Adoption of Mastitis Control Technologies in the Southeast to Reduce Mastitis and Improve Milk Quality

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Mastitis continues to be a major livestock disease afflicting the dairy industry. In the United States, this disease results in economic losses approaching $2 billion annually due to reduced milk production, milk discard, veterinary services, antibiotic use, increased labor, and reduced cow sale value (Hogan, Harmon, Langlois, Hemken, & Crist, 1984). An additional economic loss, not accounted for in this $2 billion figure, but that is well recognized, is the negative impact of mastitis on milk quality. As the industry strives to improve milk quality to meet consumer as well as exportation demands, the legal limit for bulk tank somatic cell count (SCC) will likely be reduced from 750,000/ml to 400,000/ml in the near future. It is estimated that between 10 and 20% of U.S. dairy farms, mostly located in the Southeast, are currently at or above the 400,000/ml SCC limit and will have to adopt stricter methods for controlling mastitis in their milking herds, dry cows, and heifers.

The 5-point plan of mastitis control has provided the basics of managing this disease for more than four decades and includes: 1) teat disinfection, 2) dry cow therapy, 3) use of functionally adequate milking machines, 4) therapy of clinical infections, and 5) culling of chronically infected cows (Neave, Dodd, Kingwill, & Westgarth, 1969). However, additional measures of control will have to be implemented to reduce mastitis prevalence and the associated elevation in SCC. Such management practices include maintenance of a clean and dry environment, vaccination, dietary supplementation, and mastitis control in heifers. The adoption of both the proven traditional methods and the more novel technological approaches toward mastitis management by dairy producers will have to be implemented by those with herd bulk tank SCC exceeding 400,000/ml. Extension and outreach personnel associated with agricultural universities are needed to disseminate information on appropriate mastitis management programs and assist dairy producers in attaining new quality standards.

Somatic Cell Counts and Milk Quality

Mastitis is an infectious disease associated with elevated herd bulk tank SCC, and while the legal limit for bulk tank SCC sold as Grade A milk in the United States is currently 750,000/ml, other countries have much lower limits (e.g., European Union: 400,000/ml; Australia and New Zealand: 400,000/ml; and Canada: 500,000/ml) (Lombard, Norman, Kopral, Rodriguez, & Wright, 2011). To comply with global milk quality standards, consumer demand, and exportation requirements enacted by the European Union for dairy products being exported by the United States to E.U. member countries, the U.S. dairy industry is striving to reduce the level of mastitis, improve product quality, and increase economic returns to producers. It is speculated that the U.S. legal limit for SCC in raw milk will be reduced from the current regulatory limit of 750,000/ml (U.S. Department of Health and Human Service – FDA, 2009) to 400,000/ml in the future.

The SCC is an indirect measure of the level of mastitis in a herd, and is used to assess milk quality. Elevated herd bulk tank SCC are associated with poorer milk quality as a result of management deficiencies in mastitis control. Dohoo and Meek (1982) showed that the most important factor affecting SCC was the quarter infection status, and other factors such as age, stage of lactation, season, stress, and diurnal and day-to-day variation had only minor effects.

UGA extension

Government Agency Involvement

Milk quality and mastitis control professionals recognize that it is important to improve milk quality for several stated reasons, including improved consumer confidence in the safety and wholesomeness of the U.S. milk supply and that milk is produced by healthy cows; harmonized standards for international trade of milk and milk products; improved competitive position of the U.S. dairy industry in the global market place; reduced risk of antimicrobial residues; reduced risk of human bacterial pathogens and their toxins; greater producer profits through decreased mastitis and SCC; and improved animal welfare.

In addition, it must be emphasized that: 1) elevated SCC indicate poor farm hygiene practices, improper sanitation, and mastitis, as well as an increased potential for antibiotic residues; 2) high SCC are always associated with reduced milk yield; 3) low SCC milk has a longer shelf life, better taste, and greater cheese yield; and 4) processors shipping to the European Union must prove that each supply farm's SCC is less than 400,000/ml.

Already, milk purchasers are requiring milk with lower SCC from their suppliers. Kroger recently set their SCC limit to 250,000/ml, which is down from 350,000/ml a year ago. Also, in April of 2013 a proposal to lower the U.S. legal SCC limit from 750,000 to 400,000/ml sequentially over a 2-year period was submitted to the National Committee on Interstate Milk Shipments (NCIMS). This proposal was voted down by a very narrow margin (22 to 28). Two more proposals to lower the SCC to 400,000/ml were also submitted in 2013, but received "no action" votes by the NCIMS. It is likely that similar proposals will continue to be submitted to the NCIMS and that one such proposal will be approved, thereby lowering the legal SCC limit for raw milk in the United States to 400,000/ml or lower.

Effective January 1, 2012, the U.S. dairy industry began the transition to a farm level milk sampling program to verify SCC compliance with EU regulations (SCC limit of 400,000/ml) for milk buyers that are manufacturing products for export to the EU and the producers whose milk they are receiving. Moreover, after March 31, 2012, all shipments of dairy products requiring an EU health certificate must comply with the updated certification program and must be accompanied by an updated Certificate of Conformance.

Dairymen Compliance

Complying with a legal limit of 400,000/ml set for milk destined for export or processing in the United States for the vast majority of dairy producers would not be a problem, even if it was imposed immediately. In 2008, a U.S. Animal and Plant Health Inspection Service (APHIS) survey found that the average U.S. bulk tank SCC was 245,000/ml, and that approximately 90% of individual SCC measurements were below that level. The Dairy Herd Improvement Association (DHIA) also found that the SCC of tested herds decreased from 276,000/ml in 2007 to 228,000/ml in 2010. Moreover, a 2012 Hoard's Dairyman survey (Hoard's Dairyman Research Department, 2012) showed that over 95% of U.S. bulk tanks had an SCC of less than 400,000/ml.

