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Udder and teat morphometry and its relationship with occurrence of intramammary infections in dairy cattle

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Abstract

Bovine mastitis, an inflammatory disease of the mammary gland, is often caused by bacterial infection and is a major health problem on dairy farms. A cross-sectional study of four herds was conducted to assess udder and teat-related risk factors for the development of intramammary infections in 243 lactating cows. Udder and teat morphometric parameters were determined through visual appraisal method. Intramammary infection was assessed using California mastitis test (CMT), Somatic cell count (SCC) and bacteriology of milk samples. The frequencies of udder conformations were 65.8%, 18.9%, 7.4% and 7.8% for desirable, pendulous, round and goaty-shapes, respectively. Teat conformation revealed that 76.0%, 5.3%, 6.6%, 4.5% and 7.5% for desirable, short, funnel, bottle and conical-shapes, respectively. There was a significant ($p<0.01$) effect of udder shape and teat-end shape on SCC level and intramammary infections. The mean SCC and mastitis infection levels for undesirable udder was significantly ($p<0.05$) higher as compared to the desirable shaped udder. Similarly, significant ($p<0.05$) higher level SCC was found in undesired teats compared to desirable teats. The overall proportion of quarter mastitis infection in all four farms revealed 1.23% for clinical and 36.52% for subclinical mastitis. Herd-wise subclinical mastitis prevalence showed 42.8%, 35.07%, 33.09% and 2.94% for farm A, C, B and C, respectively. The most frequently isolated bacterial species were *Staphylococcus aureus* (56.34%) followed by *Escherichia coli* (22.55%), *Streptococcus agalactiae* (9.86%) and *Bacillus* spp. (8.45%). In conclusion, undesirable udder and teats conformations were more susceptible to intramammary infection and these traits must be considered accordingly while selecting dairy animals for future milk production. Observed high occurrence of subclinical Staphylococcal mastitis needs improvements in milking hygiene, mammary gland health, regular screening of animals, and use of biosecurity as an intervention tactic to limit the spread of pathogens at dairy farms.

Keywords: *dairy cattle; mastitis; Udder, Teat, morphology*

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Introduction

Udder and teat conformation traits in cattle are highly inheritable and can be categorized according to their shape as undesirable or desirable (Guarín *et al*., 2017). Cows with undesirable shapes of udder and teats are more susceptible to injury and are in high risk of infection by pathogens responsible for mastitis (Bhutto *et al*., 2010; Singh *et al*., 2014). Similarly, udder and teat conformation characters are related to resistance to intramammary infections (Klein *et al*., 2005; Sharma *et al*., 2011). Higher incidence of subclinical mastitis has been reported in cows with pendulous shaped udder than in trough-shaped udders (Uzmay *et al*., 2003; Kamboj *et al*., 2008). In addition, animals with smaller teat are more prone to mastitis than animals with medium and large teats because the shorter teat allow microbes to move up without difficulty compared to animals with larger teat canal (Danish *et al*., 2018). Therefore, udder and teat conformation qualities can be used for improving udder health (Nakov *et al*., 2014).

Somatic cells, the milk-secreting epithelial cells from the lining of the gland, are response to injury or infection (Sharma *et al*., 2011). Increased Somatic cell count (SCC) in milk (including 75% of leukocytes and 25% of epithelial cells) is indicative of intramammary infection (Condas *et al*., 2017; Alhussien and Dang, 2018). Although, animal's age, stage of lactation, parity, seasons, stress and management practices cause variation in SCC (Alhussien and Dang, 2018; Kline *et al*., 2018), the presence of pathogens in the quarter is usually considered to be the main factor associated with the elevation of SCC in milk (Malik *et al*., 2018; Sumon *et al*., 2017). Somatic cell count in individual cow's milk or bulk milk is routinely used worldwide as direct indicator of udder health in dairy animals (Dufour and Dohoo, 2013; Stocco *et al*., 2020) and indirectly monitors the quality of milk (Alhussien *et al*., 2018). However, the normal composition of milk somatic cells varies with the type of secretion or lactation cycle. Normally, in a healthy mammary gland, the somatic cell count (SCC) in milk is lower than $1{\times}10^5$ cells/mL, while during bacterial infection SCC can increase to above $1{\times}10^6$ cells/mL (Bytyqi *et al*., 2010). More studies have revealed positive correlation between milk SCC with anatomical /morphological characteristics of teats and udder (Sharma *et al*., 2017; Guarín *et al*., 2017; Bhutto *et al*., 2010).

Association of udder morphology with the occurrence of mastitis has already been established worldwide (Bhutto *et al*., 2010; Klaas *et al*., 2004; Bharti *et al*., 2015). Nevertheless, there is paucity of information elucidating the association between the udder and teat morphology with intramammary infections in dairy cattle reared under the tropical condition, as compared to the currently available data for cows maintained on temperate conditions. In light of these facts, the objective of the present study was to evaluate the relationships between udder and teat conformations with intramammary infection in lactating dairy cows reared under tropical climate of Tanzania.

Materials and methods

Ethical clearance

Visual inspection of animals and collection of milk samples were performed in accordance with animal welfare guidelines without harming the animals. Farm data were collected with the prior consent of the farm manager.

Study design and location

A cross-sectional study was conducted to collect data from 243 lactating cows on four parastatal dairy farms in Tanzania (designated as farms A, B, C, and D). Farm A (Kitulo Livestock Multiplication Unit) is located at an altitude of 2630-2820 meters above sea level in the Makete district of the Njombe region. Kitulo farm has a semi-temperate climate with maximum and minimum temperatures of 4°C to 8°C and 14.5°C to 18.5°C, respectively. Kitulo area receives unimodal rainfall ranging from 1200 to 1600 mm per year. The wet season in Kitulo area begins in October and ends in May, followed by a cool, dry period that runs from June through August. Farms B (Mazimbu Dairy), C (Magadu Dairy) and D (Animal Research Unit) all belong to Sokoine University of Agriculture and are located in the same climate zone in Morogoro Municipality. Geographically, the municipality of Morogoro lies at an altitude of 500-600 meters above sea level and experiences a mixture of warm and cold temperatures ranging from 27-33.7 °C in the dry/warm season and 14.2-21.7 °C in cool/wet season. Morogoro municipal has a sub-humid tropical climate with a bimodal precipitation pattern (annual average of 600–900 mm) characterized by two precipitation seasons per year, with short rains (October to December) during the dry season. A moderate rainfall of 148 mm resulted in long rains (falling from March to May/June) with an average of 472 mm of precipitation (Meteorological Center, Sokoine Agricultural University). The drought peaks in September and lasts about six months.

