

**The Impact of Parlor Equipment and Milking Procedures on Milk Quality in the Southeast  
US**

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## ACADEMIC ABSTRACT

Milk quality has continued to improve over the last several decades in the US, but still remains to be a problem for dairy producers in the southeast (SE) US. The purpose of these analyses was to evaluate associations between parlor equipment function, milking procedures, and bulk tank somatic cell count (BTSCC) and bulk tank standard plate count (BTSPC) on SE US dairy farms. Data from dairies in Virginia (n = 96), Kentucky (n = 96), Tennessee (n = 84), and Mississippi (n = 7) were collected at a single visit for each farm. Monthly BTSCC and BTSPC data were retrieved from state regulatory offices for (n = 263) farms, and averaged over the 12 months prior to each farm visit and used as the dependent variables in each analysis in a backwards elimination regression model. Increased herd size was associated with lower BTSCS, but higher BTSPC. Utilization of an internal teat sealant was associated with lower BTSCS. Farms that housed cows exclusively on pasture had greater BTSCS than farms that keep lactating cows in confinement with no pasture access. Utilization of a freestall for lactating cow housing was associated with lower BTSCS. The likelihood of future dairy operation in 10 years as reported by the farm owner or manager influenced BTSPC. Beginning water temperature of the detergent wash cycle was found to influence BTSCS. These findings suggest that the most influential variables explaining milk quality are herd demographic information and farmer perceptions as well as a few management variables such as the use of an internal teat sealant and beginning water temperature of the detergent wash cycle. These findings suggest that farmer perceptions and attitudes may be influencing milk quality more than previously thought. Further research is needed to evaluate social factors that could be influencing milk quality. Milking equipment function has improved substantially over the last several decades and was not found to significantly influence milk quality among the evaluated SE US dairies in these analyses.

Milking procedures such as pre- and post-milking teat disinfection are widely accepted by most dairies in the US. Minimal differences were found between milking procedures such as teat disinfectant active ingredient or using paper towels versus cloth towels suggesting that these factors may not be the most influential factors influencing milk quality.

## GENERAL ABSTRACT

Milk quality has continued to improve over the last several decades in the US, but still remains to be a problem for dairy producers in the southeast (SE) US. Milk quality can be measured by somatic cell count and bacteria counts in raw bulk tank milk. Several factors influence these measures, but some of the most important factors are associated with properly functioning milking equipment and milking procedures. The purpose of these analyses was to evaluate farm demographics, parlor equipment function, and milking procedures, and their association with bulk tank somatic cell count (BTSCC) and standard plate count (BTSPC) on SE US dairy farms. Data from dairies in Virginia (n = 96), Kentucky (n = 96), Tennessee (n = 84), and Mississippi (n = 7) were collected at a single visit for each farm. Monthly BTSCC and BTSPC data were retrieved (n = 263) from state regulatory offices and averaged over the 12 months prior to each farm visit and used as the dependent variables in each analysis in a backwards elimination regression model. Increased herd size was associated with lower BTSCS, but higher BTSPC. Utilization of an internal teat sealant was associated with lower BTSCS. Farms that housed cows exclusively on pasture had greater BTSCS than farms that keep lactating cows in confinement with no pasture access. Utilization of a freestall for lactating cow housing was associated with lower BTSCS. The likelihood of future dairy operation in 10 years as reported by the farm owner or manager influenced BTSPC. Beginning water temperature of the detergent wash cycle was found to influence BTSCS. These findings suggest that the most influential variables explaining milk quality are herd demographic information and farmer perceptions as well as a few management variables such as the use of an internal teat sealant and beginning water temperature of the detergent wash cycle. These findings suggest that farmer perceptions and attitudes may be influencing milk quality more than previously thought. Further research is needed to evaluate

social factors that could be influencing milk quality. Milking equipment function has improved substantially over the last several decades and was not found to significantly influence milk quality among the evaluated SE US dairies in these analyses. Milking procedures such as pre- and post-milking teat disinfection are widely accepted by most dairies in the US. Minimal differences were found between milking procedures such as teat disinfectant active ingredient or using paper towels versus cloth towels suggesting that these factors may not be the most influential factors influencing milk quality.

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## Chapter 1 : INTRODUCTION

Milk quality is measured quantitatively by the somatic cell count (SCC) and the bacteria count found in raw bulk tank milk prior to pasteurization. Reduced cheese yields result when raw milk has  $SCC > 100,000$  cells/mL and product defects can result when  $SCC > 400,000$  cells/mL (Murphy et al., 2016). After it was established that SCC and bacteria in raw milk negatively influences dairy products, it became commonplace for cheese makers to offer incentives for better quality milk in the 1970's and 1990's (Barbano et al., 2006). It has also been demonstrated that a high SCC negatively affects the quality of pasteurized fluid milk by accelerating sensory defects such as rancidity and bitterness caused by lipolysis and proteolysis (Ma et al., 2000). The Pasteurized Milk Ordinance (PMO) has set the SCC limit of 750,000 cells/mL for bulk tank milk sold in the United States. However, the PMO established milk quality standards for the purpose of improving public health and it was not intended for dairy product quality standards. Today, many US milk cooperatives require milk to be below 400,000 cells/mL and offer monetary incentives to be below 200,000 cells/mL.

Mastitis is defined as inflammation of the mammary gland, and is often a response to a bacterial infection in the udder of the cow, referred to as an intramammary infection (IMI). During an IMI, the immune system responds with an influx of polymorphonuclear (PMN) leukocytes into the mammary gland (Anderson et al., 1985). This influx of PMN contributes to an increase in SCC and consequently elevated SCC in milk is often used as an indicator of detecting mastitis. If SCC is  $> 200,000$  cells/mL, it is possible that this is an immune response due to an IMI by bacterial pathogens (Harmon, 1994; Akers and Nickerson, 2011).

Another indicator of milk quality is the amount of bacteria present, typically measured as number of colony forming units (cfu/mL). Bacterial count of milk can be influenced by several

factors including the presence of an IMI, but predominantly is determined by 1) cleanliness of the udder skin 2) hygiene practices in the parlor 3) proper cleaning of milking equipment 4) quickly cooling milk in the bulk tank immediately after collection and 5) maintenance or replacement of aging rubber components (Engel, 2011). The PMO has set bacteria count limits of <100,000 cfu/mL for Grade A raw bulk tank milk. Additionally, the PMO requires that milk be cooled instantly using heat exchangers, or be cooled to 7°C or less within 2 hours of milking time. Bulk tank milk should not exceed 10°C when adding fresh milk to the bulk tank milk. Even after heat treatment, psychrotrophic bacteria live at refrigeration temperatures and limit the shelf life of conventionally pasteurized milk to a max of 14 to 17 days (Barbano et al., 2006).

The objective of this review is to discuss common dairy management practices utilized in the milking parlor that are known to influence milk quality.

## Chapter 2 : LITERATURE REVIEW

### 2.1. Mastitis

Mastitis refers to inflammation of the mammary gland. Mastitis can be a result of physical injury, chemical irritation, or most often, IMI caused by microorganisms (Philpot and Nickerson, 2000). Mastitis is the costliest disease in the dairy industry, and is estimated to cost the producer \$185 per cow per year with the highest loss being decreased milk production (Philpot and Nickerson, 2000). Nearly \$2 billion can be attributed to losses due to mastitis annually in the US alone (Philpot and Nickerson, 2000). In addition to a decrease in milk yield, cows with clinical mastitis have increased culling risk, lower conception rates and increased incidence of abortions (Santos et al., 2004). Intramammary infection occurs when microorganisms, such as bacteria, successfully enter through the teat canal, migrate into the alveoli, and establish a population by replication (Philpot, 1979; Hogan et al., 2016). In addition to economic losses due to dumped milk, antibiotic treatment in lactating animals is not always successful, as a 24-71% bacteriological cure rate has been reported depending on the causative pathogen (Serieys et al., 2005). When considering all the consequences of an IMI, prevention becomes an essential part of mastitis control.

When developing effective mastitis prevention practices, it is important to know the origin and preferred living conditions of different types of pathogens. Mastitis pathogens can be classified into 3 categories based on their primary reservoir: contagious, environmental and opportunistic. The primary source of contagious pathogens is in the udder of an infected cow; contagious pathogens are known to spread through contaminated milking equipment and flies. Specific bacterial species which are considered contagious pathogens include, *Staphylococcus aureus*, *Streptococcus agalactiae* and *Corynebacterium bovis* (Hogan et al., 2016).

Environmental pathogens originate from the environment surrounding the cow, such as bedding

and manure, and include *Streptococcus uberis*, *Escherichia coli* and *Klebsiella* spp.

Opportunistic pathogens are often found as part of the normal skin flora, but do not always cause disease, these mainly include coagulase-negative staphylococci.

Given the variation among mastitis pathogen types, there are also a variety of ways to reduce pathogen exposure and IMI risk. A main factor in bacterial control can be attributed to teat disinfectants applied before and after milking (Philpot, 1979). Contagious pathogens have further been controlled in the milking parlor by milkers wearing latex gloves, not sharing towels from cow to cow, segregating infected cows and milking these animals last to keep equipment uncontaminated. A recent review paper found that wearing gloves, and using a post-milking teat disinfectants were the most significant parlor practices influencing herd SCC (Dufour et al., 2011). Environmental pathogens are largely controlled through pre and post teat disinfectants, but also with dry bedding, vaccinations, and management strategies, such as offering fresh feed after milking to allow time for the teat sphincter to close (Hogan et al., 2016). Washing udders with soap and water, and disinfecting milking units between every cow was, at one time, seen as an essential mastitis control practice. However, bacterial reduction largely depends on surfaces being dry, too much water use can lead to increased bacteria load on teat skin, in milking units, and ultimately in the milk (Philpot, 1979; Galton et al., 1982).

The National Mastitis Council (NMC) established a ten-point plan of recommendations for mastitis management. These steps include: 1) establishing goals, 2) keeping a clean and dry environment for cows, 3) using hygienic milking practices, 4) maintaining milking equipment, 5) keeping records, 6) managing clinical mastitis cases, 7) managing mastitis in dry cows, 8) following a biosecurity protocol, 9) monitoring udder health using SCC, and 10) regularly reviewing the overall mastitis control program. The goals of mastitis management are to produce

a high quality product for monetary gain, but also to maintain proper animal welfare standards by keeping cows healthy. In order to achieve these goals, SCC needs to be monitored and managed.

### ***2.1.1. Somatic Cell Count***

The term “somatic” means “derived from the body” (Philpot and Nickerson, 2000). Somatic cells found in normal milk consist of macrophages, lymphocytes, PMN and epithelial cells (Lee et al., 1980). Macrophages are the predominant cell type present in healthy, uninfected mammary glands. When an IMI exists, a shift occurs and the predominant cell type becomes PMN (Harmon, 1994). As this shift occurs, SCC levels in the mammary gland increase and therefore, elevated SCC levels are associated with the presence of an IMI. Although this is not always the case, it has been categorized that healthy, non-infected mammary glands generally have SCC < 200,000 cells/mL and anything above that may be an indication of an IMI (Hogan et al., 2016). Additionally, PMNs will typically be present in concentrations of <100,000 cells/mL in milk from healthy glands (Hogan et al., 2016). Presence of an IMI will also result in changes in milk components such as fat, lactose and casein which contributes to decreased cheese yields and a poorer quality product (Harmon, 1994; Philpot and Nickerson, 2000).

Several indirect factors can influence average SCC of a dairy herd. Increased milking frequency has been shown to reduce SCC (Dahl et al., 2004). Each milking is removing milk, contributing to cell turnover, and removing bacteria that may be present. A study evaluated the effects of milking frequency on milk yield and SCC (Dahl et al., 2004). This study compared milking early lactation cows 3 times /d versus 6 times /d. Results from this study found that milk yield was greater and SCC was lower in cows that were milked more frequently (Dahl et al., 2004).

Another association has been observed between BTSCC and season. For example, herds in the Northeastern US were found to have greater BTSCC in the spring versus the fall (Allore et al., 1997). According to 2013 data, US dairy herds' BTSCC averages were highest in July and August and lowest in November and December (Norman and Walton, 2014). An association also exists between herd size and BTSCC. National herd data show that herds with 150 cows or less had 8 to 16% of test days where BTSCC was greater than 400,000 cells/mL, whereas herds with 1,000 or more cows had this occur less than 1% of the time (Norman and Walton, 2014). Additionally, region of the US seems to contribute to BTSCC. For example, average BTSCC for herds in Idaho and California was 174,000 cells/mL in 2013, whereas the averages for Florida and Georgia were 229,000 cells/mL and 267,000 cells/mL, respectively (Norman and Walton, 2014). A more direct factor that can be associated with SCC is proper milking equipment function and maintenance.

## **2.2. Machine Milking**

Mechanical milking of the bovine was first conceptualized more than 180 years ago and has become an integral tool in the modern dairy industry (Hall, 1979). Machine milking has been described as a compromise between milking the cow as quickly and completely as possible without compromising teat end health (Reinemann, 2012). Several inventions were created in the early 1900's to try to accomplish the perfect milking machine, but many of these designs were very damaging to the teat tissue (Schuring, 2016). The most substantial discovery, in 1903, was the 2 chambered teat cup that uses vacuum and pulsation to milk the cow, that is still used today (Hall, 1979). Further advancements have come about in recent years such as automatic cluster removers and robotic milking systems. Due to many years of perfecting machine milking, most new cases of mastitis are caused by factors not directly related to the milking machine (Mein,

2012; Hogan et al., 2016). However, despite these advancements, it has been well established that milking unit function can still damage teat tissue and ultimately be associated with mastitis risk (Neijenhuis et al., 2000; Ohnstad, 2007; Mein, 2012).

### ***2.2.1. Milk Ejection***

Less than 30% of the milk in the bovine mammary gland is contained in the gland cistern and immediately available for milk removal upon unit attachment. The remainder of the milk is unavailable until proper stimulation of the teats occur (Bruckmaier and Blum, 1998; Kaskous and Bruckmaier, 2011). The hormone oxytocin is released from the neurohypophysis upon stimulation of the teat and travels through the blood to induce myoepithelial cell contraction, stimulating ejection of milk from the alveoli (Bruckmaier and Blum, 1998). This release of oxytocin is not immediate in its action on milk let down as circulatory delivery of oxytocin is a delayed response. Because of this, a lag time between stimulation and milk ejection must be considered.

A recent study by Kaskous and Bruckmaier (2011), demonstrated that more than 60% of harvested milk was collected in the first 2 min of machine-on time for late-lactation cows when an initial stimulation to attachment lag time of 90 to 120 s was used (Kaskous and Bruckmaier, 2011). Other studies have found that attachment of the milking unit without pre-stimulation resulted in transient reduction or complete interruption of milk flow after removal of the cisternal milk (Bruckmaier and Blum, 1998). This interruption of milk flow causes excessive stress on the teat end, possibly damaging the delicate tissue which will potentiate the entry of bacteria into the gland. Although lack of pre-stimulation does not reduce milk yield, it has been shown to extend milking machine-on time, which can have undesirable impacts on teat condition (Bruckmaier and Blum, 1995; Bruckmaier and Blum, 1998).

### ***2.2.2. Teat End Condition***

The teat sphincter is a cylindrical muscle structure that acts as an essential barrier to bacterial invasion of the mammary gland by maintaining tight closure of the duct between milkings (Capuco et al., 1994; de Pinho Manzi et al., 2012; Hogan et al., 2016). Bacteria can enter through the teat canal at any time, but the highest risk times would be during milking and directly after milking when the sphincter muscle has not had adequate time to close. The teat duct remains dilated for up to 1 hour or more after milk removal, and thus is a high risk time for bacteria to enter the gland. (Hogan et al., 2016). Since bacteria enter at the teat end, it is important to keep teat ends from becoming damaged, as hyperkeratosis provides more surface area for bacteria to accumulate.

Callosity and hyperkeratosis of teat ends has been shown to significantly increase IMI risk. A study in 2012 (de Pinho Manzi et al., 2012) scored teat ends on 499 cows from seven dairy farms in Brazil using a scale of 1 to 4, where 1 described a teat as the best condition possible with characteristics of a smooth, even surface around the teat orifice with no ring present, and 4 described the worst condition possible with characteristics of a very rough surface, ring around the teat orifice, and keratin projections protruding more than 4mm from the teat orifice. The authors described a positive relationship between increasing teat end score and the incidence of IMI. Neijenhuis et al. (2000) established that stage of lactation, parity, machine-on time, and teat end shape significantly contributed to teat end roughness (Neijenhuis et al., 2000). Roughness and keratin protrusion at the teat end increases the surface area in which bacteria can better adhere, increasing the likelihood of an IMI to occur. It is also important to note that this increased number of bacteria on the teat end can also contribute to an increased number of bacteria in the milk, affecting milk quality (Galton et al., 1986).

Machine milking can increase the risk of IMI by affecting teat end condition. Additionally, machine milking can induce other undesirable physiological changes in the teat such as: 1) increased congestion and edema in the teat wall; 2) a greater degree of openness of the teat canal orifice after milking; and 3) increased hyperkeratosis of the teat end (Mein, 2012; Hogan et al., 2016).

### **2.2.3. Claw Vacuum**

Recommended claw vacuum levels aim to ensure animals are milked quickly and completely, but also gently enough to not cause teat damage. Vacuum is an important aspect of machine milking; it allows for removal of milk while also “holding” the milking unit to the udder. The 2 main components regulating vacuum stability at the teat end is the vacuum regulator and the overall design and configuration of the system components (Reinemann, 2005). For example, the widespread adoption of a low-level pipeline system in milking parlors has improved vacuum stability at the teat end (Reinemann, 2005). System vacuum is set at a higher level than claw vacuum to account for non-avoidable vacuum level drops (Besier and Bruckmaier, 2016). It is important to have the appropriate size vacuum pump to accommodate the number of milking units in the parlor to 1) have adequate vacuum for milk removal; 2) prevent unit fall-offs; and 3) control vacuum fluctuation at the teat end. Right after the unit is attached and milk flow has not begun, the teat end is briefly exposed to the intensified system vacuum. However, more damage actually occurs at the end of milking when milk flow slows or ceases in 1 or more quarters, subjecting them to high system vacuum (Besier and Bruckmaier, 2016).

Two Irish researchers, Nyhan and Cowhig, conducted research in the 1960’s that found an association between unstable vacuum and increased IMI. Further research by O’Shea and

O’Callaghan found that the occurrence of liner slips increased IMI. Contributions from these researchers resulted in the subsequent theory known as the “droplet impact mechanism,” and hypothesized that during liner slips or teat cup fall-offs, vacuum fluctuations could drive milk droplets up into the teat end (Mein and Reinemann, 2014; Hogan et al., 2016). In order for this to happen, air speeds greater than 2 m/s would have to occur (Mein and Reinemann, 2014; Hogan et al., 2016). Normal liner movement is much too slow to generate airspeeds of this magnitude, but this phenomenon is known to occur during liner slips and unit fall-offs, when unexpected air is allowed into the system (Mein and Reinemann, 2014).

There has been much debate as to what is the “ideal” vacuum level, but currently an average claw vacuum of 32 to 40 kPa during peak milk flow is the predominant recommendation (Reinemann, 2005). When vacuum levels are low (26 to 30 kPa), an increase in the frequency of liner slips (squawking), unit fall-offs, and machine-on time results (Besier and Bruckmaier, 2016; Reinemann, 2005). To decrease machine-on time and the occurrence of liner slips, it is recommended that claw vacuum be above 30 kPa (Besier and Bruckmaier, 2016). An older study reported a 61 s decrease in machine-on time as vacuum levels were increased from 34 kPa to 42 kPa, and an additional 35 s decrease as vacuum was increased from 42 kPa to 51 kPa (Stewart and Schultz, 1958). However, if the vacuum levels are too high, > 42 kPa, damage to the teat end can result (Besier et al., 2016). One study evaluating 274 Dutch dairy herds found that farms with higher vacuum levels had an increased incidence rate of clinical mastitis (Barkema et al., 1999). Authors hypothesized that this was likely due to higher vacuum levels causing teat end damage.

Over-milking or prolonged machine-on time often occurs in milking parlors not equipped with automatic take-offs. Without automatic take-offs, machine-on time is determined based on

human perception of milk flow, which may lead to longer machine-on times. Automatic take-offs were patented about 40 years ago and have been one of the greatest improvements to machine milking. This parlor device measures when milk flow hits a certain threshold, usually 200 mL/min, there is a 10 s delay, the vacuum is shut off, and the milking unit is removed (Hillerton et al., 2002). Hillerton et al. (2002) observed that over-milking can lead to teat congestion, teat damage, and irritated cows. This study found that when cows were over-milked for 2 min or 5 min, proportion and degree of teat discoloration, firmness, and visible rings increased compared to controls (Hillerton et al., 2002).

The absence of automatic take-offs has also been associated with an increase in SCC. A study evaluating dairy herds in Pennsylvania (Jayarao et al., 2004) found that herds that did not have automatic take-offs in the parlor had greater BTSCC than farms that did have automatic take-offs. Although vacuum levels highly influence teat end health, all components of the milking system need to be working synergistically to accomplish successful and gentle milking.

#### ***2.2.4. Pulsation***

The milking unit is comprised of four double-chambered teat cups connected to the claw, which collects the milk. Each teat cup consists of a rigid outer shell with a flexible inner liner generally made of silicone or rubber. The opening and closing of the liner requires an exchange of vacuum and atmospheric air to create a negative or positive pressure in the teat cup to subsequently cause the liner to open or close. The pulsation ratio relates to the amount of time the liner is open (milk phase) or closed (rest phase). Pulsation ratio is generally in the range of 50:50 to 70:30. Today, the majority of milking machines operate at pulsation rates of 55 to 65 pulsations per min (Hogan et al., 2016). The pulsation cycle can be broken into four phases: A phase; B phase; C phase; and D phase. The A phase, or the “liner opening” phase, is when a

closed liner begins opening to transform into the milk phase. The B phase is when the liner has completely opened and milk is actively flowing through the teat end. The C phase, or the “liner closing” phase, acts as a transition from milk to rest phase. The D phase, or “rest phase”, is when the liner is collapsed and “massages” the teat before the cycle begins again. This rest phase is of paramount importance and needs to be of adequate duration to avoid congestion of tissues (Hogan et al., 2016).

A study demonstrating the importance of the milking pulsation cycle used 24 Holstein cows and compared milking quarters with and without pulsation (Capuco et al., 1994). Researchers found that within a week of milking without pulsation, 30% of quarters became infected with bacterial pathogens, and after 2 weeks, infection rate increased to 68% of quarters (Capuco et al., 1994). Capuco et al. (1994) and Mein (2012) observed that the association between pulsation-less milking and IMI is related to the removal of keratin cells and bacteria from the teat canal. Only about 10 to 20% of mature keratin cells are removed when milking without pulsation, whereas up to 40% of the keratin cells are removed when milking with a normal pulsation cycle (Mein, 2012). Without pulsation, the teat will be subjected to a continual milk phase and the teat will not experience a massage phase which will increase teat congestion and edema. This establishes the importance of the rest phase.

One study used 40 Friesian cows and compared 3 different pulsation ratios in the context of increased or reduced risk of new mastitis cases (Reitsma et al., 1981). These researchers accomplished this by dipping teats in a bacterial suspension before and after milking when subjected to the 3 different pulsation ratios. The results of this trial demonstrated that having a rest phase of at least 30% of the pulsation cycle was necessary to reduce risk of new IMI (Reitsma et al., 1981). This topic was revisited with a more recent study confirming this

recommendation which compared 7 different D-phase durations on 10 cows (Upton et al., 2016). The findings confirmed the earlier recommendation of a minimum 30% rest phase duration and found no benefit of increasing or altering D-phase durations (Upton et al., 2016).

