SUMMARY: Mastitis is the economically most important disease in lactating cows and the prevalence under any management condition is considerably high. It causes economic losses due to reduction of both quantity and quality of milk. The groups of microorganisms causing mastitis are categorized as bacteria, fungi, mycoplasma and nocardia. Among the several cow side tests to trace intra-mammary infections (IMI) at early stage, i.e. sub-clinical mastitis (SCM), California Mastitis Test (CMT) is commonly used in which somatic cell count (SCC) is indirectly taken into account. The SCC of milk is an indicator of mammary infections because SCC positively correlates with the severity of infection. The SCC of >200,000 cells/ml is considered to be an indication of IMI. However, SCC in the milk can also vary with some other factors such as breed, age of the cow, stage of lactation, body condition score, etc. A few studies have shown that high SCC in milk affect the composition, organoleptic properties and keeping quality of raw milk and heat treated milk, yoghurts and cheese. One could argue that low SCC milk (sub-clinical mastitis) will not have a significant effect on product quality. But it should be emphasized that the natural infection occurs with various types of microorganisms that can precipitate product defects despite the low SCC. Also, attention must be paid to the bulk tank somatic cell count (BTSCC) rather than individual animal SCC. The quality of raw milk collected from different parts of the country is reported to be low with high bacteria counts mainly due to unhygienic milking and field practices. Milk quality directly influences the income of the small scale milk producers which in turn affects the sustainable dairy production. In Sri Lanka the majority of dairy farmers are small scale producers and they practice minimum milk hygiene practices compared to medium and large scale producers. Therefore, it is essential to make them aware of hygienic milking practices and implement milk quality based payments (MQBP) with added premium and penalties for the existing milk price, with the objective of encouraging clean milk production.

INTRODUCTION

Milk is a complex food with high nutritive value and milk-derived products are one of the main sources of food for the world population. Simultaneously with the continuous growth of the human population of the world, the demand for the food also rapidly increases. About 50% of the world’s total milk production is consumed in the form of fresh dairy products and this share will continue to increase to 52% over the next ten years due to rising milk consumption in developing countries. Developing countries consume 68% of fresh dairy products which is expected to increase up to 73% over the next decade (OECD/FAO, 2018). To meet the increasing demand and to gain the sustainable profit from dairy farms, continuous improvements are being carried out on average farm size and average yield of a cow (Vliegher et al., 2012). However, in a global perspective, the land scarcity is a major constraint for expansion of farm size. As a result, farms tend to be deviated from conventional free range or semi-intensive management to more intensive management where farm mechanisation has also been initiated. Several studies have shown that the intensive management is more prone to diseases. Mastitis is the most economically important disease in lactating cows (Tilman et al., 2002) and under any management system the prevalent rate is around 40-50% either in the form of clinical or sub clinical mastitis (SCM). Mastitis is defined as an inflammation of the mammary gland together with physical, chemical and microbiological changes, is characterised by an increase in the number of somatic cells in the milk and by pathological changes in the mammary tissue (International Dairy Federation, 1987). Mastitis has been classified in different ways and one way of classification has been done as clinical and sub-clinical, which is based on the severity of the disease (Alemu et al., 2013). It has also been classified as environmental mastitis and contagious mastitis, furthermore each group has been classified as clinical, subclinical and chronic (Kudi et al., 2009). Even though the clinical mastitis could be easily diagnosed by appearance of clinical signs or abnormalities in milk, the sub-clinical form needs more accurate diagnostic tools (Fragkou et al., 2014). It has been reported that the sub-clinical form is more prevalent (15-40%) than clinical form in any management system (Kudi et al., 2009). Identification of sub-clinical mastitis can be achieved by subjective tests, such as Californian Mastitis Test (CMT) or by the more accurate direct somatic cell count (SCC). Even though
direct SCC gives more accurate insight into the severity of the infection, more sophisticated methods are costly while conventional methods are laborious. The SCC varies with many external and internal factors associated with the cow. Many studies have evaluated the relationship between SCC, raw milk quality and processed dairy products. Therefore, the objective of this review is to critically evaluate the studies conducted in relation to mastitis, SCC, and their relationship to milk quality and processed dairy products.

Aetiology and pathogenesis of mastitis

According to the pathogens involved, mastitis has been categorized into four types: bacterial mastitis, mycotic/fungal/algal mastitis, mycoplasmal mastitis and Nocardial mastitis. Bacteria is the main causal pathogen among these groups and around 150 bacterial species have been isolated from infected bovine udders (Shaheen et al., 2016). The bacterial pathogens have been divided into two categories based on the cellular and molecular morphology: Gram-negative species such as *Escherichia coli* and *Klebsiella pneumoniae*, and Gram-positive species such as *Streptococcus agalactiae*, *Streptococcus uberis* and *Staphylococcus aureus* (Arruda et al., 2013). Further, based on the mode of transmission, mastitis can be classified as contagious and environmental mastitis (Alemu et al., 2013). Contagious mastitis is caused by the spread of pathogens from infected to uninfected udder (Smith and Hogan, 2001). Environmental mastitis is caused by the contamination of teat ends from environmental pathogens present in manure, dirt, mud, pools of standing water, feed stuffs and bedding materials (Smith and Hogan, 2008). The bacterial species such as *Staphylococcus aureus*, *Streptococcus agalactiae*, *Mycoplasma bovis* and other mycoplasma species are considered to be contagious type, while *Streptococcus uberis*, *Streptococcus dysgalactiae*, *Escherichia coli* and *Klebsiella* spp are of environmental origin (Shaheen et al., 2016). The contagious pathogens are the main reason for SCM because they could grow on skin and the teat canal. Environmental pathogens are normally harboured for a short period of infection, with streptococci and coliforms causing 30 and 10 days of infections, respectively. Environmental pathogens mostly cause clinical mastitis and are therefore less likely than subclinical mastitis to become a herd problem (Smith and Hogan, 2008). Non-infectious mastitis can also be seen, caused by trauma or injuries to mammary gland (Smith and Hogan, 2001).

