Udder health and somatic cell count in water buffalo (*Bubalus bubalis*) in Bangladesh

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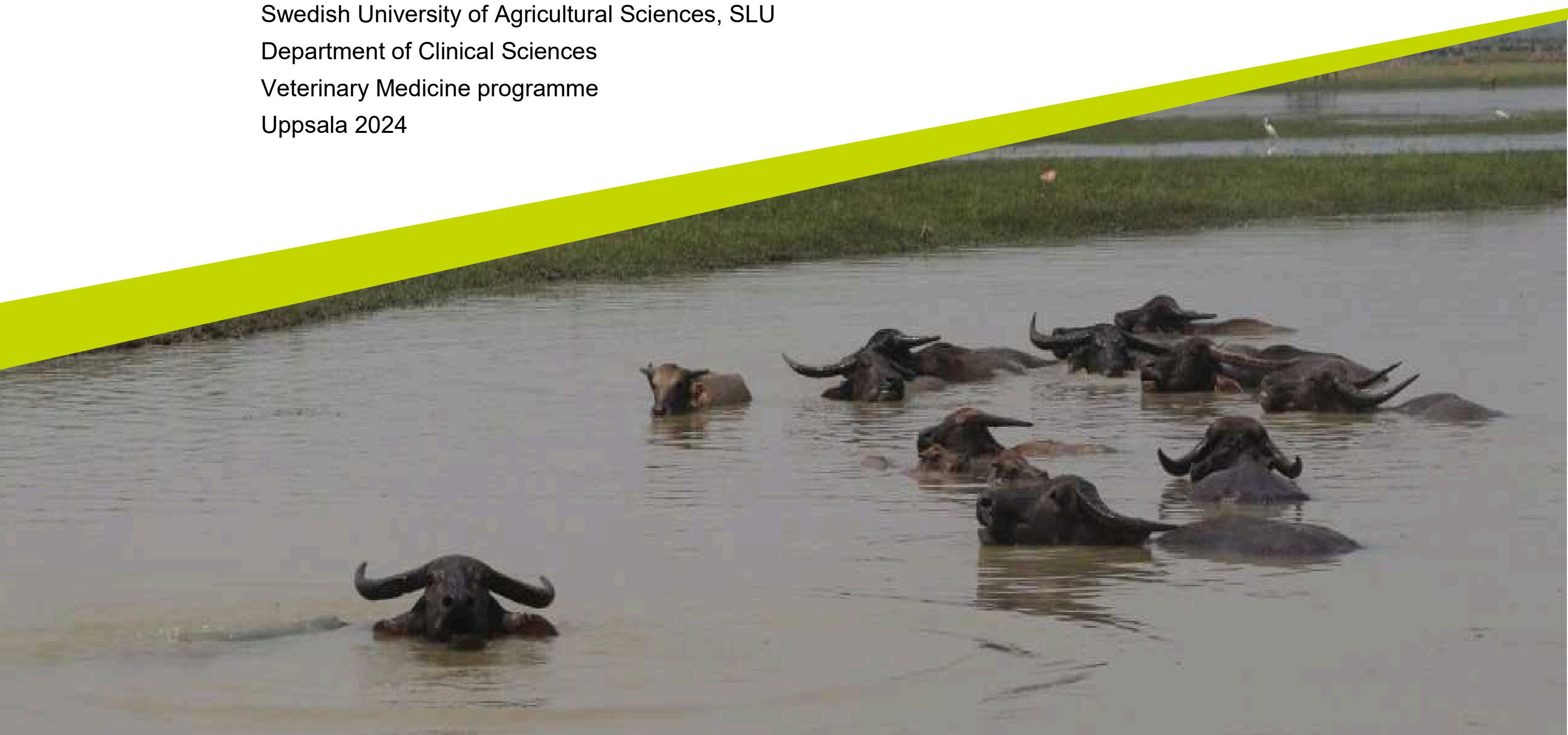

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Juverhälsa och celltal hos vattenbuffel (Bubalus bubalis) i Bangladesh

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Abstract

Bangladesh is a South Asian country that is largely dependent on its agriculture and is currently facing major challenges in its dairy sector. Due to a growing population and limited resources, the country cannot meet the demand for dairy products. The water buffalo is the world's second most common milk-producing animal, after the dairy cow, and is mainly used in Asia. The water buffalo is adapted to live in warm and humid environments and is therefore, more suitable in tropical countries, where dairy cows generally struggle.

