Management Strategies to Reduce Heat Stress, Prevent Mastitis and Improve Milk Quality in Dairy Cows and Heifers

Stephen C. Nickerson, Professor; Animal and Dairy Science Department

To maximize milk production, efficiency and profits, the dairy industry must place considerable pressure on the modern dairy cow. With animal health and welfare in mind, mature animals are bred to calve once a year and remain pregnant and lactating for at least seven months. Cows are machine-milked in parlors two, three and in some instances four times daily, and those milked by robots may choose to be milked five or more times a day. Unless they are on grazing operations, these animals are often housed in confinement barns and must walk on concrete alleyways. In addition, cows are genetically selected and bred to produce more and more milk, and are fed copious quantities of high-energy feed to support ever-increasing volumes of milk. As demands for increased milk yield and milking efficiency continue to rise in order to feed the growing world population, greater stress is placed on the dairy cow's productive capacity. Unfortunately, hot and humid environmental conditions, solar radiation, animal crowding, insect pests and poor ventilation add to this stress, and are associated with an increased risk of mastitis, resulting in lower milk quality and reduced production.

To reduce this environmental stress, it is vital to keep cows as comfortable as possible, which maximizes dry matter intake (DMI) and optimizes milk yield. This publication focuses on strategies to enhance cow comfort during the hot and humid summer conditions, with special emphasis on practices to reduce the incidence of intramammary infections (IMI) and lower somatic cell counts (SCC), thereby increasing milk quality and quantity.

Comfortable cows exhibit minimal stress, consume more feed and produce more milk.

The objective of maximizing cow comfort is to provide an environment conducive to maximum DMI and milk production; thus, cow housing is an important component of the animal's environment. For example, cows lay down for 11-12 hours per day; thus, freestalls must be of the proper dimensions and stocked at the appropriate rate for maximum utilization. Most importantly, bedding materials (sawdust, wood shavings, sand, rice hulls, etc.) should be soft, clean and dry. In the laying position, cows' teats contact bedding materials, which always contain a population of mastitis-causing bacteria. These environmental streptococci (e.g., *Streptococcus uberis*, *Streptococcus dysgalactiae*) and coliforms (e.g., *Escherichia coli*, *Klebsiella pneumonia*) must be maintained at very low numbers by keeping bedding material as clean and dry as possible to avoid outbreaks of environmental mastitis. Additionally, pastures and dry lots should be kept clean and dry to minimize bacterial contamination of teats, and shade should be provided to protect against solar radiation. Finally, cows should be afforded an environmental temperature that alleviates heat stress, promotes feed intake and maximizes milk production.

Controlling heat stress is important to animal well-being.

The major modern dairy breeds are of northern European origin, and are most comfortable at a temperature range of 41 to 77°F. These animals are tolerant of very low environmental temperatures (e.g., < 0°F) but intolerant of temperatures above 77°F, especially when the relative humidity is greater than 80%. Older, heavier, highproducing cows are more susceptible to heat stress than smaller, younger animals, and Holsteins tend to be more sensitive than Brown Swiss, Guernseys, Jerseys and Brahmans. Heat stress becomes a particular problem in the southeastern United States where elevations in heat and humidity during the summer months have a negative effect on udder health and production. In the Southeast as well as the rest of the country, the incidence of mastitis is greatest during July, August and September, concomitant with an elevation in SCC (Figure 1). This is followed by a decrease in milk production for August, September and October. Thus, as we expect greater yields from dairy cows, and place pressure on their productive capacity, controlling heat stress becomes even more critical.

