistan Available at https://wwwpcgovpk/uploads/cpec/PES_2020_21pdf (accessed July 27, 2021)

FAO (2011) Dairy development in Pakistan 26. https://www.fao.org/3/al750e/al750e00.pdf. Accessed 20 Feb 2020

FAO (2016) FAOSTAT, Available at: https://www.fao.org/faostat/en/#data. Accessed 20 Feb 2020

FAO (2018) Dairy development's impact on poverty reduction Chicago, Illinois, USA Licence: CC BY-NC-SA 30 IGO Available at: https://www.fao.org/3/CA0289EN/ca0289enpdf. Accessed 6 May 2021

Fernandes AR, Faro LE, Vercesi AE, Machado CHC, Barbero LM, Bittar ER, Igarasi MS (2019) Genetic evolution of milk yield, udder morphology and behavior in Gir dairy cattle. Rev Bras Zootec 48:1–10. https://doi.org/10.1590/rbz4820180056

Firth CL, Laubichler C, Schleicher C, Fuchs K, Käsbohrer A, Egger-Danner C, Köfer J, Obritzhauser W (2019) Relationship between the probability of veterinary-diagnosed bovine mastitis occurring and farm management risk factors on small dairy farms in Austria. J Dairy Sci 102(5):4452–4463. https://doi.org/10.3168/jds.2018-15657

Gillund P, Reksen O, Grohn YT, Karkberg K (2001) Body condition related to ketosis and reproductive performance in Norwegian dairy cows. J Dairy Sci 84:1390–1396. https://doi.org/10.3168/jds.s0022-0302(01)70170-1

GOP (2017) Agricultural Statistics of Pakistan 2016–2017 Islamabad: Ministry of Food Agriculture and Livestock, Government of Pakistan. https://www.pbs.gov.pk/agri-stat-tables. Accessed 6 May 2021

Gunawardana S, Thilakarathne D, Abegunawardana IS, Abeynayake P, Robertson C, Stephen C (2014) Risk factors for bovine mastitis in the Central Province of Sri Lanka. Trop Anim Health Prod 46(7):1105–1112. https://doi.org/10.1007/s11250-014-0602-9

Gustafson GM (1993) Effects of daily exercise on the health of tied dairy cows. Prev Vet Med 17(3–4):209–223. https://doi.org/10.1016/0167-5877(93)90030-W

Haile-Mariam M, Goddard M, Bowman P (2001) Estimates of genetic parameters for daily somatic cell count of Australian dairy cattle. J Dairy Sci 84(5):1255–1264. https://doi.org/10.3168/jds.S0022-0302(01)74587-0

Hamann J, Burvenich C, Mayntz M, Osteras O, Halder W (1994a) Machine-induced changes in the status of the bovine teat tissue with respect to new infection risk Chapter 2 in: Teat tissue reactions to machine milking and new infection risk IDF Bulletin 297, International Dairy Federation, Belgium 297:13–22

Hamann J, Osteras O, Mayntz M, Woyke W (1994b) Functional parameters of milking units with regard to teat tissue treatment Chapter 3 in: Teat tissue reactions to machine milking and new infection risk" IDF Bulletin 297, International Dairy Federation, Brussels, Belgium 297:23–34

Hamid M, Hossain K (2002) Role of private sector in the development of dairy industry in Bangladesh Growth 32225. http://www.lrrd.org/lrrd26/10/hami26179.htm. Accessed 8 May 2021

Hogeveen H, Huijps K, Lam TJGM (2011) Economic aspects of mastitis: new developments. N Z Vet J 59(1):16–23. https://doi.org/10.1080/00480169.2011.547165

Hoque MN, Das ZC, Talukder AK, Alam MS, Rahman,ANMA (2015) Different screening tests and milk somatic cell count for the prevalence of subclinical bovine mastitis in Bangladesh. Trop Anim Health Prod 47(1): 79–86. https://doi.org/10.1007/s11250-014-0688-0

Hossain M, Khatun M, Islam M, Miazi O (2012) Semen characteristics of breeding bulls at the central cattle breeding and dairy farm of Bangladesh. Bang J Anim Sci 41(1):1–5. https://doi.org/10.3329/bjas.v41i1.11968