Mastitis, inflammation of the mammary gland, is one of the biggest problems in the dairy industry and affects the health, milk production potential, and milk quality of dairy animals. Mastitis also entails financial losses in the form of veterinary costs, loss of production and poorer quality of the milk. Subclinical mastitis (SCM) is a major problem since it is more difficult to identify and diagnose but still negatively affects milk yield and quality.

Milk somatic cell count (SCC) is an important indicator of udder health and milk quality, with elevated levels indicating mastitis. Somatic cell counts in milk are generally lower in water buffaloes than in dairy cows, studies have shown that SCC above 200,000 cells/ml is a significant indicator of intra-mammary infection (IMI) in water buffaloes. In dairy cows, an SCC of 200,000 cells/ml is used as a threshold limit to determine when an udder is considered healthy or infected. Water buffaloes generally show a lower SCC than dairy cows and therefore, the same threshold limit cannot be used. The study states that it is important to determine a threshold limit for SCC in water buffaloes to be able to diagnose SCM to further enhance the water buffalo's milk yield and quality. This will in turn increase profits in the industry as well as promote animal welfare.

Keywords: IMI, SCM, mastitis, dairy production

Sammanfattning

Bangladesh är ett sydasiatiskt land som är starkt beroende av sitt jordbruk och som i nuläget står inför stora utmaningar inom sin mejerisektor. På grund av en växande befolkning och begränsade resurser kan landet inte möta efterfrågan på mejeriprodukter. Vattenbuffeln är världens näst vanligaste mjölkproducerande djur, efter mjölkkon, och används främst i Asien. Vattenbuffeln är anpassad att leva i varma och fuktiga miljöer och passar därför bra i tropiska länder, där mjölkkor generellt trivs sämre.

Mastit, inflammation i bröstkörteln, är ett av de största problemen inom mjölkindustrin och som påverkar hälsan, mjölkproduktionspotentialen och mjölkkvalitén hos mjölkdjur. Mastit medför även ekonomiska förluster i form av veterinärkostnader, förlust av produktion och sämre kvalité på mjölken. Subklinisk mastit är ett stort problem eftersom det är svårare att identifiera och diagnostisera men påverkar mjölkavkastning och kvalité negativt.

Mjölkens celltal är en viktig indikator för juverhälsa och mjölkkvalité, där förhöjda nivåer indikerar mastit. Celltal i mjölk är generellt lägre hos vattenbufflar än hos mjölkkor och studier har visat att celltal över 200 000 celler/ml är en tydlig indikator för mastit hos vattenbuffel. På mjölkkor använder man ett celltal på 200 000 celler/ml som gränsvärde för att avgöra när ett juver anses friskt eller inflammerat. Eftersom vattenbufflar generellt visar ett lägre celltal än mjölkkor kan samma gränsvärde inte användas. Studien slår fast att det är viktigt att bestämma ett gränsvärde för celltal hos vattenbuffel för att kunna diagnostisera subklinisk mastit samt för att utveckla vattenbuffelns mjölkavkastning och kvalité, vilket i sin tur gör mjölkindustrin mer lönsam och öka djurvälfärden.

Nyckeolord: Mastit, subklinisk mastit, mejeriproduktion

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Abbreviations

CMT	California Mastitis Test
DLC	Differential leukocyte counts
IMI	Intramammary infection
SCC	Somatic cell count
SCM	Subclinical mastitis
WBC	White blood cells

1. General introduction

1.1 Background

Bangladesh is located in South Asia, with borders to India in the east, west and north and Myanmar in southeast. The population in Bangladesh is approximately 170 million people (Socio-Economic Indicators of Bangladesh 2022). In Bangladesh, 18.7% of the population lives in poverty and 5.6% experiences extreme poverty (Socio-Economic Indicators of Bangladesh 2022). The largest employment sector in Bangladesh is in agriculture, which engages 45% of the population within the country (Socio-Economic Indicators of Bangladesh 2022). According to Department of Livestock Services 2022, the livestock sector employs 20% of the entire population, with another 50% partially employed. Meat and dairy products are important to meet the country's protein requirement, and with a growing population, it is important to secure and improve the food chain to ensure that everyone can access food and reduce poverty.