Animal Management

In this study, two genotypes of dairy cattle were involved; pure Friesian cattle kept at farm A, and crossbred (crosses of *Bos taurus* and *Bos indicus*) cattle reared at farms B, C and D. Farm A was planted with temperate pastures consisting primarily of *Lolium perenne, Lolium multiflurium,* and *Infolium repens* in a well-maintained paddock and animals allowed to graze for 24 hours. Animals were given water *ad libitum* in pasture and during milking. Milking cows and heavily pregnant animals were given supplements twice a day (during milking hours) of farm-made concentrates comprising of maize and rice bran concentrates (60-70%), sunflower seed cake or cotton seed cake (25%), mineral supplements 2% and 1% salt. In farm B and C, animals were allowed to graze on mixture of established pasture (*Cenchru sciliaris*, *Brachiaria brizantha, Chloris gayana* and *Panicum maximum*) and natural pastures for about 8 hours and fed with hay or green fodder as well as *ad libitum* water after returning to the housing pallor in the afternoon. The floor of the house was made up of rough concrete and having an adequate slope for better drainage. The houses were cleaned twice a day, in the morning from 6.30 AM to 8.00 AM and evening from 3.30 to 5.00 PM. Lactating and heavily pregnant cows were supplemented with farm-made concentrate during milking hours to complete the nutrient requirements. Animals managed on farm D were grazed on natural pastures for 8 hours a day (9.00 am to 2.30 pm and 4.00 to 6.30 pm) with provision of *ad libitum* water in animal sheds. Only lactating and heavily pregnant cows were supplemented with farm-made concentrate during milking hours. Farms A, B and C practiced machine-milking twice a day during the morning from 6.00 to 8.00 AM and evening from 3.00 to 5.00 PM. While farm D used hand milking twice a day during 7.00 – 8 AM and evening from 3.00 to 5.00 pm. Animal in all farms were routinely vaccinated against common diseases (Brucellosis, Contagious Bovine Pleuropneumonia, Anthrax and Black Quarter diseases), regularly dewormed and dipped against external parasites.

Evaluation and classification of udder and teat conformation

Udder and teat conformations from 243 cows were evaluated through visual examination and categorized accordingly (Danish *et al*., 2018; Basavaraj *et al*., 2019). Udder conformation was evaluated and classified into four types: pendulous, round, goaty or desirable/normal udder. Similarly shape of teats was examined grossly and categorized as desirable; short; funnel-shaped; bottle-shaped and cone-shaped as per the visual appraisal method. In addition, the dimensions (teat length and teat diameter) were measured with Vernier calipers in each quarter of individual animal. Briefly, the teat length (in millimeters) was measured as the distance from the teat base to the end of the teat, and the teat diameter was measured at the central part of the teat.

Screening for Intramammary Infection

Presence of clinical or subclinical mastitis was revealed by examining for the cardinal signs of the disease. For clinal mastitis, animals were examined for presence of udder inflammation together with or without systemic reactions whereas the subclinical mastitis was checked using California Mastitis Test (CMT) protocol as previously described by Mpatswenumugabo *et al*., (2017). Briefly, milk samples (approximately 3 mL) from each quarter /teat were put in marked CMT paddle cups (marked A, B, C and D to correspond to individual teats/quarter) and mixed with equal amount (about 3 mL) of CMT solution. The paddle was rotated in a circular motion for about 10 seconds to mix the milk and CMT solution thoroughly. The test was read quickly, as the visible reaction of gel formation grading of sub-clinical and clinical mastitis. CMT score ranging from 0 to 4 was used, where 0 is negative result (no gel formation), 1 is traceable (possible infection), and 2 or 3 indicates a positive result and 4 has the thickest gel formation. A sample was defined as positive to SCM when one or more quarters with CMT ≥ 2+ were detected.

Collection of milk samples

Proper history on the previous occurrence and treatment of mastitis was taken prior to milk sample collection for bacteriology. Before milk sample collection, the udder of cows was thoroughly washed using clean water, dried with clean towel and teats were sprayed with 70% ethanol. Few milliliters of milk (2-3 streaks) were poured off, and milk sample were aseptically collected in sterile bottles. Collected milk samples were portioned into two; one part for somatic cell count and second part for bacteriological culture. Milk samples for bacteriological culture were packed in cool box packed with ice packs to maintain cold chain environment while transported to the Microbiology laboratory at the College of Veterinary Medicine and Biomedical Sciences of Sokoine University of Agriculture (SUA).

Somatic Cell Count

Milk samples for SCC were prepared using the microscopic slides method as previously prescribed (Bharti *et al*., 2015). Briefly, dried milk smears were prepared using 10µL milk and stained with modified Newman-Lampert stain for 1–2 minutes, then the stain was drained and the smears were washed gently with tap water and dried again. Stained dry milk smears were examined under a microscope oil immersion lens (x100). Thirty different backgrounds were observed per smear and the average number of somatic cells per background was calculated. The average number of cells per background was then multiplied by the microscopic factor of the microscope which is 240807, to obtain the number of cells per milliliter of milk.

Bacteriological examination of milk samples

At the laboratory, samples were inoculated onto nutrient agar, blood agar, and Chapman's agar plates. Plates were incubated at 37°C under aerobic conditions for 24-48 hours before final observation. At least one colony forming unit (CFU) was required for the pathogens (*Bacillus* spp., *Streptococcus agalactiae, Escherichia coli* and *Staphylococcus aureus*) to be considered positive bacterial growth. Positive isolates were firstly characterized based on colony morphology, hemolytic properties, Gram reaction, catalase production, and biochemical examination. A catalase test was performed on Gram positive (+) isolates to distinguish between staphylococcal and streptococcal species. Catalase-negative colonies were tentatively identified as *Streptococcus* spp., while coagulase-positive colonies were regarded as *S. aureus. Bacillus* spp. were identified based on colony morphology and Gram staining. Gram (-) isolates were inoculated onto eosin methylene blue (EMB) agar and MacConkey agar and incubated at 37 °C for 24 h to identify *E. coli*. A greenish metallic isolate on EMB agar and a lactose-positive pink isolate were tentatively identified as *E. coli* after an IMVIC (indole, methyl red, Voges-Proskauer, Citrate) Reaction. Samples were said to be contaminated if three or more types of bacteria were isolated from one milk sample and no growth of the specified major pathogens was detected. Cultures were regarded negative if no growth was seen after 48 hours of incubation.

Statistical analysis

Information collected in this research were compiled and cleaned in Microsoft Excel® and imported into SPSS Statistical Package version 17 for analysis. Estimates of the prevalence of pathogens commonly isolated on dairy farms were determined using standard formulae (Number of positive animals/samples divided by total number of animals/samples tested). Descriptive statistics were calculated to determine the frequency of intramammary infection. A statistically significant relationship between variables was considered to be present if the p-value was less than 0.05. Figures were generated in Microsoft excel®.

Results

Udder and teat morphometrics

The occurrence of various udder and teat conformation in Friesian and crossbred cows kept in four farms under different management systems are as presented in Table 1.

Table 1. Frequency of different morphological types of udder in Friesian and crossbred dairy cattle

Udder conformation types	Farm A		Farm B		Farm C		Farm D		Total	
	AF	RF	AF	RF	AF	RF	AF	RF	AF	RF
Desirable	76	60.8	45	67.2	26	76.5	13	76.4	160	65.8
Pendulous	28	22.4	13	19.4	3	8.8	2	11.8	46	18.9
Round	9	7.2	3	4.5	4	11.8	2	11.8	18	7.4
Goaty	12	9.6	6	8.9	1	2.9	0	0	19	7.8
TOTAL	125	100	67	100	34	100	17	100	243	100

AF: Absolute Frequency; RF: Relative Frequency

The observation revealed high percentage of cows had desirable udder (65.8%) and teat (76.0%) shapes. Among the undesirable udder shapes, pendulous type udder had higher frequency (18.9%), followed with goaty (7.8%) and round (7.4%). The frequencies of undesirable teat shapes were 5.3%, 6.6%, 4.5% and 7.5% for short, funnel, bottle and conical shaped teats, respectively (Table 2). It was further observed that the percent occurrence of undesirable udder types was significantly higher (P<0.05) in farm A which had pure breed Friesian cows than in the other three farms keeping crossbred cows. Similarly, the study revealed that the frequencies of undesirable teat shapes was significantly higher (P<0.03) in machinery milked cows (32.4%) than in hand milked animals (17.6%). Among the machinery milked cows, pure breed (Friesian) had higher occurrence of undesirable teat shapes (38.2%) than crossbred cows (29.7%). The results of teat measurements (Table 2) showed variation in teat length from 49.0 mm to 72.0 mm with a mean of 49.31±0.28 mm. The average teat diameter was 16.73±0.15 mm, ranging from 13.0 mm to 28.5 mm. Pure Friesian cows had higher average teat length (52.84±0.36) and diameter (20.56±0.25) than 48.13±0.26 and 15.45±0.10 for average teat length and diameter, respectively, observed crossbreed cows.