The udder possesses its own anatomical structures and immune mechanisms to prevent and overcome infections. The anatomical structure of teats acts as a physical barrier for invading pathogens into the teat canal. Teat skin, teat sphincter muscle and keratin plug are included in the first line of defence (Capuco et al., 1992; Lacy-Hulbert and Hillerton, 1995). Keratin layer is secreted by the cells which are lining the teat canal and this substance has a bacteriocidal effect (Lacy-Hulbert and Hillerton, 1995). However, keratin plug disappears before few days of calving and during milking the teat duct is dilated. Therefore, pathogens have a chance to enter into the teat canal and further, abrasions and cracks on teat skin facilitate the action of pathogens (Lacy-Hulbert and Hillerton, 1995). Pathogens may enter into the teat canal within one to two hours after milking when the teat canal is kept open. Bacterial fixation occurs by attaching and colonizing in new tissues (Neijenhuis et al., 2001). Bacteria initially damage the tissues lining the large milk collecting ducts and cisterns and produce virulent factors, which can damage the milk secreting cells. Those damaged cells produce leukocytes attracting substances and therefore, leukocytes are recruited from blood into milk. Those leukocytes have the ability to engulf and destroy bacteria, but if bacteria are not destroyed they continue to multiply and affect entire smaller ducts and alveolar areas (Zhao and Lacasse, 2008).

Somatic cell count (SCC) in milk as an indicator of mastitis

The SCC is an important tool to predict the severity of the intra-mammary infection (IMI). Being a component of milk, SCC can be used to assess the milk quality, monitor herd health for mastitis and to decide milk quality based payment. The milk somatic cells include 75% leucocytes (i.e. neutrophils, macrophages and lymphocytes) and 25% epithelial cells and percentage of leucocytes will vary with infections in mammary tissue and various other factors (Sharma et al., 2011). Erythrocytes can be found at concentrations ranging from 0 to 1.51×10⁶/ml (Paape and Weinland, 1988). During the inflammatory period, somatic cells rapidly increase in number. The SCC varies depending on the presence, type and virulence factors of the pathogens (Nolan, 2017). It can also vary with other factors such as age, stage of lactation, parity, production level of the cows and environmental factors (Table 1). Cow milk SCC of >200,000 cells/ml indicates mastitis (International Dairy Federation, 1997; Hillerton, 1999). The SCC is the most common method to identify the IMI more accurately in many dairying countries.

Sharma et al. (2011) and Bharti et al. (2017) reported that there was a positive correlation between SCC and parity, which is attributed to epithelial damage and prevailing pathogen with repeated infections. Also, Sharma et al. (2011) and Chegini et al. (2016) reported that SCC is high in the late lactation than the early lactation which has been explained as being due to the dilation of the teat canal. A seasonal variation in SCC has been observed, being higher in cows calved in summer than that of winter (Bharti et al., 2017, and Baul et al., 2011).

The diagnosis of mastitis varies from conventional physical examination to application of modern nano technology based techniques. A comprehensive review on diagnosis of mastitis from laboratory to farm has been published by Ashraf and Imran (2018). Figure 1 illustrates an overview of mastitis diagnostic tests applied in the laboratory and the field.
Table 1: Variation of Somatic Cell Counts (SCC) with different animal factors in Jersey cows.

| Animal factors     | SCC /ml of milk |
|--------------------|-----------------|
| Overall            | 238,231         |
| Parity             |                 |
| 1st                | 82,035          |
| 2nd                | 287,739         |
| 3rd                | 313,328         |
| 4th and above      | 939,723         |
| Stage of Lactation |                 |
| Early              | 90,364          |
| Mid                | 124,738         |
| Late               | 731,113         |
| Production Level   |                 |
| Low                | 653,130         |
| Medium             | 65,917          |
| High               | 306,902         |
| Season of Calving  |                 |
| Summer             | 502,342         |
| Rainy              | 156,314         |
| Winter             | 141,905         |

Source: Bharti et al. (2017)

Among the direct and indirect techniques that are available for diagnosis of mastitis, indirect methods such as the California Mastitis Test (CMT), Sodium Lauryl Sulphate Test (SLST), Surf Field Mastitis Test (SFMT) and White Side Test (WST) can be used as cow side tests under field conditions (Sharma et al., 2011). The CMT is extensively applied all over the world despite the fact that it is very subjective. In CMT, a reagent containing mainly a detergent is used to coagulate the DNA present in the somatic cell nuclei. On the visual appearance of the gel formation, a CMT score is given and SCC can be indirectly assumed through the given score (Whyte et al., 2005). Table 2 shows the association of CMT score, SCC, and the somatic cell score (SCS).

Accuracy of SCC with mastitis causing pathogens and the threshold level of SCC for mastitis detection is very important since there can be false positive identifications. Pamela and Reniemnn (2002) reported that the sensitivity to detect mastitis at SCC 200,000 cells/ml is varied between 73-89% and when threshold value is increased to 250,000 cells/ml, positive prediction value for subclinical mastitis is also increased. Based on the mastitis causing pathogens, the SCC varies, and contagious pathogens such as *Streptococcus agalactiae* and *Staphylococcus aureus* generally cause greater SCC elevation than environmental pathogens (Bharti et al., 2017). Table 3 shows the SCC in milk for different isolated pathogens.
Table 2: Association of Somatic Cell Count (SCC), California Mastitis Test (CMT) score and Somatic Cell Scores (SCS)

| SCC Range (cells per mL) | Approximate SCC midpoint (cells per mL) | SCS | CMT Score | Visible Reaction |
|-------------------------|----------------------------------------|-----|-----------|-----------------|
| 0 – 200,000             | 12,500                                 | 0   | Negative  | Mixture remains liquid, no evidence of precipitate |
|                         | 25,000                                 | 1   |           |                 |
|                         | 50,000                                 | 2   |           |                 |
|                         | 100,000                                | 3   |           |                 |
|                         | 200,000                                | 4   |           |                 |
| 150,000 – 500,000       | 400,000                                | 5   | Trace     | Slight precipitate, best seen by tipping, disappears with continued movement |
| 400,000 -1,500,000      | 800,000                                | 6   | 1         | Distinct precipitate but no tendency toward gel formation |
| 800,000 – 5,000,000     | 1,600,000                              | 7   | 2         | Mixture thickens immediately, moves toward centre |
|                         | 3,200,000                              | 8   |           |                 |
| >5,000,000              | 6,400,000                              | 9   | 3         | Gel forms and surface becomes convex |