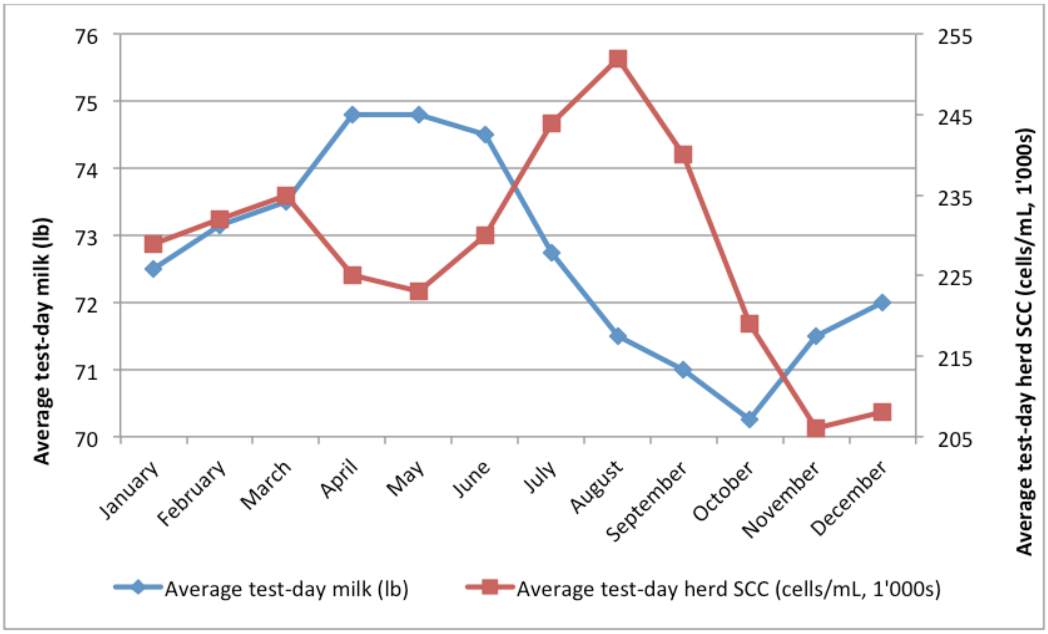

Figure 1. Association between test-day milk yield and somatic cell count by month of the year.

Heat stress exerts several adverse physiological and other deleterious effects on dairy cattle (Table 1). In fact, the overall losses to the U.S. livestock industry due to heat stress are approximately $2.4B per year, with greater than 50% of losses attributed to the dairy industry.

Table 1. Changes in animal physiology and other parameters due to heat stress in dairy cows.

Decreases in:	Increases in:
Dry matter intake	Weight loss
Rate of feed passage	Somatic cell counts
Blood flow to organs	Clinical mastitis
Rumen buffering capacity	Respiration rates
Milk yield and quality	Rectal temperature
Reproductive efficiency	Water intake
Body condition score	Sweating
Heifer growth	Salivation
Immune function	Health care costs

The cow's thermo-neutral zone and how she attempts to maintain thermoneutrality.

The cow's thermo-neutral zone ranges between 50 and 68°F, in which she maintains both a normal body temperature and basal metabolic rate, and in which she is most comfortable, therefore optimizing milk production. Above this zone, she undergoes heat stress and becomes uncomfortable because she must increase maintenance requirements (metabolic rate) to partition metabolic energy into heat-dissipating activities such as increased respiration (panting), sweating and increased blood flow to the periphery of her body. Early lactation cows and high producers are most affected. Dry matter intake is depressed, and milk production may decrease by up to 50%. Moreover, above the thermo-neutral zone, the cow's immune system becomes compromised, leading to an increase in the incidence of IMI.

The temperature-humidity index (THI) measures the effect of heat stress on cows' lactational performance and accounts for the combined effects of temperature and relative humidity above the animals' thermo-neutral zone (Figure 2). For example, at a temperature of 72°F and at a relative humidity of 30%, no stress is imposed on the dairy cow. However, at 87°F and 30% humidity, the THI value is 76, which represents mild to moderate stress on the cow. Cows adjust to mild stress by seeking shade and increasing their respiration rates slightly; there is a slight decrease in milk production. During moderate stress, the body temperature increases along with respiration, salivation and water consumption, while there are decreases in feed consumption, milk yield and reproductive efficiency. If heat stress becomes severe, body temperature continues to rise along with excessive panting, salivation and water consumption; the animal is clearly uncomfortable. Feed intake and milk production are severely depressed, and if environmental conditions continue, convulsions may occur followed by death of the animal.