### **2.3. Bacteria Counts in Milk**

Bacteria counts are measured in milk to determine quality and price for each tank load picked up at a particular farm. Milk cooperatives in the US offer monetary incentives for raw milk with extremely low bacteria counts and may reject milk that exceeds bacterial count limits. Several different measurements are used such as: standard plate count (SPC); lab pasteurization count (LPC); preliminary incubation (PI); and coliform count (CC). Standard plate count estimates the total number of aerobic type organisms in raw or pasteurized milk. Lab pasteurization count is used for measuring thermophilic bacteria after pasteurization.

Thermophilic bacteria are resistant to pasteurization; however, do not normally cause spoilage of milk. Conversely, PI count is used for psychrotrophic bacteria, which do cause spoilage of milk, and are generally not accounted for in the SPC. Psychrotrophic bacteria can grow at colder temperatures and cause spoilage in refrigerated milk products (Dragon et al., 1991). Ideally, SPC should be <5,000 cfu/mL, PI <10,000 cfu/mL, LPC <100 cfu/mL and CC <50 cfu/mL, however each milk processor requirement will differ from these values (Engel, 2011). The PMO has set bacteria count limits of <100,000 cfu/mL for Grade A raw bulk tank milk.

Standard plate count could have a number of contributors such as: poor milking time hygiene; improper cleaning of milking equipment; inadequate cooling of milk in the bulk tank; failure to replace milk filters; or a large number of mastitic cows (Engel, 2011). A study found that increased SCC in bulk tank milk was associated with greater SPC and CC (Pantoja et al., 2009). High PI and LPC counts occur due to: dirty milking equipment; aging rubber

components; improper drainage of water in the pipeline after washing; and presence of biofilms. Lastly, CC are an indication of fecal contamination in the milk. High CC can be impacted by poor udder hygiene, and milking unit fall-offs, which can result in the milking unit sucking up manure from the milking deck (Engel, 2011).

Other indirect factors have been found to be associated with increased bacteria counts in milk such as season and herd size. One study that evaluated dairy farms in Wisconsin found that bacteria counts were greater depending on the season (Pantoja et al., 2009). However, seasonal effects varied from farm to farm, some farms had increased LPC and CC in the winter, while other farms experienced increased LPC and CC in the summer months (Pantoja et al., 2009). A study that evaluated 99 dairy farms in New York found herd size to be associated with the concentration of spore-forming bacteria in pasteurized bulk tank milk (Masiello et al., 2014). Herds with < 200 cows were found to be 3.6 x more likely to have high levels ( $\geq 3 \log \text{ cfu/mL}$ ) of spore-forming bacteria than herds with  $\geq 200$  cows (Masiello et al., 2014). Udder cleanliness of cows was also found to be associated with spore-forming bacteria counts in pasteurized milk. Herds with  $\geq 25\%$  of cows with dirty udders were 3 x more likely to have high bacteria counts (Masiello et al., 2014). Other management factors have been associated with bacteria counts such as bedding type, fore-stripping in the pre-milking routine, and post-milking teat disinfectant application method (Miller et al., 2015). Although these factors have been found to contribute to bacteria counts in milk, still one of the most influential practices is the daily washing of the milk pipeline.

### ***2.3.1. Clean-in-Place Systems***

The milk pipeline should be washed promptly after each milking to remove residual milk fat and protein, bacteria, and mineral deposits. This is important to maintain milking equipment

and produce high quality milk with low bacteria counts. The entire washing process includes a pre-rinse, a detergent cycle, an acid cycle, and a sanitize cycle. The pre-rinse consists of warm water, about 38-43°C, to remove milk solids from the pipeline immediately after milking is complete (Dragon et al., 1991). If the water is too hot the rinse cycle can destabilize proteins and cause a protein film. If the water is too cold the rinse cycle will fail to remove milk fat and result in a greasy film. A study by Fan et al. (2015) examined different temperatures of the rinse cycle. It was observed that rinse water at 45°C removed residual milk films more effectively than rinse water at 22°C. However, no benefit was seen when the temperature of the rinse water was increased from 45°C to 67°C (Fan et al., 2015). After the rinse cycle is complete, it is important that the water and residual milk is thoroughly drained from the system and not used for recirculation for the detergent cycle (Dragon et al., 1991). Failure to completely drain contents after washing results in increased LPC (Engel, 2011).

The detergent wash cycle follows the rinse cycle. This should include a chlorinated alkaline cleaner that circulates for 8-10 min. This cycle needs hot water, at least 70°C, at the beginning of the cycle and should be maintained to at least 50°C, with a minimum pH of 10, at the end of the cycle to effectively remove milk fat and protein (Engel, 2011). The third cycle is an acid rinse that should circulate for 5 min at temperatures between 35 and 43°C, and at pH between 2.5 to 4.0 (Engel, 2011). The acid rinse functions to remove chlorine and minerals residues, and to inhibit bacterial growth between milkings. It has been shown that the acid cycle is the most successful at removing biofilm-embedded bacterial cells. These bacteria are resistant to the rinse and detergent cycles (Anand and Singh, 2013). The final pipeline washing step, the sanitize cycle, is often combined with the acid cycle, but sometimes it is run as a separate cycle

30 min prior to the next milking. The purpose of the sanitize cycle is to kill any remaining bacteria in the milk pipeline.

#### **2.4. Research Objective**

Somatic cell counts in the SE US have been historically, and continue to be, greater than the national average. As a result, dairies in this region are struggling to make substantial profits, and the number of farms continues to decline. Several management factors are associated with SCC and SPC. Finding the most influential management practices can help producers have better quality milk and to be more competitive and sustainable in the industry. The objective of this analysis was to identify management practices, specifically related to parlor equipment function and maintenance, and milking procedures, that have a significant influence on milk quality for SE US dairies.

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### Chapter 3 : **THE IMPACTS OF PARLOR EQUIPMENT FUNCTION AND MAINTENANCE ON BULK TANK SOMATIC CELL COUNT AND STANDARD PLATE COUNT**

#### **Abstract**

Milk quality has continued to improve over the last several decades in the US, but still remains to be a problem for dairy producers in the SE US. The purpose of this analysis was to evaluate associations between parlor equipment function and bulk tank somatic cell score (BTSCS) and bulk tank standard plate count (BTSPC) on SE US dairy farms. Data from dairies in Virginia (n = 96), Kentucky (n = 96), Tennessee (n = 84), and Mississippi (n = 7) were collected at a single visit for each farm. Monthly BTSCC and BTSPC data were retrieved from state regulatory offices, averaged over the 12 months prior to each farm visit, and used as the dependent variables in each analysis in a backwards elimination regression model. Due to incomplete data, 235 farms were analyzed in the final BTSCS model, and 214 farms were analyzed in the final BTSPC model. The final BTSCS model explained 27% of the variation in the dependent variable BTSCS and included: BTSPC; herd size; number of milking units; utilization of an internal teat sealant at dry-off; education level of the farm owner or manager; utilization of a freestall for lactating cow housing; amount of pasture access for lactating cows; and frequency of parlor maintenance as reported by the farm owner or manager. The final BTSPC model explained 29% of the variation in the dependent variable BTSPC and included: BTSCS; herd size; the likelihood of future dairy operation in 10 years as reported by the farm owner or manager; and beginning water temperature of the detergent wash cycle. Greater wash cycle water temperatures were associated with lower BTSPC. Increased herd size was associated with lower BTSCS, but higher BTSPC. Lactating cows that were exclusively on pasture had greater BTSCS compared to cows that had no pasture access. Farm owners that reported future

dairy operation was “not likely”, had greater BTSPC than farms that reported to “almost certainly” still be operating their dairy in 10 years. These models are suggesting that the most influential variables predicting milk quality on the evaluated SE US dairy farms are herd size, farmer education level, and lactating cow housing. However, beginning water temperature of the pipeline wash and utilization of a teat sealant at dry-off were also identified as factors significantly impacting milk quality. With the correction of these factors and other milk quality control measures, SE US dairy farms can improve overall milk quality.

### **3.1. Introduction**

Bulk tank SCC on SE US dairies has historically been, and continues to be, greater than the national average. In 2016, the national average BTSCC was 204,000 cells/mL, whereas the average BTSCC for Kentucky, Tennessee and Virginia were 221,000, 328,000 and 251,000 cells/mL, respectively (Norman et al., 2017). Additionally, SE US dairies continue to struggle with sustainability as the number of farms declines considerably each year. A 64% decrease in the number of dairy farms in the SE US was seen from 1995 to 2010 (Norman and Walton, 2014).

The Southeast Quality Milk Initiative (SQMI) is a collaborative project involving milk quality specialists from 6 land-grant universities in the SE US. The project involves a 5-yr. plan with several objectives to improve sustainability of SE US dairies through research and extension efforts. The project objectives include: 1) a survey evaluating producer attitudes toward milk quality; 2) on-farm evaluation of management practices; and 3) outreach programs to educate dairy farmers through printed materials, video-based training, and annual meetings. The overall goals of SQMI are to find the most significant factors influencing milk quality on SE US dairies in order to improve sustainability.

Milk quality is an all-encompassing term that can be measured quantitatively by SCC and SPC in raw bulk tank milk. Reduced cheese yields result when raw milk has SCC > 100,000 cells/mL and product defects can result when SCC > 400,000 cells/mL (Murphy et al., 2016). Milk cooperatives in the US offer monetary incentives based on SCC and bacteria counts of bulk tank milk in an effort to obtain a high quality product with a longer shelf life. Milk quality is negatively impacted during an intramammary infection (IMI) due to an increase in bacteria and SCC. Mastitis is known to be the costliest disease on dairy operations due to losses in discarded milk and a decrease in milk production (Hogan et al., 2016).

Several management factors in the milking parlor contribute to mastitis control and ultimately BTSCC and BTSPC. Proper settings and functionality of milking equipment is essential for successful milk removal without compromising udder health. Factors that have been shown to be crucial for a successful milking process include: pulsation (Capuco et al., 1994; Mein, 2012; Reitsma et al., 1981); vacuum levels (Reinemann, 2005; Besier and Bruckmaier, 2016); and machine-on time (Hillerton et al., 2002; Stewart and Schultz, 1958). If not properly managed, these factors can cause damage to teat ends and increase mastitis risk.

Bacteria counts in bulk tank milk are an important factor influencing milk quality. The PMO has set bacteria count limits of <100,000 cfu/mL for Grade A raw bulk tank milk. An important control measure for BTSPC is the use of an effective clean-in-place system after milking is completed. This process helps control bacteria counts in milk, but also provides clean and sanitized milking equipment for cows, which decreases exposure to bacterial pathogens, and reduces mastitis risk. Bacteria counts in milk can also be influenced by udder hygiene, pre-milking teat disinfection, and fecal contamination during unit fall-offs (Engel, 2011).

The objective of this study was to identify what factors in the milking parlor contribute most to BTSCC and BTSPC on dairies in the SE US so that control points may be identified to improve milk quality and sustainability of dairies in this region.

## **3.2. Materials and Methods**

### ***3.2.1. Herd Selection***

Monthly BTSCC data for the year of 2013 was retrieved from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 2013 year to identify herds for study inclusion. Study inclusion was also dependent upon a farm's willingness to allow SQMI team members to conduct an on-farm evaluation and to participate in an on-farm survey. Herds were initially identified for study inclusion based on the 2013 rolling herd average BTSCC, and separated into 3 categories based on BTSCC. The SQMI team aimed to include an equal distribution of farms representing low (< 220,000 cells/mL), moderate (220,000 to 340,000 cells/mL) and high (> 340,000 cells/mL) BTSCC in the study. Data were collected from July, 2014, through June, 2015, from 283 dairy herds which was comprised of 96 dairies in Virginia, 96 in Kentucky, 84 in Tennessee, and 7 in Mississippi. All farms were visited only once and all data discussed below, except for the latter described BTSCC, were collected from each farm on the day of the on-farm evaluation. Equal proportions of farms were visited and evaluated in the spring, summer, fall and winter. Additionally, an effort was made to include farms throughout the different geographical regions in each state. Farms that were equipped with an automatic milking system were excluded from this study.

### ***3.2.2. Questionnaire and Data Collection***

A 175-question survey, which was created by SQMI members, was proctored to the farm owner or manager during the scheduled farm evaluation, and can be viewed in **Appendix 1**. The

survey included questions pertaining to herd demographics, facilities, management practices, and parlor equipment maintenance. All questions referred to management practices that had been in effect over the previous 12 months prior to the farm evaluation. Questions from the survey that were used for these analyses include how often the milking system was inspected, how many times milking occurred per day, when parlor equipment was first installed or most recently updated, and farm demographic information such as herd size, farmer age, farmer education, and housing type for lactating cows.

### ***3.2.3. Parlor Evaluation***

SQMI members observed one milking for each visited farm. Parlor design, number of milking units, and number of milking personnel were recorded. A Digimet 3000 (L.J. Engineering Inc., Huntington Beach, CA) was used to evaluate pulsation function, claw vacuum, and air flow capacity of the vacuum system. Pulsation was tested on every milking unit prior to the beginning of milking. A single pulsation cycle generally takes 60 s which is split into 4 phases to open and close the teat liner. Appropriate pulsation settings were considered to be A phase  $\leq 20\%$ , B phase  $\geq 30\%$ , C phase  $\leq 20\%$ , and D phase  $\geq 15\%$  (Schuring, 2016). If pulsation settings of a single milking unit did not fall within these pre-determined criteria, it was recorded as a “fail”. Recorded pulsation phases of all milking units were later evaluated and each farm was assigned a percent of pulsators that failed ranging from 0 to 100%.

To measure claw vacuum during milking, the same Digimet 3000 device was attached to a single milking unit, and claw vacuum was recorded during the first 2 min of milking. Claw vacuum was recorded 3 to 8 times to account for variation among different cows, and values were subsequently averaged for each farm. Air flow capacity of the vacuum system was tested via a “drop test”. The drop test was used to determine if the milking machine has sufficient

reserve capacity during unit attachment or unit fall-off. One milking unit at a time is opened up to admit air into the teat cups while vacuum levels are recorded at the receiver. There should be enough reserve capacity to sustain all milking personnel attaching units plus one unit fall-off event. If vacuum level decreased more than 2.0 kPa during this procedure, the system had insufficient reserve capacity to cope with unit fall-off and failed the drop test (Reinemann et al., 2001).

A milking procedure application, created by SQMI team members, was used on a handheld computer tablet to record times for milking procedures. One SQMI member observed milking and entered procedures (strip, dip, wipe, unit attachment, and unit removal) into the tablet in real time. Order in which procedures occurred was also recorded along with uniformity of procedures. The application timed the procedures accordingly and calculated average and max values for preparation lag time, contact time of pre-milking teat disinfectant, machine-on time, and total milking time. Timing began as cows entered the parlor and ended when both sides were finished milking and all cows had exited the parlor. Timing of the milking procedures was repeated for 3 separate groups of cows, and subsequently averaged, to attain values that represented the typical parlor routine. Data were later compiled for each farm to calculate average machine-on time and max machine-on time for this analysis.

#### ***3.2.4. Teat End Scoring***

If cows were separated into groups, teat end scoring was done on high-producing cows, otherwise teat end scoring was done on a whole herd basis. Teat ends were scored after the milking unit was removed, but before post-milking teat disinfectant was applied. Teat end condition was assessed using a modified 5-pt. score system created from NMC guidelines and Neijenhuis et al., (2000), which can be viewed in **Appendix 2** (Minnesota, 2011). Teat end

scores ranged from 0 (no damage) to 4.5 (severe damage), depending on the amount of observed teat end damage. The whole number was assigned to represent the severity of callousing or skin thickening, which forms a ring, around the teat orifice. A half point was added to the whole score to indicate keratin protrusions or “cracking” of the teat orifice. Teat ends were scored on all functioning quarters of 80 cows or 20% of the herd, whichever was larger. If the herd consisted of less than 80 cows, teat ends of all functional quarters of all cows were scored on the entire herd. Teat end scores were later calculated and each farm was assigned: 1) average teat end score; 2) percentage of cows with cracked teat ends; 3) percentage of total cracked teat ends.

### ***3.2.5. Clean-in-Place System***

All but 4 farms had a clean-in-place system that was utilized to wash the milk pipeline after each completed milking time. With these 4 exceptions, the milk pipeline was washed once daily; however, each farm had multiple milking times per day. Beginning and end temperature of the detergent wash cycle was recorded using a digital thermometer. A pH measure was also recorded at the end of both the detergent wash cycle and the acid rinse cycle using commercially available pH testing strips (Thermo Fisher Scientific, Waltham, MA).

### ***3.2.6. Response and Predictor Variables for BTSCS Model***

Monthly BTSCC and BTSPC data were acquired from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 12 months prior to the farm evaluation for each farm. The 12-mo herd average BTSCC was converted into BTSCS using the formula  $\log_2(\text{BTSCC}/100,000) + 3$  and subsequently used as the response variable for the analyses. The BTSPC was log transformed using  $\log_{10}(\text{BTSPC})$  and included in the analyses as an independent variable to further explain the variation of BTSCS.

The independent variables of interest that were recorded and used for subsequent analysis included: 1) age of the parlor (yr); 2) number of milkings (/d); 3) presence of automatic take-offs (yes/no); 4) percent of pulsators not functioning properly; 5) producer reported frequency of pulsator inspection and cleaning (/yr); 6) producer reported frequency of vacuum regulator inspection and cleaning (/yr); 7) producer reported frequency of inspection and cleaning of rubber components in the parlor (/yr); 8) producer reported frequency of evaluation of the overall milking system (/yr); 9) average teat end score; 10) percent of cows with cracked teat ends; 11) percent of cracked teat ends; 12) average claw vacuum; 13) minimum claw vacuum (kPa); 14) max claw vacuum (kPa); 15) claw vacuum fluctuation (kPa); 16) average milking phase; 17) average rest phase; 18) average pulsations (/min); 19) vacuum reserve capacity via drop test (pass, fail); 20) average machine-on-time (min).

Farm demographic variables that were also included in the analyses included: 1) number of milking personnel; 2) season of the farm evaluation; 3) herd size; 4) number of milking units; 5) use of teat sealant for dry cows (yes/no/sometimes); 6) use of antibiotics at dry-off (yes/no/sometimes); 7) DHIA enrollment (yes/no); 8) use of an SOP for milking (yes/no); 9) age of farm owner or manager; 10) education level of farm owner or manager; 11) amount of pasture access available for lactating cows; 12) if lactating cows were housed in a freestall barn (yes/no); 13) if lactating cows were housed in a bedded pack barn (yes/no); 14) how likely the dairy would still be in operation 10 years in the future as reported by the farm owner or manager.

Some farms were excluded from analyses because of missing or inadequate data. Farms having less than 8 months of BTSCC data prior to farm evaluation date were excluded, leaving (n = 263) farms available for the analyses.

### ***3.2.7. Statistical Analyses for BTSCS Model***

All analyses were performed in SAS 9.4 using the REG procedure of SAS (SAS Institute Inc., Cary, NC). All explanatory variables were transformed into continuous variables so that the REG procedure could be utilized. Main effects were tested in a regression model to determine significant predictors of BTSCS. Non-significant variables were removed using stepwise backward elimination at  $P > 0.25$ . Remaining significant effects were then analyzed in a final regression model using a max R-squared approach in the REG procedure to determine a final best-fit model. Variables were considered to be significant in the final model at a level of  $P \leq 0.05$ .

### ***3.2.8. Response and Predictor Variables for BTSPC Model***

Monthly BTSCC and BTSPC data were acquired from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 12 months prior to the farm evaluation for each farm. The 12-mo herd average BTSPC was log transformed using  $\log_{10}(\text{BTSPC})$  and subsequently used as the response variable for the analyses. BTSCC was converted into BTSCS using the formula  $\log_2(\text{BTSCC}/100,000) + 3$  and included in the analyses as an independent variable to further explain the variation of BTSPC.

The independent variables of interest that were recorded and used for subsequent analysis included: 1) age of the parlor (yr); 2) frequency of pipeline wash (/d); 3) producer reported frequency of vacuum regulator inspection and cleaning (/yr); 4) producer reported frequency of inspection and cleaning of rubber components in the parlor (/yr); 5) producer reported frequency of evaluation of the overall milking system (/yr); 6) beginning water temperature of the detergent cycle ( $^{\circ}\text{C}$ ); 7) ending temperature of the detergent cycle ( $^{\circ}\text{C}$ ); 8) pH of the detergent cycle; and 9) pH of the acid cycle.

Farm demographic variables that were also included in the analyses included: 1) number of milking personnel; 2) season of the farm evaluation; 3) herd size; 4) number of milking units; 5) use of teat sealant for dry cows (yes/no/sometimes); 6) use of antibiotics at dry-off (yes/no/sometimes); 7) DHIA enrollment (yes/no); 8) use of an SOP for milking (yes/no); 9) age of farm owner or manager; 10) education level of farm owner or manager; 11) amount of pasture access available for lactating cows; 12) if lactating cows were housed in a freestall barn (yes/no); 13) if lactating cows were housed in a bedded pack barn (yes/no); 14) how likely the dairy would still be in operation 10 years in the future as reported by the farm owner or manager.

Some farms were excluded from analyses because of missing or inadequate data. Farms having less than 8 months of BTSCC data prior to farm evaluation date were excluded, leaving (n = 263) farms available for the analyses.

### ***3.2.9. Statistical Analysis for BTSPC Model***

All analyses were performed in SAS 9.4 using the REG procedure of SAS (SAS Institute Inc., Cary, NC). All explanatory variables were transformed into continuous variables so that the REG procedure could be utilized. Main effects were tested in a regression model to determine significant predictors of BTSPC. Non-significant variables were removed using stepwise backward elimination at  $P > 0.25$ . Remaining significant effects were then analyzed in a final regression model using a max R-squared approach in the REG procedure to determine a final best-fit model. Variables were considered to be significant in the final model at a level of  $P \leq 0.05$ .

## **3.3. Results**

### ***3.3.1. Farm Demographics***

Total number of farms evaluated in the SE US was (n = 283). Number of farms with at least 8 months of BTSCC and BTSPC data available for analyses was (n = 263). Average herd size of all visited farms was  $227 \pm 20$ , and ranged from 32 to 2,500. A variety of dairy cattle breeds were represented; with farms consisting of only Holstein cattle (n = 97); only Jersey cattle (n = 13); Holstein and Jersey (n = 21); or a mixture of the aforementioned breeds as well as Guernsey, Ayrshire, and Brown Swiss (n = 152). Distribution of breeds can be seen in **Table 3.1**. The majority of farms milked cows twice daily (79%), and some milked cows thrice daily (19%). There were 2% of farms with a milking frequency that differed from twice or thrice daily. Farms reported to house lactating cows in a free-stall (70%), compost bedded pack (16%), bedded pack (11%), or tie-stall (4%), which can be viewed in **Table 3.2**. Farms also reported to keep lactating cows in total confinement (35%), partial confinement with > 4 h access to dry lot or pasture (45%), partial confinement with < 4 h access to dry lot or pasture (9%), or exclusively on pasture (13%), which can be viewed in **Table 3.3**.

The majority of farms, 89%, reported to receive a monetary incentive from the milk cooperative if a certain BTSCC or BTSPC level was achieved. Most farms were enrolled in the Dairy Herd Improvement Association (DHIA), but 38% were not enrolled, which varied by state. Farms reported that cows were primarily milked by: 1) hired employees/ non-family (51%); 2) the owner or manager (33%); 3) family members (16%). When farm owners were asked about the probability of their dairy farm being in operation 10 years in the future, 45% answered “almost certainly”, 26% answered “very likely”, 17% answered “somewhat likely”, and 12% answered “not likely at all”. A frequency table with these results can be seen in **Table 3.4**.

### ***3.3.2. Distribution of Parlor Equipment Functionality***

National Mastitis Council recommends claw vacuum levels to be between 32 to 42 kPa or 9.5 to 12.5” hg. Some farms, 22% (n = 62), had claw vacuum levels greater than NMC recommendations and 9% of farms (n = 26) had vacuum levels that were too low. Most farms, 69% (n = 194) were within NMC recommendations. System vacuum had to drop > 2.0 kPa during the drop test in order for a farm to have insufficient reserve capacity. The majority of farms, 60% (n = 155), failed the drop test, and only 40% (n = 101) had sufficient vacuum reserve capacity.