Source: Pamela and Reniemnn (2002)

Quality of milk in Sri Lanka

In Sri Lanka, the quality of milk is far below the standards of most dairying countries. According to Silva et al. (2016) around 20% of milk collected to milk collecting centres has to be discarded. Several studies that have been carried out in different locations of the country showed exceptionally higher total bacterial counts both in raw milk and also in some processed milk (Deshapriya et al., 2007, Abeygunawardena et al., 2017, Santhoaran and Deshapriya, 2018). Abeygunawardena et al. (2017) reported that the poor microbial quality of raw milk in studied areas of Kurunegala District was attributed to the inefficient cleaning and disinfection of udder and utensils coupled with poor concern and negligence of farmers towards appropriate hygienic practices. A higher total viable count and Coliform count have been recorded even in bulk containers (Ranasinhe et al., 2017). Vairamuthu et al. (2010) stated that milk quality of Jaffna district has been drastically affected by the following practices during milking; washing the udder and hands with only water without a detergent, wiping the udder after washing only using hand, and the milking of infected and healthy cows at the same time. They have also found that the total aerobic bacteria and coliform counts were $2.2 \times 10^7$ and $4.7 \times 10^3$ CFU, respectively and these values are higher than the acceptable levels. Santhoaran and Deshapriya (2018) reported that the unhygienic milking practices, usage of plastic utensils in milking and time duration between milking to chilling affect the keeping quality of the milk in Ampara District. According to Rahularaj et al. (2019) most of the medium and small scale dairy farmers in Sri Lanka practice machine milking with improper cleaning procedure, which increases the prevalence of the subclinical mastitis and directly affects the milk quality. The high prevalence of subclinical mastitis is a major contributor for poor milk quality (Rahularaj et al., 2019, Gunawardena et al., 2014). The milk collection system is a strong contributor to poor milk quality in Sri Lanka. The number of bacteria remaining in raw milk reaching the processing factory from the small-hold farmers showed a positive trend with the milk holding time in transportation (Weerasinhe et al., 2017). Field practices such as mixing of milk from different chilling centres and long period of storage were identified as major contributing factors for microbial load and acidity level in milk collected in different areas of the country. Weerasinhe et al. (2017) also concluded that
Table 3: Somatic Cell Count (SCC) in milk for different isolated pathogens

| Isolated Pathogen               | SCC (cells/ml) | Reference                |
|---------------------------------|----------------|--------------------------|
| Staphylococcus aureus           | 871,000        | Souza et al., 2016       |
|                                 | 20,000,000     | Sharma et al., 2011      |
|                                 | 1,990,000      | Bortolami et al., 2015   |
|                                 | 173,820        | Condas et al., 2017      |
| Streptococcus agalactiae        | 1,943,125      | Souza et al., 2016       |
|                                 | 13,600,000     | Sharma et al., 2011      |
|                                 | 4,660,000      | Bortolami et al., 2015   |
|                                 | 183,450        | Condas et al., 2017      |
| Streptococcus uberis            | 803,500        | Souza et al., 2016       |
|                                 | 4,240,000      | Bortolami et al., 2015   |
|                                 | 161,570        | Condas et al., 2017      |
| Coagulase-negative staphylococci| 482,000        | Souza et al., 2016       |
|                                 | 13,600,000     | Sharma et al., 2011      |
|                                 | 1,970,000      | Bortolami et al., 2015   |
| Klebsiella spp.                 | 132,850        | Condas et al., 2017      |
| Staphylococcus chromogenes      | 67,860         | Condas et al., 2017      |
|                                 | 7,800,000      | Sharma et al., 2011      |

Quality of milk is better in the Central Province where the ambient temperature is comparatively low. A dairy value chain study carried out in the Uva Province of Sri Lanka clearly showed that the milk quality directly influences the income of the small scale milk producers, which in turn affects the sustainable dairy production at small scale level. Therefore, the study emphasized the need of milk quality improvement (Wijethilka et al., 2017; Wijethilaka, 2018).

**SCC and milk quality**

The lacteal secretion, practically free from colostrums, obtained by the complete milking of one or more healthy cows, contains not less than 8.25% of milk solid-non-fat (SNF) and not less than 3.25% milk fat. It is also affected by many animal related and environmental factors (Nobrega and Langoni, 2011). Typical bovine milk contains 87% water and 13% solid as shown in Table 4.

Table 4: The composition of typical cow milk.

| Cow milk Composition | Percentage |
|----------------------|------------|
| Water                | 87.5       |
| Total Solids         | 12.7       |
| Fat                  | 4.5        |
| Protein              | 2.9        |
| Lactose              | 4.1        |
| Ash (minerals)       | 0.8        |

Source: Fox (2003).
Mastitis causes reduction in quantity and quality of milk. Some components in milk such as fat, lactose and protein are decreased while somatic cells, whey protein, free fatty acid and enzymes are increased due to the inflammation (Pyorala, 2003). Table 5 shows the changes in milk components and milk volume due to mastitis. Sharma et al. (2011) reported that the reduction of milk components during mastitis is caused by the reduction of synthesis due to the cellular damages and elevation of some components due to leakage from blood as a result of pathological changes in the underlying tissues. The extent of changes in milk composition is specific for the mastitis causing pathogen. The elevation of free fatty acid level, proteolytic and lipolytic enzymes, and sodium and chloride ions, can cause drastic changes in keeping quality of milk.