Udder health problems e.g., mastitis play an important role in reducing milk production potentials in dairy animals. Mastitis is an inflammation of the mammary gland which causes detrimental effects on the quality and quantity in milk from water buffaloes and other dairy species e.g., cows and goats (Bari et al. 2022). Mastitis directly affects animal welfare, increases antibiotic use and treatment costs, and decreases the milk yield and the quality of milk products. Particularly subclinical mastitis (SCM) is of importance since clinical signs remain unnoticed, but there is still a risk of transmission of intramammary infection (IMI) causing pathogens from the infected to the healthy quarters within the herd. Therefore, identifying SCM is critically important for effective udder health control in water buffaloes. Somatic cell count (SCC) is considered an important parameter for the detection of udder health status in clinically healthy milk. Levels of somatic cells in milk usually increase in water buffalo with the onset of inflammation in the mammary gland, mainly in response to an IMI (Moroni et al., 2006).

The study aims to give an overview of somatic cell count in water buffaloes, primarily in Bangladesh, and the association with udder health and milk quality.

1.1.1 Methods

The study is based on literature, primarily from PubMed, Google scholar and suggestions for any missing articles from two experts Dr. Ylva Persson and Dr. Shuvo Singha by personal communication. A search string was developed for PubMed to search for relevant articles between 2010 to 2023. The search was made on 2nd February 2024. Published articles within the subject were used if relevant. Even though the study focuses on dairy production from water buffaloes in Bangladesh, studies from other countries about the subject were sometimes used if relevant to the purpose. Studies that have been conducted on cattle were used to compare water buffalos to other better known and studied cattle breeds, these studies were also used as reference points when evaluating cell counts.

1.1.2 Limitations

The sources used for this thesis had to be in English or Swedish. The literature needed to be available in Swedish University of Agricultural Sciences' web library and search engines.

2. Literature review

2.1.1 Water buffalo as a dairy producing animal

Water buffaloes (*Bubalus bubalis*) were domesticated 5,000 years ago and there are still wild populations. Domesticated water buffaloes are either of river or swamp type, with the swamp type being heavier than the river type. It is the river type which is traditionally used for milk production in Asia. There are around 204 million of water buffaloes in the world, with 98% of them located in Asia (FAO *Buffaloes* 2024). Water buffaloes are, as their name states, an animal well suited for water and humid climate. They are good swimmers and divers and eat grass growing at the bottom of lakes, and water streams. Because of the limited number of sweat glands in the body coat, they are sensitive to a high ambient temperature and prefer mud baths to cool down. Water buffaloes are considered to be more resistant to many diseases compared to cattle and have a lower prevalence of mastitis (Cockrill 1981). Their hoof health is generally good, and hoof related diseases are rarely seen. Because of their suitability to wetlands, they are thought to be more resistant to tick borne diseases and some parasites as well, including the liver fluke (Cockrill 1981). This makes them better fitted for areas where cattle grazing is not possible.

Water buffaloes are well suited to the Bangladeshi climate, and therefore the preferred dairy species. This is particularly true in coastal areas of Bangladesh where agricultural production is not optimal due to a high saline contents and occasional flooding. The hot and humid climate is a challenge for the imported cattle breeds and while indigenous and mixed cattle breeds are better suited, they still produce under capacity (Hamid et al. 2016; Choudhary & Sirohi 2019). In Southeast Asia water buffaloes are the primary milk producing species, and second worldwide. They contribute significantly to the dairy production in bordering countries with India having the biggest population of buffaloes, followed by Pakistan and China (Minervino et al. 2020).

The Bangladeshi government has seen a higher demand for animal derived food products and has therefore, initiated projects to improve the dairy industry in the country. Bangladesh faces a shortage of milk with current production methods. At present there's only 63 g of milk available per person and day in Bangladesh, compared to 598 g in Sweden (Food and Agriculture Organization of the United Nations 2023). Furthermore, milk producing animals in Bangladesh produce far less milk per animal compared to Sweden. During 2022 milk producing animals in Bangladesh produced 415.50 kg per animal, compared to 9,288.30 kg per animal in Sweden (Food and Agriculture Organization of the United Nations 2023). The development of increased milk yields are continuing, as cows in Sweden produced 10,584 kg per cow during 2023 (Växa; Livestock statistic 2024). As the milk yield is much lower, this leaves Bangladesh in need of further development of milk production.