Hussain R, Khan A, Javed MT, Rizvi F (2016) Possible risk factors associated with mastitis in indigenous cattle in Punjab. Pak Vet J 32(4):605–608

Islam M, Rahman A, Rony S, Islam M (2010) Prevalence and risk factors of mastitis in lactating dairy cows at Baghabari milk shed area of Sirajganj. Bangladesh J Vet Med 8(2):157–162

Islam NN, Farzana Z, Chowdhury A, Mannan A, Kamaruddin K, Siddiki A, Uddin I (2014) Characterization of bovine subclinical mastitis caused by *Staphylococcus aureus* in southern Bangladesh by bacteriological and molecular approaches. Asian J Bio Sci 7(7):1–12

Islam S, Goswami A, Mazumdar D (2016) Comparative profitability of cross breed and indigenous cattle in West Bengal. Indian Res J Ext Educ 8(1):28–30

Islam S, Barua SR, Islam A, Moni SP, Uddin H, Ferdous J, Rahman MK, Hassan MM, Rahman AA, Chawdhury S (2019) Epidemiology of sub-clinical mastitis in dairy cows in urban areas of Chittagong, Bangladesh. Turk J Agric Food Sci Tech 7(6):845–850

Ismail ZB, Muhaffel MM, Abu-Basha E (2018) The effect of dry cow therapy using systemic tylosin in combination with common intramammary medications on mastitis rate, cull rate, somatic cell count, and milk production in dairy cows affected with subclinical mastitis. Vet world 11(9):1266

Kälber T, Barth K (2014) Practical implications of suckling systems for dairy calves in organic production systems-a review. Landbau Volk 64(1):45–58

Kathiriya J, Kabaria B, Saradava D, Sanepara D (2014) Prevalence of subclinical mastitis in dairy cows in Rajkot district of Gujarat. Int J Sci Nat:5433–5436

Kayesh MEH, Talukder M, Anower A (2014) Prevalence of subclinical mastitis and its association with bacteria and risk factors in lactating cows of Barisal district in Bangladesh. Int J Biomed Res 2(2):35–38

Kee C (2012) Bovine mastitis: an Asian perspective. Asian J Anim Vet Adv 7(6):454–476

Khan JM, Rasool MH, Arshad M, Rahman SU, Tahir MF, Aslam B, Jing W, Jun Z, Ghani M (2013) Comparative evaluation of Leukotoxic activities of indigenous *Staphylococcus aureus* isolates from subclinical and clinical mastitic milk samples of buffalo and cattle. Open Vet Sci J 7(1):24–27

Khan MA, Shafee M, Akbar A, Ali A, Shoaib M, Ashraf F, Khan N (2017) Occurrence of mastitis and associated pathogens with antibiogram in animal population of Peshawar, Pakistan. The Thai J Vet Med 47(1):103

Klaas IC, Enevoldsen C, Ersbøll AK, Tölle U (2005) Cow-related risk factors for milk leakage. J Dairy Sci 88(1):128–136. https://doi.org/10.3168/jds.S0022-0302(05)72670-9

Koovapra S, Bandyopadhyay S, Das G, Bhattacharyya D, Banerjee J, Mahanti A, Samanta I, Nanda PK, Kumar A, Mukherjee R, Dimri U (2016) Molecular signature of extended spectrum β-lactamase producing *Klebsiella pneumoniae* isolated from bovine milk in eastern and North-Eastern India infection. Genet Evol 44:395–402. https://doi.org/10.1016/j.meegid.2016.07.032

Kranepuhl M, May D, Hillmann E, Gygax L (2021) Association of body condition with lameness in dairy cattle: a single-farm longitudinal study. J Dairy Res 88(2):162–165. https://doi.org/10.1017/S0022029921000297

Krishnamoorthy P, Goudar AL, Suresh KP, Roy P (2021) Global and countrywide prevalence of subclinical and clinical mastitis in dairy cattle and buffaloes by systematic review and meta-analysis. Res Vet Sci 136:561–586