Table 6 shows the relationships between different SCC ranges and the changes in milk constituents. Coulona et al. (2002) stated that some mastitis causing pathogens alter only specific components of milk and some other pathogens do not alter the milk components. As an example Corynebacterium bovis does not alter the milk composition. Streptococcus dysgalactiae and E. coli significantly increase the protease enzymes (peptone and plasmin) in milk but do not affect fat and protein content.

Ma et al. (2000) reported that protein and fat percentages are higher in mastitis milk than in normal milk. High SCC (849,000 cells/ml) in milk mainly affects the flavour of the milk. During the milk storage and processing, somatic cells release proteases and lipases that react with proteins and fat leading to bitterness and rancidity in milk (Irma et al., 2013). Also the lipases act on the fat globule membrane thereby exposing the milk triglycerides to further degradation by milk lipoprotein lipase. Increased lipolysis leads to increased free fatty acid (FFA) in the milk. Therefore, high FFA in milk leads to the development of rancidity and off flavour during storage (Santos et al., 2003b; Irma et al., 2013). Further, during storage of infected fresh milk in cold condition, casein/true protein ratio is reduced due to the activity of a plasmin enzyme which causes lysis of the major protein, casein.

Lactose concentration is low in infected milk which is a result of the secretary cell damage. Mastitis pathogens severely affect the tight junctions of the secretary cells therefore, low secretion of lactose and changes in osmotic pressure cause low level of water transfer for milk synthesis, which causes low yield in infected cows (Nobrega and Langoni, 2011; Bruckmaier et al., 2004). Ogola et al. (2007) stated that there can be changes in minerals in milk due to mastitis, sodium and chlorine concentrations are increased in infected milk because of the leakage from ruptured mammary cells but calcium concentration is at low level because calcium is incorporated with casein micelles and decreases in casein reduce the calcium concentration. However, changes in major constituents are more prominent and it can vary in a pathogen specific manner as summarised in Table 7.
Table 7: The changes in major milk constituents with different mastitis causing pathogens

| Mastitis Pathogens | Fat %  | Protein % | Lactose % | Reference         |
|--------------------|--------|-----------|-----------|-------------------|
| *Staph. aureus*    | -0.082 | -0.044    | -0.041    | Reis et al., 2013 |
| Coagulase negative | -0.175 | -0.033    | -0.023    |                    |
| Staphylococci      | -0.24  | -1.7      | -67.4     | Bezman et al., 2015|
| Streptococcus spp. | -0.232 | -0.031    | -0.062    | Reis et al., 2013 |
| Corynebacterium spp.| -0.138 | +0.052    | -0.082    | Reis et al., 2013 |
| E. coli            | -3.6   | +0.56     | -47.37    | Bezman et al., 2015|

SCC and Dairy Products

The quality of milk products mainly depends on the composition and quality of the raw milk. High SCC will influence the dairy product quality by affecting keeping quality, flavour, and the structure of the product (Ogola et al., 2007; Ma et al., 2000). The impact of SCC on dairy products, including pasteurized or Ultra High Temperature (UHT) milk, yoghurt and cheese are presented in the following paragraphs.

High SCC and heat treated milk quality

Fresh milk is subjected to various levels of heat treatment with the objectives of eliminating milk borne pathogens and extending keeping quality. However, depending on the temperature applied and holding time the effect of heat treatment on milk is varied. Most of the novel heat treatment methods such as Pasteurization, UHT treatment and sterilization can be applied to fresh milk to eliminate viable microorganisms, but still the activity of heat stable enzymes remains. The presence of exogenous enzymes is high when there is high SCC in milk. Ma et al. (2000) have observed a higher Acid Degree Value (ADV), an indication of high lipolysis activity and casein hydrolysis leading to reduction in CN/TP ratio in pasteurised (74°C/34S) milk with high SCC (849,000 cells/ml, 2.5% fat) during storage at 5°C for 21 days. Also they have detected poor organoleptic attributes such as bitterness and rancidity that consisted with proteolysis and lipolysis in high SCC milk. Santos et al. (2003a) have also detected reduction in casein percentage in total protein (CN/TP) during the storage time and this reduction is higher in high SCC (376,000 cells/ml) than low SCC (26,000 cells/ml) pasteurized milk stored at 6°C.

Three main parameters such as bacteria in milk, proteolysis and lipolysis are responsible for the off flavour development and reduced shelf life (Santos et al., 2003b; Ma et al., 2000). In pasteurized unpreserved milk, psychotrophic bacterial count (PBC) was increased >10 cfu/ml at 5°C storage on 26 days for low SCC (26,000 cells/ml) but PBC was increased >10 cfu/ml at 5°C storage on 26 days for high SCC (1,113,000 cells/ml) but PBC was increased >10 cfu/ml at 5°C storage on 26 days for low SCC (26,000 cells/ml) (Santos et al., 2003a). Plasmin is a proteolytic enzyme which hydrolyses β-casein and α-casein and when this enzyme is elevated in milk even after SCC has decreased, its activity remains (Leitner et al., 2006; Bugaud et al., 2001; Santos et al., 2003a). Plasmin and plasminogen are heat resistant and therefore, the activity is not affected by the High Temperature Short Time (HTST) pasteurized treatment and by UHT treatment. Therefore, during storage of pasteurized and UHT milk, plasmin is still in active form leading to further proteolysis (Newstead et al., 2006; Prado et al., 2006). Alichanidis et al. (1986) found that inactivation of plasmin was higher in lower temperature (85°C or below) than the higher temperature (130 or 143°C) heat treatment and they suggested the reasons being that in lower temperature, enzyme protein is gradually unfolded and becomes partially denatured. Thereafter, it will be hydrolysed by remaining enzymes in active form, but in high temperature, enzymes quickly unfold to inactive form and thereafter at normal temperature those inactive enzymes gradually refold to active form. Therefore, even though milk is subjected to high temperature heat treatment, enzymes remain active throughout the storage period.