2.1.2 Mammary gland physiology in water buffaloes

The word mammals come from the Latin word mammary and includes all vertebrate animals who feed their young with milk from mammary glands. Mammary glands are sweat glands that consist of mamma and teat (Alhussien & Dang 2018). The mammary gland in water buffaloes consists of two pairs of mammary glands that together form the udder. Two sulci, one transverse and one longitudinal (Sulcus intermammarius), separate the udder into four separate quarters (Bragulla & Konig, 2004). The quarters are divided into two cranial and two caudal quarters. The mammary glands have a conical appearance with a teat placed ventral on each gland. Water buffaloes have one galactophore system per mammary gland, which can be seen due to only one papillary ostium in the teat apex (Tătaru et al. 2022). The teat canal's epithelial cells and sphincter is thicker in water buffaloes than in cattle, which leads to the milk travelling through a longer and narrow teat canal during milking in water buffaloes (Sagor et al. 2024). In water buffaloes the posterior teats are usually longer than the anterior teats, compared to cows where the anterior teats are longer than the posterior teats. The cranial teats in water buffaloes are on average 6 cm long and 2.2 cm in diameter and the caudal teats are 6.3 cm long with a diameter of 2.3 cm (Sagor et al. 2024).

There are different shapes of the buffalo udder; bowl-shaped is the most common, followed by globular, goaty, cylindrical, pendulous, pear-shaped, conical, bottle and funnel shaped. There's a great variation in udder shape in water buffaloes compared to cattle (Sagor et al. 2024). The udder is located in the inguinal region in the female water buffalo and consists of blood vessels, nerve plexus, lymphatic vessels, secretory glands, a secretory system of epithelial cells and ducts for storage and transport of milk (Ferreira et al., 2013). Ligamentum suspensorium uber, rich in elastic fibers, fixes the udder to the central abdomen wall firmly. The udder is covered in skin with sparse and fine hair. The skin is flexible, allowing the udder to expand when filled with milk and contract when empty (Tătaru et al. 2022). The skin of the udder has sebaceous and sweat glands, while the teat lacks these types of glands. During lactation the skin is smooth and during milk rest when the udder decreases in volume the skin gets transverse wrinkled (Tătaru et al. 2022).

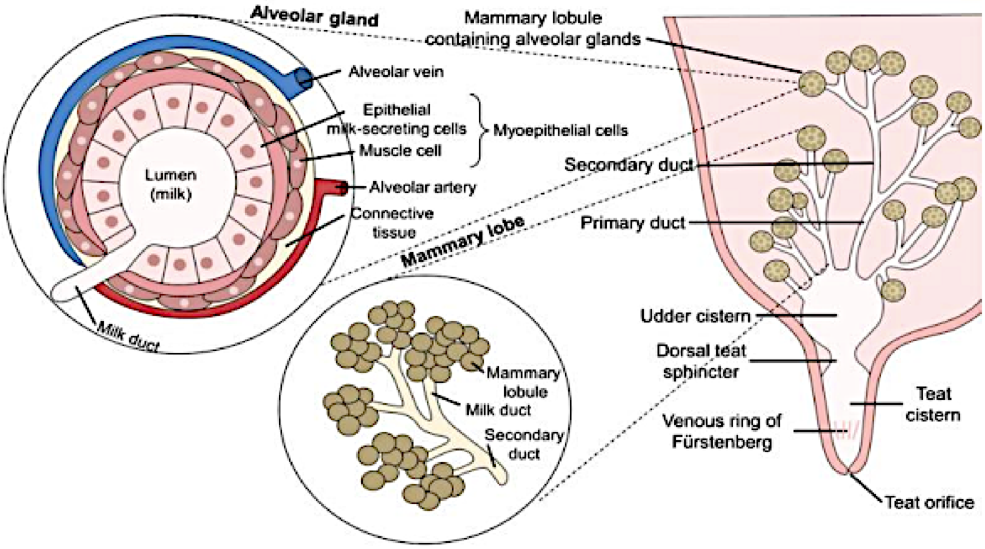


Figure 1: Sagittal section of a water buffalo udder quarter showing alveolar glands, enlarged alveolar glands and milk storage area with excretion ducts (Sagor et al. 2024).