Although the average SCC for the vast majority of U.S. dairy farms is well below the proposed legal limit, it appears that the 5 to 10% of farms that would have problems complying are mainly located in the Southeast. This poses a significant problem for the sustainability of dairy farms in the Southeastern region. On a positive note, a recent survey revealed that producers in the Southeastern state of Kentucky recognized that mastitis and milk quality were the most important management topic issues, suggesting their awareness of the problem (Russell & Bewley, 2011).

The Southeastern Dairy Industry

A recent trend analysis regarding dairy industry sustainability indicates that the 12 Southeastern states, (i.e., Alabama, Arkansas, Florida, Georgia, Kentucky, Louisiana, Missouri, Mississippi, North Carolina, South

Carolina, Tennessee, and Virginia) are more distressed economically and less profitable. The Southeastern dairy industry had a 37% decline in milk production from 1995 to 2010. During this same period, the U.S. dairy industry experienced a 24% increase in production. Extending these trends reveals that production is forecasted to decline by 35% in the Southeast between 2010 and 2025, whereas U.S. production is projected to increase by 23% (Herndon, 2011).

Likewise, on a per cow basis, the Southeastern dairy industry had only a 13% increase in milk production per cow, from 6,350 kg per year in 1995 to 7,185 kg per year in 2010; however, elevation in production in the United States overall was 29%, increasing from 7,439 to 9,593 kg per year (Herndon, 2011).

Moreover, the 12 states making up the Southeast have seen a 64% decline in the number of dairy farms over this time period compared with a 52% decline for U.S. farms (Table 1). Alabama, Arkansas, Kentucky, Louisiana, Mississippi, and Tennessee lost the most farms (between 66 and 81% lost). Over this same period, the Southeast lost 47% of its dairy cow population (Table 1), with Alabama, Arkansas, Kentucky, Louisiana, Mississippi, and Tennessee again losing the most cows (between 52 and 80% lost) (Herndon, 2011). Such reductions in dairy operations and cow numbers invoke questions regarding the long-term sustainability of the Southeastern industry.

Table 1. Changes in the Number of Dairy Farms and Dairy Cows in the Southeast, 1995-2010

	Number of Dairy Farms					Number of Dairy Cows (thousands)				
State	**1995**	**2000**	**2005**	**2010**	**% Change 1995-2010**	**1995**	**2000**	**2005**	**2010**	**% Change 1995-2010**
AL	246	154	90	60	76	34	25	16	11	68
AR	693	427	210	130	81	60	39	22	12	80
FL	300	231	180	140	53	162	157	137	114	30
GA	536	404	320	260	52	100	88	81	78	22
KY	2,731	1,932	1,335	940	66	162	132	106	78	52
LA	646	468	280	150	77	76	58	35	20	74
MS	515	356	234	130	75	55	36	25	17	69
NC	683	447	365	290	58	86	71	54	44	49
SC	178	116	110	85	52	27	23	18	16	41
TN	1,544	999	710	490	68	127	95	70	52	59
VA	1,225	998	815	705	42	129	120	105	95	26
Total	**9,297**	**6,532**	**4,649**	**3,380**	**64**	**1,018**	**844**	**669**	**537**	**47**

Adapted from USDA-ARS Animal Improvement Programs Laboratory reports on somatic cell counts of milk from DHI herds (1995-2010). Information from all states can be found at http://aipl.arsusda.gov/publish/arr.htm.

By focusing on milk production per farm as an indicator of profitability, the sustainability of Southeastern herds is further brought into question: from 1995 to 2010 the Southeastern dairy industry realized a 51% increase in output per farm, whereas output for the United States increased 161%—a 3-fold rise in production (Herndon, 2011).

Table 2 illustrates the test day milk production in Southeastern herds enrolled in the Dairy Herd Improvement (DHI) Program from 2001 to 2010 (U.S. Department of Agriculture – AIPL, 2001-2012). The 10-year Southeastern average production was 13% less than the national average (28.6 vs. 32.1 kg). While average U.S. production increased by 1.68 kg per day from 2001 to 2010, the Southeastern average increase was only 0.68 kg per day (approximately 50% as much)—three states actually realized a decrease in daily yield. Clearly, based on milk production, the profitability of the dairy industry in the Southeast is less competitive with the rest of the nation (Herndon, 2011).

Table 2. Test Day Milk Production and SCC in Southeastern DHI program herds, 2001-2010

	Milk Production (lb/day)						Somatic Cell County (thousands)					
State	2001	2003	2005	2007	2010	Avg.	2001	2003	2005	2007	2010	Avg.
AL	51.8	51.4	51.5	50.6	48.5	51.1	444	517	433	407	415	445
AR	51.7	56.7	58.4	55.1	53.0	55.3	486	387	448	441	421	433
FL	66.3	67.4	72.9	69.0	68.6	68.8	548	633	473	333	274	421
GA	62.8	60.6	63.1	61.2	64.0	62.5	407	479	433	422	337	406
KY	59.4	60.8	65.0	63.3	65.2	62.8	413	419	392	354	313	375
LA	53.9	55.1	55.1	51.2	53.8	54.1	479	498	416	446	380	450
MS	60.4	63.2	64.1	64.9	62.9	63.1	442	480	386	337	290	388
NC	66.9	66.0	66.8	68.2	66.2	66.7	364	414	358	324	279	345
SC	61.3	60.3	62.4	62.8	63.3	62.2	404	448	387	355	349	379
TN	59.0	58.9	60.7	59.6	60.7	60.0	413	476	504	418	396	434
VA	67.3	66.0	69.0	68.5	70.0	68.5	333	374	320	309	285	320
SE avg.	60.1	60.6	62.6	61.3	61.5	61.3	430	466	414	377	342	400
US avg.	69.0	69.6	71.1	71.4	72.7	70.8	322	319	296	276	228	284
% diff.	-13	-13	-12	-14	-15	-13	+25	+20	+28	+27	+33	+29

Adapted from USDA/ARS Animal Improvement Program Laboratory reports on somatic cell counts of milk from DHI herds (2001-2010). Information from all states can be found at http://aipl.arsusda.gov/publish/arr.htm.