Recommendations from NMC advise that the starting water temperature of the detergent wash cycle be above 65°C in order to properly clean the milk pipeline. Most farms, 67% (n = 168), achieved this goal, but 33% of farms did not have sufficient water temperature at the start of the detergent wash cycle. It is also recommended from NMC that the end temperature of the detergent wash cycle be above 48°C. Some farms achieved this goal, but 43% of farms failed to have water temperatures > 48°C at the end of the detergent wash cycle.

### ***3.3.3. Bulk Tank Somatic Cell Score Model***

The 12-mo mean BTSCS recorded during the 12-mo immediately prior to each farm’s evaluation was  $4.35 \pm 0.03$  and ranged from 2.79 to 5.83. A total of 235 farms had complete records and were included in the final model. Mean values of the parlor equipment variables tested in the analyses can be viewed in **Table 3.6**. The final BTSCS model yielded an  $R^2 = 0.27$  and included the fixed effects of: 1) BTSPC; 2) herd size; 3) number of milking units in the parlor; 4) utilization of an internal teat sealant at dry-off; 5) education level of the farm owner or manager; 6) utilization of a freestall for lactating cow housing; 7) number of hours per day lactating cows were allowed on pasture; 8) Frequency of parlor maintenance per year as reported

by the farm owner or manager. Parameter estimates and *P*- values of the effects included in the final model are depicted in **Table 3.7**.

Overall, mean BTSPC for all visited farms was  $3.93 \pm 0.4$  and ranged from 3.00 to 5.99. Bulk tank standard plate count significantly influenced the dependent variable, 12-mo BTSCS, according to the final model ( $P < 0.001$ ) and a positive relationship was identified between these 2 factors, depicted in **Figure 3.1**. The mean herd size for all farms was  $227 \pm 20$  and ranged from 32 to 2500 (**Table 3.5**). Herd size was included in the final BTSCS model ( $P < 0.001$ ) and had a negative relationship with BTSCS, which is illustrated in **Figure 3.2**. The mean number of milking units in the parlor was  $14 \pm 0.55$  and ranged from 2 to 72. Number of milking units significantly influenced BTSCS ( $P < 0.001$ ) and had a positive relationship with BTSCS; this relationship is illustrated in **Figure 3.3**.

Utilization of an internal teat sealant at dry-off was reported by the farm owner or manager. Distribution of farms that utilized an internal teat sealant at dry-off were as follows: 1) used on 100% of cows: (n = 120) 45%; 2) used on < 100% of cows: (n = 9) 3%; 3) used on 0% of cows: (n = 127) 52% (**Table 3.5**). Utilization of a teat sealant significantly influenced BTSCS ( $P < 0.01$ ) and is illustrated in **Figure 3.4**. Farms that administered an internal teat sealant at dry-off had lower BTSCS than farms that did not utilize an internal teat sealant at dry-off.

Distribution of education level of the farm owner or manager were as follows: 1) less than a high school degree (n = 47) 18%; 2) high school degree (n = 72) 27%; 3) some college or technical training (n = 42) 16%; 4) college degree (n = 104) 39% (**Table 3.5**). Education level of the farm owner or manager significantly influenced BTSCS ( $P < 0.05$ ) and is illustrated in **Figure 3.5**. The largest proportion of farmer owners/managers reported to have a college degree (n = 104) 39%. The least squares mean BTSCS for each category were as follows: 1) less than

high school degree (4.31); 2) high school degree (4.35); 3) some college or technical education (4.61); 4) college degree (4.46). Farmers that reported to have a high school degree had the lowest mean BTSCS, and farmers that reported to have some college or technical training had the greatest mean BTSCS.

Whether a farm had a freestall ( $n = 193$ ) for lactating cow housing significantly influenced BTSCS ( $P < 0.05$ ) and is illustrated in **Figure 3.6**. Farms that had a freestall for lactating cows had lower BTSCS than farms that did not have a freestall. Farms that were not equipped with a freestall for lactating cows, instead had a tie-stall ( $n = 11$ ), bedded pack ( $n = 73$ ), or cows were exclusively on pasture ( $n = 38$ ) (**Table 3.2**) (**Table 3.3**). Number of hours pasture access was available for lactating cows on farms were as follows: 1) 0 hours ( $n = 100$ ) 35%; 2) < 4 hours /d ( $n = 25$ ) 9%; 3) > 4 hours /d ( $n = 121$ ) 43% 4) 24 hours /d ( $n = 38$ ) 13% (**Table 3.3**). Amount of time lactating cows had pasture access per day significantly influenced BTSCS ( $P < 0.01$ ) and is illustrated in **Figure 3.7**. Farms that kept lactating cows in total confinement, with no pasture access, had the lowest BTSCS. Farms that had cows exclusively on pasture had the greatest BTSCS.

#### **3.3.4. Bulk Tank Standard Plate Count Model**

The 12-mo average  $\log_{10}$ BTSPC was  $3.93 \pm 0.03$  across all farms and ranged from 3.00 to 5.99. A total of 214 farms had complete data and were included in the final model with an  $R^2 = 0.29$ . The final BTSPC model included the fixed effects of: 1) BTSCS; 2) herd size; 3) probability of the future operation of the dairy in 10 years as reported by the farm owner or manager; 4) beginning water temperature of the detergent wash cycle. Parameter estimates and  $P$ - values of the effects included in the final model are provided in **Table 3.8**.

The 12-mo mean BTSCS recorded during the 12-mo immediately prior to each farm's evaluation was  $4.35 \pm 0.03$ . Bulk tank somatic cell count significantly influenced BTSPC ( $P < 0.001$ ) and is illustrated in **Figure 3.1**. A positive relationship existed between BTSCS and BTSPC, as one increases, the other increases as well. The mean herd size for all farms was  $227 \pm 20$  and ranged from 32 to 2500 (**Table 3.5**). Herd size was included in the final BTSPC model ( $P < 0.001$ ) and had a positive relationship with BTSCS, which is illustrated in **Figure 3.8**.

When farm owners were asked about the probability of their dairy farm being in operation 10 years in the future, 45% answered "almost certainly", 26% answered "very likely", 17% answered "somewhat likely", and 12% answered "not likely at all" (**Table 3.4**). Farmer perception of probability of future operation of the dairy farm significantly influenced BTSPC ( $P < 0.001$ ) and is illustrated in **Figure 3.9**. Farmers that reported to "almost certainly" be operating their dairy in 10 years had the lowest BTSPC, and farmers that reported to most likely not be operating the dairy farm in 10 years had the greatest BTSPC.

The mean overall beginning water temperature of the detergent wash cycle was  $67.8^\circ\text{C} \pm 0.65^\circ\text{C}$  and ranged from  $19.89^\circ\text{C}$  to  $92.61^\circ\text{C}$ . The effect of beginning water temperature significantly influenced the dependent variable, 12-mo  $\log_{10}$ BTSPC ( $P < 0.001$ ), and is illustrated in **Figure 3.11**. A negative relationship existed between BTSPC and beginning water temperature, as temperature increased, BTSPC decreased.

### **3.4. Discussion**

These analyses were part of a large multi-state project with an overall goal to assess producer perceptions, management practices, and farm demographics of SE US dairies, and to determine how these factors influence milk quality. The purpose of these specific analyses was to determine the impacts of parlor equipment function and maintenance on BTSCC and BTSPC.

This study was designed as a cross-sectional study which allowed for data to be collected from a larger number of farms, but conversely, disadvantages exist when data collection is limited to one day per farm, and may not be a complete representation of data for each farm. Given this study design, a 12-mo average of BTSCC and BTSPC were chosen as dependent variables for the respective models to control for seasonal variation and with the goal of producing a more accurate model.

#### ***3.4.1. Bulk Tank Somatic Cell Score Model***

The results of the model suggest that the most significant factors influencing milk quality of the evaluated SE US farms were farm demographics including herd size, farmer education level, and lactating cow housing. Larger herd size was shown to be associated with lower BTSCS. Milking unit function and maintenance was not found to significantly influence milk quality on the evaluated SE US dairies. The National Mastitis Council has stated that the majority of new IMI are caused by factors other than the milking machine; however, it is still essential that milking equipment be functioning correctly to successfully milk the cow without compromising udder health. (Hogan et al., 2016).

Utilization of an internal teat sealant was associated with lower BTSCS. However, utilization of an intramammary antibiotic at dry-off was not observed to significantly influence milk quality in the current study. This agrees with research regarding dry cow treatment for low-SCC cows. Internal teat sealant has been shown to be an effective control measure alone (without antibiotic) for reducing IMI during the dry period for low-SCC cows (Huxley et al., 2002; Bradley et al., 2010). Additionally, dry-cow antibiotic alone has been shown to have limitations of preventing new IMI without the combination of a teat sealant (Huxley et al., 2002; Bradley et al., 2010). These studies have shown that selective dry cow therapy can be successfully utilized,

depending on the mastitis pathogens prevalent on a particular farm and when proper management practices are used. Farms from the current study that reported to be using teat sealant selectively had numerically lower BTSCS than farms that did not utilize a teat sealant, but it was not significantly different. Although selective dry-cow therapy can be used to reduce antibiotic use and reduce treatment costs, certain pathogens will persist through the dry period if not treated with an antibiotic. Therefore, farmers need to use caution when choosing to utilize a selective dry-cow therapy protocol, and be responsive to the prevalent mastitis pathogens on their particular farm.

Farmer education level significantly influenced BTSCS. Producers with the least amount of education had the lowest BTSCS and farmers with some college or technical education had the highest BTSCS. Some of the geographical areas where study herds were evaluated consisted of a large Amish or Mennonite population, which may explain the proportion of producers with less than a high school degree. However, it is unclear exactly why we observed this effect in education level, but it is an indication that social factors of the dairy farm may be influencing milk quality more than factors specifically related to the cow.

Pasture access was shown to significantly influence BTSCS. Cows that were exclusively on pasture had the greatest BTSCS, while cows with no pasture access had the lowest BTSCS. Although most research on grazing systems have been done outside of the U.S., grazing systems can provide a low-risk environment for mastitis pathogen exposure if certain conditions are met. Heat, humidity, and rain, common weather conditions for the SE US, are not ideal for mastitis management as this will encourage bacterial growth (Hogan and Smith, 2012). Additionally, bacterial load will be more concentrated in pasture areas that are overstocked and overgrazed, as this does not allow for regrowth to occur. Feeding and watering areas can also be concentrated

with environmental pathogens for this reason. Ultimately, providing clean and dry bedding, with minimal organic matter, is a highly influential factor for environmental mastitis risk whether in confinement housing or on pasture (Hogan and Smith, 2012). Our data suggests that due to the climate in the SE US, housing lactating cows exclusively on pasture may not be the best management practice for milk quality.

Parlor maintenance frequency was included in the final best fit model, but did not significantly influence BTSCS. Parlor maintenance frequency was reported by the farm owner or manager and may have been an inaccurate representation of how often parlor maintenance actually occurred. Our data suggests study herds had a more reactive than preventative approach to performing parlor maintenance, and 16% of producers reported performing parlor maintenance “as needed”, which implied that maintenance only occurred when a problem arose. Additionally, parlor maintenance was often reported to be done by the farm owner or manager rather than a trained technician. It is suspected that this is partially contributing to the decreasing number of dairies in the SE US due to limited availability of technical support in the region.

Although the final model explained 27% of the variation of BTSCS, it must be recognized that other management practices contribute to udder health. Examples of such variables include, but are not limited to: cow cleanliness (Pankey, 1989; Schreiner and Ruegg, 2003; Sant'anna and Paranhos da Costa, 2011); teat disinfectants (Pankey et al., 1987; Williamson and Lacy-Hulbert, 2013; Enger et al., 2016); bedding materials (Hogan et al., 1989; van Gastelen et al., 2011); lameness (Heuer et al., 1999; van Gastelen et al., 2011); and nutrition (Smith et al., 1997; Heinrichs et al., 2009). Regardless of these other factors, it was the intention of this analysis to focus on what aspects of parlor equipment function and maintenance most contributed to BTSCC.

### ***3.4.2. Bulk Tank Standard Plate Count Model***

Similar to the BTSCS model, the variables in the final BTSPC model explained 29% of what determines BTSPC. This value was lower than expected since effectiveness of the pipeline wash is always the first thing evaluated when spikes in BTSPC occur. Regardless, pipeline wash is an important control measure for BTSPC as shown in this analysis and other studies (Walker et al., 2003; Anand and Singh, 2013; Fan et al., 2015).

It was evident in the model that BTSCS and BTSPC are related as BTSCS significantly influenced BTSPC this analysis. Presence of an IMI has been known to increase BTSCS and BTSPC (Hogan et al., 2016; Philpot and Nickerson, 2000). Pre-milking preparation, including proper teat disinfection has been shown to contribute to BTSPC (Galton et al., 1982). However, this analysis was focused on milking equipment and did not include pre-milking teat preparation.

Herd size was found to significantly influence BTSPC in the current study, as well as another study by Cicconi-Hogan, et al. (2013). Additionally, a study that evaluated 99 dairy farms in New York found herd size to be associated with the concentration of spore-forming bacteria in pasteurized bulk tank milk (Masiello et al., 2014). Herds with < 200 cows were found to be 3.6 x more likely to have high levels ( $\geq 3$  log cfu/mL) of spore-forming bacteria than herds with  $\geq 200$  cows (Masiello et al., 2014). This finding was opposite of the effect found in the current study, which was that increasing herd size led to greater BTSPC. Udder cleanliness of cows was also found to be associated with spore-forming bacteria counts in pasteurized milk. Herds with  $\geq 25\%$  of cows with dirty udders were 3 x more likely to have high bacteria counts (Masiello et al., 2014). Although udder hygiene score was not significant on the evaluated SE US dairies, it is known that poor pre-milking preparation can lead to increased BTSPC (Galton et al., 1982). Other management factors have been associated with bacteria counts such as bedding

type, fore-stripping in the pre-milking routine, and post-milking teat disinfectant application method (Miller et al., 2015). Although these factors have been found to contribute to bacteria counts in milk, still one of the most influential practices is the daily washing of the milk pipeline.

Beginning temperature of the detergent wash cycle was observed to have a negative relationship with BTSPC in this analysis. Other studies have come to the same conclusion (Elmoslemany et al., 2009; Dev et al., 2014). Water temperature of the detergent wash cycle is discussed as being especially important to react with detergents to effectively remove milk fat, proteins, and bacteria (Dragon et al., 1991; Reinemann et al., 2001; Schuring, 2016).

Dairy producers were asked how confident they were that they would be operating their dairy 10 years in the future. How dairy producers perceived their future involvement in the dairy industry significantly influenced BTSPC. Farmers that reported that future operation was “not likely” had the greatest BTSPC, whereas farmers that reported to “almost certainly” be in operation in 10 years had the lowest BTSPC. A recent study observed that producer attitudes, perceptions, and goals are associated with BTSCC (Schewe et al., 2015). These findings suggest that farmer perceptions and attitudes may influence milk quality more than previously thought. Dairy researchers tend to focus on biology of the cow, since social factors are more difficult to control, measure, or change. Further research is needed to investigate social factors that could be influencing milk quality.

Other factors can influence bacteria counts in milk such as cow hygiene measured by hair removal and teat end cleanliness (Elmoslemany et al., 2009). Other factors found to influence BTSPC in one study, included body condition score, hock score, grazing system type, antibiotic use records, and use of a nutritionist (Cicconi-Hogan et al., 2013). Something that is often overlooked when considering BTSPC is water quality. Hardness and bacterial count in water

used for the pipeline wash has been shown to significantly contribute to BTSPC (Reinemann et al., 2001; Elmoslemany et al., 2009). One study evaluated water quality of dairies in Ontario, Canada, to find that wash water was often contaminated with *E. coli*, and resulted in elevated BTSPC (Perkins et al., 2009). It would have been beneficial to include evaluation of water quality on dairies in the SE US in the current study to see if a geographical pattern of contamination existed and influenced milk quality as was seen previously (Perkins et al., 2009). What can be concluded from these studies is that several factors are associated with milk quality, and it is difficult to measure all possible contributors. Additionally, many inconsistencies exist among factors found to influence milk quality (Dufour et al., 2011; Emanuelson and Nielsen, 2017) and this should be taken into consideration when developing standard operation procedures for milk quality on a dairy farm.

### **3.5. Conclusion**

Differences among milking equipment function were not identified in the models as significantly influencing milk quality on the evaluated SE US farms. However, it is still essential that milking equipment be functioning correctly to successfully milk the cow without compromising udder health. These models indicate that the most influential factors associated with milk quality are farm demographics such as herd size, lactating cow housing, and farmer education level. Utilization of an internal teat sealant at dry-off was associated with lower BTSCS. The results from the BTSPC model reaffirm the importance of the pipeline wash, particularly the significance of water temperature at the start of the detergent cycle in its ability to control BTSPC. Farms that had lactating cows exclusively on pasture had the highest BTSCS, and farms that did not have any pasture access for lactating cows had the lowest BTSCS. Farmer perception of future operation of their dairy significantly influenced BTSPC. These findings

suggest that farmer perceptions and attitudes may be influencing milk quality more than previously thought. Further research is needed to evaluate social factors that could be influencing milk quality.

**Table 3.1** Distribution of breeds among study herds evaluated in the southeast US.

<b>Breed</b>	<b>Number of farms</b>	<b>Percent</b>
Holstein	97	34%
Holstein and other	64	23%
Holstein, Jersey and other	33	12%
Holstein and Jersey	21	7%
Jersey	13	5%
Holstein, Brown Swiss, and other	10	4%
Holstein, Jersey, Brown Swiss, and other	8	3%
Holstein and Brown Swiss	5	2%
Jersey and other	5	2%
Other	28	10%

**Table 3.2** Frequency data of housing facilities for lactating cows in study herds evaluated in the southeast US.

<b>Housing facility</b>	<b>Number of farms</b>	<b>Percent</b>
Free-stall	193	70%
Tie-stall	11	4%
Bedded Pack	30	11%
Compost bedded pack	43	16%

**Table 3.3** Frequency data regarding the amount of pasture access for lactating cows in study herds evaluated in the southeast US.

<b>Amount of pasture access</b>	<b>Number of farms</b>	<b>Percent</b>
Total confinement	100	35%
Mostly confinement with < 4 h access to dry lot or pasture	25	9%
Partial confinement with > 4 h access to dry lot or pasture	121	43%
Exclusively pasture	38	13%

**Table 3.4** Frequency data of study herds in the southeast US regarding monetary incentives, DHIA enrollment, and future dairy farm operation.

<b>Variable</b>	<b>Answer</b>	<b>Number of farms</b>	<b>Percent</b>
Monetary incentive <sup>1</sup>	Yes	248	89%
	No	32	11%
DHIA enrolled <sup>2</sup>	Yes	199	72%
	No	76	28%
Dairy 10 years <sup>3</sup>	Almost certainly	123	45%
	Very likely	73	26%
	Somewhat likely	46	17%
	Not likely at all	32	12%
<sup>1</sup> Farms that are offered a monetary incentive from milk cooperative to achieve certain SCC and SPC goals <sup>2</sup> Farms that are enrolled in the Dairy Herd Improvement Association <sup>3</sup> How farm owners responded to the possibility of continued operation of their dairy farm 10 years in the future <sup>4</sup> Personnel primarily responsible for milking the majority of cows on the dairy			

**Table 3.5** Frequency data of study herds in the southeast US regarding herd size, season of farm evaluation, farmer education level, farmer age, utilization of an internal teat sealant, and utilization of intramammary antibiotics.

<b>Variable</b>	<b>Category</b>	<b>Number of farms</b>	<b>Percent</b>
Herd size	≥ 125	137	51%
	126 - 500	108	40%
	> 500	24	9%
Season	Summer	65	24%
	Fall	74	28%
	Winter	55	20%
	Spring	75	28%
Farmer education	Less than high school degree	47	18%
	High school degree	72	27%
	Some college or technical education	42	16%
	College degree	104	39%
Farmer age	26-35	14	5%
	36-45	58	22%
	46-55	49	19%
	56-65	83	32%
	66-75	45	17%
	> 76	14	5%
	Teal sealant for dry cows <sup>1</sup>	100% of cows	120
< 100% of cows		9	3%
0% of cows		137	52%
Antibiotic for dry cows <sup>2</sup>	100% of cows	217	82%
	< 100% of cows	28	11%
	0% of cows	19	7%

<sup>1</sup>Whether an internal teat sealant is administered to cows at dry-off  
<sup>2</sup>Whether an intramammary antibiotic is administered to cows at dry-off

**Table 3.6** Mean values of parlor variables tested as factors influencing bulk tank milk quality in study herds in the southeast US.

<b>Variable</b>	<b>N</b>	<b>Mean</b>	<b>Std Dev</b>	<b>Min</b>	<b>Max</b>
Parlor age (yrs)	273	14.54	11.51	0.0	48.0
Milking frequency (/d)	282	2.21	0.44	1.0	5.0
Automatic take-offs (y/n)	281	0.68	0.47	0.0	1.0
Pulsator failure (%)	271	0.17	0.28	0.0	1.0
Pulsator maintenance frequency (/yr)	265	2.35	4.26	0.0	36.0
Vacuum maintenance frequency (/yr)	267	5.93	8.48	0.0	36.0
Rubber components maintenance frequency (/yr)	260	12.90	14.54	0.0	36.0
Overall parlor maintenance frequency (/yr)	271	2.65	5.79	0.0	36.0
Average teat end score	281	1.72	0.38	0.45	3.08
Cows with cracked teat ends (%)	281	0.60	0.22	0.0	1.0
Cracked teat ends (%)	281	0.42	0.19	0.0	0.98
Average claw vacuum (kPa)	260	40.33	3.11	29.77	51.74
Minimum claw vacuum (kPa)	259	31.70	6.47	3.22	46.70
Maximum claw vacuum (kPa)	261	44.06	3.01	31.12	54.31
Claw vacuum fluctuation (kPa)	260	6.30	3.01	0.0	16.42
Milk phase (%)	270	62.50	4.19	50.60	81.0
Rest phase (%)	271	37.67	4.10	27.58	54.13
A phase	271	0.14	0.05	0.00	0.34
B phase	271	0.48	0.06	0.27	0.67
C phase	271	0.12	0.04	0.01	0.25
D phase	271	0.26	0.05	0.11	0.46
Pulsations (/min)	260	59.45	3.88	42.60	90.0
Drop test (p/f)	256	0.39	0.49	0.0	1.0
Average machine-on time	246	5.89	1.48	2.74	12.13
Maximum machine-on time	246	8.96	2.28	3.68	15.48
Beginning wash temperature (°C)	251	67.80	-7.61	19.89	92.61
End wash temperature (°C)	248	49.51	-9.77	17.11	71.78
Detergent wash pH	253	11.87	1.55	4.0	14.0
Acid wash pH	241	3.59	1.52	1.0	8.0

**Table 3.7** Final regression model<sup>1</sup> showing the association of significant variables ( $P < 0.05$ ) and bulk tank somatic cell count of study herds in the southeast US.

<b>Variable</b>	<b>Estimate</b>	<b>SE</b>	<b>P - value</b>
Intercept	2.729	0.272	< 0.001
Bulk tank standard plate count <sup>2</sup>	0.312	0.059	< 0.001
Herd size	< - 0.001	< 0.001	< 0.001
Number of milking units	0.025	0.007	< 0.001
Internal teat sealant <sup>3</sup>	- 0.210	0.068	0.002
Farmer education level	0.066	0.029	0.022
Freestall <sup>4</sup>	-0.197	0.077	0.012
Pasture access <sup>5</sup>	0.095	0.034	0.006
Parlor maintenance <sup>6</sup>	0.010	0.006	0.083

<sup>1</sup>The model included 235 observations  $R^2 = 0.27$ .