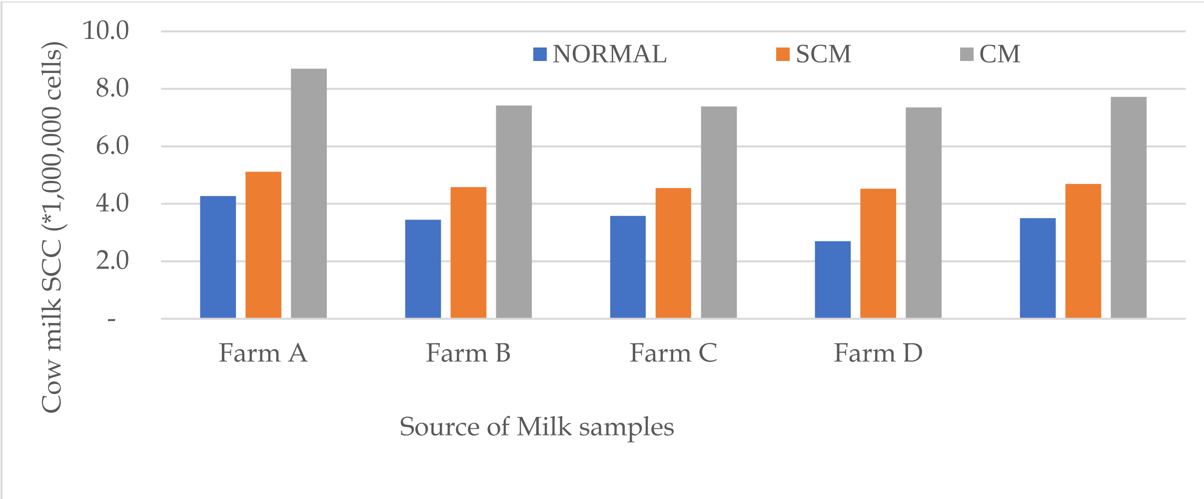
Table 2. Classification of morphological shapes and biometrics of cow teats from four dairy farms

	Farm A		Farm B		Farm C		Farm D		Total	
	AF	RF	AF	RF	AF	RF	AF	RF	AF	RF
Type of teats shape										
Desirable	373	74.6	209	78.0	101	74.3	56	82.4	739	76.0
Short	24	4.8	18	6.7	6	4.4	4	5.9	52	5.3
Funnel	34	6.8	16	6.0	12	8.8	2	2.9	64	6.6
Bottle	26	5.2	8	3.0	8	5.9	2	2.9	44	4.5
Cone	43	8.6	17	6.3	9	6.6	4	5.9	73	7.5
TOTAL	500	100	268	100	136	100	68	100	972	100
Teats biometrics										
Average Length (millimeter)	52.84±0.36		48.42±0.26		51.74±0.36		44.24±0.15		49.31±0.28	
Average diameter (millimeter)	20.56±0.25		15.49±0.09		15.87±0.15		14.98±0.07		16.73±0.15	

AF: Absolute Frequency; RF: Relative Frequency

Milk somatic cell count

Results showed (Figure 1) that there were significant differences (P<0.01) between cattle genotypes on SCC and the analysis revealed that the effects of intramammary infections were also statistically significant (P<0.01). The overall SCC means for normal udder, subclinical mastitis and clinical mastitis were 3.5 million cells, 4.7 million cells and 7.7 million cells, respectively. Further analysis revealed high correlation between SCC and udder/teat shapes. The mean ± SE of SCC for desirable, pendulous, round and goaty shaped udders was 3.110±0.024, 6.235±0.027, 4.962±0.021, and 4.728±0.014, respectively. Similarly, mean ± SE of SCC for desirable, short, funnel, bottle and conical-shaped teats was 3.189±0.105, 6.850±0.068, 5.989±0.195, 4.899±0.168, and 5.030±0.145, respectively. Furthermore, analysis showed a significantly (p<0.01) positive correlation between SCC and teat diameter as well as teat length with correlation coefficient of 0.443 and 0.419, respectively.

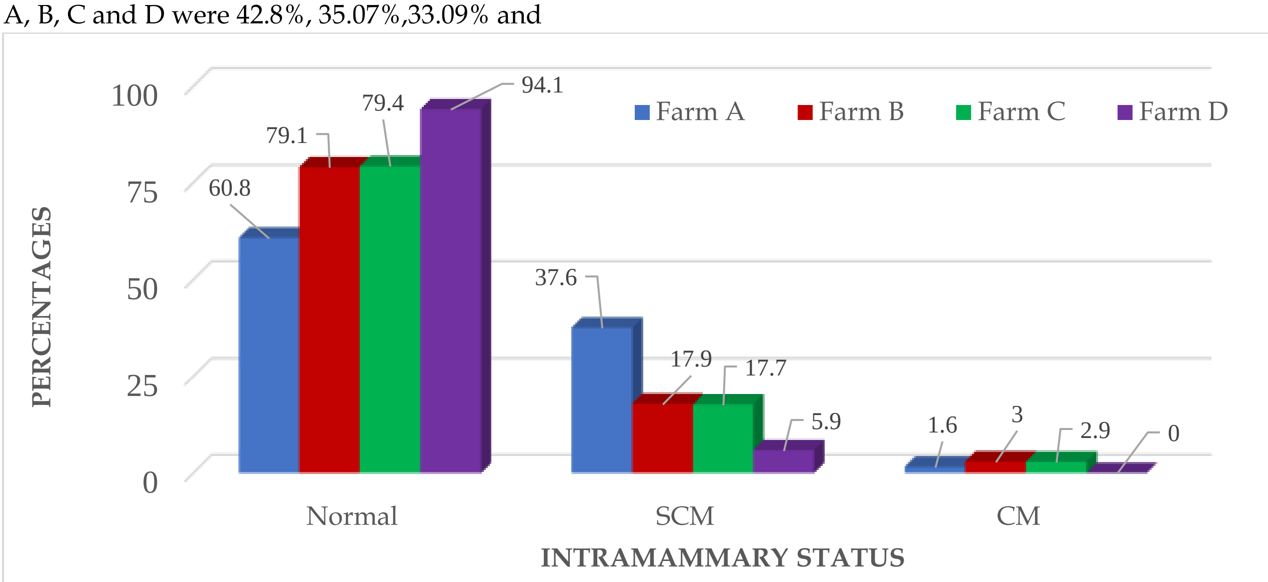


SCM = subclinical mastitis CM = clinical mastitis

Figure 1. Relationship between SCC and intramammary infection status in cows kept in four dairy farms.