In addition to overall milk production, milk quality in the Southeast is also at issue. Poor quality milk is associated with an elevated SCC. This milk is an inferior product with reduced processing properties, resulting in reduced shelf life of dairy products (Jayarao, Pillai, Sawant, Wolfgang, & Hegde, 2004).

Conversely, high quality milk has a very low SCC, a longer shelf life, tastes better, and is more nutritious. Milk from uninfected mammary glands contains greater than 100,000 somatic cells/ml. A milk SCC greater than 200,000/ml suggests that an inflammatory response has been elicited and that a mammary quarter is infected or recovering from an infection; it is a clear indication that milk has reduced manufacturing properties. It is not uncommon for milk from cows with mastitis to contain several hundred thousand and even millions of somatic cells per milliliter of milk.

Thus, an increase in milk SCC is a good indicator of mastitis, which alters milk composition and reduces milk yield. Most studies that evaluated the influence of mastitis on milk composition used SCC as the basis for determining the infection status of udders and for determining the degree of inflammation as reviewed by Sharif and Muhammad (2008).

The U.S. average Dairy Herd Improvement Association (DHIA) SCC in 2010 as a measure of quality was 228,000/ml, but this figure for the Southeast was 342,000/ml (range 274,000-421,000)—approximately 50% higher than the national average (Table 2). Over the 10-year period covering 2001-2010, the 12 Southeastern states, for the most part, have progressively decreased their DHIA SCC; however, each state's 10-year average is still greater than 100,000 cells/ml higher than the national average, demonstrating poorer milk quality in this region.

It should be noted that although climactic differences likely contribute to the differences in SCC, differences in mean SCC between geographically close or adjacent Southeastern states are substantial. This difference suggests that implementation of mastitis control programs can have a positive impact regardless of climactic conditions and that milk quality in the Southeast can be improved by using cost effective control strategies.

Adopting Better Mastitis Control Measures

Dairy producers in the Southeast will have to adopt stricter methods of mastitis control in their milking herds, dry cows, as well as in their heifers in order to reduce the incidence of mastitis, increase production, and successfully lower their bulk tank SCC to be competitive with the rest of the nation. Producers have had several tools at their disposal that have been available for many years to incorporate into mastitis control programs.

Heat and humidity are thought to be factors that make it difficult and perhaps impossible to lower SCC in this region. Heat and humidity do not cause mastitis, but these factors do increase the ability of mastitis-causing bacteria to grow and thrive in the cows' environment.

However, it is the management deficiencies on many Southeastern farms that allow these potential pathogens to actually cause infections. There are many well-managed operations in the Southeast that consistently have SCC well under 400,000/ml throughout the year; thus, implying that this level can be achieved. A 2012 survey revealed that among Georgia, Kentucky, Tennessee, and Virginia dairy farmers, the percentage of bulk tank SCC below 400,000/ml ranged between 64.3% (August) and 87.9% (November). Traditional mastitis control measures as well as newer management strategies have been proven to work, and have been adopted by those Southeastern dairymen producing high quality (low SCC) milk; those struggling with milk quality need to follow the lead of their successful neighbors.

Full adoption of both proven traditional methods and the more novel technological approaches toward mastitis management by dairy producers will be necessary to lower the prevalence of this disease, lower bulk tank SCC, and improve milk quality. The effect of udder health management practices on herd SCC was recently reviewed (Dufour, Frechette, Barkema, Mussell, & Scholl, 2011). The review emphasized the importance of a comprehensive understanding of the management practices that influence SCC and revealed the SCC control tools that are ineffective.

This bulletin discusses both the traditional and supplemental mastitis control recommendations, and the extent that they have been adopted (or not adopted) by U.S. dairymen based on two national surveys. The outcome should help milk quality and mastitis control experts to prioritize the practices needed for more successful management of this disease.

Mastitis control measures were assessed and their rates of adoption determined in two recent surveys. The 2012 Hoard's Dairyman Continuing Market Study (Hoard's Dairyman Research Department, 2012) was based on a questionnaire mailed out to 3,000 producer names selected randomly from a subscription list by a computer count and covered the year 2011. The return rate was 1,310 questionnaires or 43.6%. The 2007 National Animal Health Monitoring System (NAHMS) survey was based on 17 of the nation's major dairy states in the Western and Eastern regions representing 79.5% of U.S. dairy operations and 82.5% of U.S. dairy cows (U.S. Department of Agriculture – NAHMS, 2008). Where possible, the NAHMS survey reported data from small (less than 100 cows), medium-sized (100 to 499 cows), and large (more than 500 cows) herds. Most management practices evaluated revolve around the milking process itself, and each practice is discussed in sequence from the beginning of milking to the end of this process. Additional mastitis management practices not directly related to milking are also discussed.

Mastitis Control Measures Surveyed and Their Rates of Adoption

The Milking Process

Wearing of Gloves. The wearing of disposable latex or nitrile gloves in the milking parlor is recommended to reduce the transfer of mastitis-causing bacteria from milkers' hands to cows' teats during the milking process (Figure 1). Rodrigues, Caraviello, and Ruegg (2005) demonstrated that wearing gloves during milking was significantly associated with lower bulk tank SCC. For example, in low bulk milk SCC (less than 250,000/ml) herds, 86.1% of herds used gloves, whereas in high bulk milk SCC (greater than 400,000/ml) herds, only 55% of herds used gloves.

Bacteria that can cause mastitis naturally colonize the skin of human hands, and bacteria originating from infected udders can contaminate human hands; both serve as sources of new infection during the udder preparation process as milkers forestrip the teats. By wearing gloves, cows' teat skin is protected against bacteria residing on milkers' hands. Additionally, bacteria are less likely to adhere to the smooth surface of gloves compared with the rough texture of milkers' hands, thus fewer pathogens are transferred to cows' teats. Of course, if gloves become heavily soiled with organic material, they should be replaced or washed in sanitizing solution.