<sup>2</sup>Average bulk tank standard plate count from 12 months of test days prior to farm evaluation, log transformed using  $\log_{10}(\text{BTSPC})$

<sup>3</sup>Utilization of infusing an internal teat sealant at dry-off

<sup>4</sup>Utilization of a freestall barn for lactating cow housing

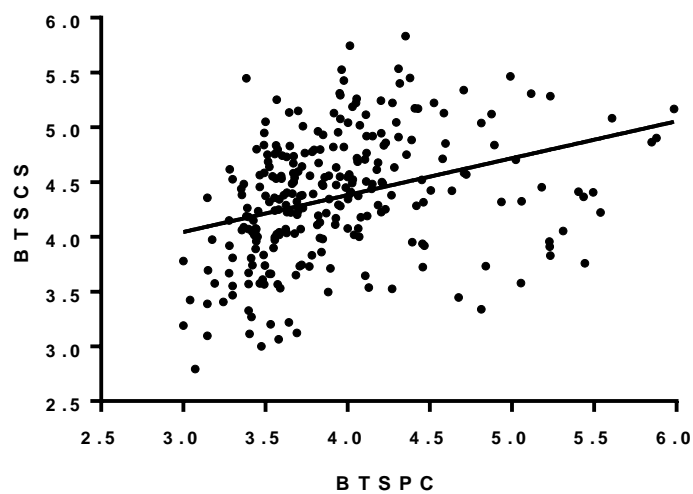
<sup>5</sup>Amount of pasture access included in lactating cow housing

<sup>6</sup>Frequency of parlor maintenance occurrence per year as reported by the farm owner or manager

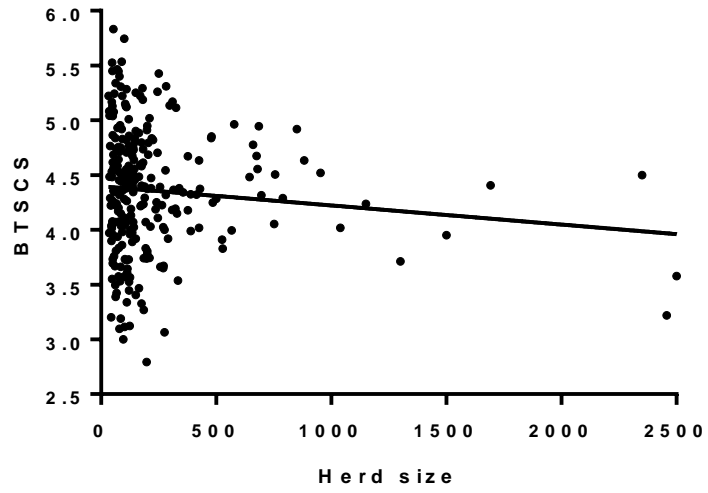
**Table 3.8** Final regression model<sup>1</sup> showing the association of significant variables and bulk tank standard plate count ( $\log_{10}$ BTSPC) of study herds in the southeast US.

<b>Variable</b>	<b>Estimate</b>	<b>SE</b>	<b>P - value</b>
Intercept	3.962	0.461	< 0.001
Bulk tank somatic cell count	0.310	0.063	< 0.001
Herd size	< 0.001	< 0.001	< 0.001
Dairy 10 years <sup>2</sup>	-0.124	0.036	< 0.001
Beginning temperature <sup>3</sup>	-0.007	0.002	< 0.001

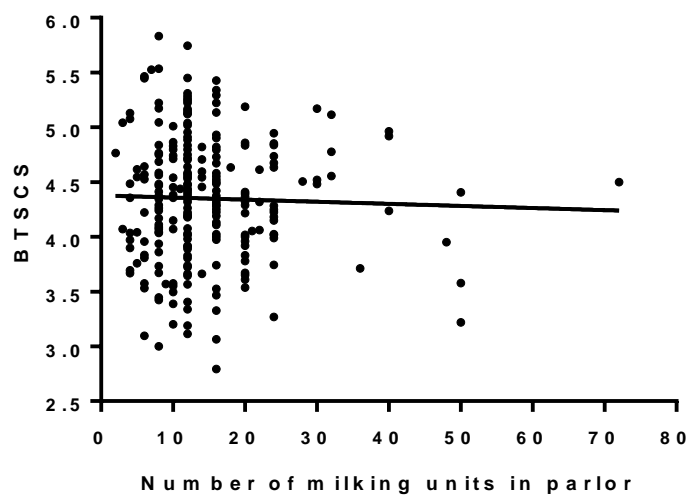
<sup>1</sup>The final model had 214 observations  $R^2 = 0.29$ .  
<sup>2</sup>Probability of the future operation of the dairy in 10 years as reported by the farm owner or manager  
<sup>3</sup>Water temperature at the start of the detergent cycle during the pipeline wash process



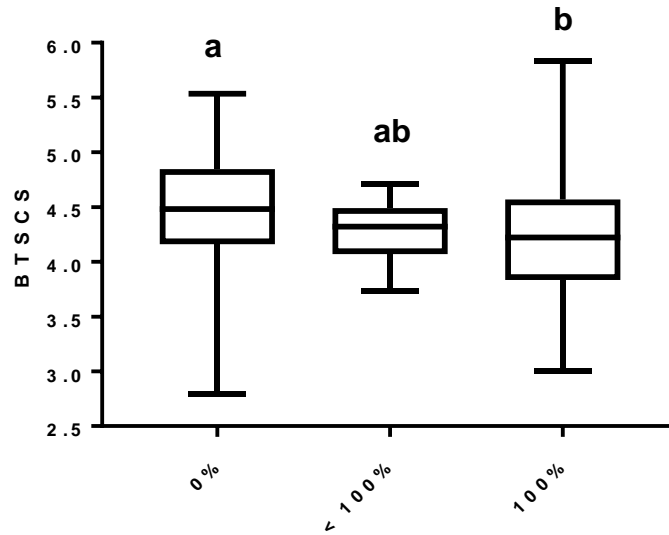
**Figure 3.1** The linear relationship of 12-mo average bulk tank somatic cell count and 12-mo average bulk tank standard plate count on dairy farms evaluated in the southeast US.



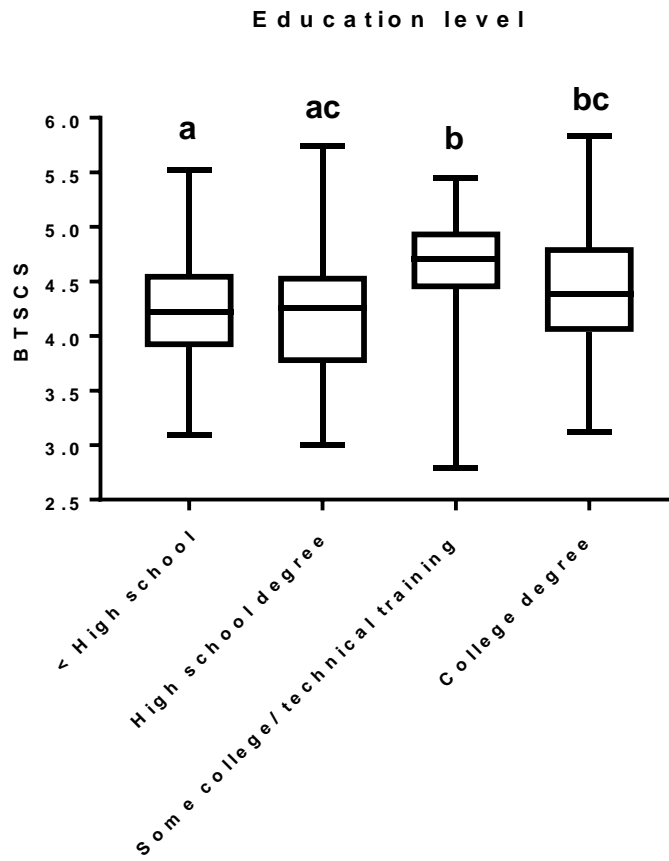
**Figure 3.2** The linear relationship of 12-mo average bulk tank somatic cell count and herd size of dairy farms evaluated in the southeast US.



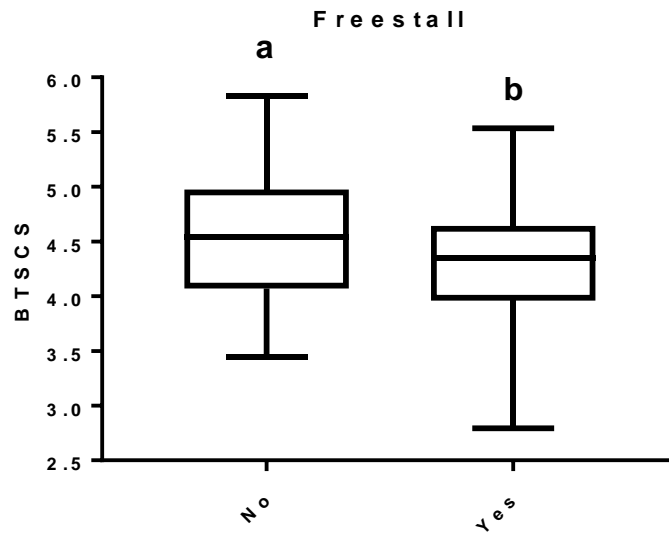
**Figure 3.3** The relationship of 12-mo average bulk tank somatic cell count and the number of milking units available to milk cows on dairy farms evaluated in the southeast US.



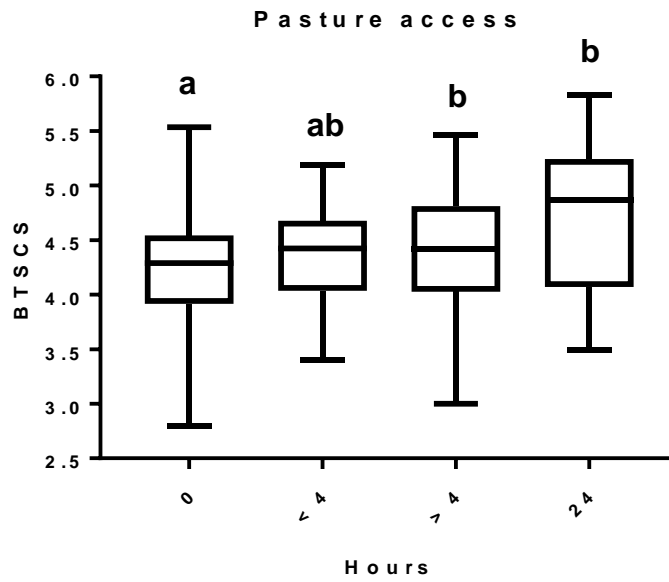
**Figure 3.4** The relationship of 12-mo average bulk tank somatic cell count and utilization of an internal teat sealant on cows at dry-off. Farms reported to administer internal teat sealant to no cows (0%) at dry-off, some cows (< 100%), or all cows (100%). Significant differences are denoted by the letters ( $P < 0.05$ ).



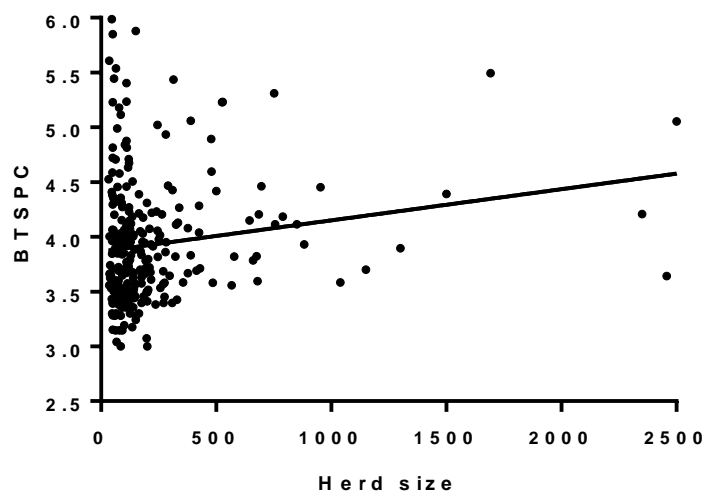
**Figure 3.5** The relationship of 12-mo average bulk tank somatic cell score and education level of the farm owner or manager. Significant differences are denoted by the letters ( $P < 0.05$ ).



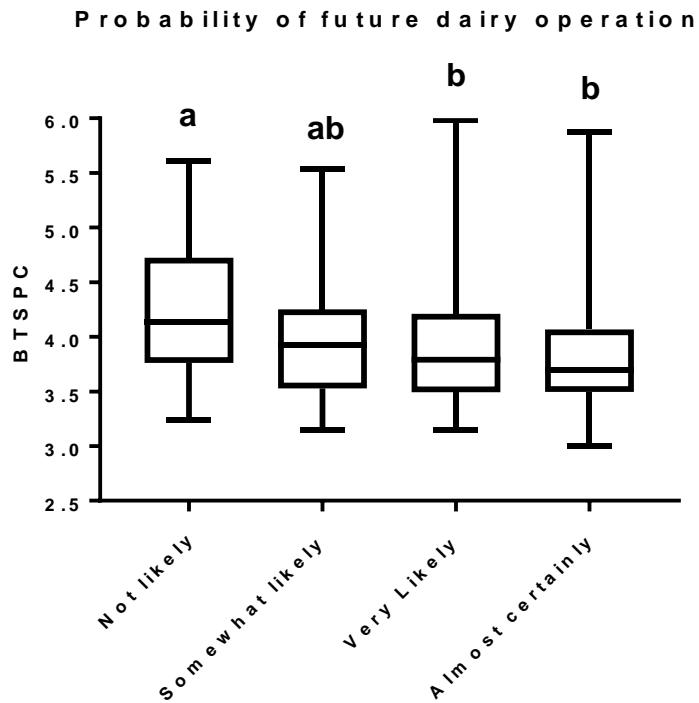
**Figure 3.6** The relationship of 12-mo average bulk tank somatic cell score and the utilization of a freestall barn for lactating cow housing ( $P < 0.05$ ).



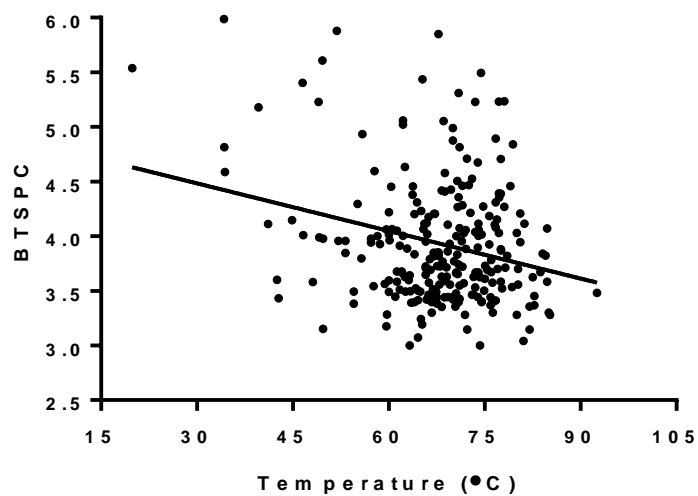
**Figure 3.7** The relationship of 12-mo average bulk tank somatic cell score and number of hours per day lactating cows have access to pasture. Significant differences are denoted by the letters ( $P < 0.05$ ).



**Figure 3.8** The linear relationship of 12-mo average bulk tank standard plate count and herd size of dairy farms evaluated in the southeast US.



**Figure 3.9** The relationship of 12-mo average bulk tank standard plate count and the probability of the future operation of the dairy in 10 years as reported by the farm owner or manager. Significant differences are denoted with letters ( $P < 0.05$ ).



**Figure 3.10** The linear relationship of 12-mo average bulk tank standard plate count and beginning water temperature of the detergent wash cycle on dairy farms evaluated in the southeast US.

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## Chapter 4 : **THE IMPACTS OF MILKING PROCEDURES ON BULK TANK SOMATIC CELL COUNT AND STANDARD PLATE COUNT**

### **Abstract**

Milk quality has continued to improve over the last several decades in the US, but still remains to be a problem for dairy producers in the SE US. The purpose of these analyses was to evaluate associations between milking procedures and bulk tank somatic cell score (BTSCS) and bulk tank standard plate count (BTSPC) on SE US dairy farms. Data from dairies in Virginia (n = 96), Kentucky (n = 96), Tennessee (n = 84), and Mississippi (n = 7) were collected at a single visit for each farm. Monthly BTSCC and BTSPC data were retrieved for (n = 263) farms from state regulatory offices, averaged over the 12 months prior to each farm visit, and used as the dependent variables in each analysis in a backwards elimination regression model. Due to incomplete data, 217 farms were analyzed in the BTSCC model, and 218 farms were analyzed in the BTSPC model. The final BTSCC model explained 30% of the variation in the dependent variable BTSCS and included: BTSPC; herd size; number of milking units; utilization of an internal teat sealant at dry-off; farmer education level; utilization of a bedded pack for lactating cow housing; amount of pasture access for lactating cows; utilization of paper towels for wiping teats; percent of teat ends that were cracked or had hyperkeratosis; average contact time of pre-milking teat disinfectant. The final BTSPC model explained 26% of the variation in the dependent variable BTSPC and included: BTSCS; udder hair removal; herd size; amount of access to pasture for lactating cows; probability of future dairy operation in 10 years as reported by the farm owner or manager; percent of teats that were cracked or had hyperkeratosis; average preparation lag time. It was evident in both the BTSCS and BTSPC models that utilization of an internal teat sealant at dry-off significantly influences milk quality for SE US dairies. The significance of preparation lag time in the BTSPC model indicates that timing of milking

procedures proves to be a challenge for SE US dairies. Lactating cows that were exclusively on pasture had greater BTSCS compared to cows that had no pasture access. Farm owners that reported future dairy operation was “not likely”, had greater BTSPC than farms that reported to “almost certainly” still be operating their dairy in 10 years. These models are suggesting that the most influential variables predicting milk quality on SE US dairy farms are herd size, farmer education level, and lactating cow housing. These findings suggest that farmer perceptions and attitudes may be influencing milk quality more than previously thought. Further research is needed to evaluate social factors that could be influencing milk quality. Milking procedures such as pre- and post-milking teat disinfection are widely accepted by most dairies in the US. Minimal differences were found between milking procedures such as teat disinfectant active ingredient or using paper towels versus cloth towels suggesting that these factors may not be the most influential factors influencing milk quality.

#### **4.1. Introduction**

Bulk tank SCC on SE US dairies has historically been, and continues to be, greater than the national average. In 2016, the national average BTSCC was 204,000 cells/mL, whereas the average BTSCC for Kentucky, Tennessee and Virginia were 221,000, 328,000 and 251,000 cells/mL, respectively (Norman et al., 2017). As a result, SE US dairies continue to struggle with sustainability as the number of farms declines considerably each year. A 64% decrease in the number of dairy farms in the SE US was seen from 1995 to 2010 (Norman and Walton, 2014).

The Southeast Quality Milk Initiative (SQMI) is a collaborative project involving milk quality specialists from 6 land-grant universities in the SE US. The project involves a 5-yr. plan with several objectives to improve sustainability of SE US dairies through research and extension efforts. The project objectives include: 1) a survey evaluating producer attitudes toward milk quality; 2) on-farm evaluation of management practices; 3) outreach programs to educate dairy farmers through printed materials, video-based training, and annual meetings. The overall goals of SQMI are to identify the most significant factors influencing milk quality on SE US dairies in order to improve sustainability.

Milk quality is an all-encompassing term that can be measured quantitatively by SCC and SPC in raw bulk tank milk. Reduced cheese yields result when raw milk has  $SCC > 100,000$  cells/mL and product defects can result when  $SCC > 400,000$  cells/mL (Murphy et al., 2016). Milk cooperatives in the US offer monetary incentives based on SCC and bacteria counts of bulk tank milk in an effort to obtain a better quality product with a longer shelf life. Milk quality is negatively impacted during an intramammary infection (IMI), due to the presence of pathogenic bacteria and an increase in SCC. Mastitis is known to be the costliest disease on dairy operations due to losses in discarded milk and a decrease in milk production (Hogan et al., 2016).

Several management factors in the milking parlor contribute to mastitis control and ultimately BTSCC and BTSPC. Proper timing and application of pre-milking procedures are essential for successful milk removal without compromising udder health. Factors that have been shown to be crucial for a successful milking process include teat stimulation, oxytocin release, and preparation lag time (Bruckmaier and Blum, 1998; Kaskous and Bruckmaier, 2011). Preparation of the teats before milking, particularly teat disinfection, is important for controlling mastitis risk as well as BTSPC.

Bacteria counts in bulk tank milk are an important factor influencing milk quality. The PMO has set bacteria count limits of <100,000 cfu/mL for Grade A raw bulk tank milk. Some important control measures for BTSPC include: 1) cleaning and drying of the udder and teats before unit attachment (Galton et al., 1982); 2) the use of an effective teat disinfectant (Pankey et al., 1987; Enger et al., 2016); and 3) sufficient teat disinfectant contact time (Galton et al., 1988; Enger et al., 2015).

The objective of this study was to identify which factors in the milking procedure contribute most to BTSCC and BTSPC on dairies in the SE US, so that control points may be identified to improve milk quality and sustainability of dairies in this region.

## **4.2. Materials and Methods**

### ***4.2.1. Herd Selection***

Monthly BTSCC data for the year of 2013 was retrieved from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 2013 year to identify herds for study inclusion. Study inclusion was also dependent upon a farm's willingness to allow SQMI team members to conduct an on-farm evaluation and to participate in an on-farm survey. Herds were initially identified for study inclusion based on the 2013 rolling herd average

BTSCC, and separated into 3 categories based on BTSCC. The SQMI team aimed to include an equal distribution of farms representing low (< 220,000 cells/mL), moderate (220,000 to 340,000 cells/mL) and high (> 340,000 cells/mL) BTSCC in the study. Data were collected from July, 2014, through June, 2015, from 283 dairy herds which was comprised of 96 dairies in Virginia, 96 in Kentucky, 84 in Tennessee, and 7 in Mississippi. All farms were visited only once and all data discussed below, except for the latter described BTSCC, were collected from each farm on the day of the on-farm evaluation. Equal proportions of farms were visited and evaluated in the spring, summer, fall and winter. Additionally, an effort was made to include farms throughout the different geographical regions in each state. Farms that were equipped with an automatic milking system were excluded from this study.

#### ***4.2.2. Questionnaire and Data Collection***

A 175-question survey, created by SQMI members, was proctored to the farm owner or manager during the scheduled farm evaluation, and can be viewed in **Appendix 1**. The survey included questions pertaining to herd demographics, facilities, management practices, and parlor equipment maintenance. All questions referred to management practices that had been in effect over the previous 12 months prior to the farm evaluation. Questions from the survey that were used for this analysis include what type of towels were used for pre-milking teat disinfection (paper or cloth), if towels were single or multiple use among cows, how teat disinfectants were applied (cup, spray or foam), and if the teat disinfectant was a commercial product or homemade. Farm demographic information was also evaluated from the survey such as herd size, farmer age, farmer education, and housing type for lactating cows.

#### ***4.2.3. Evaluation of Parlor Practices***

SQMI members observed one milking for each farm. Parlor design, number of milking units, and number of milking personnel was recorded. A milking procedure application, created by SQMI team members, was used on a handheld computer tablet to record times for milking procedures. One SQMI member observed milking and entered procedures (strip, dip, wipe, unit attach, and unit removal) into the tablet in real time. The order in which procedures occurred was also recorded along with uniformity of procedures. The application timed the procedures accordingly and calculated average and max values for preparation lag time, contact time of pre-milking teat disinfectant, machine-on time, and total milking time. Timing began as cows entered the parlor and ended when both sides were finished milking and all cows had exited the parlor. Timing of the milking procedures was repeated for 3 separate groups of cows, and subsequently averaged, to attain values that represented the typical parlor routine.