Kumar A, Rahal A, Dwivedi SK, Gupta MK (2010) Bacterial prevalence and antibiotic resistance profile from bovine mastitis in Mathura. India Egypt J Dairy Sci 38(1):31–34

Kumar P, Sharma N, Ranjan R, Kumar S, Bhat Z, Jeong DK (2013) Perspective of membrane technology in dairy industry: a review Asian-australas. J Anim Sci 26(9):1347

Kurjogi MM, Kaliwal BB (2014) Epidemiology of bovine mastitis in cows of Dharwad district. Int Schol Res Noti 10(6):1037–1042. https://doi.org/10.30954/2277-940X.06.2020.24

Mahato S, Mistry HU, Chakraborty S, Sharma P, Saravanan R, Bhandari V (2017) Identification of variable traits among the methicillin resistant and sensitive coagulase negative staphylococci in milk samples from mastitic cows in India. Front Microbiol 8(1446):1–7. https://doi.org/10.3389/fmicb.2017.01446

Mekonnen SA, Koop G, Melkie ST, Getahun CD, Hogeveen H, Lam TJ (2017) Prevalence of subclinical mastitis and associated risk factors at cow and herd level in dairy farms in north-West Ethiopia. Prev Vet Med:14523–14531. https://doi.org/10.1016/j.prevetmed.2017.06.009

Mishra A, Sharma N, Singh D, Gururaj K (2018) Prevalence and bacterial etiology of subclinical mastitis in goats reared in organized farms. Vet. World 11(1):20–24. https://doi.org/10.14202/vetworld.2018

Mistry H, Sharma P, Mahato S, Saravanan R, Kumar PA, Bhandari V (2016) Prevalence and characterization of oxacillin susceptible mecA-positive clinical isolates of *Staphylococcus aureus* causing bovine mastitis in India. PLoS One 11(9):e0162256

MoFAD 2017-18 (2018) Dairy development minister of animal husbandry. Dairying and Fisheries, India. https://www.dahd.nic.in/reports/annual-report-2017-18. Accessed 8 May 2021

MoFL 2018-19 (2019) Livestock population of Bangladesh Ministry of Fisheries and Livestock (MoFL). http://dls.portal.gov.bd/sites/default/files/files/dls.portal.gov.bd/page/ee5f4621_fa3a_40ac_8bd9_898fb8ee4700/2020-07-22-19-34-e4cd5ed65f45419ee038e00b8939c1a0.pdf. Accessed 8 May 2021

Moosavi M, Mirzaei A, Ghavami M, Tamadon A (2014) Relationship between season, lactation number and incidence of clinical mastitis in different stages of lactation in a Holstein dairy farm in veterinary research forum: an international quarterly journal (Vol 5, No 1, p 13) Faculty of Veterinary Medicine, Urmia University, Urmia, Iran

Moyes K, Larsen T, Friggens N, Drackley JK, Ingvartsen KL (2009) Identification of potential markers in blood for the development of subclinical and clinical mastitis in dairy cattle at parturition and during early lactation. J Dairy Sci 92(11):5419–5428. https://doi.org/10.3168/jds.2009-2088

Muhammad A, Jones K, Blayney D (2020) Asian dairy markets: a focus on production, consumption and trade 273–297. Accessed 6 May 2021

Mustacich D, Powis G (2000) Thioredoxin reductase. Biochem J 346(1):1–8

Neijenhuis F (2004) Teat condition in dairy cows Utrecht University Available at https://dspacelibraryuunl/handle/1874/1759 (accessed June 01, 2020)

Oliver S, Sordillo L (1988) Udder health in the periparturient period. J Dairy Sci 71(9):2584–2606

Omore AO, McDermott JJ, Arimi S, Kyule M (1999) Impact of mastitis control measures on milk production and mastitis indicators in smallholder dairy farms in Kiambu district, Kenya. Trop Anim Health Prod 31(6):347–361

Pachauri S, Varshney P, Dash SK, Gupta MK (2013) Involvement of fungal species in bovine mastitis in and around Mathura, India. Vet World 6(7):393–395