2.1.3 Udder health and mastitis

Inflammation of the mammary gland and parenchyma is called mastitis. Mastitis is one of the most common diseases in milk producing animals worldwide and very costly for dairy farmers (Seegers et al. 2003). It can be especially devastating for farmers in developing countries like Bangladesh, with culling of productive animals, increased costs of veterinary care, reduced milk yield, antibiotic residues in milk, chronic cases and occasional deaths (Seegers et al. 2003). Mastitis can also be a concern for zoonotic cases with bacteria and toxins present in the milk (González & Wilson 2003). Water buffaloes are less prone to get mastitis than cattle, likely due to their differences in anatomical structure (Sagor et al. 2024).

Mastitis can be caused by infection of microorganisms or trauma, where infection is more common (Sandholm et al. 1995; Srivastava et al. 2015; Presicce 2017). The inflammation can be confined to the mammary gland or part of a systemic infection (Sandholm et al. 1995). Mastitis can be defined by symptoms and duration. Clinical mastitis is defined as inflammation in the udder with visible symptoms like redness and swelling of the udder, changes in the milk such as fibrin, clots or pus and systemic signs such as increased body temperature and lack of appetite (*Mastitis in Cattle - Reproductive System* n.d.). Clinical mastitis can be fatal in severe cases (Gruet et al. 2001).

Subclinical mastitis is an inflammation without any visible symptoms and can only be diagnosed by assessment of the chemical or cellular changes in the milk (Singha 2023). The most common method is to measure the amount of white blood cells in milk, the SCC, which can be measured directly with a somatic cell counter or indirectly with the California Mastitis Test (CMT) or similar tests. SCM can also be assessed by measuring chemical changes in milk e.g., pH (Singha 2023). Acute mastitis is defined by its sudden onset and clinical signs. On the other hand, chronic mastitis can present both with and without clinical signs and occurs in the same animal for a longer period of time (Sagor et al. 2024).

Mastitis in water buffaloes is most commonly caused by IMI with pathological alterations in milk, udder and animal (Singha 2023). Studies have seen a threefold higher prevalence of SCM compared to clinical mastitis in water buffaloes (Singha 2023). Subclinical mastitis leads to a declined milk quality and processability. In a study conducted in the Bhola district in Bangladesh, prevalence of SCM in water buffaloes ranged between 11-28%, however more research needs to be done in order to make any conclusions. Intramammary infections can be tested with bacteriological culture. Despite IMI being frequently encountered, testing for it is not a standard practice in Bangladesh due to unawareness of farmers and inadequate access to technical resources (Singha 2023).

2.1.4 What is SCC?

Somatic cells are a mixture of polymorphonuclear cells, epithelial cells and immune cells which are normally found in low concentrations in milk and secreted during the process of milking. Somatic cell count is used globally as an indicator for measuring udder health and milk quality (Alhussien & Dang 2018). In normal milk, somatic cells originate mainly from epithelial cells from the udder secretory tissue and a smaller number of leukocytes. Somatic cells are the second line of defense against pathogens after the chemical and anatomical barriers of the teat apex and teat canal in the mammary gland. When milk flows through the alveoli and teat canal, epithelial cells peel off and exit with the milk. This process is a normal physiological occurrence and essential for the regeneration of epithelial cells (Boutinaud & Jammes 2002; Alhussien & Dang 2018).

Leukocytes found in milk are all blood-borne and part of the immune system (Hillerton 1999). The proportion of leukocytes changes during a high SCC, with the proportion of neutrophils substantially increased in the initial phase of inflammation. Neutrophils remaine predominante but as the inflammation progresses, the amount of mononuclear cells increase (Rivas et al. 2001). Their main function is to fight pathogens and assist in restoration of gland tissue. Mastitis increases the number of leukocytes and can therefore be a measurement for udder health. Furthermore, leukocytes can in some cases indicate a high bacteria count caused by IMI (Hillerton 1999).

Somatic cell count is the quantification of the number of cells per mL milk. A SCC of around 100,000 cells/mL indicates a healthy udder and an unaffected animal in dairy cows (Hillerton 1999) while an SCC over 200,000 cells/mL indicates infection in at least one quarter of the udder (Dang 2007).