#### ***4.2.4. Teat End Scoring***

If cows were separated into groups, teat end scoring was done on high-producing cows, otherwise teat end scoring was done on a whole herd basis. Teat ends were scored after the milking unit was removed, but before post-milking teat disinfectant was applied. Teat end condition was assessed using a modified 5-pt. score system created from NMC guidelines and Neijenhuis et al., (2000) (Minnesota, 2011), which can be viewed in **Appendix 2**. Teat end scores ranged from 0 (no damage) to 4.5 (severe damage), depending on the amount of observed teat end damage. The whole number was assigned to represent the severity of callousing or skin thickening, which forms a ring, around the teat orifice. A half point was added to the whole score to indicate keratin protrusions or “cracking” of the teat orifice. Teat ends were scored on all functioning quarters of 80 cows or 20% of the herd, whichever was larger. If the herd consisted of less than 80 cows, teat ends of all functional quarters of all cows were scored on the entire

herd. Teat end scores were later calculated and each farm was assigned: 1) average teat end score; 2) percentage of total cracked teat ends.

#### ***4.2.5. Response and Predictor Variables for BTSCS Model***

Monthly BTSCC and BTSPC data were acquired from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 12 months prior to the farm evaluation for each farm. The 12-mo herd average BTSCC was converted into BTSCS using the formula  $\log_2(\text{BTSCC}/100,000) + 3$  and subsequently used as the response variable for the analyses. The BTSPC was log transformed using  $\log_{10}(\text{BTSPC})$  and included in the analyses as an independent variable to further explain the variation of BTSCS.

The independent variables of interest that were recorded and used for analysis included:

- 1) pre-milking teat disinfectant active ingredient; 2) post-milking teat disinfectant active ingredient; 3) utilization of a dry-wipe before applying pre-milking teat disinfectant (y/n); 4) utilization of a commercial pre-milking teat disinfectant foam (y/n); 5) utilization of a commercial pre-milking teat disinfectant spray (y/n); 6) utilization of a commercial pre-milking teat disinfectant cup (y/n); 7) utilization of a homemade pre-milking teat disinfectant spray or cup (y/n); 8) utilization of a single use cloth towel to wipe teats (y/n); 9) utilization of a multiple use cloth towel to wipe teats (y/n); 10) utilization of a paper towel to wipe teats (y/n); 11) utilization of a post-milking teat disinfectant spray (y/n); 12) utilization of a post-milking teat disinfectant cup (y/n); 13) utilization of pre-stripping a few streams of milk from each teat (y/n); 14) utilization of gloves during milking (y/n/sometimes); 15) order of pre-milking procedures; 16) utilization of udder hair removal (y/n); 17) average udder hygiene score; 18) average teat end score; 19) percent of cracked teat ends; 20) average pre-milking teat disinfectant contact time (s);

21) average preparation lag time (s). Variables that applied to < 5% of farms were combined with other groups or placed into an “other” category.

Farm demographic variables that were also included in the analyses included: 1) number of milking personnel; 2) season of the farm evaluation; 3) herd size; 4) number of milking units; 5) use of teat sealant for dry cows (yes/no/sometimes); 6) use of antibiotics at dry-off (yes/no/sometimes); 7) DHIA enrollment (yes/no); 8) use of an SOP for milking (yes/no); 9) age of farm owner or manager; 10) education level of farm owner or manager; 11) amount of pasture access available for lactating cows; 12) if lactating cows were housed in a freestall barn (yes/no); 13) if lactating cows were housed in a bedded pack barn (yes/no); 14) how likely the dairy would still be in operation 10 years in the future as reported by the farm owner or manager.

Some farms were excluded from analyses because of missing or inadequate data. Farms having less than 8 months of BTSCC data prior to farm evaluation date were excluded, leaving (n = 263) farms available for the analyses.

#### ***4.2.6. Statistical Analyses for BTSCS Model***

All analyses were performed in SAS 9.4 (SAS Institute Inc., Cary, NC). All main effects were tested in the GLIMMIX procedure to determine significant categorical predictors of BTSCS. No categorical variables significantly influenced BTSCS. The REG procedure was used for stepwise backward elimination to remove non-significant variables at  $P > 0.25$ . Remaining significant effects were then analyzed in a final regression model using a max R-squared approach in the REG procedure to determine a final best-fit model. Variables were considered to be significant in the final model at a level of ( $P \leq 0.05$ ).

#### ***4.2.7. Response and Predictor Variables for BTSPC Model***

Monthly BTSCC and BTSPC data were acquired from state regulatory offices in Virginia, Kentucky, Tennessee, and Mississippi and averaged for the 12 months prior to the farm evaluation for each farm. The 12-mo herd average BTSPC was log transformed using  $\log_{10}(\text{BTSPC})$  and subsequently used as the response variable for the analyses. BTSCC was converted into BTSCS using the formula  $\log_2 (\text{BTSCC}/100,000) + 3$  and included in the analyses as an independent variable to further explain the variation of BTSPC.

The independent variables of interest that were recorded and used for analysis included:

- 1) pre-milking teat disinfectant active ingredient; 2) post-milking teat disinfectant active ingredient; 3) utilization of a dry-wipe before applying a pre-milking teat disinfectant (y/n); 4) utilization of a commercial pre-milking teat disinfectant foam (y/n); 5) utilization of a commercial pre-milking teat disinfectant spray (y/n); 6) utilization of a commercial pre-milking teat disinfectant in a teat dip cup (y/n); 7) utilization of a homemade pre-milking teat disinfectant spray or cup (y/n); 8) utilization of a single use cloth towel to wipe teats (y/n); 9) utilization of a multiple use cloth towel to wipe teats (y/n); 10) utilization of a paper towel to wipe teats (y/n); 11) utilization of a post-milking teat disinfectant spray (y/n); 12) utilization of a post-milking teat disinfectant cup (y/n); 13) utilization of pre-stripping a few streams of milk from each teat (y/n); 14) utilization of gloves during milking (y/n/sometimes); 15) order of pre-milking procedures; 16) utilization of udder hair removal (y/n); 17) average udder hygiene score; 18) average teat end score; 19) percent of cracked teat ends; 20) average pre-milking teat disinfectant contact time (s).

Farm demographic variables that were also included in the analyses included: 1) number of milking personnel; 2) season of the farm evaluation; 3) herd size; 4) number of milking units; 5) use of teat sealant for dry cows (yes/no/sometimes); 6) use of antibiotics at dry-off (yes/no/sometimes); 7) DHIA enrollment (yes/no); 8) use of an SOP for milking (yes/no); 9) age

of farm owner or manager; 10) education level of farm owner or manager; 11) amount of pasture access available for lactating cows; 12) if lactating cows were housed in a freestall barn (yes/no); 13) if lactating cows were housed in a bedded pack barn (yes/no); 14) how likely the dairy would still be in operation 10 years in the future as reported by the farm owner or manager.

Some farms were excluded from analyses because of missing or inadequate data. Farms having less than 8 months of BTSCC data prior to farm evaluation date were excluded, leaving (n = 263) farms available for the analyses.

#### ***4.2.8. Statistical Analysis for BTSPC Model***

All analyses were performed in SAS 9.4 (SAS Institute Inc., Cary, NC). All main effects were tested in the GLIMMIX procedure to determine significant categorical predictors of BTSCS. No categorical variables significantly influenced BTSCS. The REG procedure was used for stepwise backward elimination to remove non-significant variables at  $P > 0.25$ . Remaining significant effects were then analyzed in a final regression model using a max R-squared approach in the REG procedure to determine a final best-fit model. Variables were considered to be significant in the final model at a level of ( $P \leq 0.05$ ).

### **4.3. Results**

#### ***4.3.1. Farm Demographics***

Total number of farms evaluated in the SE US was (n = 283). Number of farms with at least 8 months of BTSCC and BTSPC data available for analyses was (n = 263). Average herd size of all visited farms was  $227 \pm 20$ , and ranged from 32 to 2,500. A variety of dairy cattle breeds were represented; with farms consisting of only Holstein cattle (n = 97); only Jersey cattle (n = 13); Holstein and Jersey (n = 21); or a mixture of the aforementioned breeds as well as Guernsey, Ayrshire, and Brown Swiss (n = 152). Distribution of breeds can be seen in **Table 4.1**.

The majority of farms milked cows twice daily (79%), and some milked cows thrice daily (19%). There were 2% of farms with a milking frequency that differed from twice or thrice daily. Farms reported to house lactating cows in a free-stall (70%), compost bedded pack (16%), bedded pack (11%), or tie-stall (4%), which can be viewed in **Table 4.2**. Farms also reported to keep lactating cows in total confinement (35%), partial confinement with > 4 h access to dry lot or pasture (45%), partial confinement with < 4 h access to dry lot or pasture (9%), or exclusively on pasture (13%), which can be viewed in **Table 4.3**.

The majority of farms, 89%, reported to receive a monetary incentive from the milk cooperative if a certain BTSCC or BTSPC level was achieved. Most farms were enrolled in the Dairy Herd Improvement Association (DHIA), but 38% were not enrolled, which varied by state. Farms reported that cows were primarily milked by: 1) hired employees/ non-family (51%); 2) the owner or manager (33%); 3) family members (16%). When farm owners were asked about the probability of their dairy farm being in operation 10 years from now, 45% answered “almost certainly”, 26% answered “very likely”, 17% answered “somewhat likely”, and 12% answered “not likely at all”. A frequency table with these results can be seen in **Table 4.4**.

#### ***4.3.2. Distribution of Parlor Practices***

Stripping foremilk from teats as part of the pre-milking routine was done on 63% of farms. Pre-milking teat disinfectants used on farms were either homemade or a commercial product. Farms reported applying a commercially available pre-milking teat disinfectant 3 different ways, as a foam (19%), as a spray (18%), or with a teat dip cup (63%). A small number of farms, 8%, used a homemade pre-milking teat disinfectant, and applied it as a spray (n = 7), or with a teat dip cup (n = 14). Post-milking teat disinfectant was applied 3 different ways, with a teat dip cup (90%), as a spray (8%), or as a foam (2%).

The following active ingredients were used by farms for pre-milking teat disinfectants: dodecyl benzene sulfonic acid and lactic acid (DBSLA) (11%); hydrogen peroxide (H<sub>2</sub>O<sub>2</sub>) (27%); iodine (39%); other (15%). The following active ingredients were used by farms for post-milking teat disinfectants: DBSLA (17%); iodine (66%); lactic acid (12%); other (12%). Chlorohexidine and hypochlorous acid were less common active ingredients that were used on < 5% of farms and were consequently combined into the “other” category. Distribution of parlor practices can be seen in **Table 4.5**.

#### ***4.3.3. Bulk Tank Somatic Cell Score Model***

The mean BTSCS recorded during the 12-mo immediately prior to each farm’s evaluation was  $4.35 \pm 0.03$  and ranged from 2.79 to 5.83. A total of 217 farms had complete records and were included in the final model. The final BTSCS model yielded an  $R^2 = 0.30$  and included the fixed effects of 1) BTSPC; 2) herd size; 3) number of milking units in the parlor; 4) utilization of an internal teat sealant at dry-off; 5) education level of the farm owner or manager; 6) utilization of a bedded pack for lactating cow housing; 7) number of hours per day lactating cows were allowed on pasture; 8) Utilization of paper towels to wipe teats after application of teat disinfectant; 9) Percent of teats that were cracked or had hyperkeratosis; 10) average contact time of pre-milking teat disinfectant. Parameter estimates and *P*- values of the effects included in the final model are depicted in **Table 4.7**.

Overall, mean BTSPC for all visited farms was  $3.93 \pm 0.4$  and ranged from 3.00 to 5.99. Bulk tank standard plate count significantly influenced the dependent variable, 12-mo BTSCS, according to the final model ( $P < 0.001$ ) and a positive relationship was identified between these 2 factors, depicted in **Figure 4.1**. The mean herd size for all farms was  $227 \pm 20$  and ranged from 32 to 2500 (**Table 4.6**). Herd size was included in the final BTSCS model ( $P < 0.001$ ) and had a

positive relationship with BTSCS, which is illustrated in **Figure 4.2**. The mean number of milking units in the parlor was  $14.38 \pm 0.55$  and ranged from 2 to 72. Number of milking units significantly influenced BTSCS ( $P < 0.01$ ) and had a positive relationship with BTSCS; this relationship is illustrated in **Figure 4.3**.

Utilization of an internal teat sealant at dry-off was reported by the farm owner or manager. Distribution of farms that utilized an internal teat sealant at dry-off were as follows: 1) used on 100% of cows: (n = 120) 45%; 2) used on < 100% of cows: (n = 9) 3%; 3) used on 0% of cows: (n = 127) 52% (**Table 4.6**). Utilization of a teat sealant significantly influenced BTSCS ( $P < 0.05$ ) and is illustrated in **Figure 4.4**. Farms that utilized an internal teat sealant at dry-off on 100% of cows had lower BTSCS than farms that did not utilize an internal teat sealant at dry-off. However, there was no difference between farms that used an internal teat sealant selectively (on < 100% of cows), compared to farms that utilized a teat sealant on 0% or 100% of cows.

Distribution of education level of the farm owner or manager were as follows: 1) less than a high school degree (n = 47) 18%; 2) high school degree (n = 72) 27%; 3) some college or technical training (n = 42) 16%; 4) college degree (n = 104) 39% (**Table 4.6**). Education level of the farm owner or manager significantly influenced BTSCS ( $P < 0.01$ ) and is illustrated in **Figure 4.5**. The largest proportion of farmer owners/managers reported to have a college degree (n = 104) 39%. The least squares mean BTSCS for each category were as follows: 1) less than high school degree (4.24); 2) high school degree (4.23); 3) some college or technical education (4.56); 4) college degree (4.40). Farmers that reported to have a high school degree had the lowest mean BTSCS, and farmers that reported to have some college or technical training had the greatest mean BTSCS.

Number of hours of pasture access was available for lactating cows on farms were as follows: 1) 0 hours (n = 100) 35%; 2) < 4 hours /d (n = 25) 9%; 3) > 4 hours /d (n = 121) 43% 4) 24 hours /d (n = 38) 13% (**Table 4.3**). Amount of time lactating cows had pasture access per day significantly influenced BTSCS ( $P < 0.001$ ) and is illustrated in **Figure 4.6**. Farms that kept lactating cows in total confinement, with no pasture access, had the lowest BTSCS. Farms that had cows exclusively on pasture had the greatest BTSCS.

Whether a farm had a bedded pack for lactating cow housing did not significantly influence BTSCS ( $P > 0.05$ ), but was included in the final best-fit model. Percent of teats that were cracked or had hyperkeratosis, average contact time of pre-milking teat disinfectant, and utilization of paper towels to wipe teats after application of teat disinfectant were also included in the final best-fit model, although did not significantly influence BTSCS ( $P > 0.05$ ) (**Table 4.7**).

#### **4.3.4. Bulk Tank Standard Plate Count Model**

The 12-mo average  $\log_{10}$ BTSPC was  $3.93 \pm 0.04$  across all farms and ranged from 3.00 to 5.99. A total of 218 farms had complete data and were included in the final model. The final BTSPC model yielded an  $R^2 = 0.26$  and included the fixed effects of: 1) BTSCS; 2) udder hair removal; 3) herd size; 4) Probability of the future operation of the dairy in 10 years as reported by the farm owner or manager; 5) Number of hours per day lactating cows had access to pasture; 6) Percent of teat ends that were cracked or had hyperkeratosis; 7) average preparation lag time. Parameter estimates and  $P$ - values of the effects included in the final model are provided in **Table 4.8**.

The 12-mo mean BTSCS recorded during the 12-mo immediately prior to each farm's evaluation was  $4.35 \pm 0.03$ . Bulk tank somatic cell count significantly influenced BTSPC ( $P <$

0.001) and is illustrated in **Figure 4.1**. A positive relationship existed between BTSCS and BTSPC, as one increases, the other increases as well. The mean herd size for all farms was  $227 \pm 20$  and ranged from 32 to 2500. Herd size was included in the final BTSPC model ( $P < 0.01$ ) and had a positive relationship with BTSPC, which is illustrated in **Figure 4.8**.

Dairy producers were asked if they utilized udder singeing or clipping as a routine management practice. Udder hair removal was reported to be used by 47% ( $n = 125$ ) of farms. Utilization of udder hair removal significantly influenced the dependent variable, 12-mo BTSPC, according to the final model ( $P < 0.05$ ), and is illustrated in **Figure 4.7**. Removal of udder hair was associated with increased BTSPC. According to the final model equation least squares mean, farms that removed udder hair had a mean BTSPC of  $4.09 \pm 0.06$ , whereas farms that did not remove udder hair had a lower mean BTSPC of  $3.89 \pm 0.05$ .

When farm owners were asked about the probability of their dairy farm being in operation 10 years in the future, 45% answered “almost certainly”, 26% answered “very likely”, 17% answered “somewhat likely”, and 12% answered “not likely at all” (**Table 4.4**). Farmer perception of probability of future operation of the dairy farm significantly influenced BTSPC ( $P < 0.001$ ) and is illustrated in **Figure 4.9**. Farmers that reported to “almost certainly” be operating their dairy in 10 years had the lowest BTSPC, compared to farmers that reported to be uncertain about the future operation of the dairy.

The overall mean percent of cracked teat ends was  $42 \pm 1$ . and ranged from 0% to 98%. Percent of cracked teat ends significantly influenced BTSPC ( $P < 0.05$ ) and is illustrated in **Figure 4.11**. A negative relationship existed between percent of cracked teat ends and BTSPC; as percent of cracked teat ends increased, BTSPC decreased. The overall mean preparation lag time for all farms was  $95 \text{ s} \pm 4 \text{ s}$ . Preparation lag time significantly influenced the dependent

variable, 12-mo average BTSPC ( $P < 0.05$ ) and is illustrated in **Figure 4.12**. A negative relationship existed between preparation lag time and BTSPC; as preparation lag time increased, BTSPC decreased. Number of hours that lactating cows had access to pasture per day did not significantly influence the dependent variable, 12-mo BTSPC, according to the final model ( $P > 0.05$ ), but was included in the final best-fit model based on maximum r-squared value.

#### **4.4. Discussion**

These analyses were part of a large multi-state project with an overall goal to assess producer perceptions, management practices, and farm demographics of SE US dairies, and to determine how these factors influence milk quality. The purpose of these specific analyses was to determine the impacts of parlor procedures on BTSCC and BTSPC. This study was designed as a cross-sectional study which allowed for data to be collected from a larger number of farms, but conversely, disadvantages exist when data collection is limited to one day per farm, and may not be a complete representation of data for each farm. Given this study design, a 12-mo average of BTSCC and BTSPC were chosen as dependent variables for the respective models to control for seasonal variation and with the goal of producing a more accurate model.

##### ***4.4.1. Bulk Tank Somatic Cell Count Model***

The results of the model suggest that the most influential factors influencing milk quality of study herds are farm demographic information such as herd size, farmer education level and lactating cow housing. Larger herd size was shown to be associated with lower BTSCS. Parlor procedures were not found to significantly influence milk quality on the evaluated study herds. Parlor procedures such as pre- and post-milking teat disinfection have been widely accepted among dairies across the US for some time, and differences among these practices such as active

ingredient of disinfectant or using paper or cloth towels to wipe teats were not found to significantly influence milk quality in the current study.

The final best-fit model based on max r-squared included utilization of paper towels to wipe teats, although this did not significantly affect BTSCS ( $P > 0.05$ ). Contrary to these results, a study that surveyed 47 dairy herds in Spain found that the use of paper towels was associated with lower SCC compared to farms that used cloth towels (Bach et al., 2008). However, farms with lower SCC also had greater milk yield compared to their counterparts, which could influence SCC by dilution of cells in a greater volume of milk. Although paper towel use did not significantly influence BTSCS in the current study, there is enough evidence to suggest that further investigation may be necessary to test the effectiveness of using paper towels versus cloth towels.

Percent of teat ends that were cracked or had hyperkeratosis was included in the final best-fit model, but did not significantly influence BTSCS. The relationship between teat end condition and SCC is not well understood and conflicting results have been reported in scientific literature. One study in particular found that with every increase in teat end score, using a 1-4 scale, a 30% increase in IMI risk results, however there was no association with elevated SCC (de Pinho Manzi et al., 2012). Additional studies have failed to find an association between high teat end scores and elevated SCC (Isaksson and Lind, 1992; Shearn and Hillerton, 1996). Several factors can influence teat end condition including stage of lactation, parity, milk yield, machine-on time, and teat end shape (Mein and Thompson, 1993; Shearn and Hillerton, 1996; Neijenhuis et al., 2000).

Average contact time of pre-milking teat disinfectant was included in the final best-fit model based on the max r-squared value, but did not significantly influence BTSCS ( $P > 0.05$ ).

Pre-milking teat disinfectant is most effective at reducing microbial load at a contact time of 15 to 30 s, depending on the active ingredient, and significant bacterial reduction does not occur beyond this point (Enger et al., 2015). Average contact time for dairies that were evaluated in the SE US were twice as long as the recommendation. The inclusion of disinfectant contact time in the final model suggests that dairies in the SE US should consider adjusting the timing of their milking procedures.

It was expected that the model would identify gloves and post-milking teat disinfectant to be significantly associated with BTSCS since these procedures have been found to be the most effective practices in influencing herd SCC and reducing IMI risk (Pankey et al., 1984; Dufour et al., 2011). However, only 11% of farms reported to never use gloves during milking time, and 98% of farms reported to use a post-milking teat disinfectant. Consequently, when the majority of farms have already adopted these practices, no differences are available to be detected. Additionally, since these variables did not end up in the final model, this is an indication that these practices are not a challenge for SE US dairies.

#### ***4.4.2. Bulk Tank Standard Plate Count Model***

Udder hair removal was reported to be utilized by the farm owner or manager, but was not actually measured on-farm by SQMI team members. Although dairy producers may have reported to be removing udder hair, there was no evidence of how often it was done. Udder hair removal significantly influenced BTSPC in the final model. Farms that reported to remove hair by singeing or clipping had a greater average BTSPC than farms that did not. Removal of udder hair has revealed conflicting results in scientific literature. Removal of udder hair has been found to be associated with teat cleanliness, lower BTSPC (Elmoslemany et al., 2009), and lower SCC (Dufour et al., 2011). However, two studies found no difference in bacterial concentrations on

teat skin or in milk, and no increase in IMI risk for singed udders versus controls (Silk et al., 2003; Fox, 2016). However, Fox (2016) noted that average udder hygiene score of cows in the study were low compared to another study by Schreiner and Ruegg (2003), that analyzed udder hygiene score and SCC (Schreiner and Ruegg, 2003). Thus, udder hair removal may be beneficial for herds with high udder hygiene scores, but not for herds with cleaner cows. Climate and housing conditions were likely contributing factors in these studies as well, which may explain varying results.

Average preparation lag time was found to significantly influence BTSPC in the final model. Longer preparation lag times were associated with lower BTSPC. Among the study herds, pre-milking teat disinfectant contact time was observed to be twice as long as what is recommended, which will make preparation lag time longer than recommended as well. Preparation lag time is recommended to be 90 to 120 s in order to allow for oxytocin to initiate milk let-down before attaching the milking unit (Kaskous and Bruckmaier, 2011). It was unexpected to find longer preparation lag time to be associated with lower BTSPC. This finding suggests that timing of milking procedures on SE US dairies needs to be adjusted to recommendations according to previous literature.