Intramammary infection

Nine hundred and seventy-two quarters from 243 lactating dairy cows (125 Friesian and 118 crossbred) were screened for the presence of mastitis in the study. Out of the 972 quarters examined, normal, clinical and sub-clinical abnormalities were detected in 605 (62.24%), 12 (1.23%) and 355 (36.52%), respectively. The prevalence of subclinical mastitis in cows at farm A, B, C and D were 42.8%, 35.07%,33.09% and 2.94%, respectively (Figure 2); and there was a significant difference (P<0.01) in the prevalence between machine milked farms (A, B & C) and hand milked animals (farm D) (Figure 1). Most of subclinical mastitis cases were observed affecting one quarter (30.06%) followed with two quarters (24.18%) and, three and four quarters (22.88%) (Table 3).



SCM = subclinical mastitis CM = clinical mastitis

Figure 2. The intramammary status of cows in relation to prevalence of mastitis in four dairy farms

Table 3. Distribution of intramammary infection in cows' quarters in the four herds

Farm	Number of cows affected with intramammary infections				Total number of cows affected
	One quarter	Two quarters	Three quarters	Four quarters	
Farm A	24	11	8	6	49
Farm B	4	3	4	3	14
Farm C	3	1	1	2	7
Farm D	0	0	0	1	1
TOTAL	31 (43.66%)	15 (21.13%)	13 (18.31%)	12 (16.90%)	71 (100%)

The most prevalent microorganisms isolated from the intramammary infected animals (clinical and subclinical mastitis) included *Staphylococcus aureus* (56.34%), *Escherichia coli* (22.55%), *Streptococcus agalactiae* (9.86%), *Bacillus* spp. (8.45%), and none typed microorganisms (2.82%) as shown in Table 4.

Table 4. Frequency of bacterial isolates from cases of mastitis in four dairy farms

Bacterial isolates	Number of isolates					% isolates
	Farm A	Farm B	Farm C	Farm D	Total	
Bacillus spp.	4	1	1	0	6	8.45
Escherichia coli	8	5	2	1	16	22.55
Staphylococcus aureus	28	8	4	0	40	56.34
Streptococcus agalactiae	7	0	0	0	7	9.86
Others	2	0	0	0	2	2.82

Relationship between udder/teat Morphometry and incidence of intramammary infection

The udder and teats are the first line of defense against intramammary infection. Among various shape of the udder examined in the present study, pendulous shaped udder was having highest incidence of mastitis (76.10%) followed by round (50.0%) and goaty (47.37%) shaped udder (Table 5). Similarly, the present study revealed that teat shapes may be a risk factor for intramammary infection as we found higher incidence of mastitis in undesirable teats (73.08%, 50.0%, 43.75% and 41.10%) in short, funnel, bottle and conical shaped teats, respectively) than in desirable teat shapes (Table 5). Furthermore, our results indicated an increase in the degree of intramammary infection with a decrease in teat length and teat diameter as log SCC and mastitis were found to be significantly positively correlated with teat morphometry.

Table 5. Incidence of mastitis in dairy cows with respect to different udder and teat morphology

Type of udder and teat morphological shape	Farm A % (n)	Farm B % (n)	Farm C % (n)	Farm D % (n)	Total % (n)
UDDER					
Desirable udder	14.47% (11)	8.87% (4)	11.54% (3)	0 (0)	11.25% (18)
Pendulous udder	85.71% (25)	53.85% (7)	66.67% (2)	50% (1)	76.10% (35)
Round udder	66.67% (6)	33.33% (1)	50% (2)	0 (0)	50% (9)
Goaty udder	58.33% (7)	33.33% (2)	0 (0)	0 (0)	47.37% (9)
TEATS					
Desirable teat	5.90% (22)	2.39% (5)	1.98% (2)	0 (0)	3.92% (29)
Short teat	75.0% (18)	55.56% (10)	50.0% (3)	100% (4)	73.08% (35)
Funnel teat	52.94% (18)	43.75% (7)	25.0% (3)	0 (0)	43.75% (28)

Bottle teat	57.69% (15)	62.5% (5)	25.00% (2)	0 (0)	50.00% (22)
Conical teat	48.84% (21)	41.18% (7)	22.22% (2)	0 (0)	41.10% (30)

Discussion

Intramammary infection is an imperative menace affecting the dairy sector with udder and teat conformation being a risk factors for intramammary infection (Bhutto *et al.*, 2010; Singh *et al.*, 2014). Cows with undesirable shaped udders and teats are more susceptible to lesions and contamination by mastitis-causing pathogens, which increase the risk of mastitis (Singh *et al.*, 2014). Therefore, the udder conformation traits with strong arguments can be used to improve udder health (Nakov *et al.*, 2014). In this study, the overall frequencies of desirable (65.8%), pendulous (18.9%), goaty (7.8%), and round shaped udder (7.4%) were recorded. The recorded undesirable udder shapes (pendulous, goaty and round shaped udder) are in agreement with the findings reported elsewhere (Modh *et al.*, 2017; Basavaraj *et al.*, 2019). Teat shape plays an important role in milk flow of milk from the udder, which also helps in selection of high milk yielding cattle and the different shapes of the teat might be its genetic heritability. In the present study, teats from examined animals exhibited the following frequencies: 74.6% (373/500) teats of desirable shape, 7.5% (73/500) conical-shaped teats, 6.6% (64/500) funnel-shaped teats, 5.3% (52/500) short teats, and 4.5% (44/500) bottle-shaped teats. These data are consistent with the findings reported by Okano *et al.*, (2015) in Holstein cows in two dairy farms in Brazil. However, our findings are different from those observed in dairy cattle kept in United Kingdom (Rathore, 1976), India (Bharti *et al.*, 2015) and Bangladesh (Islam *et al.*, 2020). The dimension (length and diameter) of teats recorded in this study ranged from 44.24±0.15 to 52.84±0.36 and 14.98±0.07 to 20.56±0.25 in pure Friesian and crossbreed cows, respectively. Pure Friesian cows had longer (length) and larger (diameter) teats than crossbreed cows. Observed teat measurements from crossbred cows are comparable with findings reported by Islam *et al.*, (2020) in crossbred dairy cows in Bangladesh. Similarly, Friesian teat dimension findings reported here are in line with other studied conducted previously in the different parts of the world including Turkish Holstein-Friesian farms (Bardakcioglu *et al.*, 2011) and Belgian Holstein-Friesian cows (Zwertvaegher *et al.*, 2012). Nevertheless, teat diameters are dependents of the breed of cows (Zwertvaegher *et al.*, 2011), parity (Seker *et al.*, 2009), stage of lactation (Tilki *et al.*, 2005) and quarter position (Zwertvaegher *et al.*, 2012)