Results of the NAHMS (2008) survey showed that 55.2% of all dairy operations used gloves, and in these operations, gloves were worn when milking 76.8% of cows. Thus, 45% of farms do not use gloves when milking cows, and the reduction in spread of mastitis-causing bacteria, especially contagious bacteria such as *Staphylococcus aureus* could be accomplished by following this simple mastitis management technique. The practice of wearing gloves was not evaluated by the Hoard's (2012) survey.

Forestripping. This practice involves the manual removal of several streams of milk from each mammary quarter of the udder prior to machine attachment as part of the premilking udder preparation routine (See Figure 1). The purpose of forestripping is to: 1) flush the teat canal of bacteria and other organic contaminants that could elevate bulk tank bacteria counts and cause machine-induced infections; 2) allow the milker to observe milk for any abnormalities, such as clots or flakes associated with clinical mastitis, so that affected cows can be separated and treated; and 3) promote milk let-down. In a study of herd management practices and their association with bulk tank SCC, Wenz, Jensen, Lombard, Wagner, and Dinsmore (2007) observed that herds that practiced forestripping of all or some (i.e., mastitic and fresh cows) of the cows tended to have lower SCC (less than 400,000/ml) than higher SCC herds (greater than 400,000/ml) that did not forestrip.

Figure 1.

According to the NAHMS (2008) survey, 58.9% of all dairy operations forestrip all cows as part of their udder prep procedure. Larger herds (83.5%) followed the practice of forestripping all cows more than medium-sized (66.9%) and smaller herds (53.7%). The approximate 41% of operations that do not forestrip all cows are most likely omitting this procedure in order to save time in the parlor. However, all sized operations with high herd bulk tank SCC should be utilizing this practice to prevent new cases of mastitis as well as to identify existing clinical cases of mastitis for treatment. The practice of forestripping was not evaluated by the Hoard's (2012) survey.

Surprisingly, 43.3% of all operations forestripped teats after disinfection (predipping) and/or drying, which is not a recommended practice. Smaller herds were the biggest culprit (47%) followed by medium herds

(38.7%) and larger herds (22.4%). Only 27.4% of all herds forestripped prior to teat disinfection, which is the recommended practice, and 29.3% forestripped after teat disinfection but prior to drying of teats.

By forestripping first, any bacteria already present on the teat skin as well as from milkers' hands are killed by the premilking teat disinfectant. However, milkers should not forestrip after predipping and drying. By forestripping the sanitized and dried teat with contaminated hands, bacteria are redeposited on teat surfaces, which can potentially cause mastitis, and this is the case in 43.3% of all operations. Based on regional data, the percentage of operations that forestripped after disinfection and drying (not the recommendation) was 2-fold higher in the East (45.2%) than the West (22.8%).

Predipping. The practice of immersing teats in a germicidal solution prior to milking (predipping as shown in Figure 2) kills a large number of bacteria on the teat skin and reduces the chances of them entering the teat canal and causing intramammary infections (IMI). The germicide is applied by dipping, spraying, with towels, or as a foam, and must remain on the teat skin for 30 seconds to allow sufficient time for microbiocidal activity to take place. Predipping is 40 to 50% effective in preventing new IMI by environmental pathogens such as *Escherichia coli, Klebsiella, Enterobacter, Citrobacter, Serratia, Streptococcus uberis,* and *Streptococcus dysgalactiae*. It is even effective against the contagious pathogen *S. aureus* (Nickerson, 2001).

Figure 2.

The NAHMS (2008) survey showed that across all modes of germicide application and across all herd sizes, 79% of operations used a form of teat preparation. Dipping by immersion was most popular followed by spraying, and use of foam was very low; use of presanitized towels to prepare teats was not reported. Larger herds (38.2%) used spray application of labeled disinfectant more than medium (25.4%) and smaller (13.6%) herds, and use of a predip cup to apply labeled disinfectant was more popular in smaller herds (49.8%) compared with medium (51%) and large (32.3%) herds. Western herds were more likely to apply germicide as a spray, whereas Eastern herds were more likely to apply via dipping.

Likewise, the Hoard's (2012) survey showed that 72.9% of operations use predipping or spraying prior to milking. Based on these two surveys, approximately 20 to 25% of dairy operations do not sanitize teats prior to milking. Predipping (as well as postdipping) is one of the best and inexpensive milking management practices to prevent new infections, especially with environmental pathogens, and with the trend toward larger dairies and confined operations with greater exposure to these bacterial species, all producers should be sanitizing teats prior to milking to reduce the level of mastitis in their herds.

According to the NAHMS (2008) survey, the most common germicide in predip formulations was iodine (59.7%), followed by chlorhexidine (11.8%), other-unspecified (7.9%), chlorine (7.2%), fatty acid-based (2.5%), quaternary ammonium (0.3%), and phenol (0.1%).

Drying teats prior to milking. After sanitization, teats must be dried prior to machine attachment to remove germicidal residues, bacteria, and organic material such as dirt, bedding material, and manure. Recommendations for drying include single-service paper towels or individual, rewashable cloth towels. A study of management practices associated with low, medium, and high bulk milk SCC showed that herds that practiced drying of teats prior to milking were associated with low bulk milk SCC (less than 150,000/ml) whereas herds did not follow this practice were associated with high bulk milk SCC (251 to 400/ml) (Barkema et al., 1998).

According to the Hoard's (2012) survey, 67.4% of respondents follow the drying recommendation: 44% use single-service paper towels and 23.4% use rewashable cloths. Unfortunately, 5.2% use either common rags (4.5%) or common sponges (0.7%), both which become contaminated and actually promote the spread of mastitis-causing bacteria.