Percent of teat ends that were cracked or had hyperkeratosis significantly influenced BTSPC. The relationship between teat end condition and SCC is not well understood and conflicting results have been reported in scientific literature. Unexpectedly, as percent of cracked teat ends increased, BTSPC decreased. Several studies have attempted to find associations between mastitis risk or SCC and teat end score (de Pinho Manzi et al., 2012; Neijenhuis et al., 2000; Shearn and Hillerton, 1996), but not much research has reported how teat end score influences bacteria counts in milk. Several factors can influence teat end condition including

stage of lactation, parity, milk yield, machine-on time, and teat end shape (Mein and Thompson, 1993; Shearn and Hillerton, 1996;). It is thought that increasing teat end callosity provides a larger surface area for bacteria to attach to, thereby increasing mastitis risk and overall bacterial load on the teat end. Interestingly, teat end condition influences colonization of bacteria differently depending on the mastitis pathogen type (Paduch et al., 2012). For example, prevalence of *E. coli* in teat canals increased as teat end score increased, whereas prevalence of *S. aureus* was not different between teat canals of both healthy and damaged teat ends (Paduch et al., 2012). *S. aureus* is naturally occurring on teat skin, which acts as the primary reservoir for *staphylococcus spp.*; *E. coli* on the other hand thrive in manure and are less likely to be found on teat skin. Considering the lack of literature comparing teat end score to BTSPC, further research is needed to investigate how teat end score may affect milk quality.

Dairy producers were asked how confident they were that they would be operating their dairy 10 years in the future. How dairy producers perceived their future involvement in the dairy industry significantly influenced BTSPC. Farmers that reported that future operation was “not likely” had the greatest BTSPC, whereas farmers that reported to “almost certainly” be in operation in 10 years had the lowest BTSPC. A recent study observed that producer attitudes, perceptions, and goals are associated with BTSCC (Schewe et al., 2015). These findings suggest that farmer perceptions and attitudes may influence milk quality more than previously thought. Dairy researchers tend to focus on their areas of expertise, which revolve around the biology of the cow, not social factors which are difficult to control, measure, or change. Further research is needed to investigate social factors that could be influencing milk quality.

#### **4.5. Conclusion**

These models indicate that the most influential factors associated with milk quality are farm demographics such as herd size, lactating cow housing, and farmer education level. It was evident in both the BTSCS and BTSPC models that utilization of an internal teat sealant at dry-off significantly influences milk quality for the evaluated SE US dairies. The significance of preparation lag time in the BTSPC model indicates that timing of milking procedures proves to be a challenge for SE US dairies. Farms that had lactating cows exclusively on pasture had the highest BTSCS, and farms that did not have any pasture access for lactating cows had the lowest BTSCS. Farmer perception of future operation of their dairy significantly influenced BTSPC. These findings suggest that farmer perceptions and attitudes may be influencing milk quality more than previously thought. Further research is needed to evaluate social factors that could be influencing milk quality. Milking procedures such as pre- and post-milking teat disinfection are widely accepted by most dairies in the US. Minimal differences were found between milking procedures such as teat disinfectant active ingredient or using paper towels versus cloth towels and may not be the most influential factors influencing milk quality.

**Table 4.1** Distribution of breeds among study herds evaluated in the southeast US.

<b>Breed</b>	<b>Number of farms</b>	<b>Percent</b>
Holstein	97	34%
Holstein and other	64	23%
Holstein, Jersey and other	33	12%
Holstein and Jersey	21	7%
Jersey	13	5%
Holstein, Brown Swiss, and other	10	4%
Holstein, Jersey, Brown Swiss, and other	8	3%
Holstein and Brown Swiss	5	2%
Jersey and other	5	2%
Other	28	10%

**Table 4.2** Frequency data of housing facilities for lactating cows from study herds in the southeast US.

<b>Housing facility</b>	<b>Number of farms</b>	<b>Percent</b>
Free-stall	193	70%
Tie-stall	11	4%
Bedded Pack	30	11%
Compost bedded pack	43	16%

**Table 4.3** Frequency data regarding the amount of pasture access for lactating cows in study herds in the southeast US.

<b>Amount of pasture access</b>	<b>Number of farms</b>	<b>Percent</b>
Total confinement	100	35%
Mostly confinement with < 4 h access to dry lot or pasture	25	9%
Partial confinement with > 4 h access to dry lot or pasture	121	43%
Exclusively pasture	38	13%

**Table 4.4** Frequency data of study herds in the southeast US regarding monetary incentives, DHIA enrollment, and future dairy farm operation.

<b>Variable</b>	<b>Answer</b>	<b>Number of farms</b>	<b>Percent</b>
Monetary incentive <sup>1</sup>	Yes	248	89%
	No	32	11%
DHIA enrolled <sup>2</sup>	Yes	199	72%
	No	76	28%
Dairy 10 years <sup>3</sup>	Almost certainly	123	45%
	Very likely	73	26%
	Somewhat likely	46	17%
	Not likely at all	32	12%
<sup>1</sup> Farms that are offered a monetary incentive from the milk cooperative to achieve certain somatic cell count and standard plate count goals <sup>2</sup> Farms that are enrolled in the Dairy Herd Improvement Association <sup>3</sup> How farm owners responded to the possibility of continued operation of their dairy farm 10 years in the future <sup>4</sup> Personnel primarily responsible for milking the majority of cows on the dairy			

**Table 4.5** Frequency of parlor practices among dairy farms evaluated in the southeast US.

<b>Variable</b>	<b>Application</b>	<b>Frequency</b>	<b>Percent</b>
Fore-strip <sup>3</sup>	Yes	170	63%
	No	99	37%
Pre-milking teat disinfectant	Foam	45	19%
	Spray	41	18%
	Cup	147	63%
Wipe - Cloth towel	Single use	88	39%
	Multiple use	40	18%
Wipe - Paper towel	Single use	85	38%
	Multiple use	13	6%
Post-milking teat disinfectant	Foam	4	2%
	Spray	18	8%
	Cup	216	90%
Pre-milking teat disinfectant active ingredient	Homemade	21	8%
	DBSLA <sup>1</sup>	27	11%
	H2O2 <sup>2</sup>	68	27%
	Iodine	98	39%
	Other	39	15%
Post-milking teat disinfectant active ingredient	Homemade	8	3%
	DBSLA <sup>1</sup>	17	7%
	Iodine	164	66%
	Lactic Acid	31	12%
	Other	30	12%
Udder hair removal	Yes	125	47%
	No	140	53%
Gloves <sup>4</sup>	Always	186	69%
	Sometimes	51	19%
	Never	31	12%
<sup>1</sup> Dodecyl benzene sulfonic acid and lactic acid <sup>2</sup> Hydrogen Peroxide <sup>3</sup> Removal and inspection of the first few streams of milk from each teat <sup>4</sup> Farms reported how frequently milking personnel wore gloves			

**Table 4.6** Frequency data of study herds in the southeast US regarding herd size, season of farm evaluation, farmer education level, farmer age, utilization of an internal teat sealant, and utilization of intramammary antibiotics.

<b>Variable</b>	<b>Category</b>	<b>Number of farms</b>	<b>Percent</b>
Herd size	≥ 125	137	51%
	126 - 500	108	40%
	> 500	24	9%
Season	Summer	65	24%
	Fall	74	28%
	Winter	55	20%
	Spring	75	28%
Farmer education	Less than high school degree	47	18%
	High school degree	72	27%
	Some college or technical education	42	16%
	College degree	104	39%
Farmer age	26-35	14	5%
	36-45	58	22%
	46-55	49	19%
	56-65	83	32%
	66-75	45	17%
	> 76	14	5%
	Teal sealant for dry cows <sup>1</sup>	100% of cows	120
< 100% of cows		9	3%
0% of cows		137	52%
Antibiotic for dry cows <sup>2</sup>	100% of cows	217	82%
	< 100% of cows	28	11%
	0% of cows	19	7%
<sup>1</sup> Whether an internal teat sealant is administered to cows at dry-off			
<sup>2</sup> Whether an intramammary antibiotic is administered to cows at dry-off			

**Table 4.7** Final regression model<sup>1</sup> showing the association of significant variables and bulk tank somatic cell count on dairies evaluated in the southeast US.

<b>Variable</b>	<b>Estimate</b>	<b>SE</b>	<b>P-value</b>
Intercept	2.092	0.310	< 0.0001
Bulk tank standard plate count	0.345	0.063	< 0.0001
Herd size	< - 0.001	< 0.001	0.011
Number of milking units	0.020	0.007	0.009
Internal teat sealant <sup>2</sup>	- 0.194	0.072	0.008
Farmer education level	0.085	0.030	0.004
Bedded pack <sup>3</sup>	0.129	0.078	0.100
Pasture access <sup>4</sup>	0.131	0.037	< 0.001
Paper towels <sup>5</sup>	0.139	0.073	0.059
Cracked teat ends <sup>6</sup>	0.003	0.002	0.159
Average teat disinfectant contact time	0.001	0.001	0.190

<sup>1</sup>The final model included 217 observations  $R^2 = 0.30$

<sup>2</sup>Utilization of an internal teat sealant on cows at dry-off

<sup>3</sup>Utilization of a bedded pack barn for lactating cow housing

<sup>4</sup>Amount of time per day pasture access is available for lactating cows

<sup>5</sup>Utilization of paper towels to wipe teats after pre-milking teat disinfectant is applied

<sup>6</sup>Percent of teat ends that were evaluated that were cracked or had hyperkeratosis

**Table 4.8** Final regression model<sup>1</sup> showing the association of significant variables and bulk tank standard plate count on dairies evaluated in the southeast US.

<b>Variable</b>	<b>Estimate</b>	<b>SE</b>	<b>P-value</b>
Intercept	3.116	0.338	<.0001
Udder hair removal <sup>2</sup>	0.177	0.070	0.012
Bulk tank somatic cell count	0.339	0.062	< 0.0001
Herd size	< 0.001	< 0.001	0.009
Pasture access <sup>3</sup>	-0.053	0.036	0.140
Dairy 10 years <sup>4</sup>	-0.135	0.035	< 0.001
Cracked teat ends <sup>5</sup>	-0.004	0.002	0.037
Average preparation lag time <sup>6</sup>	< - 0.001	< 0.001	0.033

<sup>1</sup>The final model included 218 observations  $R^2 = 0.26$

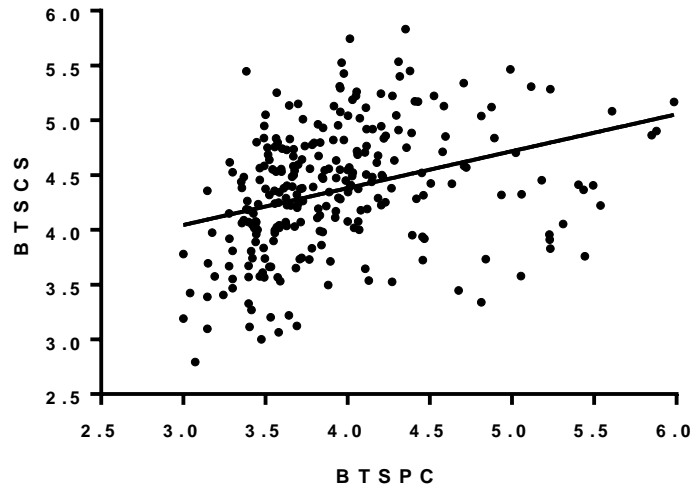
<sup>2</sup>Utilization of an udder hair removal technique such as singeing or clipping

<sup>3</sup>Amount of time per day pasture access is available for lactating

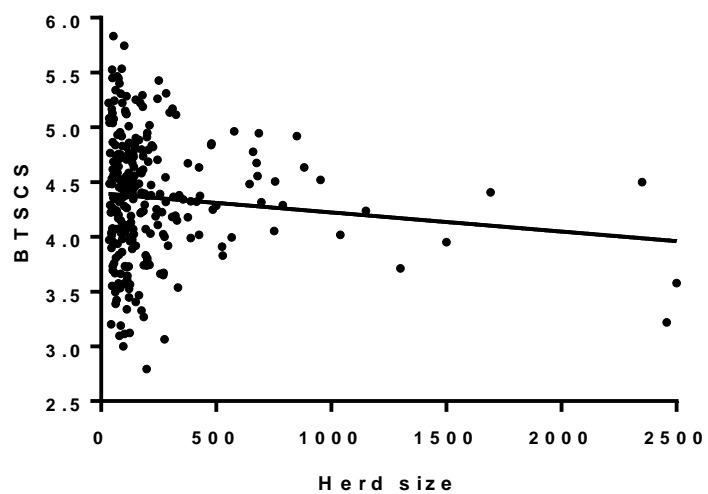
<sup>4</sup>Probability of the future operation of the dairy in 10 years as reported by the farm owner or manager

<sup>5</sup>Percent of teat ends that were evaluated that were cracked or had hyperkeratosis

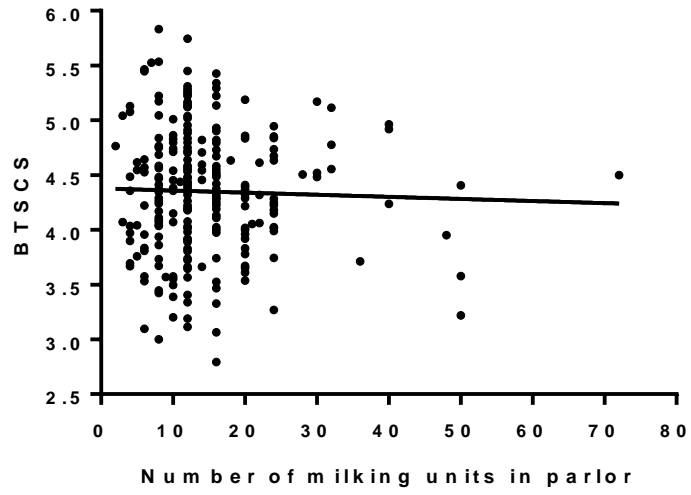
<sup>6</sup>Average time between first stimulation of the udder to attaching the milking unit



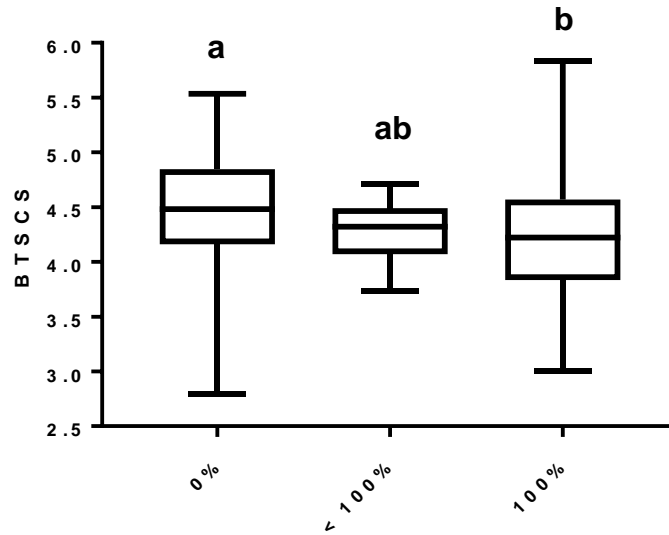
**Figure 4.1.** The linear relationship of 12-mo average bulk tank somatic cell count and 12-mo average bulk tank standard plate count on dairy farms evaluated in the southeast US.



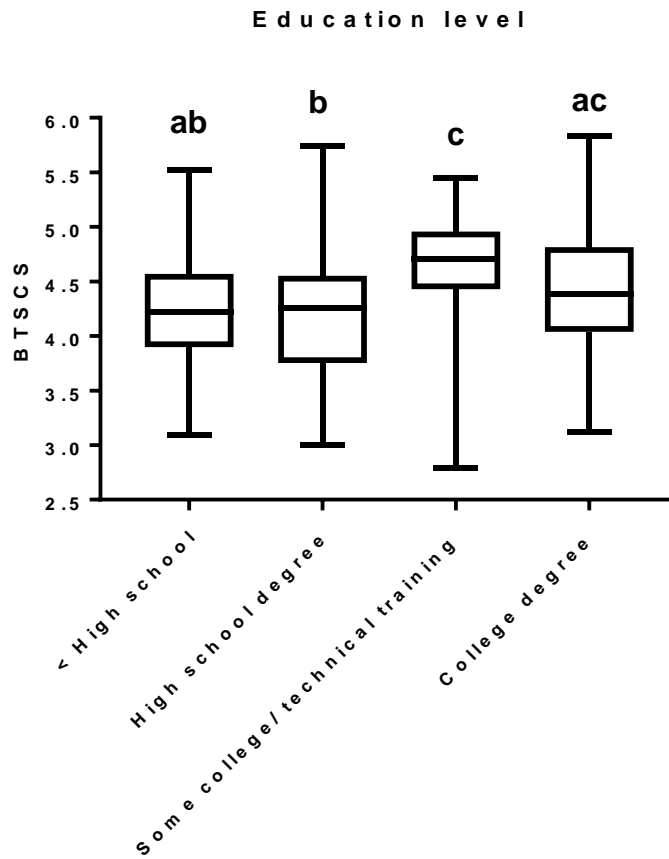
**Figure 4.2** The linear relationship of 12-mo average bulk tank somatic cell count and herd size of dairy farms evaluated in the southeast US.



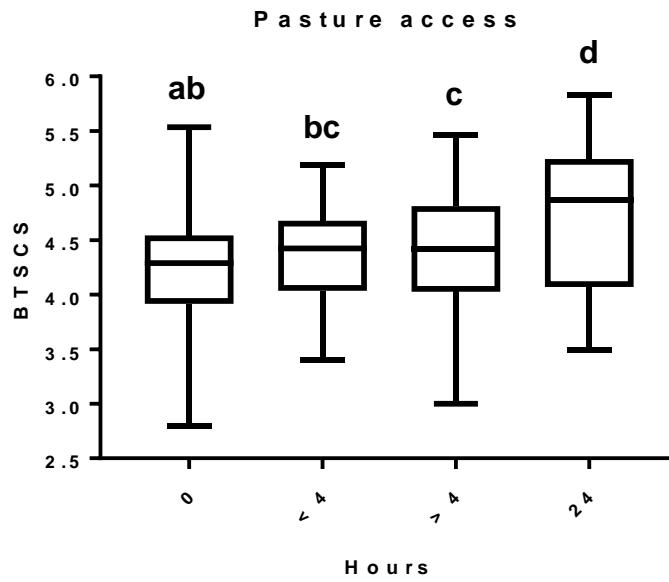
**Figure 4.3** The relationship of 12-mo average bulk tank somatic cell count and the number of milking units available to milk cows on dairy farms evaluated in the southeast US.



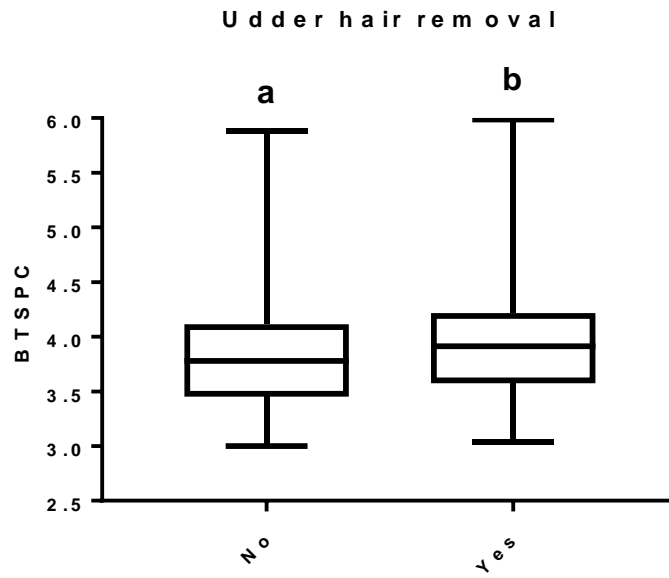
**Figure 4.4** The relationship of 12-mo average bulk tank somatic cell count and utilization of an internal teat sealant on cows at dry-off. Farms reported to administer internal teat sealant to no cows (0%) at dry-off, some cows (< 100%), or all cows (100%). Significant differences are denoted by the letters ( $P < 0.05$ ).



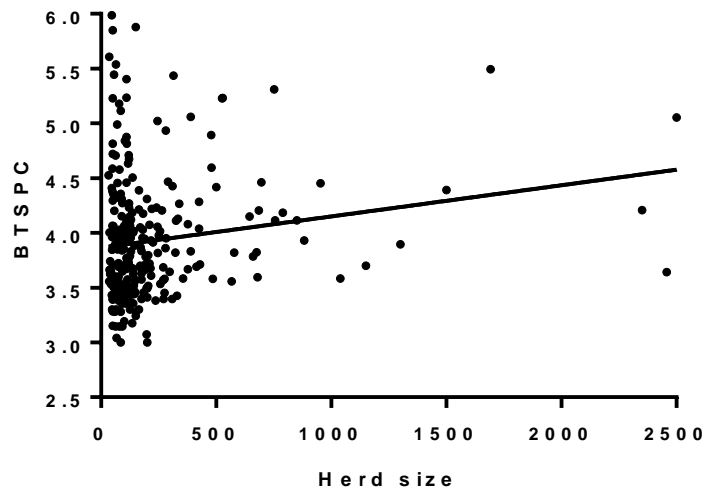
**Figure 4.5** The relationship of 12-mo average bulk tank somatic cell score and education level of the farm owner or manager. Significant differences are denoted by the letters ( $P \leq 0.05$ ).



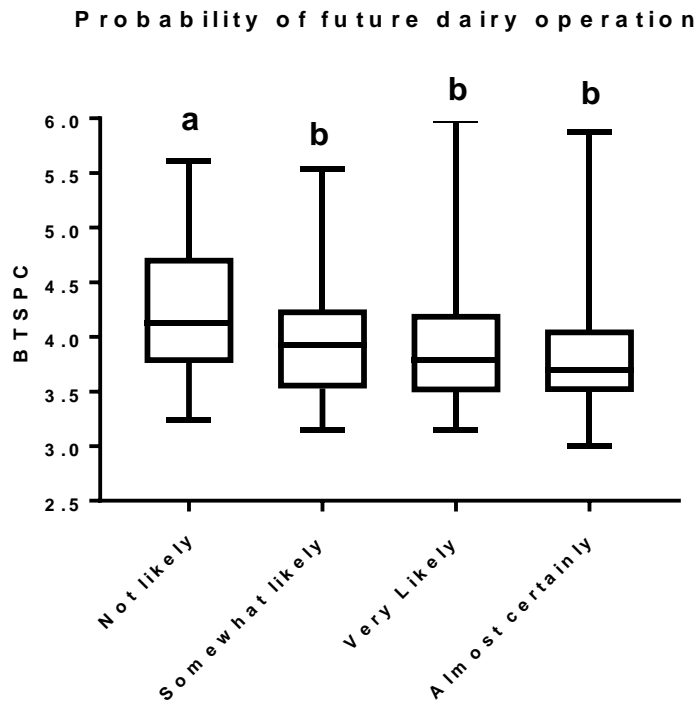
**Figure 4.6** The relationship of 12-mo average bulk tank somatic cell score and number of hours per day lactating cows from study herds have access to pasture. Significant differences are denoted by the letters ( $P < 0.05$ ).



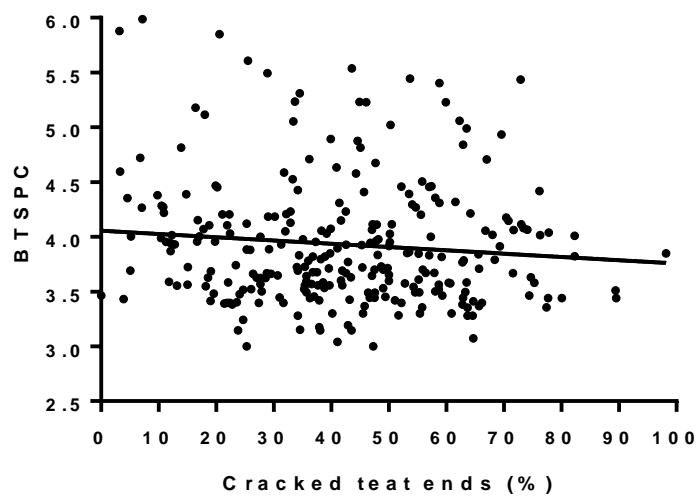
**Figure 4.7** The relationship of 12-mo average bulk tank standard plate count and utilization of udder hair removal technique such as singeing or clipping as reported by the farm owner or manager on dairy farms evaluated in the southeast US ( $P < 0.05$ ).