Paul A, Mondal S, Kumar S, Kumari T (2020) Body condition scoring in dairy cows-a conceptual and systematic review. Indian J Anim Res 54:929–935

Phesatcha K, Phesatcha B, Wanapat M, Cherdthong A (2020) Roughage to concentrate ratio and *Saccharomyces cerevisiae* inclusion could modulate feed digestion and in vitro ruminal fermentation. Vet Sci 7(4)(151):1–13

Prabhu KN, Isloor S, Hegde R, Rathnamma D, Veeregowda BM (2013) Development of polymerase chain reaction for detection of predominant streptococcal isolates causing subclinical bovine mastitis. Indian J Biotechnol 12:208–212

Prebavathy T, Thanislass J, Dhanammal L, Ganesan R, Mukhopadhyay H (2015) Association between SNPs in TLR2 gene segment corresponding to LRR functional domain of TLR2 receptor and bovine mastitis. Asian. J Anim Sci:945–956

Prieto Jimenez C (2014) The importance of feeding during milking and take off level for milk yield, milking time, milk flow and udder emptying in the Automatic Milking System, P503, Available at https://studepsilonsluse (accessed June 01, 2020)

Pugliese M, Biondi V, Passantino A, Licitra F, Alibrandi A, Zanghi A, Conte F, Marino G (2021) Welfare assessment in intensive and semi-intensive dairy cattle management system in Sicily. Anim Sci J 92(1):e13546. https://doi.org/10.1111/asj.13546

Qayyum A, Khan JA, Hussain R, Avais M, Ahmed N, Khan A, Khan MS (2016) Prevalence and association of possible risk factors with sub-clinical mastitis in cholistani cattle. Pakistan J Zool 48(2):519–525

Rabbani A, Samad M (2010) Host determinants based comparative prevalence of subclinical mastitis in lactating Holstein-Friesian cross cows and red Chittagong cows in Bangladesh. Bangladesh J Vet Med 8(1):17–21

Rafiullah KMA, Shafee M, Akbar A, Ali A, Shoaib M, Ashraf F, Khan N (2017) Occurrence of mastitis and associated pathogens with antibiogram in animal population of Peshawar, Pakistan. The Thai J Vet Med 47(1):103–108

Rahman M, Bhuiyan M, Kamal M, Shamsuddin M (2009) Prevalence and risk factors of mastitis in dairy cows. Bang Vet 26(2):54–60

Raina V, Sharma N, Khajuria S, Kumar K, Choudhary S, Hussain K (2017) Training needs of dairy farmers. Int J Agri Environ Biotech 10(2):245–251

Rasmussen MD, Larsen H (1998) The effect of post milking teat dip and suckling on teat skin condition, bacterial colonisation, and udder health. Acta Vet Scand 39(4):443–452

Rigby C, Ugarte J, Boucourt R (1976) Rearing dairy calves by restricted suckling VII effect on mastitis development caused by *Staphylococcus aureus*. Cuban J Agri Sci:35–40

Roche JR, Berry DP (2006) Periparturient climatic, animal, and management factors influencing the incidence of milk fever in grazing systems. J Dairy Sci 89:2775–2783

Roche JR, Friggens NC, Kay JK, Fisher MW, Stafford KJ, Berry DP (2009) Invited review: body condition score and its association with dairy cow productivity, health, and welfare. J Dairy Sci 92:5769–5801

Roche JR, Kay JK, Friggens NC, Loor JJ, Berry DP (2013) Assessing and managing body condition score for the prevention of metabolic disease in dairy cows. Vet Cli: Food Anim Prac 29(2):323–336

Sadashiv SO, Kaliwal BB (2014) Isolation, characterization and antibiotic resistance of *Bacillus* spp from bovine mastitis in the region of North Karnataka, India. Int J Curr Microbiol App Sci 3(4):360–373

Sağlam AG, Şahin M, Çelik E, Çelebi Ö, Akça D, Otlu S (2017) The role of staphylococci in subclinical mastitis of cows and lytic phage isolation against to *Staphylococcus aureus*. Vet World 10(12):1481–1485. https://doi.org/10.14202/vetworld.2017.1481-1485