Similarly, the NAHMS (2008) survey demonstrated that approximately 76% of producers use single-service paper (54.7%) or rewashable cloth (21.5%) towels; however, 7.8% are spreading mastitis-causing bacteria using multiple-use cloth or paper towels. Thus, based on the two surveys, 25 to 30% of producers are not following recommendations for drying teats prior to milking. Between 7.8 and 9.7% are actually promoting the development of infections by using either common rags and sponges or multiple-use cloth or paper towels.

After teats are prepared, the milking machine is applied, usually within 1 min of forestripping to take maximum advantage of the milk letdown response. The milker holds the claw in hand, the vacuum is turned on, and the four teat cups are applied with minimal intake of air. Milk begins flowing immediately, and the machine may need adjusting so that it hangs squarely and straight down from the cow. Maximal intramammary pressure caused by milk letdown continues for about 5 min, and most cows will milk out in 5 to 7 min. Shortly after that, milk flow will decrease to a point where automatic take-offs cause the milking machine to detach.

Automatic take-offs. Automatic take-offs detect a low flow of milk from the teat end and cause the milking cluster to detach from the udder, whether the cow is fully milked out in all four quarters or not. This action prevents overmilking and helps to maintain proper teat end condition. Healthy teat canals and teat orifices are less prone to bacterial colonization and subsequent development of IMI. In an effort to develop guidelines for monitoring bulk milk SCC, Jayaro et al. (2004) observed that dairy herds that used automatic milking detachers had significantly lower bulk tank SCC than herds that did not use detachers (298,560/ml vs. 352,650/ml).

Results of the NAHMS (2008) survey indicated that only 45.4% of dairy operations use automatic take-offs. Use of these devices was more common in large dairies (89.5%), followed by medium dairies (76.9%), and small operations (30.2%). The 55% that do not use takeoffs should consider doing so to improve teat end condition and reduce the prevalence of IMI associated with poor teat end condition. The use of automatic take-offs was not evaluated by the Hoard's (2012) survey.

Backflushing the milking unit. The process of backflushing sanitizes the milking cluster between cows to reduce the spread of contagious pathogens among cows during milking (Figure 3). This action includes a blast of sanitizer through

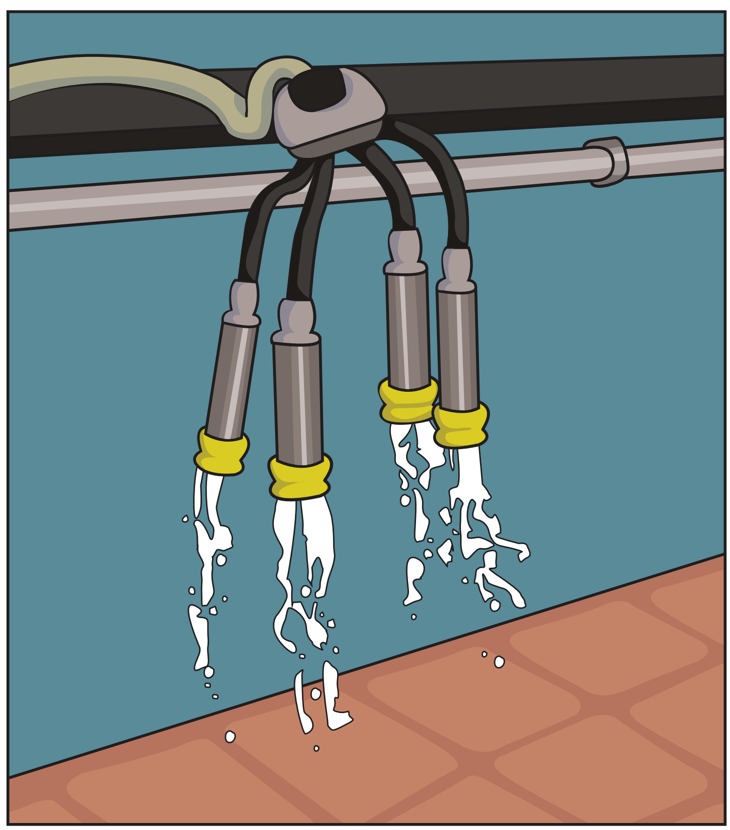

Figure 3.

the cluster and teat cups to disinfect the lining, followed by a blast of water to rinse out the sanitizer, and lastly, a blast of air to dry the system. This process is effective in removing contaminants from teat cup liners before placement on teats of uninfected cows and helps to reduce spread of the contagious mastitis-causing bacteria such as *S. aureus*.

Two trials conducted to test the efficacy of an iodine backflush system for reducing new IMI demonstrated that the back-flushing of milking clusters reduced infections caused by *S. aureus* and *Corynebacterium bovis*; however, use of the system produced no clear advantage for reducing new IMI with coagulase-negative staphylococci, Gram-negative bacilli, or the environmental streptococci (Hogan et al., 1984). In Trial 1, numbers of new *S. aureus* IMI were reduced in quarters exposed to backflushing compared with controls (3 vs. 10); numbers of new *C. bovis* IMI were also reduced (7 vs. 17). In Trial 2, numbers of new *S. aureus* IMI were reduced in quarters exposed to backflushing compared with controls (1 vs. 4); numbers of new *C. bovis* IMI were also reduced (10 vs. 39).

The NAHMS (2008) survey showed that across all dairy operations, only 6.8% used backflush systems, which were slightly more common in large operations (9.3%) than medium (8.6%) or small operations (5.9%). Thus, over 93% of operations have not installed a backflush system. Most experts agree however, that if an effective postmilking teat disinfectant is being used, a backflush system is not necessary. Backflushing was more common in Western herds vs. Eastern herds. The use of backflushing was not evaluated by the Hoard's (2012) survey.