Somatic cells are part of the udder's innate immune system and consist of 75-85% white blood cells (macrophages, polymorphonuclear neutrophils (PMNs), lymphocytes) and 15-25% epithelial cells (Barrett, 2002). Determining the number somatic cells in milk is internationally recognized as the gold standard for diagnosing subclinical mastitis in ruminants and humans (Hunt *et al.*, 2013; Bharti *et al.*, 2017; Malik *et al.*, 2018). This study observed higher level of somatic cell count in pure breed Friesian cattle than in crossbreeds. Similarly, it has been reported that high-milk producing cattle breeds such as Brown Swiss and Holstein Friesian have a higher presence of SCC/mL in milk than crossbreed cow breeds (Alhussien *et al.*, 2016; Alhussien and Dang, 2018). Further analysis yielded higher level of somatic cell count in undesirable udder and teats in comparison to desirable shaped udder teats. Several researchers have reported SCC variation with respect to various breeds of cows (Ahlawat *et al.*, 2008; Koc and Kizilkaya, 2009; Alhussien and Dang, 2018). The relationship of the teat conformation and size on SCC observed in the current study is similar to report of Sharma *et al.*, (2016) that SCC in milk is usually higher in short teats with a larger width of teat canal. However, other researchers have not found the relationship of udder and teat shapes and dimensions on SCC (Coban *et al.*, 2009; Orban *et al.*, 2009). Other researchers had also stated a significant impact of udder shape and reported that cows with pendulous udders have higher SCC compared to regular udder shapes (Ahlawat *et al.*, 2008). Correspondingly, this study revealed a good correlation between intramammary infection and teat dimensions (length and diameter). Several researches have reported similar trend of presence of higher value of somatic cell counts in shorter teats (Nemcova *et al*., 2007) and thin teat diameter (Orban *et al*., 2009). Nevertheless, others have reported no effects of teat length and thickness on SCC (Juozaitiene *et al*., 2006). Other researchers have however reported that long and thick teats are potential risk factor for occurrence of intramammary infection in cows (Haghkhah *et al*., 2011; Singh *et al*., 2014; Bharti *et al*., 2015).

This study also reported that, the quarter level prevalence for subclinical mastitis was 30.06%, 24.18% and 22.88% for one quarter, two quarters, and three and four quarters, respectively. These findings are almost similar to that reported in Uruguay (Gianneechini *et al*., 2002), Zimbabwe (Katsande *et al*., 2013) and Bangladesh (Sumon *et al*., 2017). However, quarter SCM prevalence of 16.90% to 43.66% are higher than previously reported in Riverine buffaloes (Gagandeep *et al*., 2018) and Dairy cattle (Milesa *et al*., 2019). Difference in SCM between herds can be associated with farmers' awareness about the disease and adaption toward the use different control measures for maintaining good hygiene around animals' udder and teats. Several researchers have highlighted udder and teat shape as risk factors for intramammary infection in dairy cows. This is because cows with undesirable udder shapes and long, thick teats are more prone to lesions and contamination with mastitis-causing organisms, increasing the risk of mastitis (Bharti *et al*., 2015; Bhutto *et al*., 2010; Singh *et al*., 2014). Results regarding the occurrence of intramammary infection in relation to udder and teat morphometrics reported here are comparable to those observed elsewhere (Kamboj *et al*., 2008; Uzmay *et al*., 2003; George *et al*., 2007; Danish *et al*., 2018). It is hypothesized that animals with pendulous udder have positive correlation with high incidence of mastitis because long and pendulous udders get in contact with ground more frequently causing injuries and thus predisposing the animals to pathogens that are associated with mastitis.

Bovine mastitis is one of the main diseases affecting dairy herds worldwide and inadequate milking practices or poorly maintained milking equipment (Capuco *et al*., 1994; Schukken *et al*., 2003) are among the risk factors for the occurrence of this intramammary infection. In this study, the prevalence of subclinical mastitis was higher (farms average of 36.99%) in machinery milked cows than in hand milked cows (2.94%). Similar findings have been reported in Cuba (Ruiz *et al*., 2014) and Dutch dairy herds (Barkema *et al*., 1999). The milking machine, especially when not functioning properly, is implicated in the occurrence of mastitis by transmitting infections between cows or quarters, or adversely affecting udder health through damaging or changing the resistance of the cow's first line of defense. In addition, it is hypothesed that milking machine that lack enough vacuum, inappropriate milking practices, poor udder cleaning prior to milking are among of risk factors of occurrence of mastitis (Oliveria *et al*., 2015).

Most of the intramammary infections were caused by *Staphylococcus aureus* (56.34%) which suggests that the prevention of spread of this contagious bacterium during milking was not effective. High prevalence of *S. aureus* in mastitic cattle has been reported previously in Tanzania (Mdegela *et al*., 2004; Mdegela *et al*., 2005; Mdegela *et al*., 2009; Kashoma *et al*., 2015), Rwanda (Mpatswenumugabo *et al*., 2017; Ndahetuye *et al*., 2020), Algeria (Saidi *et al*., 2013), Italy (Moroni *et al*., 2006), Brazil (Dittmann *et al*., 2017), Morocco (Bendahou *et al*., 2008), Ethiopia (Daka *et al*., 2012; Zeryehun and Abera, 2012) and Kenya (Shitandi and Sternesjö, 2004). *Stapphylococcus aureus* are the most prevalent pathogen on the skin of udder of clinically healthy cattle and animal environment (Kashoma *et al*., 2015), and has the capacity to penetrate into the tissue, producing deep seated foci protected by a tissue barrier (Barkema *et al*., 2009; Ranjan *et al*., 2010; Rall *et al*., 2013). The reported high frequency of staphylococcal mastitis is considered to be due to poor milking hygiene and lack of proper attention to the health of the mammary gland in general. Thus, hygiene at milking is of paramount importance in control of these infections because the bacteria are likely to be spread during the milking process. In this study, the result of isolation of *Escherichia coli* was almost similar to that reported elsewhere (Kivaria *et al*., 2007; Mpatswenumugabo *et al*., 2017) but lower than that reported in Bangladesh (Kayesh *et al*., 2014; Sumon *et al*., 2017). Variations in *E. coli* isolation may be attributable to poor cleanliness, drainage and manure disposal in farms as well as poor milking practice. Even though contagious *Streptococcus agalactiae* (9.86%) were ranked in third position in the present study, the bacteria have been stated as the most famous bacteria in cow mastitis in some countries (Hegde *et al*., 2013; Östensson *et al*., 2013). The prevalence rate of *S. agalactiae* revealed in the present study agrees with preceding findings observed elsewhere (Mdegela *et al*., 2009; Persson *et al*., 2011). *Bacillus* spp., were present in 8.45% of cases in the present study. *Bacillus* spp. has also been recognized as important bacteria in both CM and SCM in earlier studies (Nieminen *et al*., 2007; Amer *et al*., 2018). However, these findings disagree with other studies showing that mastitis caused by *Bacillus* spp is uncommon in dairy cows (Sori *et al*., 2005; Abera *et al*., 2012). The presence of *Bacillus* spp. could be associated with poor hygienic conditions of milkers as the bacteria are broadly dispersed in dairy environment, including on teat skin, milkers' skin, and farm floors, which signify reservoirs of bacteria related with intramammary infections (Amer *et al*., 2018; De Visscher *et al*., 2014).

Conclusion

The present study revealed the association between some udder and teat morphometric traits and poor udder health in lactating dairy cows. Most of cows with pendulous udder and funnel shaped teats were more susceptible to intramammary infections. Among the animals, Friesian cows which were machinery-milked cows had high prevalence of undesirable udder and teat shapes as well as intramammary infection than cross-bred cows maintained under hand milking management. High prevalence of contagious *Staphylococcus aureus* in mastitic cattle was among of observation. Therefore, udder and teat conformation traits should be considered will selecting animals for milk production. Similarly, high prevalence of *Staphylococcus aureus*, the contagious pathogens, and well spread via milking machine components, hands of milking personnel, and through washcloths, thus calls for hygienic improvement during milking practices.