Effect of high SCC on Yoghurt

Yoghurt is a fermented product which includes well known set, blended, and strained yoghurts. A limited number of research show that high SCC had little impact on the properties of the unstrained yoghurt. When yoghurt is produced from high SCC milk, there are no changes in pH, titratable acidity, fat and protein during 30 days of storage at 5°C. Yoghurt produced from milk with low SCC (400,000 cells/ml) could be stored at 5°C for 30 days without any organoleptic changes, but consistency of yoghurt prepared using milk with high SCC (>400,000 cells/ml) was affected on day 20 and the taste was decreased after day 30 (Oliveira et al., 2002).
Fernandes et al. (2007) reported that the viscosity and free fatty acids (FFA) in the stirred yoghurt prepared from high SCC (1,943,000 cells/ml) milk was higher than the low SCC (147,000 cell/ml) yoghurt during storage on days 10, 20 and 30. The viscosity, proteolysis and lipolysis were increased and pH was decreased in cold stored yoghurt which was made from milk of SCC 398,000 cells/ml than from milk of 95,000 cells/ml. High FFA level was found in yoghurt made from above 1,150,000 cells/ml (Hachana and Paape, 2012). When yoghurt is produced with high SCC milk (400,000 cells/ml) the yoghurt culture activity is reduced by 35%. But if the milk has been boiled for 2 min or heated at 90°C for 20 min somatic cells will be completely inactivated. However, if the cell count is above 400,000 cells/ml the growth of the yoghurt culture organisms will be inhibited even though the heat treatments are given (Tamime and Robinson, 2004).

Mastitis on Cheese quality

When high SCC milk is used to produce cheese, low cheese yield, inefficiency in yield, improper texture and poor overall organoleptic properties can be seen (Talukder and Ahmed, 2017). High SCC promotes the retention of more moisture in cheese and depending on the type of cheese off-flavour development can be seen (Bobbo et al., 2017). Further, lipolysis and proteolysis can be seen in most types of cheese leading to reduced curd firmness, loss of fat and protein in whey (Talukder and Ahmed, 2017) and influence the rennet coagulation resulting low yield of poor quality cheese (Pirisi et al., 1996).

Similarly, Mazal et al. (2007) have produced Prato cheese from high SCC milk (>600,000 cells/ml) and low SCC milk (<200 cells/ml) and they detected significantly higher total protein and non-protein nitrogen, lower true protein and casein concentrations, and higher proteolysis during ripening, resulting in higher whey protein concentration.

Klei et al. (1998) reported that cottage cheese made from high SCC milk (872×10³ cell/ml) had higher proteolytic activity resulting in loss of more protein in whey and wash water, higher moisture content in the curd, lower lactose content and lower yield, when compared to cheese made from low SCC (83×10³ cell/ml) milk from same Holstein cows whose teats were inoculated experimentally with 1000 cfu of Strep. agalactiae.

Conclusion

The severity of mastitis, intensity of udder damage and effect on milk quality depend on many animal related and environmental factors. In terms of minimising the losses, dry cow management, early detection of sub-clinically infected animals, and application of hygienic milking practices are of utmost importance. Early diagnosis of sub-clinical mastitis can minimize the economic losses due to cost of treatment, milk volume loss, premature culling and milk rejection due to poor hygienic quality parameters at milk reception. Most importantly, indiscriminate use of antibiotics in lactating cows as dry and lactating cow therapies can be minimized if the occurrence of new mastitis cases and spread of existing cases are controlled. Thus, many dairying countries are deviating from more intensive management to semi-intensive/free grazing systems with an aim of improved animal welfare, with genetic improvement for disease resistance, climate smart dairy farming, nature loving dairy farming, use of herbal drugs, etc. Although there are various tests available at laboratory level and as cow side tests the cost per cow is a major concern. SCC is one of the most important and reliable indicators of IMI that can be used to detect SCM, but it is expensive and cumbersome than more conventional way of counting. Therefore, more reliable and cost effective methods must be developed at an affordable cost for small scale farmers. When mammary tissue is damaged from infections, milk fat, lactose and casein concentrations are decreased but total protein concentration is elevated. Milk from infected udder contains an elevated microbial population, somatic cells, and higher concentration of exogenous enzymes. They exert a synergistic deleterious effect on both raw milk and processed dairy products. However, there are only a limited number of studies that have been carried out to show the effect of SCC on processed dairy products. In many studies, experimental inoculation of lactating udder with a specific pathogen showed very high SCC milk and when this milk was used to produce pasteurised milk, yoghurt or cheese those products have shown extremely deleterious effects. Therefore, it could be argued that low SCC milk (sub-clinical mastitis) will not have a significant effect on product quality. But it should be emphasized that the natural infection occurs with various types of microorganisms that can precipitate product defects despite the low SCC. Attention must be paid to the bulk tank somatic cell count (BTSCC) rather than individual animal SCC. In Sri Lanka the majority of dairy farmers are small scale producers and they use minimum milk hygiene practices compared to medium and large scale producers. Therefore, it is essential to make them aware of hygienic milking practices and implement milk quality based payments (MQBP) with added premium and penalties for the existing milk price with the objective to encourage clean milk production. Moreover, there must be institutional emphasis towards research and development, and to disseminate knowledge on dairy science and technology, if Sri Lanka is to be self-sufficient in milk and to have a sustainable dairy production.