Postdipping. The practice of immersing teats in a germicidal solution immediately after milking (postdipping) kills a large number of contagious bacteria on the teat skin that originate from contaminated teat cup liners and reduces the chances of them entering the dilated teat canal and causing IMI. Postdipping is one of the points in the 5-point plan of mastitis control developed in the 1960s (Neave et al., 1969), and continues to be a major milking management practice to prevent new IMI. The germicide is applied by dipping, spraying, inline sprayers, or as a foam. Postdipping is 50 to 95% effective in preventing new IMI with the contagious pathogens such as *S. aureus* and *S. agalactiae* (Nickerson, 2001).

The NAHMS (2008) survey showed that across all modes of germicide application and across all seasons, 94.8% of operations used some form of postmilking teat antisepsis. Dipping by immersion was most popular followed by spraying; use of foam was very low. Likewise, the Hoard's (2012) survey showed that 90.5% of operations followed the practice of postdipping after milking.

Based on these two surveys, approximately 5 to 10% of dairy operations do not sanitize teats after milking. Postdipping is one of the best milking management practices to prevent new infections, especially with contagious pathogens, so all producers should be sanitizing teats after milking to reduce the level of mastitis in their herds.

According to the NAHMS (2008) survey, the most common germicide in postdip formulations was iodine (68.8%), followed by chlorhexidine (12.8%), fatty acid-based (6.8%), other-unspecified (3.9%), chlorine (2%), and quaternary ammonium (0.6%).

Other Mastitis Management Practices

Vaccination against mastitis. Immunization is used to stimulate the production of antibodies against mastitis-causing bacteria in the cow's body to prevent the establishment of infection as well as to reduce the severity of infection. The majority of research trials have focused on coliform and *S. aureus* vaccines. Early studies on the commercially available J5 mutant coliform bacterin revealed that the percentage of clinical mastitis cases caused by *E. coli* and *Klebsiella* spp. was lower in vaccinated cows (2.4%) compared with unvaccinated controls (12.1%) (Gonzalez et al., 1989).

Efficacy studies on the only commercial *S. aureus* vaccine (Lysigin®) suggests that it will increase the spontaneous cure rate against *S. aureus* IMI and lower SCC, but does not prevent new IMI in adult cows (Pankey, Boddie, Watts, & Nickerson, 1985). However, this vaccine was shown to be effective in preventing new *S. aureus* IMI when administered to bred dairy heifers (Nickerson, Owens, Tomita, & Widel, 1999).

The NAHMS (2008) survey showed that 39.7% of dairy operations reported using some type of mastitis vaccine on all of their cows. The most common vaccine was directed against coliforms (32.6%), followed by *Salmonella* (11.1%), *S. aureus* (5.7%), siderophore receptors and porins (3.3%), and *Mycoplasma* (1.4%). In the Hoard's (2012) survey, the percentage usage was slightly higher but similar at 41.9%; however, it was not broken down into vaccine types. Thus, overall, approximately 60% of farms do not use a mastitis vaccine.

Certainly most farms would benefit by using some type of coliform vaccine program. It is well known that 20 to 40% of clinical cases are caused by environmental pathogens including coliforms, and that fresh, high-producing cows are very susceptible to new infections. In addition, the cost for each clinical episode of coliform mastitis ranges from $100 to $400. In one study, a partial budget analysis of vaccinating dairy cattle against coliform mastitis demonstrated that the cost to benefit ratio of immunizing all cows in the herd with a coliform vaccine was $1 to $57 (DeGraves & Fetrow, 1991).

Among the three coliform vaccines commercially available in the United Stated, the J-5 Bacterin enjoys the majority of the market (42.3%) followed by the J-Vac (37.8%), and Endovac-Bovi (16.7%), whereas the *S. aureus vaccine* comes in at 2.6% (Figure 4).

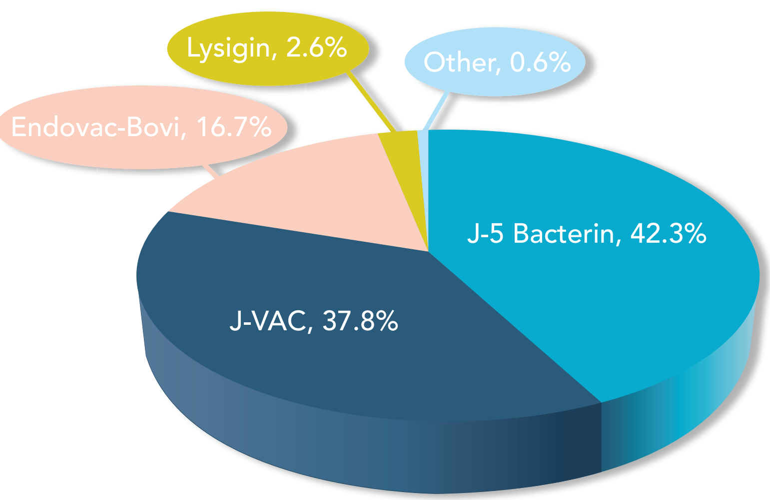

Figure 4.

Antibiotic treatment of clinical mastitis cases during lactation. As with postdipping, the prompt treatment of clinically infected quarters with antibiotics is also one of the points in the 5-point plan of mastitis control (Neave et al., 1969). This practice decreases the duration of IMI as long as treatment is successful in curing the infecting organism. Although a true cure, whereby all infecting microorganisms are eliminated from the affected quarter, occurs in only 10 to 50% of cases, successful therapy removes the main source of contagious pathogens from the herd. Therefore, treatment of clinical infections is still a recommended practice (Nickerson, 1996).

The Hoard's (2012) survey reported that 59.6% of dairy operations use some type of remedy for treating lactating cows for mastitis, and of these operations, 89.9% infused antibiotics into the affected quarter (e.g., 53.5% of all operations used lactating cow therapy to treat clinical cases of mastitis). Other means of administering antibiotics included intramuscular and intravenous injections. Thus, nearly 50% of producers do not follow the practice of prompt treatment of clinical mastitis as recommended in the 5-point plan. Treatment of clinical cases was not evaluated by the NAHMS (2008) survey.