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References

Abera, M., Elias, B., Aragaw, K., Denberga, Y., Amenu, K., & Sheferaw D. (2012). Major causes of mastitis and associated risk factors in smallholder dairy cows in Shashemene, southern Ethiopia. *African Journal of Agricultural Research*, 7: 3513–18.

Ahlawat, K., Dang, A.K., & Singh, C. (2008). Relationships of teat and udder shape with milk SCC in primiparous and multiparous Sahiwal cows. *Indian Journal of Dairy Science*, 61: 152-156.

Alhussien, M., Manjari, P., Mohammed, S., Sheikh, A.A., Reddi, S., Dixit, S., & Dang, A.K. (2016). Incidence of mastitis and activity of milk neutrophils in Tharparkar cows reared under semi-arid conditions. *Tropical Animal Health and Production*. 48: 1291-1295.

Alhussien, M.N., & Dang, A.K. (2018). Milk somatic cells, factors influencing their release, future prospects, and practical utility in dairy animals: An overview. *Veterinary World*, 11(5): 562-577.

Amer, S., Gálvez, F.L.A., Fukuda, Y., Tada, C., Jimenez, I.L., Valle, W.F.M., &

Nakai, Y. (2018). Prevalence and etiology of mastitis in dairy cattle in El Oro Province, Ecuador. *Journal of Veterinary Medical Science*, 80(6):861-868.

Bardakcioglu, H.E., Sekkin, S., & Oral-Toplu, H.D. (2011). Relationship between some teat and body measurements of Holstein cows and sub-clinical mastitis and milk yield. *Journal of Animal and Veterinary Advances*, 10(13): 1735-1737.

Barkema, H.W., Green, M.J., Bradley, A.J., & Zadoks, R.N. (2009). Invited review: The role of contagious disease in udder health. *Journal of Dairy Science*, 92: 4717–4729.

Barkema, H.W., Schukken, Y.H., Lam, T.J., Beiboer, M.L., Benedictus, G., & Brand, A. (1999). Management practices associated with the incidence rate of clinical mastitis. *Journal of Dairy Science*, 82(8):1643-54. Doi: 10.3168/jds. S0022-0302(99)75393-2.

Barrett, D. (2002). High somatic cell counts-a persistent problem. *Irish Veterinary Journal*, 55(4): 173.

Basavaraj, H., Waghmare, P., Patil, V.M., Suranagi, M.D., Biradar, U.S., Chandra, S., Desai, A.R., Mallikarjun, H., & Prasad, M. (2019). Study the Morphological Characteristics of Udder and Teat and Its Relation with Lactation Milk Yield in Deoni Cattle. *International Journal of Current Microbiology and Applied Sciences*, 8(10): 2369-2376.

Bendahou, A., Lebbadi, M., Ennanei, L., Essadqui, F.Z., & Abid, M. (2008). Characterization of *Staphylococcus* species isolated from raw milk and milk products (lben and jben) in North Morocco. *Journal of Infection in Developing Countries*, 2: 218–225.

Bharti, P., Bhakat, C., Japheth, K., Bhat, S., Chandra, S., & Kumar, A. (2017). Influence of Animal Factors on Milk Somatic Cell Count in Crossbred Cows Reared Under Hot-Humid Climatic Condition. *International Journal of Livestock Research,* 7(4), 228-235. http://dx.doi.org/10.5455/ijlr.20170324031931

Bharti, P., Bhakat, C., Pankaj, P.K., Bhat, S.A., Prakash, M.A., Thul, M.R., & Japheth, K.P. (2015). Relationship of udder and teat conformation with intramammary infection in crossbred cows under hot-humid climate. *Veterinary World*, 8(7): 898-901.

Bhutto, A.L., Murray, R.D., & Woldehiwet, Z. (2010). Udder shape and teat-end lesions as potential risk factors for high somatic cell counts and intramammary infections in dairy cows. *Veterinary Journal*, 183(1): 63-67.

Bytyqi, H., Zaugg, U., Sherifi, K., Hamidi, A., Gjonbalaj, M., & Muji, S, (2010). Influence of management and physiological factors on somatic cell count in raw milk in Kosova. *Veterinarski Archives*, 80(2):173-183.

Capuco, A.V., Mein, G.A., Nickerson, S.C., Jack, L.J., Wood, D.L., Bright, S.A., Aschenbrenner, R.A., Miller, R.H., & Bitman, J. (1994). Influence of pulsationless milking on teat canal keratin and mastitis. *Journal of Dairy Science*, 77: 64-74.

Coban, O., Sabuncuoglu, N., & Tuzemen, N. (2009). A study on relationships between somatic cell count (SCC) and some udder traits in dairy cows. *Journal of Animal Veterinary advances*, 8: 134-138.

Condas, L.A., De Buck, J., Nobrega, D.B., Carson, D.A., Roy, J.P., & Keefe, G.P. (2017). Distribution of non-aureus staphylococci species in udder quarters with low and high somatic cell count, and clinical mastitis. *Journal of Dairy Science*, 100:5613–27;

Daka, D., Solomon, G., & Yihdego, D. (2012). Antibiotic-resistance *Staphylococcus aureus* isolated from cow's milk in the Hawassa area, South Ethiopia. *Annals of Clinical Microbiology and Antimicrobials*, 11:26-37.

Danish, Z., Bhakat, M., Paray, A.R., Lone, S.A, Rahim, A., Mohanty, T.K., & Sinha, R. (2018). Udder and teat morphology and their relation with incidence of sub-clinical and clinical mastitis in Sahiwal, Karan Fries cows and Murrah buffaloes. *Journal of Entomology and Zoology Studies*, 6(5): 2138-2141.

De Visscher, A., Supré, K., Haesebrouck, F., Zadoks, R.N., Piessens, V., Van Coillie, E., Piepers, S., & De Vliegher, S. (2014). Further evidence for the existence of environmental and host-associated species of coagulase-negative Staphylococci in dairy cattle. *Veterinary Microbiology*, 172: 466–474.

Dittmann, K.K., Chaul, L.T., Lee, S.H.I., Corassin, C.H., de Oliveira, C.A.F., De Martinis, E.C.P., Alves, V.F., Gram, L., & Oxaran,

V. (2017). *Staphylococcus aureus* in Some Brazilian Dairy Industries: Changes of Contamination and Diversity. *Front Microbiology*, 8: 2049. doi: 10.3389/fmicb.2017.02049

Dufour, S., & Dohoo, I.R. (2013). Monitoring herd incidence of intramammary infection in lactating cows using repeated longitudinal somatic cell count measurements. *Journal of Dairy Science*, 96:1568-1580.

Gagandeep, K., Baljinder, K.B., Raj, S.S., Neeraj, K. & Sharma, S. (2018). Associations of teat morphometric parameters and subclinical mastitis in riverine buffaloes. *Journal of Dairy Research*, 85(3):1-6

George, S., Joshi, H.C., Suman, C.L., Rathore, R.S., & Bisht, G.S. (2007). Incidences of subclinical mastitis in crossbred cattle herd. *Indian Journal of Animal Production and Management*, 23:1-4.

Gianneechini, R., Concha, C., Rivero, R., Delucci, I., & Moreno Lopez, J. (2002). Occurrence of Clinical and Sub-Clinical Mastitis in Dairy Herds in the West Littoral Region in Uruguay. *Acta Veterinary Scandinavia*, 43: 221–230.