In water buffaloes and cattle, milk is produced constantly by the milk-secreting epithelial cells in mammary glands. These epithelial cells take up milk components from blood vessels and synthesize it into milk, then release it into the alveolar lumen. The epithelial cells are surrounded by myoepithelial cells and muscle cells that contract when oxytocin levels rise to release milk from the alveolar lumen to the ducts (Alhussien & Dang 2018). Buffalo milk let down is largely affected by environmental stimuli. Although not advised on a regular basis, oxytocin injections can be used for pre-milking teat stimulation to boost milk release in water buffaloes. Oxytocin injections are preferred over other methods like calf sucking, due to increased risk of SCM (Singha 2023).

2.1.5 How to measure SCC

There are different ways to measure somatic cells in milk, direct and indirect. The gold standard of direct methods is direct microscopic somatic cell count (DMSCC). Fresh milk is collected and sampled on a degreased microscopic slide, air dried and stained. The method is used to calculate the percentage of various cell types in milk, like lymphocytes and neutrophiles. The microscope can be adjusted to differentiate the cell types in the milk sample. Direct microscopic somatic cell count is cheap and easy to use, but time consuming (Alhussien & Dang 2018).

One problem with DMSCC is its tendency to color artifacts, as well as cell aggregation, giving an uncertain number of cells. An alternative method is to use an electronic cell counter. With this method dying reagent, containing fluorescent dye, is mixed with the milk sample and pipetted to a disposable chip and read by the device. The device contains a sensitive CCD camera which captures the dyed cells, and the analysis algorithms determine the number of cells by the dimension of fluorescent and concentration of the cells in the sample (Alhussien & Dang 2018). Flow cytometry uses the same technique while simultaneously determining cell types using specific antibodies, which has been proved to be a more reliable technique than DMSCC. Exclusion markers like 7-Aminoactinomycin D, propidium iodide, acridine orange or a combination of them are normally used to quantify the cell viability (Li et al. 2015).

California mastitis test is the most commonly used indirect method for measuring SCC in milk. The amount of DNA and WBC are directly linked, therefore CMT measures the amount of DNA in milk in order to detect WBC. This method is mostly used to identify SCM (*California Mastitis Test - an overview | ScienceDirect Topics* 2008). California mastitis test is a simple method to perform, cost-effective and executed by mixing the reagent fluid with sampled milk. If there's inflammation present in the udder, the mixture will form a gel-like formula and change colour (Sagor et al. 2024).

2.1.6 SCC in cattle

Dairy cows' lactation can be divided into early, mid, and late lactation. Milk yield reaches its maximum during early lactation and then decreases. Somatic cell count rises to its highest values shortly after calving and then rapidly decreases to rarely being present between day 25 and 45. After day 45, SCC rises slowly throughout the rest of the lactation period (Kennedy et al. 1982). Subclinical mastitis is diagnosed when SCC exceeds the threshold levels. A mammary quarter is considered healthy when SCC is below 100,000 cells/mL. In field diagnostics, the threshold SCC of 200,000 cells/mL is widely used to reduce diagnostic error (Sumon et al. 2020).

According to Mukherjee et al. (2013) SCC was higher in high yielding cow breeds and lower in low yielding cow breeds regardless of lactation stages. SCC in high yielding cow breeds differ among the lactation stages with its highest being during mid lactation. This correlation is not seen in low yielding cow breeds (Mukherjee et al. 2013). In the same study no difference in differential leukocyte counts (DLC) in milk between high and low yielding cows, nor different stages of lactation, were shown. Lymphocytes are predominant in DLC, followed by macrophages and third neutrophils (Mukherjee et al. 2013; Mukherjee et al. 2015).