Acknowledgement: Authors wish to acknowledge the National Research Council of Sri Lanka (NRC2015-87) for financially supporting a graduate student.
REFERENCES

Abeygunawardana, D.I., Ranasinghe, R.M.S.B.K. and Deshapriya, R.M.C. (2017). Hygienic practices and quality of raw milk produced in a small scale dairy farming area in Sri Lanka. *International Journal of Scientific and Research Publications*, 7: 72-77.

Alemu, S., Tamiru, F., Almaw, G. and Tsega, A. (2013). Study on bovine mastitis and its effect on chemical composition of milk in and around Gondar town, Ethiopia. *Journal of Veterinary Medicine and Animal Health*, 5: 215-221.

Alichanidis, E., Wrathall, J.H.M. and Andrews, A.T. (1986). Heat stability of plasmin (milk protein) and plasminogen. *Journal of Dairy Research*, 53: 259-269. https://doi.org/10.1017/S0022029900024869

Arruda, A.G., Godden, S., Rapnicki, P., Gorden, P., Timms, L., Aly, S.S., Lehenbauer, T.W. and Champagne, J. (2013). Randomized noninferiority clinical trial evaluating 3 commercial dry cow mastitis preparations: I. Quarter-level outcomes. *Journal of Dairy Science*, 96: 4419–4435. https://doi.org/10.3168/jds.2012-6461

Ashraf, A. and Imran, M. (2018). Diagnosis of bovine mastitis: from laboratory to farm. *Tropical Animal Health and Production*, 50: 1193-1202. https://doi.org/10.1007/s11250-018-1629-0

Baul, S., Cziszter, L.T., Acatincai, S., Cismas, T., Gavojdian, D., Tripon, I., Erina, S. and Raducan, G.G. (2011). Researches regarding the influence of calving interval on the number of somatic cells during lactation in Romanian Black and White Cows. *Animal Science and Biotechnologies*, 44: 282 – 284.

Bezman, D., Kuzinl, L.L., Katzl, G., Merin, U. and Leitner, G. (2015). Influence of intramammary infection of a single gland in dairy cows on the cow’s milk quality. *Journal of Dairy Research*, 82: 304–311. https://doi.org/10.1007/s11250-018-1629-0

Bharti, P., Bhakat, C., Japheth, K., Bhat, S., Chandra, S. and 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: 228-235. https://doi.org/10.5455/ijlr.20170324031931

Bortolami, A., Fiore1, E., Gianesella, M., Corro, M., Catania, S. and Morgante, M. (2015). Evaluation of the udder health status in subclinical mastitis affected dairy cows through bacteriological culture, somatic cell count and thermographic imaging. *Polish Journal of Veterinary Sciences*, 18: 799–805. https://doi.org/10.1515/pjvs-2015-0104

Capuco, A.V., Bright, S.A., Pankey, J.W., Wood, D.L., Miller, R.H., and Bitman, J. (1992). Increased susceptibility to intramammary infection following removal of teat canal keratin. *Journal of Dairy Science*, 75: 2126–2130. https://doi.org/10.3168/jds.S0022-0302(92)77972-7

Condas, L.A.Z., Buck, J.D., Nobrega, D.B., Carson, D.A., Roy, J.P., Keefe, G.P., DeVries, T.J., Simon Dufour, J.R.M.I.S. and Barkema, H.W. (2017). Distribution of non-aureusstaphylococci species in udder quarters with low and high somatic cell count, and clinical mastitis. *Journal of Dairy Science*, 100: 5613–5627. https://doi.org/10.3168/jds.2016-12479

Coulona, J.B., Gasqub, P., Barmouin, J., Ollier, A., Pradel, P. and Ponnies, D. (2002). Effect of mastitis and related-germ on milk yield and composition during naturally-occurring udder infections in dairy cows. *Animal Research*, 51: 383–393. https://doi.org/10.1051/animres:2002031

Chegini, A., Zadeh, N.G.H., Moghadam, H.H. and Shadparvar, A.A. (2016). Effect of somatic cell count on milk yield in different parities and stages of lactation in Holstein cows of Iran. *Agriculturae Conpectus Scientificus*, 81: 55-60.

Deshapriya, R.M.C., Silva, K.F.S.T. and Wilbey, R.A. (2007). Investigation of suitable pasteurisation conditions for raw milk in Sri Lanka. *Sri Lanka Veterinary Journal*, 53: 1-6.
Fernandes, A. M., Oliveira, C. A. F., and Lima, C. G. (2007). Effects of somatic cell counts in milk on physical and chemical characteristics of yoghurt. *International Dairy Journal, 17*: 111–115. https://doi.org/10.1016/j.idairyj.2006.02.005

Fox, P. F. (2003). Milk Proteins: General and Historical Aspects. 3rd Edn. Fox, P.F. and McSweeney, P.L.H. (Eds). *Advanced Dairy Chemistry—1: Proteins*, Springer, USA 1–48. https://doi.org/10.1007/978-1-4419-8602-3_1

Fragkou, I. A., Boscos, C. M., and Fthenakis, G. C. (2014). Diagnosis of clinical or subclinical mastitis in ewes. *Small Ruminant Research, 118*: 86–92. https://doi.org/10.1016/j.smallrumres.2013.12.015

Gunawardana, S., Thilakarathne, D., Abegunawardana, I.S., Abeynayake, P., Robertson, C. and Stephen, C. (2014). Risk factors for bovine mastitis in the Central Province of Sri Lanka. *Tropical Animal Health and Production, 46*: 1105–1112. https://doi.org/10.1007/s11250-014-0602-9

Hachana, Y. and Paape, M. J. (2012). Physical and chemical characteristics of yoghurt produced from whole milk with different levels of somatic cell counts. *International Journal of Food Sciences and Nutrition, 63*: 303–309. https://doi.org/10.3109/09637486.2011.627839

Hillerton, J. E. (1999). Redefining mastitis based on somatic cell count. *International Dairy Federation Bulletin, 345*: 4-6.

International Dairy Federation. (1987). Bovine mastitis definitions and guidelines for diagnosis. *International Dairy Federation Bulletin, 211*: pp. 3-8.