Guarín, J.F., Paixão, M.G., & Ruegg, P.L. (2017). Association of anatomical characteristics of teats with quarter-level somatic cell count. *Journal of Dairy Science*, 100:643–652

Haghkhah, M., Ahmadi, M.R., Gheisari, H.R., & Kadivar, A. (2011). Preliminary bacterial study on subclinical mastitis and teat condition in dairy herds around Shiraz. *Turkish Journal of Veterinary and Animal Sciences*, 35: 387-394.

Hegde, R., Isloor, S., Nithin, P.K., Shome, B.R., Rathnamma, D., Suryanarayana, V.V.S., Yatiraj, S., Prasad, R., Krishnaveni, C., Sundareshan, N., Akhila, D.S., Gomes, A.R., & Hegde, N.R. (2013). Incidence of sub-clinical mastitis and prevalence of major mastitis pathogens in organized farms and unorganized sectors. *Indian Journal of Microbiology*, 53(3): 315–320.

Hunt, K.M., Williams, J.E., Shafii, B., Hunt, M.K., Behre, R., Ting, R., McGuire, M.K., & McGuire, M.A. (2013). Mastitis is associated with increased free fatty acids, somatic cell count, and interleukin-8 concentrations in human milk. *Breastfeeding Medicine*, 8(1):105-110.

Islam, M.R., Islam, R.M., & Islam, M.M. (2020). Importance of Teat Characteristics in Selecting Cross-Bred Dairy Cows on Milk Yield at the Villages of Tangail in Bangladesh. *Journal of Agriculture and Veterinary Science*, 13(7): 57-59.

Juozaitiene, V., Juozaitis, A., & Micikeviciene, R. (2006). Relationship between somatic cell count and milk production or morphological traits of udder in Black and White cows. *Turkish Journal of Veterinary and Animal Sciences*, 30: 47-51.

Kamboj, M.L., Singh, A., & Prasad, S. (2008). Effect of udder and teat characteristics on incidences of subclinical mastitis in crossbred cows. *Indian Veterinary Journal*, 85(8):846-848.

Kashoma, I.P., Lalata, E.P., Maiga, C.J., Mtemela, B.O., & Medardus, J.J. (2015). Prevalence and antimicrobial susceptibility profiles of *Staphylococcus aureus* from cow's milk, nasal and environmental swabs in selected dairy farms in Morogoro, Tanzania. *Tanzania Veterinary Journal*, 30(2): 61- 75.

Katsande, S., Matope, G., Ndengu, M., & Pfukenyi, D.M. (2013). Prevalence of mastitis in dairy cows from smallholder farms in Zimbabwe. *Journal of Veterinary Research*, 80(1): E1–7. Doi: 10.4102/ojvrv80i1.523.

Kayesh, M.E.H., Talukder, M., & Anower, A.K.M.M. (2014). Prevalence of subclinical mastitis and its association with bacteria and risk factors in lactating cows of Barisal district in Bangladesh. *International Journal of Biological Research*, 2 (2): 35–38.

Kivaria, F.M., Noordhuizen, J.P.T.M., & Nielen, M. (2007). Interpretation of California mastitis test scores using *Staphylococcus aureus* culture results for screening of subclinical mastitis in low yielding smallholder dairy cows in the Dar es Salaam region of Tanzania. *Preventive Veterinary Medicine*, 78(3-4): 274–285.

Klaas, I.C., Enevoldsen, C., Vaarst, M., & Houe, H. (2004). Systematic clinical examinations for identification of latent udder health types in Danish dairy herds. *Journal of Dairy Science,* 87:1217–1228.

Klein, D., Flock, M., Khol, J.L., Franz, S., Stuger, H.P., & Baumgartner, W. (2005). Ultrasonographic measurement of the bovine teat: breed differences, and the significance of the measurements for udder health. *Journal of Dairy Research*, 72: 296-302.

Kline, K., Flores, S., & Joyce, F. (2018). Factors affecting Somatic Cell Count in milk of dairy cows in Costa Rica. *International Journal of Veterinary Science and Research*, 4:001–8.

Koç, A., & Kizilkaya, K. (2009). Some factors influencing milk somatic cell count of Holstein Friesian and Brown Swiss cows under the Mediterranean climatic conditions. *Archiv Tierzucht*, 52(2):124-133.

Malik, T.A., Mohini, M., Mir, S.H., Ganaie, B.A., Singh, D., Varun, T.K., Howal, S., & Thakur, S. (2018). Somatic cells in relation to udder health and milk quality- A review. *Journal of Animal Health and Production,* 6(1): 18-26.

Mdegela, R.H., Karimuribo, E.D., Kusiluka, L.J.M., Kabula, B., Manjurano, A., Kapaga, A.M., & Kambarage, D.M. (2005). Mastitis in smallholder dairy and pastoral cattle herds in the urban and peri-urban areas of the Dodoma municipality in Central Tanzania. *Livestock Research for Rural Development*, 17: 123. http://www.lrrd.org/lrrd17/11/mdeg17123.htm

Mdegela, R.H., Kusiluka, L.J.M., Kapaga, A.M., Karimuribo, E.D., Turuka, F.M., Bundala, A, Kivaria, F.M., Kabula, B., Manjurano, A., Loken, T., & Kambarage, D.M. (2004). Prevalence and determinants of mastitis and milk borne zoonoses in smallholder dairy farming sector in Kibaha and Morogoro districts in eastern Tanzania. *Journal of Veterinary Medicine B,* 51: 123–128.

Mdegela, R.H., Ryoba, R., Karimuribo, E.D., Phiri, E.J., Løken, T., Reksen, O., Mtengeti, E., & Urio, N.A. (2009). Prevalence of clinical and subclinical mastitis and quality of milk in smallholder dairy farms in Tanzania. *Journal of the South African Veterinary Association*, 80 (3): 163–168.

Milesa. A.M., McArtb, J.A.A., Yepesa, FA.L., Stambuka, C.R., Virklerb, P.D., & Huson, H.J. (2019). Udder and teat conformational risk factors for elevated somatic cell count and clinical mastitis in New York Holsteins. *Preventive Veterinary Medicine*, 163: 7–13.

Modh, R.H., Nauriyal, D.S., Islam, M.M., Modi, R.J., & Wadhwani, K.N. (2017). Morphological study on types of udder and teats in association with subclinical Mastitis in Gir cows. *International Journal of Science, Environment and Technology*, 6 (4): 2688 – 2693.

Moroni, P., Pisoni, G., Antonini, M., Villa, R., Boettcher, P., & Carli, S. (2006). Antimicrobial drug susceptibility of Staphylococcus aureus from subclinical bovine mastitis in Italy. *Journal of Dairy Science*, 89: 2973–2976.

Mpatswenumugabo, J.P., Bebora, L.C., Gitao, G.C., Mobegi, V.A., Iraguha, B., Kamana, O., Shumbusho, B., & Mestorino, N. (2017). Prevalence of Subclinical Mastitis and Distribution of Pathogens in Dairy Farms of Rubavu and Nyabihu Districts, Rwanda. *Journal of Veterinary Medicine*. 2017; 8. https://doi.org/10.1155/2017/8456713

Nakov, D., Hristov, S., Andonov, S., & Trajchev, M. (2014). Udder-related risk factors for clinical mastitis in dairy cows. *Veterinarski Arhiv*, 84, 111-127.