Antibiotic therapy at the beginning of the nonlactating period. Also known as dry cow therapy, this practice also is a component of the 5-point plan (Neave et al., 1969), and involves infusing all quarters of all cows with a nonlactating cow infusion product at the end of lactation. The purpose of this therapy is 2-fold as it: 1) cures existing IMI and 2) prevents new cases of mastitis during the early dry period when mammary glands are highly susceptible to new infection.

Dry cow therapy is very advantageous to udder health because the practice prevents mastitis in the early dry period, reduces the prevalence of infection at calving, minimizes antibiotic contamination, allows milk-producing tissue to redevelop in cured quarters, and reduces clinical mastitis at freshening. Efficacy against pathogens such as *S. aureus* may range from 33 to 70% but despite this low cure rate, the end of lactation provides the optimum time for treatment because efficacy of lactational therapy is even lower and requires milk withdrawal (Erskine et al., 1998).

The NAHMS (2008) survey showed that 72.3% of all operations dry treat all cows, and the Hoard's (2012) survey found that this figure was 82.2%; thus, about 23% of U.S. dairies do not use dry cow therapy. According to the NAHMS survey, the most used antibiotic for dry cow therapy was penicillin G/dihydrostreptomycin (36.9%) followed by cephapirin benzathine (31%), penicillin/novobiocin (13.2%), cloxacillin benzathine (7.9%), ceftiofur hydrochloride (7%), and other products.

Use of internal teat sealants at drying off. Internal teat sealants, commonly composed of bismuth and paraffin, are infused into each quarter at the end of lactation. The teat sealant material is very heavy and viscous, and forms a physical seal in the distal teat cistern as well as in the teat canal against bacterial penetration (Figure 5). It is removed after calving at the first milking, but it is inert, so does no harm if ingested by the calf.

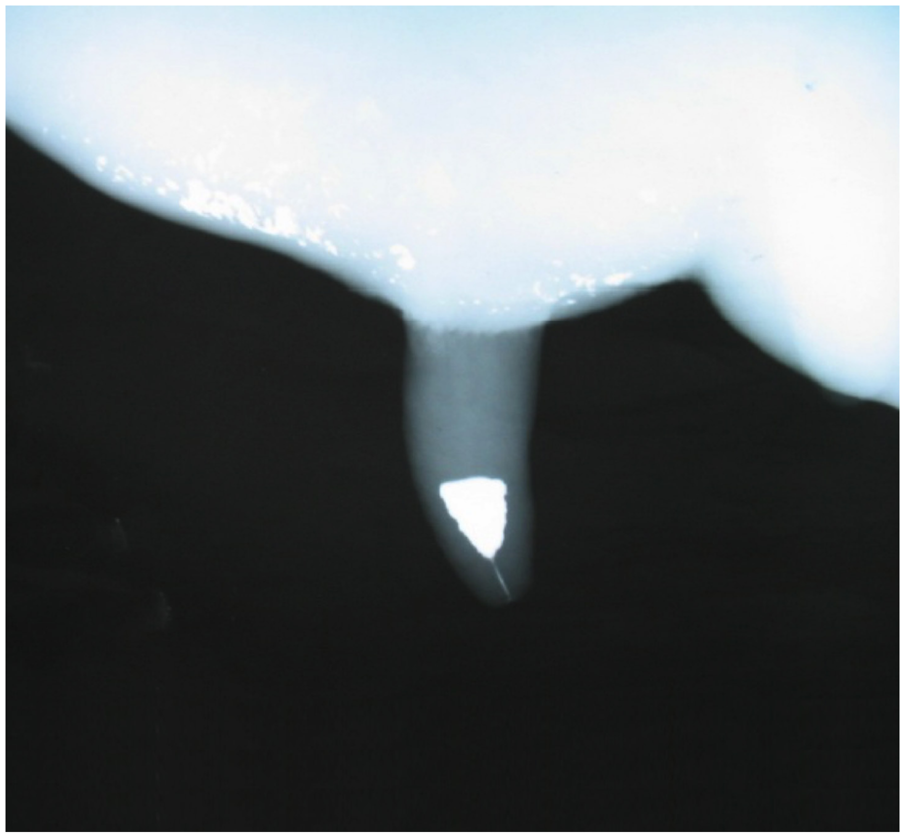

Figure 5.

Studies have shown that use of teat sealants is 50 to 90% effective in preventing new IMI. For example, Laven and Lawrence (2008) showed that cows and heifers treated with a teat sealant at dry-off (cows) or 1-month prepartum (heifers) experienced greater than a 2-fold reduction in clinical mastitis during early lactation compared with untreated controls (6.9% vs. 14.2%).

Results of the NAHMS (2008) survey showed that 30.1% of all operations used a sealant in all cows at drying off. Teat sealants were more commonly used in larger (49%) and medium herds (45.7%) than smaller herds (22.7%). Likewise, the Hoard's (2012) survey showed that 32% of operations used a teat sealant. So, based on results of these two surveys, close to 70% of dairy operations do not use this management technique.

Potential Mastitis Management Practices

Fly control. Fly control is used to reduce these insect pests on farm premises, and subsequently to reduce animal stress; its application as an adjunct management practice for preventing new cases of mastitis and reducing SCC has not been considered or embraced by producers. However, an initial survey in Louisiana showed that prevalence of mastitis in bred heifers was significantly lower in dairy herds that used some form of fly control for their lactating cows, dry cows, and heifers compared with herds applying no fly control (Nickerson, Owens, & Boddie, 1995).