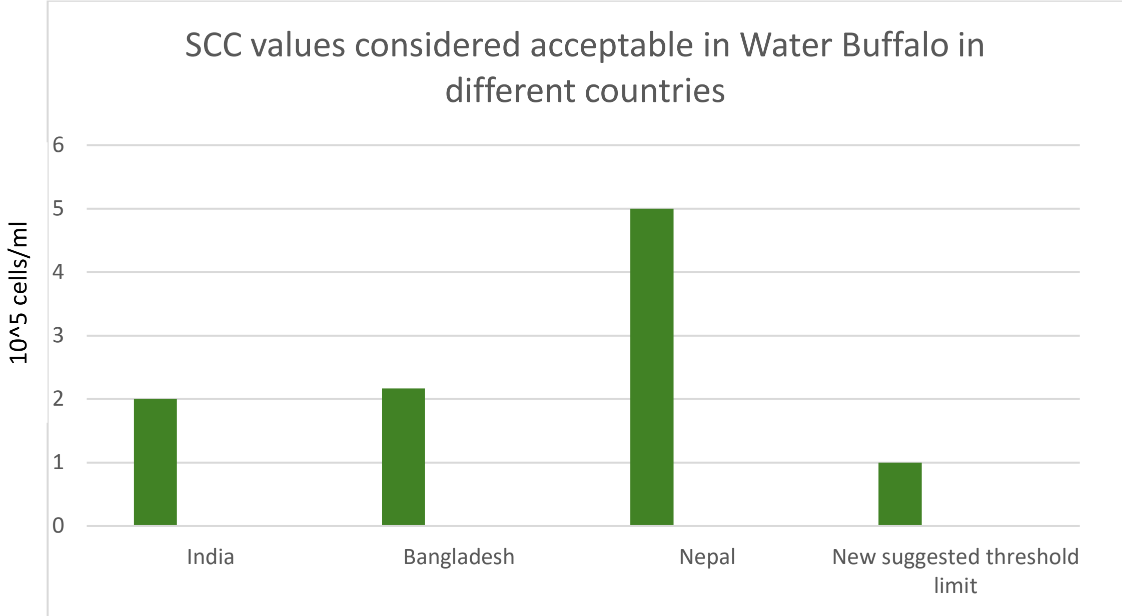
An earlier study by Mukherjee et al. (2015) demonstrated that SCC was considerably ($p < 0.01$) higher in elite cows compared to non-elite cows regardless of season. Milk SCC increased significantly ($p < 0.05$) during hot-humid season and decreased during winter season in both elite and non-elite cows. In a study made by Castro et al. (2015) samples of milk collected from machine-milked and hand-milked crossbred cows were compared. The study showed that SCC was higher ($p<0.01$) in hand-milked cows compared to machine-milked cows, and practices to prevent high SCC such as dipping the teat in disinfectant solution after milking decreased the SCC in subsequent milking. SCC differs in values between breeds and are higher in elite cows like Brown Swiss and Holstein, with an average of around 241,000±83,000 cells per mL whereas indigenous breeds like Tharparkar have a lower SCC with a mean of 100,000-150,000 cells per mL (Alhussien & Dang 2018).

2.1.7 SCC in water buffalos

The standard value of SCC in milk from water buffaloes is below 500,000 cells/mL (Priyadarshini & Kansal 2002). Studies have not been able to determine a difference in SCC correlated to time of the day (Singh & Ludri 2001). Season were observed to have a significant impact on SCC, with higher values during hot-humid climate and lower during the dry season. SCC values were high during the first 90-days of lactation with a range of 110,000-127,000 cells/mL and subsequently decreased to lower values (90,000-99,000 cells/mL) during mid-lactation (90-210 days) and then moderately rose again during late lactation (Singh & Ludri 2001). Priyadarshini and Kansal (2002) investigated lysozyme activity in buffalo milk and found that certain buffaloes showed 1000-fold higher lysozyme activity alongside moderately elevated SCC in milk, without displaying symptoms of mastitis. Elevated lysozyme activity could have potentially helped the buffaloes to not develop mastitis (Priyadarshini & Kansal 2002). The lysozyme activity reported in water buffaloes is higher than that reported in cattle and could be a factor as to why udder infections are less common in water buffaloes compared to cattle (Priyadarshini & Kansal 2002).

A study performed in Bangladesh showed that the SCC in bulk milk in water buffaloes was 217,000 cells/mL (Singha et al. 2023). An SCC of 200,000 cells/mL of milk in water buffaloes is considered acceptable in India whilst in Nepal an SCC of 500,000 cells/mL of milk is accepted (Singha et al. 2023). Currently there is no set global regulation of SCC in buffalo-milk. The National Dairy Research Institute (NDRI) in India, suggested a threshold limit of 100,000 cells/mL of milk in Murrah buffalo and a SCC >100,000 cells/mL to be considered SCM (Sagor et al. 2024).