Ndahetuyea, J.B., Twambazimana, J., Nyman, A.K., Karege, C., Tukei, M., Ongol, M.P., Persson, Y., & Båge, R. (2020). Cross sectional study of prevalence and risk factors associated with subclinical mastitis and intramammary infections, in dairy herds linked to milk collection centers in Rwanda. *Preventive Veterinary Medicine*, 179:105007. doi: 10.1016/j.prevetmed.2020.105007.

Nemcova, E., Stipkova, M., Zavadilova, L., Bouska, J., & Vacek, M. (2007). The relationship between somatic cell count, milk production and six linearly scored type traits in Holstein cows. *Czech Journal of Animal Science*, 52(12): 437-446.

Nieminen, T., Rintaluoma, N., Andersson, M., Taimisto, A.M., Ali-Vehmas, T., Seppälä, A., Priha, O., & Salkinoja-Salonen, M. (2007). Toxinogenic *Bacillus pumilus* and *Bacillus licheniformis* from mastitic milk. *Veterinary Microbiology*, 124:329–339.

Okano, W., Junior, C.K., Bogado, A.L.G., Filho, L.C.N., Bronkhorst, D.E., Borges, M.H.F., Barca, F.A., Diniz, M., de Santana, E.H.W., & da Silva, C.B. (2015). Relationship Between Shape of Teat and Teat Tip and Somatic Cell Count (SCC) in Dairy Cows. *Acta Scientiae Veterinariae*, 43: 1276.

Oliveira, C.S.F., Hogeveen, H., Botelho, A.M., Maia, P.V., Coelho, S.G., & Haddad, J.P.A. (2015). Cow-specific risk factors for clinical mastitis in Brazilian dairy cattle. *Preventive Veterinary Medicine*, 121(3-4):297-305.

Orban, M., Gulyas, L., Nemeth, S., & Gergacz, Z. (2009). Morphometric evaluation of udders in jersey cows. *Scientific Papers Animal Science and Biotechnologies*, 42(2): 327-332.

Östensson, K., Lam, V., Sj¨ogren, N., & Wredle, E. (2013). Prevalence of subclinical mastitis and isolated udder pathogens in dairy cows in Southern Vietnam. *Tropical Animal Health and Production*, 45(4): 979–986.

Persson, Y., Nyman, A.K.J., & Grönlund-Andersson, U. (2011). Etiology and antimicrobial susceptibility of udder pathogens from cases of subclinical mastitis in dairy cows in Sweden. *Acta Veterinary Scandinavia*, 53:36. Doi:10.1186/1751-0147-53-36

Rall, V.L.M., Miranda, E.S., Castilho, I.G., & Camargo, C.H. (2013). Diversity of Staphylococcus species and prevalence of enterotoxin genes isolated from milk of healthy cows and cows with subclinical mastitis. *Journal of Dairy Science*, 97: 829–837.

Ranjan, R., Gupta, M.K., Singh, S., & Kumar, S. (2010). Current trend of drug sensitivity in bovine mastitis. *Veterinary World*, 3(1):17-20.

Rathore, A.K. (1976). Relationships between teat shape, production and mastitis in Friesian cows. *British Veterinary Journal*, 132(4): 389-392.

Ruiz, A.K., Peña, J., González, D., & Ponce, P. (2014). Prevalence, somatic cell count and etiology of bovine mastitis in Cuban herds from Mayabeque province using hand and machine milking. *Revista Salud Animal*, 36: 7-13.

Saidi, R., Khelef, D., & Kaidi, R. (2013). Subclinical mastitis in cattle in Algeria: Frequency of occurrence and bacteriological isolates. *Journal of the South African Veterinary Association*, 84(1): 84: E1-5.

Schukken, Y.H., Wilson, D.J., Welcome, F., Garrison-Tikofsky, L., & Gonzalez, R.N. (2003). Monitoring udder health and milk quality using somatic cell counts. *Veterinary Research*, 34: 579-596.

Seker, I., Risvanli, A., Yuksel, M., Saat, N., & Ozmen, O. (2009). Relationship between California Mastitis Test score and ultrasonographic teat measurements in dairy cows. *Australian Veterinary Journal*, 87: 480-483.

Sharma, T., Das, P.K., Ghosh, P.R., Banerjee, D., & Mukherjee, J. (2017). Association between udder morphology and in vitro activity of milk leukocytes in high yielding crossbred cows. *Veterinary World*, 10: 342–347.

Sharma, T., Kumar, D.P., Ghosh, P.R., Banerjee, D., Chandra, D.B., & Mukherjee, J. (2016). Alteration in the in vitro activity of milk leukocytes during different parity in high yielding cross-bred cows. *Biological Rhythm Research*, 47: 519-527.

Sharma, N., Singh, N.K., & Bhadwal, M.S. (2011). Relationship of somatic cell count and mastitis: An overview. Asian-Aust. *Journal of Animal Science*.24: 429-438.

Shitandi, A., & Sternesjö. Å. (2004). Prevalence of multidrug resistant *Staphylococcus aureus* in milk from large and small-scale producers in Kenya. *Journal of Dairy Science*, 87:4145–4149.

Singh, R.S., Bansal, B.K., & Gupta, D.K. (2014). Udder health in relation to udder and teat morphometry in Holstein Friesian × Sahiwal crossbred dairy cows. *Tropical Animal Health and Production*, 46: 93-98.

Sori, H., Zerihun, A., & Abdicho, S. (2005). Dairy cattle mastitis in and around Sebeta, Ethiopia. *International Journal of Applied Research in Veterinary Medicine*, 2005; 3: 332–338.

Stocco, G., Summer, A., Cipolat-Gotet, C., Zanini, L., Vairani, D., Dadousis, C., & Zecconi, A. (2020). Differential somatic cell count as a novel indicator of milk quality in dairy cows. *Animals,* 10: 753. https://doi.org/10.3390/ani10050753

Sumon, S., Ehsan, M., & Islam, M. (2017). Subclinical mastitis in dairy cows: somatic cell counts and associated bacteria in Mymensingh, Bangladesh. *Journal of Bangladesh Agricultural University*, 15:266–271.

Tilki, M., İnal, S., Çolak, M., & Garip, M. (2005). Relationships between milk yield and udder measurements in Brown Swiss cows. *Turkish Journal of Veterinary and Animal Sciences*, 29: 75-81.

Uzmay, C., Kaya, Y., Abbas, Y., & Kaya, A. (2003). Effect of udder and teat morphology, parity and lactation stage on sub-clinical mastitis on Holstein cows. *Turkish Journal of Veterinary and Animal Sciences*, 27:695-710.

Zeryehun, T., & Abera, G. (2017). Prevalence and Bacterial Isolates of Mastitis in Dairy Farms in Selected Districts of Eastern Harrarghe Zone, Eastern Ethiopia. *Journal of Veterinary Medicine*, 2017: 6498618. https://doi.org/10.1155/2017/6498618

Zwertvaegher, I., Baert, J., Vangeyte, J., Genbrugge, A., & Van Weyenberg, S. (2011). Objective measuring technique for teat dimensions of dairy cows. *Journal of Biosystems Engineering*, 110: 206-212.

Zwertvaegher, I., Van Weyenberg, S., Piepers, S., Baert, J., & De Vliegher, S. (2012). Variance components of teat dimensions in dairy cows and associated factors. *Journal of Dairy Science,* 95(9): 4978-4988.