International Dairy Federation. (1997). Recommendations for presenting of mastitis related data. *International Dairy Federation Bulletin, 321*. Brussels, Belgium. pp. 7-25. https://doi.org/10.1016/S0958-6946(97)87641-8

Irm, V., Bergamini, C., Perotti, M. and Hynes, E. (2013). Sensory and Flavor Characteristics. In: Y. Park and G. Haenlein, (Eds). *Milk and Dairy Products in Human Nutrition: Production, Composition and Health*. John Wiley & Sons, New York, USA. pp. 310-336. https://doi.org/10.1002/9781118354168.ch15

Kitchen, B.J. (1981). Review of progress of dairy science: Bovine mastitis; milk compositional changes and related diagnostic tests. *Journal of Dairy Research, 48*: 167-188. https://doi.org/10.1017/S0022029990021580

Klel, L., Joseph, Y., Sapru, A., Lynch, J., Barbano, D., Sears P. and Galton D. (1998) Effects of milk somatic cell count on cottage cheese yield and quality. *Journal of Dairy Science, 81*: 205–1213. https://doi.org/10.3168/jds.S0022-0302(98)75680-2

Kudi, A.C., Bray, M.P., Niba, A.T. and Kalla, D.J.V. (2009). Mastitis causing pathogen within the dairy cattle environment. *International Journal of Biology, 1*: 3-13. https://doi.org/10.5539/ijb.v1n1p3

Lacy-Hulbert, S. J. and Hillerton, J. E. (1995). Physical characteristics of the bovine teat canal and their influence on susceptibility to streptococcal infection. *Journal of Dairy Research, 62*: 395-404. https://doi.org/10.1016/0022-0302(95)80011-7

Leitner, G., Krüfucks, O., Merin, U., Lavi, Y., and Silanikove, N. (2006). Interactions between bacteria type, proteolysis of casein and physico-chemical properties of bovine milk. *International Dairy Journal, 16*: 648–654. https://doi.org/10.1016/j.idairyj.2005.10.020

Ma, Y., Ryan, C., Barbano, D.M., Galton, D.M., Rudan, M.A. and Boor, K.J. (2000). Effects of somatic cell count on quality and shelf-life of pasteurized fluid milk. *Journal of Dairy Science, 83*: 264–274. https://doi.org/10.3168/jds.S0022-0302(00)74873-9

Mazal, G., Vianna, P.C.B., Santos, M.V. and Gigante, M.L. (2007). Effect of somatic cell count on prato cheese composition. *Journal of Dairy Science, 90*: 630–636. https://doi.org/10.3168/jds.S0022-0302(07)71545-X

Neijenhuis, F., Klungel, G. H., and Hogeveen, H. (2001). Recovery of cow teats after milking as determined by ultrasonographic scanning. *Journal of Dairy Science, 84*: 2599–2606. https://doi.org/10.3168/jds.S0022-0302(01)74714-5

Newstead, D.F., Paterson, G., Anema, S.G., Coker, C.J. and Wewala, A.R. (2006). Plasmin activity in direct-steam-injection UHT-processed reconstituted milk: Effects of preheat treatment. *International Dairy Journal, 16*: 573–579. https://doi.org/10.1016/j.idairyj.2005.11.011

Nobrega, D.B. and Langoni, H. (2011). Breed and season influence on milk quality parameters and in mastitis occurrence. *Pesquisa Veterinária Brasileira,*
Nolan, D.T. (2017). An Examination of Milk Quality Effects on Milk Yield and Dairy Production Economics in the Southeastern United States. *Theses and Dissertations-Animal and Food Sciences*. 71. University of Kentucky, UKnowledge. http://uknowledge.uky.edu/animalsci_etds/7.

OECD/FAO. https://www.oecd-ilibrary.org/sites/agr_outlook-2018-10-en. Accessed on 23.06.2019.

Oliveira, C.A.F., Fernandes, A.M., Neto, O.C.C., Fonseca, L.F.L., Silva, E.O.T. and Balian, S.C. (2002). Composition and sensory evaluation of whole yogurt produced from milk with different somatic cell counts. *Australian Journal of Dairy Technology*, 57: 192–196.

Ogola, H., Shitandi, A. and Nanua, J. (2007). Effect of mastitis on raw milk compositional quality. *Journal of Veterinary Science*, 8: 237- 242. https://doi.org/10.4142/jvs.2007.8.3.237

Paape, M.J., and Weinland, B.T. (1988). Effect of abraded intramammary device on milk yield, tissue damage, and cellular composition. *Journal of Dairy Science*, 71: 250-256. https://doi.org/10.3168/jds.S0022-0302(88)79549-1

Prado, B. M., Sombers, S. E., Ismail, B. and Hayes, K. D. (2006). Effect of heat treatment on the activity of inhibitors of plasmin and plasminogen activators in milk. *International Dairy Journal*, 16: 593–599. https://doi.org/10.1016/j.idairyj.2005.09.018

Pirisi, A., Piredda, G., Podda, F. and Pintus, S. (1996). Effect of somatic cell count on sheep milk composition and cheese-making properties. In: Somatic Cells and Milk of Small Ruminants. EAAP Publication No. 77. Wageningen Press, Wageningen, The Netherlands, pp. 245–251.

Pyorala, S. (2003). Indicators of inflammation in the diagnosis of mastitis. *Veterinary Research*, 34: 565–578. https://doi.org/10.1051/vetres:2003026

Rahularaj, R., Deshapriya, R.M.C. and Ranasinghe, R.M.S.B.K. (2019). Influence of bovine sub-clinical mastitis and associated risk factors on calving interval in a population of crossbreed lactating cows in Sri Lanka. *Tropical Animal Health and Production*, https://doi.org/10.1007/s11250-019-01957-4.