Sahu B, Mukherjee R, Ajay K, Amit K, Jyoti S (2014) Prevalence of coagulase gene positive *Staphylococcus aureus* bovine mastitis in three distinct geoclimatic regions of India. Buffalo Bull 33(2):208–214

Samarakoon SJMRR, Dangolla A, Karunarathne WMSK (2014) Some finding of mastitis control program in Badulla district in Sri Lanka in 2012 Sri Lanka. Vet J 61(A):11–13

Sanotharan N, Pagthinathan M, Nafees M (2016) Prevalence of bovine subclinical mastitis and its association with bacteria and risk factors in milking cows of Batticaloa District in Sri Lanka. Int J Sci Res Inno Tech 3(6):137–150

Sarker SC, Parvin MS, Rahman AA, Islam MT (2013) Prevalence and risk factors of subclinical mastitis in lactating dairy cows in north and south regions of Bangladesh. Trop Anim Health Prod 45(5):1171–1176

Sarrazin S, Cay AB, Laureyns J, Dewulf J (2014) A survey on biosecurity and management practices in selected Belgian cattle farms. Prev Vet Med 117(1):129–139

Senthilkumar A, Murugesan S, Balamurugan P (2020) Prevalence and detection of subclinical mastitis by California mastitis test (CMT) in dairy farms of Theni District in Tamil Nadu, India. Int J Curr Microbiol App Sci 9(7):988–993

Shamsuddoha A, Edwards GW (2000) Dairy industry in Bangladesh: Problems and prospects. Australian Agricultural and Resource Economics Society (AARES) Conferences January 23-25, Sydney, Australia, 1–26

Sharma I, Brinty A (2014) Isolation and identification of Staphylococcus aureus from bovine mastitis milk and their drug resistance patterns in Silchar town dairy farms, NE India. Online Int Interdiscip Res J 4:256–260

Sharma N, Singh N, Singh O, Pandey V, Verma P (2011) Oxidative stress and antioxidant status during transition period in dairy cows Asian-Australas. J Anim Sci 24(4):479–484

Sharma T, Das PK, Ghosh PR, Banerjee D, Mukherjee J (2017) Association between udder morphology and in vitro activity of milk leukocytes in high yielding crossbred cows. Vet World 10(3):342

Shome BR, Bhuvana M, Mitra SD, Krithiga N, Shome R, Velu D, Banerjee A, Barbuddhe SB, Prabhudas K, Rahman H (2012) Molecular characterization of Streptococcus agalactiae and Streptococcus uberis isolates from bovine milk. Trop Anim Health Prod 44(8):1981–1992

Shortall O, Green M, Brennan M, Wapenaar W, Kaler J (2017) Exploring expert opinion on the practicality and effectiveness of biosecurity measures on dairy farms in the United Kingdom using choice modeling. J Dairy Sci 100(3):2225–2239

Shum LWC, McConnel CS, Gunn AA, House JK (2009) Environmental mastitis in intensive high-producing dairy herds in New South Wales. Aust Vet J 87(12):469–475

Siddiquee N, Tripura T, Islam M, Bhuiyan S, Rahman A, Bhuiyan A (2013) Prevalence of sub-clinical mastitis in high yielding crossbred cows using Draminski mastitis detector. Bangl J Vet Med 11(1):37–41

Silanikove N, Merin U, Shapiro F, Leitner G (2014) Subclinical mastitis in goats is associated with upregulation of nitric oxide-derived oxidative stress that causes reduction of milk antioxidative properties and impairment of its quality. J Dairy Sci 97(6):3449–3455

Singha S, Koop G, Persson Y, Hossain D, Scanlon L, Derks M, Hoque MA, Rahman MM (2021) Incidence, etiology, and risk factors of clinical mastitis in dairy cows under semi-tropical circumstances in Chattogram, Bangladesh. Animals 11(8):2255. https://doi.org/10.3390/ani11082255