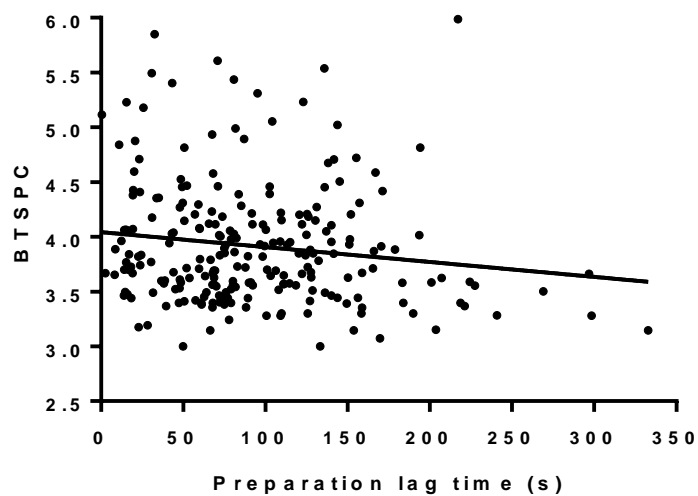
**Figure 4.8** The linear relationship of 12-mo average bulk tank standard plate count and herd size on dairy farms evaluated in the southeast US.



**Figure 4.9** The relationship of 12-mo average bulk tank standard plate count and the probability of the future operation of the dairy in 10 years as reported by the farm owner or manager. Significant differences are denoted with letters ( $P < 0.05$ ).



**Figure 4.10** The linear relationship of 12-mo average bulk tank standard plate count and percent of teat ends that were cracked or had hyperkeratosis on dairy farms evaluated in the southeast US.



**Figure 4.11** The linear relationship of 12-mo average bulk tank standard plate count and preparation lag time on dairy farms evaluated in the southeast US.

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## Chapter 5 : GENERAL CONCLUSIONS

The current average BTSCC for the US is approximately 200,000 cells/mL, which is a substantial decrease from just 10 to 15 years ago. When innovative milk quality control measures were first being tested, drastic improvements could be made on a farm by employing one or two practices, such as pre- and post-milking teat disinfection. Today, the majority of farms are employing all of the proven mastitis control practices and on many farms the average BTSCC is < 200,000 cells/mL. As milk cooperatives continue to offer monetary incentives for lower SCC and SPC, producers are attempting to fine-tune management practices to try to get BTSCC < 200,000. Trying to detect which factors are significantly influencing SCC on farms with BTSCC < 200,000 cells/mL proves to be a challenge because of the complex relationships between the cow, environment, and management factors that differ across farms.

Producers in the SE US struggle to contend with the high standards that the rest of the US is achieving. The current study identified management practices that have been well established to influence milk quality, including use of an internal teat sealant at dry-off, and water temperature of the pipeline wash. This is an indication that these factors still prove to be problems for SE US dairies. However, some management practices were unexpectedly found to be significant, including preparation lag time influencing BTSPC. There is minimal scientific literature exploring how some of these variables are influencing BTSPC. Further research is necessary to verify how changes in these variables would influence bacteria counts in milk.

Preparation lag time and contact time of pre-milking teat disinfectant were included in the final BTSCS and BTSPC models. The average length of these measurements were double the length or more of what is recommended according to previous literature. Timing of pre-milking procedures is crucial to the overall milking process, as it influences oxytocin release and milk flow. Improper timing of stimulation and milking procedures could lead to uncomfortable cows,

teat end damage, and increased mastitis risk. It is also essential for milking procedures and parlor equipment to be perfectly coordinated to achieve a successful milking process. These models indicate that timing of milking procedures proves to be an issue for SE US dairies and should be re-evaluated to improve overall milk quality.

These models suggest that the most influential factors associated with milk quality are farm demographic variables such as herd size, lactating cow housing, and farmer perception of the future operation of their dairy. Findings regarding farmer perceptions and attitudes from the current study are largely uninvestigated. Thus, further examination of the social aspects that could be influencing milk quality should be conducted. Nevertheless, management factors were identified as significant contributors of milk quality on SE US dairies, and with the re-evaluation and correction of these factors, SE US dairies can improve overall milk quality.

**APPENDICES**

**Appendix 1: SQMI 2 - Producer Survey**

Q1 Farm ID Number: \_\_\_\_\_

Q2 Date (yyyymmdd): \_\_\_\_\_

Q4 Start Time (military time): \_\_\_\_\_

Q5 Interviewer (First name, Last name): \_\_\_\_\_

**How would you like your report sent:  
Circle One**

**Regular Mail**

**Email:**

Q6 As of today, what is the total number of adult cows (all lactations; milking and dry) on the farm?

\_\_\_\_\_

Q7 What breeds? Check all that apply

- Holstein (1)
- Jersey (2)
- Ayrshire (3)
- Brown Swiss (4)
- Guernsey (5)
- Other (6) \_\_\_\_\_

Q8 Has the approximate number of adult cows changed in the last 12 months?

- No, the herd size is about the same (1)
- Yes, the herd size increased by (%) (2) \_\_\_\_\_
- Yes, the herd size decreased by (%) (3) \_\_\_\_\_

Q9 Are the heifers raised entirely on this operation?

- Yes (1).... SKIP to Q12
- No (2)

Answer If Are the heifers raised entirely on this operation? No Is Selected

Q10 If not, heifers leave the farm at (months of age)

Answer If Are the heifers raised entirely on this operation? No Is Selected

Q11 Heifers return to the farm at (months of age)

Q12 What is the name of the cooperative or processor to which you currently sell your milk?

- Bordens (1)
- Cobblestone (2)
- Continental (3)
- Dairy Farmers of America (4)
- Lanco (5)
- Lonestar (6)
- Maryland and Virginia (7)
- Mayfields (8)
- Piedmont (9)
- Southeast (10)
- Dean's (27)
- Organic Valley (28)
- Other (11) \_\_\_\_\_

Q13 Does the co-op or processor you sell your milk to offer an incentive for achieving a particular bulk tank SCC?

- Yes (1)
- No (2)

Q14 Does the co-op or processor you sell your milk to offer an incentive for achieving a particular bulk tank Bacteria load (e.g. Standard Plate Count, SPC; Preliminary Incubation (PI) Count)?

- Yes (1)
- No (2)

Q15 Which of the following best describes the housing system for your lactating dairy cows?

- Total confinement (no pasture access) (1)
- Mostly confinement with less than four hours access to dry lot or pasture all year (2)
- Partial confinement with at least four hours access to dry lot or pasture (3)
- Exclusively pasture (4)

Q16 Does this vary with season?

- Yes (1)
- No (2)... Skip to Q18

Answer If Does this vary with season? Yes Is Selected

Q17 If yes,

	Spring (March - May) (1)	Summer (May - August) (2)	Fall (September - November) (3)	Winter (December - February) (4)
Total Confinement (no pasture access) (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mostly Confinement with less than four hours access to dry lot or pasture (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Partial confinement with at least four hours access to dry lot or pasture (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Exclusively pasture (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q18 How are your lactating cows housed?

- Free Stall (1)... Go to Q19
- Tie Stall (2)... Go to Q19
- Bedded Pack (3)... Go to Q20
- Compost Bedded Pack (4)... Go to Q20
- Pasture with portable shade access (5)... Go to Q21
- Pasture with non-portable shade access (e.g. trees, permanent structure) (11)... Go to Q21
- Pasture without shade access (6)... Go to Q21
- Outdoor Lot (7)... Go to Q21
- Other (8) \_\_\_\_\_

Answer If How are your lactating cows housed? Free Stall Is Selected Or How are your lactating cows housed? Tie Stall Is Selected

Q19 If either tie or free stall, what base is used?

- Concrete (1)
- Rubber mats (2)
- Rubber-filled mattress (3)
- Waterbed (4)
- Deep-bedded sand (5)
- Deep -bedded organic (sawdust or straw) (7)
- Other (6) \_\_\_\_\_

Answer If How are your lactating cows housed? Pasture with shade access Is Not Selected And How are your lactating cows housed? Outdoor Lot Is Not Selected And How are your lactating cows housed? Pasture without shade access Is Not Selected

Q20 What type of bedding is used for your lactating cows?

- None (1)
- Limestone (2)
- Sand, fresh (3)
- Sand, recycled (4)
- Sawdust or wood shavings (5)
- Straw (6)
- Other (7) \_\_\_\_\_

Q21 Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable).... If no, skip to Q24

	Far-off dry cows (1)	Close-up dry cows (2-3 weeks prior to calving) (2)	Springing heifers (3)	Calving Pen (4)	Fresh Cows (5)	Hospital or Dump Pen (6)
Yes (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
No (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Free stall (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Tie stall (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Bedded pack (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Compost bedded pack (6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pasture w/ portable shade access (7)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pasture with non-portable shade access (e.g. trees, permanent structure) (12)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Pasture w/o shade access (8)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Outdoor lot (10)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (11)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Answer If Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Pasture w/ shade access Is Empty And Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Pasture w/o shade access Is Empty And Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Outdoor lot Is Empty

Q22 If in a tie stall or free stall, what base material is used?

	Far-off dry cows (1)	Close-up dry cows (2-3 weeks prior to calving) (2)	Springing heifers (3)	Calving Pen (4)	Fresh Cows (5)	Hospital or Dump Pen (6)
Concrete (1)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rubber mat (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Rubber filled mattress (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Water bed (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Deep bedded sand, sawdust, or straw (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (10)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Answer If Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Pasture w/ shade access Is Empty And Are any of the following special groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Pasture w/o shade access Is Empty And Are any of the following special

groups of cows housed separately from lactating cows? If yes, indicate the type of housing and bedding (if applicable). Outdoor lot Is Empty

Q23 If bedding material is needed, which of the following is used?

	Far-off dry cows (1)	Close-up dry cows (2-3 weeks prior to calving) (2)	Springing heifers (3)	Calving Pen (4)	Fresh Cows (5)	Hospital or Dump Pen (6)
Limestone (7)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Straw bedding (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sand, fresh (8)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sand, recycled (9)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Sawdust or wood shavings (6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Straw (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Other (10)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q24 Has bedding material and/or stall base changed in the last 12 months? If yes, what was the change?

- No (1)
- Yes, we switched from (2) \_\_\_\_\_

Q25 Are any of the following groups of cows housed separate from each other?

	Yes (1)	No (2)
Far off dry cows are housed separately from close-up dry cows (1)	<input type="radio"/>	<input type="radio"/>
Fresh cows are housed separately from hospital/dump cows (2)	<input type="radio"/>	<input type="radio"/>
Fresh cows are housed separately from other lactating cows? (3)	<input type="radio"/>	<input type="radio"/>
First lactation cows are separated from older lactating cows (4)	<input type="radio"/>	<input type="radio"/>
Mastitis treated (e.g. milk withhold) cows are separated from lactating cows? (5)	<input type="radio"/>	<input type="radio"/>
High SCC (e.g. chronic, contagious, Staph aureus mastitis) cows are separated from lactating cows? (6)	<input type="radio"/>	<input type="radio"/>

Q26 Age of Facilities

	Date built (1)	Last major renovation (2)	Renovation Description (i.e. new roof, replaced loops, etc) (3)
Milking facilities (8) Lactating cows facility (7) Fresh cows facility (5) Calving pen (4) Close-up dry cows (2-3 wk prior to calving) facility (2) Springing heifers facility (3) Far-off dry cows facility (1) Hospital or dump pen facility (6)			

Q27 How often do you flush or scrape standing areas?

- Automatic system, number of times per day? (1) \_\_\_\_\_
- Manual system, about 2-3 times per day (2)
- Manual system, one time per day (3)
- Manual system, less than one time per day (indicate number of times per week below) (4) \_\_\_\_\_
- Other (5) \_\_\_\_\_

Q28 If a manual system, how many man hours are required per day to flush or scrape standing areas?

\_\_\_\_\_

Q29 How often do you manually scrape standing areas in the pen that cannot be done automatically (e.g. cross-over alleys, in front of waterers, etc.)?

- About 2-3 times per day (1)
- One time a day (2)
- Less than one time per day (indicate number of times per week below) (3)
- \_\_\_\_\_
- Other (4) \_\_\_\_\_

Q30 How many man hours are required to scrape standing areas? \_\_\_\_\_

Q31 How often do you flush/scrape the transfer alleys to the milking parlor (excluding holding pens)?

- Automatic System, number of times per day? (1) \_\_\_\_\_
- About 2-3 times per day (2)
- One time per day using a manual system (3)
- Less than one time per day (indicate number of times per week below) (4)
- \_\_\_\_\_
- Other (5) \_\_\_\_\_

Q32 If a manual system, how many man hours are required per day to scrape the transfer alleys?

\_\_\_\_\_

Q33 For a stall based system, how often do you rake out stalls and remove cow patties?

- Once a day (1)
- Twice a day (2)
- More than once a week (3)
- About once a week (4)
- Less than once a week (5)

Q34 How many man hours are required to rake out stalls? \_\_\_\_\_

Q35 For your primary lactating cow facility, how often is new bedding material added?

- Once a day (1)
- Twice a day (2)
- More than once a week (3)
- About once a week (4)
- Less than once a week (5)
- About once a month (6)
- About every 2 months (7)
- About every 3-4 months (8)
- Other (9) \_\_\_\_\_

Q36 How many man hours are required to add new bedding material? \_\_\_\_\_

Q37 For compost bedded packs, how frequently is the bedded pack aerated or stirred?

- Once a day (1)
- Twice a day (2)
- About once a week (3)
- More than once a week (4)
- About twice a month (5)
- About once a month (6)
- About every 2 months (7)
- About every 3-4 months (8)
- Other (9) \_\_\_\_\_

Q38 How many man hours are required to aerate the pack? \_\_\_\_\_

Q39 Are any conditioners or treatment applied to the bedding?

- Yes, hydrated lime (1)
- Yes, ag lime (2)
- Yes, other (write in type below) (3) \_\_\_\_\_
- No (4)

If No Is Selected, Then Skip To Q44 Are fans available?

Q40 How often are conditioners or treatments applied?

- Daily (1)
- Every other day (2)
- Twice a week (3)
- Once a month (4)
- Other (5) \_\_\_\_\_

Q41 For stall barns, how much is applied?

- 2 lbs/stall/day (1)
- <2 lbs/stall/day (2)
- >2 lbs/stall/day (3)
- Other (4) \_\_\_\_\_

Q42 For compost barns, how much is applied? Describe rate below (e.g. lbs per sq ft)

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Q43 Do the answers to 40, 41 and 42 vary with season?

- Yes (1)
- No (2)

Q44 Are fans available?

- Yes, only in parlor (1)
- Yes, only in housing (4)
- Yes, in parlor and housing (3)
- No (2)

If No Is Selected, Then Skip To Q48 Do you use water to help keep cows cool?

Q45 If yes, fans are turned on based on:

- Calendar year (1)... Go to Q46
- Visual observation of the cows (2)... Go to Q48
- Temperature (3)... Go to Q47
- Other (5) \_\_\_\_\_... Go to Q48

Answer If If yes, when do the fans turn on? Based on calendar year Is Selected

Q46 Fans are typically on during the months of:

- Jan (1)
- Feb (2)
- Mar (3)
- Apr (4)
- May (5)
- Jun (6)
- Jul (7)
- Aug (8)
- Sep (9)
- Oct (10)
- Nov (11)
- Dec (12)

Answer If If yes, when do the fans turn on? Based on temperature Is Selected

Q47 Fans are turned on when the temperature exceeds:

- 65 (1)
- 70 (2)
- 75 (3)
- other (4) \_\_\_\_\_

Q48 Do you use water to help keep cows cool?

- No (1)
- Yes, Misters (2)
- Yes, Soakers (3)
- Yes, Center Pivot (4)
- Yes, cooling pond (5)

If No Is Selected, Then Skip To Q52... If cows have access to outside areas,...

Q49 If yes, water systems are turned on based on:

- Calendar year (1)... Go to Q50
- Visual observation of the cows (2)...
- Temperature (3)... Go to Q51
- Other (4) \_\_\_\_\_

Answer If If yes, water systems are turned on based on: Calendar year Is Selected

Q50 Water cooling systems are typically used during the months of:

- Jan (1)
- Feb (2)
- Mar (3)
- Apr (4)
- May (5)
- Jun (6)
- Jul (7)
- Aug (8)
- Sep (9)
- Oct (10)
- Nov (11)
- Dec (12)

Answer If If yes, water systems are turned on based on: Temperature Is Selected

Q51 Water cooling systems are turned on when the temperature exceeds:

- 75 (1)
- 80 (2)
- 85 (3)
- other (4) \_\_\_\_\_

Q52 If cows have access to outside areas, do they have access to the following water sources?

	Yes (1)	No (2)
Pond (1)	<input type="radio"/>	<input type="radio"/>
Stream (2)	<input type="radio"/>	<input type="radio"/>
Free-standing water after a storm (3)	<input type="radio"/>	<input type="radio"/>

Q53 Who milked the majority of the cows on this operation during the past year?  
(NAHMS)

- Owner/Operator (1)
- Family member(s) of owner (2)
- Hired worker(s) non-family members (3)

Q54 How many different people milk your cows during an average week? \_\_\_\_\_

Q55 Have you gained/hired any new milkers over the past 12 months? If so, how many?

- Yes (1) \_\_\_\_\_
- No (2)

Q56 What is the total number of people who milk each milking? \_\_\_\_\_

Q57 Is that consistent for each milking?

- Yes (1)
- No (2)

Q58 Over the past 12 months, how many times a day did you milk your cows? Are they even intervals?

- 2x with 12 hr intervals (1)
- 2x with uneven intervals (2)
- 3x with 8 hr intervals (3)
- 3x with uneven intervals (4)
- Other (5) \_\_\_\_\_

Q59 Does the number of milkings vary with season? (ex. Summer vs. Winter)

- Yes (1)
- No (2)

Q60 Are fresh cows milked more frequently?

- Yes (1)
- No (2)

Q61 Briefly describe the pre- and post- milking teat preparation routine used for the majority of cows. This question will be followed up with more specific questions. Check all that apply. (*Can use milking procedure form for Q61- Q67*)

- Wash pen (wash animals in holding pen before they enter the parlor) (1)
- Water hose (2)
- Dry wipe (to clean teats of debris, not to dry teats) (3)
- Wet wipe (4)
- Predip (5)
- Strip (9)
- Dry teats (to dry after wet wipe or predip) (6)
- Postdip (7)
- Other (8) \_\_\_\_\_

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows. Water hose Is Selected

Q62 If a water hose is used, is this with or without disinfectant?

- With disinfectant (1)
- Without disinfectant (2)

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows. This question will be followed up with more specific questions. Dry wipe (to clean teats of debris, not to dry teats) Is Selected

Q63 When dry wiping teats, do you use cloth or paper towels? Are the towels single or multiple use?

- Cloth towel, single use (1)
- Cloth towel, multiple use (2)
- Paper towel, single use (3)
- Paper towel, multiple use (4)

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows.&nbsp; This question will be followed up with more specific questions. Wet wipe Is Selected

Q64 Is the wet wipe purchased commercially? If not, is a towel or sponge used with either commercial or purchased disinfectant? Is the wipe single or multiple use?

- Single use commercial wipe (1)
- Multiple use commercial wipe (2)
- Single use towel with commercial disinfectant (3)
- Multiple use towel with commercial disinfectant (4)
- Single use towel with homemade disinfectant (5)
- Multiple use towel with homemade disinfectant (6)
- Multiple use sponge with disinfectant (7)

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows.&nbsp; This question will be followed up with more specific questions. Predip Is Selected

Q65 How is the pre-dip applied? Is the pre-dip commercial or homemade?

- Applied by sprayer with commercial disinfectant (1)
- Applied by sprayer with homemade disinfectant (2)
- Applied with predip cup with commercial disinfectant (3)
- Applied with predip cup with homemade disinfectant (4)
- Applied as foam with commercial disinfectant (5)
- Applied as foam with homemade disinfectant (6)

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows.&nbsp; This question will be followed up with more specific questions. Dry teats (to dry after wet wipe or predip) Is Selected

Q66 After either wet wipe or predip, are teats air dried, with a cloth towel, or a paper towel? Is the towel used once per cow or multiple cows?

- Air dry (1)
- Single use cloth towel (2)
- Multiple use cloth towel (3)
- Single use paper towel (4)
- Multiple use paper towel (5)

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows.&nbsp; This question will be followed up with more specific questions. Postdip Is Selected

Q67 How is the post-dip applied? Is the post-dip commercial or homemade?

- Applied by sprayer with commercial disinfectant (1)
- Applied by sprayer with homemade disinfectant (2)
- Applied with post-dip cup with commercial disinfectant (3)
- Applied with post-dip cup with homemade disinfectant (4)
- Applied as foam with commercial disinfectant (5)
- Applied as foam with homemade disinfectant (6)
- Teats covered in commercial powder (8)
- Other (7) \_\_\_\_\_

Answer If Briefly describe the pre-milking teat preparation routine used for the majority of cows.&nbsp; This question will be followed up with more specific questions. Postdip Is Selected

Q68 Did you stop using a wet post-milking disinfectant product during extremely cold temperatures? (NAHMS)

- Yes (1)
- No (2)

Q69 Which of the following best describes your use of barrier teat dips?

- Used on all cows, all of the times (1)
- Used on all cows during the winter or adverse weather (2)
- Used only on selected cows (e.g. Mastitis) (3)
- Used only at dry off (4)
- No barrier teat dip used on this farm (5)
- Other (6) \_\_\_\_\_

Q70 Selection of pre- and post-milking teat disinfectants has typically been based on (rank your answer):

- \_\_\_\_\_ Cost (1)
- \_\_\_\_\_ Historical effectiveness (2)
- \_\_\_\_\_ Convenience (3)
- \_\_\_\_\_ Recommendation by veterinarian (4)
- \_\_\_\_\_ Recommendation by industry personnel (5)
- \_\_\_\_\_ Recommendation by other producers (6)
- \_\_\_\_\_ Other (7)

Q71 What is the average cost of pre-milking and post-milking teat disinfectant?

	Cost per unit (1)	Size unit purchased (2)	How long does unit last? (3)
Premilking teat disinfectant (1)			
Postmilking teat disinfectant (2)			

Q72 Is a standard operating procedure developed for milking?

- Yes (1)
- No (2)... Skip to Q76

Answer If Is a standard operating procedure developed for milking? Yes Is Selected

Q73 If yes, is the milking procedure written?

- Yes (1)
- No (2)

Answer If Is a standard operating procedure developed for milking? Yes Is Selected

Q74 Is the milking procedure available in the parlor?

- Yes (1)
- No (2)

Answer If Is a standard operating procedure developed for milking? Yes Is Selected

Q75 Is the milking procedure available in the primary language spoken by the milking personnel?

- Yes (1)
- No (2)

Q76 How frequently does the owner/manager observe milking? (If they don't milk themselves)

- Never (1)
- When there is a problem (2)
- Less than once a month (3)
- About once each month (4)
- About once each week (5)
- About once each day, only one milking time (6)
- About once each day, alternating between different milking times (7)
- Each milking (8)

Q77 How often did milkers wear latex or nitrile gloves during milking cows over the last 12 months? (NAHMS)

- Always (1)
- Sometimes (2)
- Never (3)

Q78 How are the milking units cleaned between cows?

- They are not (1)
- Automatic back flush with disinfectant (2)
- Automatic back flush with water (3)
- Manually dipping units in bucket (4)
- Rinsed with hose if dirty (5)

Q79 Do you use automatic take-offs for your milking units?

- Yes (1)
- No (2)

Answer If Do you use automatic take-offs for your milking units? Yes Is Selected

Q80 If automatic take-offs are used, how often are the units set to manual or the unit replaced on cows after being automatically removed?