A subsequent study demonstrated that horn flies are responsible for teat lesions on heifers' teats (Figure 6). Lesions can develop into *S. aureus* IMI, which are then spread among heifers by these insect vectors. These pathogens may be transmitted to the entire lactating and nonlactating herds (Owens, Oliver, Gillespie, Ray, & Nickerson, 1998). The use of an insecticidal pour-on every 2 weeks for 6 weeks followed by treatment with insecticidal ear tags reduced fly populations and decreased the incidence of new *S. aureus* IMI by 83% during a 6-month trial in heifers during the warm season in Louisiana (Owens, Nickerson, & Ray, 2002).

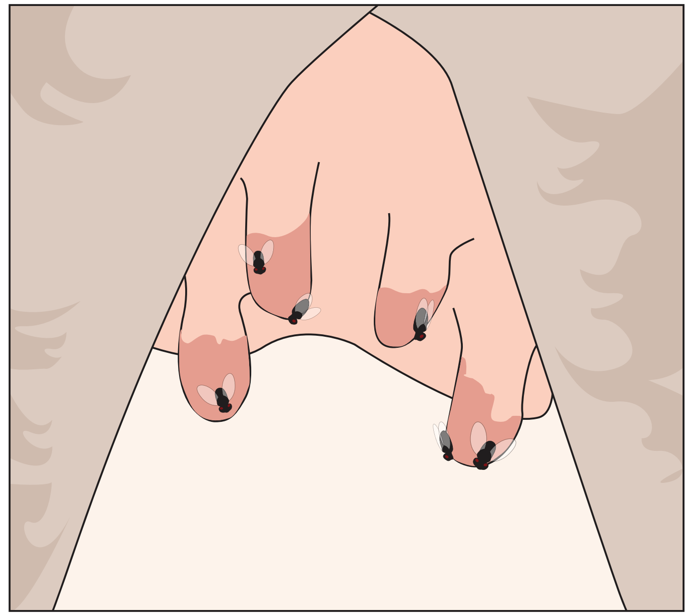

Figure 6.

Although not specifically used to control mastitis, the Hoard's (2012) survey reported that 81.1% of producers used some type of fly control. The majority of products were used as a pour-on (44.3%) and aerosol (32.4%) followed by bait, paper, foggers, and others. The good news is that over 80% of operations use fly control, it just needs to be incorporated into a heifer mastitis program.

Dietary supplementation. Supplementing cows' diets with certain trace minerals and vitamins (e.g., vitamin E, selenium, vitamin A, beta-carotene, vitamin D, copper, and zinc) has been shown to have immunomodulatory effects on the mammary gland (Sordillo, Shafer-Weaver, & DeRosa, 1997). Most of these substances serve as fundamental components of antioxidant processes that are involved in the reduction of reactive oxygen species released during phagocytosis (cell digestion) and killing of bacteria by leukocytes, or they facilitate epithelial (tissue) barriers to infection.

Commercial feed additives incorporating an array of the above supplements plus microbial by-products have been formulated. The Hoard's (2012) survey reported that 32.3% of dairy operations use some type of commercial yeast or yeast culture as a feed additive. It is believed that yeast supplements act as probiotics, positively influencing rumen microflora, digestion, and subsequently improving milk yield, especially in early lactation.

More recently, a nutritional specialty product for ruminants (OmniGen-AF®, Prince Agri Products, Inc., Quincy, IL) has been developed and is believed to function at the level of the gastrointestinal tract by modulating immune function. Livestock supplemented with this product exhibit heightened immunity during periods of stress and to microbial challenge. For example, Wang, Puntenney, Burton, and Forsberg (2007) found that immunosuppression in sheep could be reversed in animals supplemented with OmniGen-AF®. Likewise, Rowson, Wang, Aalseth, Forsberg, and Puntenney (2010) infused various mastitis-causing pathogens into the mammary glands of mice, and found that animals receiving dietary OmniGen-AF® daily for 2 weeks prior to infusion exhibited significantly reduced bacterial loads, indicating a positive effect of the feed supplement on the ability of the murine mammary gland to resist IMI.

In cows, Eubanks et al. (2012) demonstrated that feeding of OmniGen-AF® to a limited number of dairy heifers prior to calving resulted in a 3-fold reduction in prevalence of mastitis in early lactation, a 4-fold reduction in SCC, and a 3.2-kg increase in milk production compared with unsupplemented controls, suggesting that dietary supplementation may alleviate stress associated with calving and enhance immunity during the periparturient period (the time immediately around calving). However, results are preliminary, and further testing is required before making a general recommendation.

Implications for Future Udder Health Control

Based on the responses from the two surveys, adoption rates for recommended milking procedures and other management practices (e.g., vaccination, antibiotic therapy, teat sealants) are summarized in Table 3. Adoption rates observed in both surveys were surprisingly similar across all mastitis management practices evaluated, and the overall adoption rate is an average of the two surveys where applicable; some practices were only evaluated by one of the surveys, not both.

Table 3. Surveyed Adoption Rates of Recommended Milking Practices and Other Management Practices to Control Mastitis in Dairy Cows

Recommended Milking Procedure	Adoption Rate (%)
Forestripping	60
Predipping	77.5
Postdipping	92.5
Wearing Gloves	55
Segregate/Milk Last	65
Use Automatic Take-offs	45
Other Management Practices	
Vaccination	45
Treating Clinical Mastitis	50
Dry Cow Therapy	77
Teat Sealants	35
Overall Adoption Rates	**~60**

Survey results revealed that approximately 40% of dairy producers are not following the recommended management practices to control mastitis in their herds, and it is likely that many of these producers are located in the Southeast. In view of these findings, it will be necessary for extension and outreach personnel to train producers and employees on how best to utilize current and newly developed mastitis management tools to make on-farm decisions that improve milk quality and increase milk production.

Likewise, continuing education programs need to be developed to create human resources needed for a more knowledgeable work force to promote mastitis control and improved milk quality. Implementation of cost effective mastitis prevention and control strategies for the Southeastern region will result in higher milk quality, increased milk production, and improved profitability, all of which will benefit dairy producers in the Southeast and enhance the sustainability of the dairy industry in this region.

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