Ranasinghe, D.K.P.C., Abeygunawardana, D.I. and Ranasinghe, R.M.S.B.K. (2017). Evaluation of possible sources of raw milk contamination and hygienic practises of small scale dairy farmers in Makandura area. *Proceeding of Undergraduate Research Symposium*, September 08, 2017. Faculty of Livestock, Fisheries and Nutrition, Wayamba University of Sri Lanka. p. 116.

Reis, C.B.M, Barreiro, J.R, Mestieri, L., de Felício Porcionato, M.A., dos Santos, M.V. (2013). Effect of somatic cell count and mastitis pathogens on milk composition in Gyr cows. *BioMed Central Veterinary Research*, 9: 67. https://doi.org/10.1186/1746-6148-9-67

Sanotharan, N. and Deshapriya, R.M.C. (2018) A preliminary investigation on milk quality in Ampara District of Sri Lanka. *International Journal of Scientific Research*, 8: 7. https://doi.org/10.29322/IJSRP.8.7.2018.p7938

Santos, M.V., Ma, Y. and Barbano, D.M. (2003a). Effect of somatic cell count on proteolysis and lipolysis in pasteurized fluid milk during shelf-life storage. *Journal of Dairy Science*, 86: 2491–2503. https://doi.org/10.3168/jds.S0022-0302(03)73843-0

Santos, M. V., Ma, Y., Caplan, Z. and Barbano, D. M. (2003b). Sensory threshold of off-flavors caused by proteolysis and lipolysis in milk. *Journal of Dairy Science*, 86: 1601–1607. https://doi.org/10.3168/jds.S0022-0302(03)73745-X

Schallibaum, M. (2001). Impact of SCC on the quality of fluid milk and cheese. National Mastitis Council, Inc. 40th Annual Meeting Proceedings. New Prague, MN, USA. pp. 38-46.

Shaheen, M., Tantary, H.A. and Nabi, S.U. (2016). A treatise on bovine mastitis: disease and disease economics, etiological basis, risk factors, impact on human health, therapeutic management, prevention and control strategy. *Journal of Advanced Dairy Research*, 4:150.

Sharma, N., Singh, N. K. and Bhandwal, M. S. (2011). relationship of somatic cell count and mastitis: an overview. *Asian-Australasian Journal of Animal Science*, 24: 429 – 438. https://doi.org/10.5713/ajas.2011.10233
Silva, S.D., Kanugala, K. and Weerakkody, N. (2016). Microbiological quality of raw milk and effect on quality by implementing good management practices. *International Conference of Sabaragamuwa University of Sri Lanka*, 2015, pp. 92-96. https://doi.org/10.1016/j.profoo.2016.02.019

Smith, K.L. and Hogan, J.S. (2008). Environmental mastitis: know your opponent. Paper presented at National Mastitis Council Regional Mooty Proceeding. Green bag, Wisconsin, USA.

Smith, K.L. and Hogan, J.S. (2001). The world of mastitis. Paper presented at 2nd international symposium on mastitis and milk quality, Vancouver, British Columbia, Canada. p.1.

Souza, F.N., Cunha, A.F., Rosa, D.L.S.O., Brito, M.A.V., Guimarães, A.S., Mendonça, L.C., Souza, G.N., Lage, AP., Blagitz, M.G., Libera, A.M.M.P., Heinemann, M.B. and Cerqueira, M.M.O.P. (2016). Somatic cell count and mastitis pathogen detection in composite and single or duplicate quarter milk samples. *Pesquisa Veterinária Brasileira*, 36: 811–818. https://doi.org/10.1590/s0100-736x2016000900004

Talukder, M. and Ahmed, H.M.M. (2017). Effect of somatic cell count on dairy products: a review. *Asian Journal of Medical and Biological Research*, 3: 1-9. https://doi.org/10.3329/ajmbr.v3i1.32030

Tamime, Y.A. and Robinson, R.K. (2004). Yoghurt science and technology. Woodhead publishing, Sawston, Cambridge.

Tilman, D., Cassman, K.G., Matson, P.A., Naylor, R. and Polasky, S. (2002). Agricultural sustainability and intensive production practices. *Nature*, 418: 671-677. https://doi.org/10.1038/nature01014

Vairamuthu, S., Sinniah, J. and Nagalingam, K. (2010). Factors influencing production of hygienic raw milk by small scale dairy producers in selected areas of the Jaffna district, Sri Lanka. *Tropical Animal Health and Production*, 42: 357–362. https://doi.org/10.1007/s11250-009-9427-3

Vliegher, S.D., Fox, L.K., Piepers, S., McDougall, S. and Barkema, H.W. (2012). Invited review: Mastitis in dairy heifers: Nature of the disease, potential impact, prevention, and control. *Journal of Dairy Science*, 95: 1025-1040. https://doi.org/10.3168/jds.2010-4074

Weerasinghe, W.P.C.G., Hettiarachi, S. and Jayarathne, M.P.K. (2017). Factors affecting the quality of raw milk: Effect of time taken for transportation and practices at field level in small farms in Sri Lanka, *Journal of Food and Dairy Technology*, 05: 9-15.

Whyte, D., Walmsley, M., Liew, A., Claycomb, R. and Mein, G. (2005). Chemical and rheological aspects of gel formation in the California Mastitis Test. *Journal of Dairy Research*, 72: 115–121. https://doi.org/10.1017/S0022029904000561

Wijethilaka, D., de Silva, S. and Deshapriya, R.M.C (2017). Value chain analysis for dairy industry development in the Uva Province of Sri Lanka. Conference in Economic Review – Saga University, Japan

Wijethilaka, D. (2019). MPhil thesis: Dairy Value Chain Analysis in the Uva Province of Sri Lanka, Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka. pp 1-250

Zhao, X. and Lacasse, P. (2008). Mammary tissue damage during bovine mastitis: Causes and control. *Journal of Animal Science*, 86: 57–65. https://doi.org/10.2527/jas.2007-0302