Studies have shown a significant correlation between SCC and IMI. According to Moroni et al. (2006) 100% of quarters with an SCC over 200,000 cells/mL had IMI and 98% of quarters with an SCC lower than 200,000 cells/mL were uninfected.



Graph 1: SCC values considered acceptable in water buffaloes in different countries compared to the new suggested threshold limit.

3. Discussion

It is crucial to look at our resources and how to use them as efficiently as possible if we are to produce food in enough quantity to feed every person. Improving the productivity of our dairy animals to produce greater quantities of milk per animal is more sustainable from both an economic and environmental perspective. High yielding animals are also more space efficient, which is an advantage in densely populated countries e.g. Bangladesh. Currently, Bangladesh's milk yield only makes up 4.5% of Sweden's annual milk yield (Food and Agriculture Organization of the United Nations 2023). Animal and udder health may be two crucial factors related to this low per animal milk yield in Bangladesh. Nutrition and genetic merits may also be a contributing factor, but good genetics cannot compensate for inadequate feed.

Water buffaloes are better equipped to survive in challenging climates and have a more efficient system to protect them from pathogens than cattle. Buffaloes are also better at maximizing the nutritional value of low-quality feed and are more resilient to saline waters (Cockrill 1981), making them more suitable for areas with freshwater and feed shortage such as regions in Bangladesh. Cattle are more prone to get diseases and mastitis in hotter and more humid climates (Mukherjee et al. 2015), which affects the milk yield and quality negatively. Broadening the use of water buffaloes for dairy production in Bangladesh can therefore increase the milk yield and be part of the solution for milk shortage.

Water buffaloes and dairy cows share a lot of similarities in their anatomy, physiology and function as a food producing animal. Multiple factors are involved in and contribute to SCC in milk. Water buffaloe's longer and more narrow teat canal (Sagor et al. 2024) makes it more difficult for bacteria and microorganisms to travel up the teat canal and colonize the mammary gland thus inducing mastitis. The water buffalo's anatomical structure of its udder can therefore serve as an extra barrier against pathogens, compared to cattle. Water buffaloes have a higher lysozyme-activity (Priyadarshini & Kansal 2002), which can be another factor as to why water buffaloes are less prone to develop mastitis and generally more resistant to diseases than cattle breeds.

Studies have shown a significant correlation between different breeds of dairy cows and their mean SCC. Diagnosing IMI is a key factor in order to prevent SCM, since clinical signs go unnoticed and affected animals can be reservoirs and spread the infections throughout the herd (Singha 2023). Somatic cell count is strongly connected to IMI, where studies show that a SCC over 200,000 cells/mL indicate IMI in 100% of tested quarters in water buffaloes (Moroni et al. 2006). There is no current global regulation for SCC in buffalo milk and values considered acceptable vary greatly between countries (Singha et al. 2023). Water buffaloes generally have lower SCC values compared to cattle both in affected and healthy udders (Moroni et al. 2006; Sagor et al. 2024). The National Dairy Research Institute's suggested threshold limit of 100,000 cells/mL in Murrah buffalo (Sagor et al. 2024) is therefore a more appropriate threshold limit for water buffaloes and a good start for a global guideline.

Benchmarking SCC in water buffaloes in Bangladesh will provide the information needed to prevent SCM which in turn increases both milk yield, quality and safety of milk. Improving milk quality may improve the quality of products with a high percentage of milk fat e.g. butter, cream, ghee as well as protein-based products e.g. cheese and sweets. Better udder health will also increase the shelf life of milk and milk products and improve food safety for consumers. Establishing a threshold SCC for water buffaloes is therefore important as the quality and safety of both milk and milk products will increase and make buffalo farming in Bangladesh safe and profitable. Another important factor to consider is that establishing a threshold limit for SCC in water buffaloes will aid farmers in identifying buffaloes with IMI, which in turn will improve animal welfare and reduce the use of antibiotics.

In addition, more studies need to be done in the area in order to fill research gaps and provide us with more knowledge about SCC, IMI and SCM in water buffaloes. Heat stress in an important issue in subtropical climate like Bangladesh, but there are currently no known studies exploring the effects on SCC in water buffaloes. To effectively implement a global threshold limit for SCC in water buffaloes, department of livestock services and farmers cooperatives need to initiate measures, like routine testing of bulk milk, and further develop international cooperation.

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