- Often (1)
- Rarely (2)
- Never (3)

Q81 How frequently is the milking deck washed where the cows stand? (RA)

- Floors are washed during and between milking groups (1)
- Floors are washed only between groups (2)
- Floors are washed as needed during milking (3)
- Floors are washed after each milking (4)
- Floors are not washed between every milking (5)

Q82 How frequently is the milking system/pipeline washed?

- After each milking (1)
- Once daily (2)
- Other (3) \_\_\_\_\_

Q83 What steps are included in washing the pipeline?

- Rinse (1)
- Hot wash/detergent (2)
- Acid rinse (3)
- Acid rinse combined with sanitizer (4)
- Sanitizer (5)

Q84 If sanitizing cycle is used, when does it occur?

- Before every milking (1)
- After every milking (2)
- Before and after every milking (3)
- A separate sanitizing cycle is not run (4)

Q85 How often do you typically clean and inspect pulsators?

- Never (1)
- Less than once a year (2)
- About once a year (3)
- About twice each year (4)
- About 4 times a year (5)
- About once each month (6)
- About twice each month (7)
- At each milking (8)
- Other (11) \_\_\_\_\_

Q86 How often do you typically clean and inspect vacuum control and/or regulator?

- Never (1)
- Less than once a year (2)
- About once a year (3)
- About twice each year (5)
- About 4 times a year (6)
- About once each month (7)
- About twice each month (8)
- At each milking (9)
- Other (11) \_\_\_\_\_

Q87 How often do you typically check for cracks and aging in rubber components?

- Never (1)
- Less than once a year (2)
- About once a year (3)
- About twice each year (4)
- About 4 times a year (5)
- About once each month (6)
- About twice each month (7)
- At each milking (8)
- Other (11) \_\_\_\_\_

Q88 How often do you perform overall milking system maintenance checks and evaluations?

- Never (1)
- Less than once a year (2)
- About once a year (3)
- About twice each year (4)
- About 4 times a year (5)
- About once each month (6)
- About twice each month (7)
- At each milking (8)
- Other (11) \_\_\_\_\_

Q89 Are the following milking system checks performed by on-farm personnel or a qualified technician?

	On farm personnel (1)	Qualified technician (2)	Both (3)
Pulsators cleaned and inspected (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Vacuum control / regulator inspected (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
System maintenance check and evaluation (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Cracks and aging in rubber components (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Answer If Are the following milking system checks performed by on-farm personnel or a qualified technician? - Qualified technician Is Selected Or Are the following milking system checks performed by on-farm personnel or a qualified technician? - Both Is Selected

Q90 If milking system checks are performed by a qualified technician, what is the name of the company and the person performing the checks.

Company\_\_\_\_\_

Person\_\_\_\_\_

Q91 Over the past 12 months, what type of inflation has been used? List company and model below.

Company\_\_\_\_\_ Model\_\_\_\_\_

Q92 Over the past 12 months, what has been the typical replacement strategy for inflations?

\_\_\_\_\_

Q93 Who of the following are responsible for diagnosing mastitis? (NAHMS)

- Owner (1)
- Milkers (2)
- Manager/Herdsman (3)
- Other (4) \_\_\_\_\_

Q94 How many people treat cases of mastitis on your farm? \_\_\_\_\_

Q95 How do you check for clinical mastitis?

- See abnormal milk on filter (1)
- Check for abnormal milk once per day or less (2)
- Check for abnormal milk every milking (3)
- CMT positive (4)
- Swollen quarter (5)
- Decreased milk yield and sick cow (6)
- Veterinarian diagnosis (7)
- Other (8) \_\_\_\_\_

Q96 How much do you estimate a clinical case of mastitis costs you? \_\_\_\_\_  
\_\_\_\_\_

Q97 When would you start IMM antibiotic therapy for clinical mastitis?

- Electrical conductivity or any other automatic parameter changed (1)
- A few flakes present in milk that disappear after a few strips (2)
- A moderate number of flakes still present after 10-15 strips, but no thick or stringy clots in milk (3)
- Thick or stringy clots in milk and/or the quarter is red, hot and swollen (4)
- Sick cow (dehydrated, lethargic, drop in milk production) with abnormal milk and/or quarter (5)
- Wait a few days to see if signs continue (7)
- After culturing (6)
- Other (8) \_\_\_\_\_

Q98 On a scale of 1-10, how painful do you think a mild clinical case of mastitis is... with 1 being no pain and 10 being the most painful?

- 0 (0)
- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- 6 (6)
- 7 (7)
- 8 (8)
- 9 (9)
- 10 (10)

Q99 On a scale of 1-10, how painful do you think a severe clinical case of mastitis is... with 1 being no pain and 10 being the most painful?

- 0 (0)
- 1 (1)
- 2 (2)
- 3 (3)
- 4 (4)
- 5 (5)
- 6 (6)
- 7 (7)
- 8 (8)
- 9 (9)
- 10 (10)

Q100 What traditional products do you use to manage a case of clinical mastitis?

	Product name (1)	How is the product administered? (2)	What is the dose given per day (3)	How many days do you give this product (4)	What % cases do you use this product on? (5)	What is the unit size purchases? (6)	Cost of one unit purchased? (7)
1 (1)							
2 (2)							
3 (3)							
4 (4)							
5 (5)							
6 (6)							
7 (7)							
8 (8)							

Q101 What alternative products do you use to manage a case of clinical mastitis?

	Product name (1)	How is the product administered? (2)	What is the dose given per day (3)	How many days do you give this product (4)	What % cases do you use this product on? (5)	What is the unit size purchases? (6)	Cost of one unit purchased? (7)
1 (1)							
2 (2)							
3 (3)							
4 (4)							
5 (5)							
6 (6)							
7 (7)							
8 (8)							

Q102 Are any of these additional procedures used for clinical mastitis?

- Strip quarter frequently (1)
- Oxytocin (2)
- Call veterinarian (3)
- Dry off quarter if non-responsive to therapy (4)
- Early dry off if non-responsive to therapy (5)
- Other (6) \_\_\_\_\_

Q103 How many cases of clinical mastitis were treated over the past month?

Q104 Is this number of treated clinical cases greater or less than most months?

- Greater than (1)
- Less than (2)
- About the same (3)

Q105 Is this number of treated cases based on records or memory?

- Records (1)
- Memory (2)

Q106 How do you recognize subclinical mastitis? (PR)

- CMT Positive (1)
- Other cowside SCC test (2)
- Automatic/Inline testing (e.g. electrical conductivity, individual milk components, SCC) (3)
- Monthly DHIA SCC (4)
- Don't know what subclinical mastitis is (5)
- Never have subclinical mastitis (6)
- Don't check for subclinical mastitis (7)

Q107 How much do you think a case of subclinical mastitis costs you?

Q108 Do you treat subclinical mastitis?

- Always (1)
- Sometimes (2)
- Never (3)

If Never Is Selected, Then Skip To Q112 Choice of IMM antibiotics for mastitis...

Q109 What traditional products do you use to manage a case of subclinical mastitis?

	Product name (1)	How is the product administered? (2)	What is the dose given per day (3)	How many days do you give this product (4)	What % cases do you use this product on? (5)	What is the unit size purchased? (6)	Cost of one unit purchased? (7)
1 (1)							
2 (2)							
3 (3)							
4 (4)							
5 (5)							
6 (6)							
7 (7)							
8 (8)							

Q110 What alternative products do you use to manage a case of subclinical mastitis?

	Product name (1)	How is the product administered? (2)	What is the dose given per day (3)	How many days do you give this product (4)	What % cases do you use this product on? (5)	What is the unit size purchases? (6)	Cost of one unit purchased? (7)
1 (1)							
2 (2)							
3 (3)							
4 (4)							
5 (5)							
6 (6)							
7 (7)							
8 (8)							

Q111 Are any additional procedures used to treat subclinical mastitis?

- Strip quarter frequently (1)
- Oxytocin (2)
- Call veterinarian (3)
- Dry off quarter if non-responsive to therapy (4)
- Early dry off if non-responsive to therapy (5)
- Other (6) \_\_\_\_\_

Q112 Choice of IMM antibiotics for mastitis was based on: (NAHMS)

- Veterinarian recommendation (1)
- Historical effectiveness (2)
- Historical culture and antimicrobial sensitivity results (3)
- Individual cow culture results before therapy (4)
- Cost of antibiotic (6)
- Milk withdraw time (7)
- Other (5) \_\_\_\_\_

Q113 Do you have written treatment protocols for clinical mastitis?

- Yes (1)
- No (2)

Q114 Do you keep a record of clinical mastitis cases treated with antibiotics?

- Yes (1)
- No (2)... Skip to Q118

Answer If Do you keep a record of clinical mastitis cases treated with antibiotics? Yes Is Selected

Q115 If yes, how are they recorded?

- Cow numbers are recorded on a piece of paper or dry erase board while cows are being treated (1)
- Written records on a notepad or calendar by date (2)
- Written records are kept for individual cows (3)
- Electronic records are kept by calendar date (4)
- Electronic records are kept for individual cows (5)

Answer If Do you keep a record of clinical mastitis cases treated with antibiotics? Yes Is Selected

Q116 Are these recorded in any of the following programs?

- Excel (1)
- PC-DART (2)
- DairyComp305 (3)
- Other (4) \_\_\_\_\_

Answer If Do you keep a record of clinical mastitis cases treated with antibiotics? Yes Is Selected

Q117 What types of information are recorded?

- Date (1)
- Cow (2)
- Quarter (3)
- Severity of signs (4)
- Treatment applied (5)
- Organism (if cultured) (6)
- Other (7) \_\_\_\_\_

Q118 Do you participate in Dairy Herd Improvement Association testing for SCC?

- Yes (1)
- No (2)... Skip to Q120

Q119 If Yes, ask them to sign a letter of agreement to access their DHI records.

Q120 How often do you monitor bulk tank reports?

- Rarely (1)
- If there is an issue (2)
- Check about once a month (3)
- Check about once a week (4)
- Check each delivery (5)
- Monitor each delivery using a spreadsheet (6)

Q121 At what level of bulk tank SCC do you take action?

- >600,000 cells/ml (1)
- 600,000 cells/ml (2)
- 500,000 cells/ml (3)
- 400,000 cells/ml (4)
- 300,000 cells/ml (5)
- 200,000 cells/ml (6)
- Other (7) \_\_\_\_\_

Q122 At how many treated cases per week do you start troubleshooting?

- >15% (1)
- 15% (2)
- 10% (3)
- 5% (4)
- (5)
- Other (6) \_\_\_\_\_

Q123 In the past 12 months, have you made any management changes to deal with mastitis?

- Yes (1)
- No (2)... Skip to Q126

Answer If In the past 12 months, have you made any management changes to deal with mastitis? Yes Is Selected

Q124 If yes, what was the reason for change?

- Increased clinical mastitis in the herd (1)
- Increased SCC (2)
- Bulk tank SCC greater than goal of (3) \_\_\_\_\_
- Bulk tank SCC greater than 750,000 (4)
- Other (5) \_\_\_\_\_

Answer If In the past 12 months, have you made any management changes to deal with mastitis? Yes Is Selected

Q125 What changes were made?

Q126 Do you discard milk from high SCC cows?

- Yes, If yes, describe when below. (1) \_\_\_\_\_
- No (2)

Q127 Do you feed discard milk to calves?

- Yes (1)
- No (2)

Q128 When selecting sires, which of the following do you include in your genetic selection decisions?

- SCS - Somatic cell score (1)
- PL - Productive Life (2)
- Semex scoring system - Immunity Plus (3)
- Net Merit Index (4)
- TPI/JPI or similar index (5)
- Other (6) \_\_\_\_\_
- None of the above (7)

Q129 Do you routinely singe or clip udders?

- Yes (1)
- No (2)

Q130 When are the udders typically singed or clipped?

- Around calving (1)
- At dry off (2)
- During the dry period (3)
- Spring (4)
- Summer (5)
- Fall (6)
- Winter (7)
- Other (8) \_\_\_\_\_

Q131 During the past 12 months, have you vaccinated your cows to control mastitis? (NAHMS)

- Yes (1)
- No (2)... Skip to Q133

Answer If During the past 12 months, have you vaccinated your cows to control mastitis? (NAHMS) Yes Is Selected

Q132 Which mastitis vaccine have you used?

	Yes or No (1)	# Injections x Volume (2)	Size of Bottle (3)	\$/Bottle (4)
Coliform vaccine (e.g. J5, J-Vac, Endovac-Bovi) (1)				
Staph. aureus (2)				

Q133 For cows or heifers purchased or raised off-site, which of the following practices have routinely been used in the past 12 months?

- Quarantine animals from the herd for 2-3 weeks to observe for disease (1)
- Check SCC in lactating cows (2)
- Culture milk quarters (3)
- None of the above (4)

Q134 During the past 12 months, what percentage of cows was dried off based on: (NAHMS)

	% (1)
Set Schedule (so many days prior to calving) (1)	
Minimum milk production level (2)	

Q135 During the past 12 months, what percentage of cows were dried off by:

	% (1)
Abruptly stopping milking (1)	
Reducing milk production first (2)	

Answer If During the past 12 months, what percentage of cows were dried off by:  
Reducing milk production first - % Is Greater Than 0

Q136 Milk production was reduced by which of the following methods:

- Skip milkings before complete dry off (e.g. milk once a day) (1)
- Reduce the quality / energy content of feed (2)
- Restrict access to feed (3)
- Restrict access to water (4)
- Other (5) \_\_\_\_\_

Q137 What percentage of cows received intramammary antibiotics at dry off during the last 12 months?

- 0% (3)
- 100% (1)
- < 100%, Write in the percentage treated below (2) \_\_\_\_\_

Q138 What percentage of cows received intramammary teat sealants at dry off during the last 12 months?

- 0% (3)
- 100% (1)
- < 100%, Write in the percentage treated below (2) \_\_\_\_\_

Q139 What percentage of cows received external teat sealants at dry off during the last 12 months?

- 0% (3)
- 100% (1)
- < 100%, Write in the percentage treated below (2) \_\_\_\_\_

Q140 If selective use of intramammary antibiotics, internal teat sealants, or external teat sealants was done (e.g. <100%), how were cows selected?

	IMM Antibiotics (1)	Internal Teat Sealant (2)	External Teat Sealant (3)
High SCC (2)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
History of mastitis (clinical/chronic) (3)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Milk production (4)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
During adverse weather only (5)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
During one or more seasons (6)	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q141 Do you use alcohol pads before administering dry-cow IMM antibiotics? (NAHMS)

- Yes (1)
- No (2)

Q142 Of all cows treated during the past 12 months with dry-cow IMM antibiotics, which of the following products were used? (NAHMS)

- Spectramast DC (ceftiofur hydrochloride) (1)
- Cefa-Dri/Tomorrow (cephapirin benzathine) (2)
- Boviclox, Dry-Clox, Dry-Clox Intramammary Infusion; Orbenin-DC (cloxacillin benzathine) (3)
- Gallimycin-Dry (erythromycin) (4)
- Biodry (novobiocin) (5)
- Hanford's/US Vet Go Dry (penicillin G procaine) (6)
- Quartermaster Dry Cow Treatment (penicillin G procaine/dihydrostreptomycin) (7)
- Albadyr Plus Suspension (penicillin G procaine/novobiocin) (8)
- Other (9) \_\_\_\_\_

Q143 Were any IMM antibiotics administered to dairy heifers during the past 12 months? (NAHMS)

- Yes (1)
- No (2)... Skip to Q145

Answer If Were any IMM antibiotics administered to dairy heifers during the past 12 months? (NAHMS) Yes Is Selected

Q144 If yes, what percentage of heifers were treated?

Q145 Were milk cultures performed on any of the following during the last 12 months? (NAHMS)

	Yes (1)	No (2)
Individual cows (1)	<input type="checkbox"/>	<input type="checkbox"/>
Bulk tank milk (2)	<input type="checkbox"/>	<input type="checkbox"/>
String samples (samples representing a group/pen of cows) (3)	<input type="checkbox"/>	<input type="checkbox"/>

If No Is Equal to 3, Then Skip To Q152

Q146 During the past 12 months, what types of cows were typically selected for milk culturing? (NAHMS)

	Yes (1)	No (2)
Fresh cows (1)	<input type="checkbox"/>	<input type="checkbox"/>
All clinical mastitis cases (2)	<input type="checkbox"/>	<input type="checkbox"/>
Chronic clinical mastitis cases (3)	<input type="checkbox"/>	<input type="checkbox"/>
Clinical mastitis cases that did not respond to treatment (4)	<input type="checkbox"/>	<input type="checkbox"/>
High somatic cell count cows (5)	<input type="checkbox"/>	<input type="checkbox"/>
Other (6)	<input type="checkbox"/>	<input type="checkbox"/>

Q147 During the past 12 months, were any of the milk cultures performed by: (NAHMS)

	Yes (1)	No (2)
Farm personnel, done on farm (1)	<input type="checkbox"/>	<input type="checkbox"/>
A state or university diagnostic lab (2)	<input type="checkbox"/>	<input type="checkbox"/>
A commercial lab (3)	<input type="checkbox"/>	<input type="checkbox"/>
A private veterinary lab (veterinary clinic) (4)	<input type="checkbox"/>	<input type="checkbox"/>

Q148 Were any of the following organisms identified from milk cultured during the past 12 months? (NAHMS)

	Yes (1)	No (2)
Strep. agalactiae (1)	<input type="checkbox"/>	<input type="checkbox"/>
Staph. aureus (2)	<input type="checkbox"/>	<input type="checkbox"/>
Mycoplasma (3)	<input type="checkbox"/>	<input type="checkbox"/>
E. coli/Klebsiella/other Gram negative (4)	<input type="checkbox"/>	<input type="checkbox"/>
Coagulase negative staph (CNS) (staph. Spp) non-aureus (5)	<input type="checkbox"/>	<input type="checkbox"/>
Environmental strep (Strep. Spp.) non-agalactiae (6)	<input type="checkbox"/>	<input type="checkbox"/>

Q149 How much does it cost to culture a sample?

Q150 How many samples were cultured over the past month?

Q151 Was the number of samples cultured the past month similar to other months of the year?

- Yes (1)
- No (2)

Q152 Which of the following management practices do you regularly use for your transition cows - close up and fresh cows?

- A specific close up ration is fed (1)
- A calcium gel is given near calving (2)
- Check for sub-clinical ketosis using cow-side or other tests (3)
- Temperature check post calving (4)
- Monitoring technology data (activity, rumination, etc.) (7)
- Other (5) \_\_\_\_\_

Q153 What type of ration do you feed to your lactating herd?

- Total mixed ration (1)
- Grazing (2)
- Grazing with supplementation (3)
- Component feeding (4)
- Other (5) \_\_\_\_\_

Q154 How many times per day do you offer fresh feed? \_\_\_\_\_

Q155 How many times a day do you push up feed? \_\_\_\_\_

Q156 Is fresh feed available to cows after milking?

- Yes (1)
- No (2)

Q157 Do you feed for refusal?

- Yes (1)
- No (2)

Answer If What type of ration do you feed to your lactating herd? Grazing Is Selected Or What type of ration do you feed to your lactating herd? Grazing with supplementation Is Selected

Q158 If grazing, do you graze rotationally or continuously?

- Rotationally (1)
- Continuously (2)

Answer If If grazing, do you graze rotationally or continuously? Rotationally Is Selected

Q159 If rotationally grazing, how many hours/days/time between rotations from pasture to pasture?

\_\_\_\_\_

Answer If What type of ration do you feed to your lactating herd? Grazing Is Selected Or What type of ration do you feed to your lactating herd? Grazing with supplementation Is Selected

Q160 What is your stock rate per acre?

\_\_\_\_\_

Q161 Do you use feed additives to manage SCC?

- Yes (1)
- No (2)... Skip to Q163

Answer If Do you use feed additives to manage SCC? Yes Is Selected

Q162 If yes, what products do you use?

---

Q163 What is your average feed cost for the lactating per cow per day?

Q164 What is the cost of raising a replacement heifer from birth to calving? (Do not include the initial cost of the heifer)

---

Q165 What veterinarian(s) do you use? Name, city, state

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Q166 Do you have regularly scheduled visits from your veterinarian?

- Yes (1)
- No (2)... Skip to Q168

Answer If Do you have regularly scheduled visits from your veterinarian? Yes Is Selected

Q167 If yes, how often does the vet vist? (# times/year)

---

Q168 On average, how many paid and unpaid personnel, including owners and family members, had duties directly related to the dairy's operation? (Exclude people that worked exclusively with crop activities) (NAHMS)

	# (1)
Full time (40+ hr per week) (1)	
Part time (< 40 hr per week) (2)	

Q169 Do your employees primarily speak the same language as you?

- Yes (1)
- No (2)

Q170 What is the average hourly wage for general farm labor? (milking, feeding, routine animal-related tasks)

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---

Q171 What is the average hourly wage or salary for management?

---

---

Q172 Were personnel trained in the following procedures during the past 12 months?

	Training provided		Person providing training					
	Yes (1)	No (2)	Owner (1)	Manager/herd sperson (2)	Other employee (3)	Veterinarian (4)	University/ex tension (5)	Industry personnel (6)
Milking (1)	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Mastitis detection (2)	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
Intramammary infusion (3)	<input type="radio"/>	<input type="radio"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>

Q173 During the past 12 months, how frequently were milkers trained?

- Trained new personnel (1)
- Regularly scheduled training during the year (2)
- When there was a problem (3)
- Other (4) \_\_\_\_\_

Q174 Which of the following milker training methods were used during the past 12 months? (NAHMS)

	Yes (1)	No (2)
Video/web based training (1)	<input type="checkbox"/>	<input type="checkbox"/>
Discussion/lecture (2)	<input type="checkbox"/>	<input type="checkbox"/>
On the job training (3)	<input type="checkbox"/>	<input type="checkbox"/>

Q175 How many meetings regarding milk quality have you attended in the past 12 months?

---

Q176 How many meetings regarding milk quality have your employees attended in the past 12 months?

---

Q177 What is your position on the farm?

- Owner (solely or jointly) (1)
- Manager (2)
- Non-family business (3)
- Other (4) \_\_\_\_\_

Q178 What is the highest level of education you have reached?

- Less than a high school degree (1)
- High school degree (2)
- Some college or technical education (3)
- College degree (4)

Q179 How old are you?

- (1)
- 26-35 (2)
- 36-45 (3)
- 46-55 (4)
- 56-65 (5)
- 66-75 (6)
- 76-85 (7)
- 86-95 (8)
- >95 (9)

Q180 How likely is each of these scenarios? (Check one box for each)

	Not likely at all (1)	Somewhat likely (2)	Very likely (3)	Almost certainly (4)
You or a close family member will be operating your farm 5 years from now (1)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
You or a close family member will be operating your farm 10 years from now (2)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your farming operation will include dairy 5 years from now (3)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>
Your farming operation will include dairy 10 years from now (4)	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>	<input type="radio"/>

Q181 Approximately what percentage of your total 2013 household income was from off farm employment?

- None (1)
- 1-25% (2)
- 26-50% (3)
- 51-75% (4)
- 76-100% (5)


Q182 Time finished (military time) \_\_\_\_\_

Q183 Producer data quality

















- Good to excellent (1)
- OK (2)
- Poor (3)



## Appendix 2: Teat Condition Scoring (Minnesota, 2011)



### TEAT CONDITION SCORE

Score	 				Score
0	<p><b>CRACKS</b> Teats with cracks are scored a half point higher. i.e. 1.5 or 3.5</p>				
1					1.5
2					2.5
3					3.5
	<p>Cracked teat ends have been associated with incidents of mastitis. Quantification of cracked teat ends in a herd maybe important to help improve overall udder health.</p>				
					4.5



### TEAT SHAPES

	
<b>ROUND - 1</b>	
	
<b>INVERTED / FLAT - 2</b>	
	
<b>TAPERED - 3</b>	