Sirohi S, Oberoi PS (2018) Influence of roughage: concentrate ratio in the ration and feed prices on profitability of commercial dairy farms. Indian J Anim Nutr 35(3):320–325

Smith E, Green L, Medley G, Bird H, Dowson C (2005) Multilocus sequence typing of Staphylococcus aureus isolated from high-somatic-cell-count cows and the environment of an organic dairy farm in the United Kingdom. J Clin Microbiol 43(9):4731–4736

Spears JW, Weiss WP (2008) Role of antioxidants and trace elements in health and immunity of transition dairy cows. Vet J 176(1):70–76

Steeneveld W, Hogeveen H, Barkema HW, van den Broek J, Huirne RB (2008) The influence of cow factors on the incidence of clinical mastitis in dairy cows. J Dairy Sci 91(4):1391–1402

Taponen S, Liski E, Heikkilä AM, Pyörälä S (2017) Factors associated with intramammary infection in dairy cows caused by coagulase-negative staphylococci, Staphylococcus aureus, Streptococcus uberis, Streptococcus dysgalactiae, Corynebacterium bovis, or Escherichia coli. J Dairy Sci 100(1):493–503

Tarfarosh MH, Qadri SGJ, Qurashi AM, Shah KA, Qureshi S, Nasreen S, Jeelani G, Sheikh FD, Teli SA, Ali SL (2007) Bacterial isolation and drug sensitivity pattern of bovine mastitis in Kashmir. Vet Scan Online Vet Med J 2(1):1–7

Tedla M, Mehari F, Kebede H (2018) A cross-sectional survey and follow up study on major dairy health problems in large and small scale urban farms in Mekelle, Tigray, Ethiopia. BMC Res Note 11(1):1–5. https://doi.org/10.1186/s13104-018-3347-0

Timofte D, Maciuca IE, Evans NJ, Williams H, Wattret A, Fick JC, Williams NJ (2014) Detection and molecular characterization of Escherichia coli CTX-M-15 and Klebsiella pneumoniae SHV-12 β-lactamases from bovine mastitis isolates in the United Kingdom. Antimicrob Agents Chemother 58(2):789–794

Tripura T, Sarker S, Roy S, Parvin M, Sarker R, Rahman A, Islam M (2014) Prevalence of subclinical mastitis in lactating cows and efficacy of intramammary infusion therapy. Bangladesh J Vet Med 12(1):55–61

Uddin M, Sultana MN, Ndambi O, Alqaisi Shawabkeh O, Hemme T, Peters K (2011) Milk production trends and dairy development in Bangladesh. Out Agric 40. https://doi.org/10.5367/oa.2011.0056

Vairamuthu S, Sinniah J, Nagalingam K (2010) Factors influencing production of hygienic raw milk by small scale dairy producers in selected areas of the Jaffna district, Sri Lanka. Trop Anim Health Prod 42(3):357–362

Vishnupriya S, Antony PX, Mukhopadhyay HK, Pillai RM, Thanislass J, Srinivas VV, Kumar RS (2014) Methicillin resistant staphylococci associated with bovine mastitis and their zoonotic importance. Vet World 7(6):422–427

Warren DH (2018) Minerals for better fertility, less mastitis Available at https://wwwdairyglobalnet/Health/Articles/2018/2/Minerals-for-better-fertility-less-mastitis-241532E/, (accessed June 01, 2020)

Zecconi A, Sesana G, Vairani D, Cipolla M, Rizzi N, Zanini L (2019) Somatic cell count as a decision tool for selective dry cow therapy in Italy. Italian J Anim Sci 18(1):435–440

Zhang Z, Li XP, Yang F, Luo JY, Wang XR, Liu LH, Li HS (2016) Influences of season, parity, lactation, udder area, milk yield, and clinical symptoms on intramammary infection in dairy cows. J Dairy Sci 99(8):6484–6493. https://doi.org/10.3168/jds.2016-10932

Zigo F, Vasil M, Ondrašovičová S, Výrostková J, Bujok J, Pecka-Kielb E (2021) Maintaining optimal mammary gland health and prevention of mastitis. Front Vet Sci 8:69

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