Temperature		% Relative Humidity																		
°F	°C	0	5	10	15	20	25	30	35	40	45	50	55	60	65	70	75	80	85	90
72	22.0	64	65	65	65	66	66	67	67	67	68	68	69	69	69	70	70	70	71	71
73	23.0	65	65	66	66	66	67	67	68	68	68	69	69	70	70	71	71	71	72	72
74	23.5	65	66	66	67	67	67	68	68	69	69	70	70	70	71	71	72	72	73	73
75	24.0	66	66	67	67	68	68	68	69	69	70	70	71	71	72	72	73	73	74	74
76	24.5	66	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75
77	25.0	67	67	68	68	69	69	70	70	71	71	72	72	73	73	74	74	75	75	76
78	25.5	67	68	68	69	69	70	70	71	71	72	73	73	74	74	75	75	76	76	77
79	26.0	67	68	69	69	70	70	71	71	72	73	73	74	74	75	76	76	77	77	78
80	26.5	68	69	69	70	70	71	72	72	73	73	74	75	75	76	76	77	78	78	79
81	27.0	68	69	70	70	71	72	72	73	73	74	75	75	76	77	77	78	78	79	80
82	28.0	69	69	70	71	71	72	73	73	74	75	75	76	77	77	78	79	79	80	81
83	28.5	69	70	71	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82
84	29.0	70	70	71	72	73	73	74	75	75	76	77	78	78	79	80	80	81	82	83
85	29.5	70	71	72	72	73	74	75	75	76	77	78	78	79	80	81	81	82	83	84
86	30.0	71	71	72	73	74	74	75	76	77	78	78	79	80	81	81	82	83	84	84
87	30.5	71	72	73	73	74	75	76	77	77	78	79	80	81	81	82	83	84	85	85
88	31.0	72	72	73	74	75	76	76	77	78	79	80	81	81	82	83	84	85	86	86
89	31.5	72	73	74	75	75	76	77	78	79	80	80	81	82	83	84	85	86	86	87
90	32.0	72	73	74	75	76	77	78	79	79	80	81	82	83	84	85	86	86	87	88
91	33.0	73	74	75	76	76	77	78	79	80	81	82	83	84	85	86	86	87	88	89
92	33.5	73	74	75	76	77	78	79	80	81	82	83	84	85	85	86	87	88	89	90
93	34.0	74	75	76	77	78	79	80	80	81	82	83	85	85	86	87	88	89	90	91
94	34.5	74	75	76	77	78	79	80	81	82	83	84	86	86	87	88	89	90	91	92
95	35.0	75	76	77	78	79	80	81	82	83	84	85	86	87	88	89	90	91	92	93
96	35.5	75	76	77	78	79	80	81	82	83	85	86	87	88	89	90	91	92	93	94
97	36.0	76	77	78	79	80	81	82	83	84	85	86	87	88	89	91	92	93	94	95
98	36.5	76	77	78	80	80	82	83	83	85	86	87	88	89	90	91	92	93	94	95
99	37.0	76	78	79	80	81	82	83	84	85	87	88	89	90	91	92	93	94	95	96
100	38.0	77	78	79	81	82	83	84	85	86	87	88	90	91	92	93	94	95	96	98
101	38.5	77	79	80	81	82	83	84	86	87	88	89	90	92	93	94	95	96	98	99
102	39.0	78	79	80	82	83	84	85	86	87	89	90	91	92	94	95	96	97	98	100
103	39.5	78	79	81	82	83	84	86	87	88	89	91	92	93	94	96	97	98	99	101
104	40.0	79	80	81	83	84	85	86	88	89	90	91	93	94	95	96	98	99	100	101

Mild
(68-72 THI)

Moderate
(72-79 THI)

Severe
(80-89 THI)

Figure 2. Temperature-humidity index values that measure the effects of heat stress on dairy cows.

As ambient temperature and relative humidity rise, heat loss from the cow decreases, and her body temperature increases. As a result, several and varied physiological and behavioral mechanisms of heat loss take over to maintain thermoneutrality. For example, blood vessels undergo dilation to radiate heat from the surface of the body, respiration (panting) increases and the animal begins to sweat, allowing the perspiration to conduct heat from her body. The cow also alters her behavior by seeking shade, locating air currents and laying in mud to conduct body heat into the earth. Unfortunately, this later mechanism of heat loss leads to environmental mastitis, which increases during the summer season along with a rise in the SCC (see Figure 1). The major environmental mastitis bacteria affecting udder health during times of heat stress are the coliforms and environmental streptococci, which thrive under warm and moist conditions, and increase the bacterial load on the teat end. Another reason that cows are more susceptible to mastitis during the summer is that the stress induced by heat makes cows uncomfortable, leading to an increase in blood corticoid (stress hormone) levels. Elevated cortisol leads to immunosuppression and a decrease in the ability of white blood cells (neutrophils) to recognize, engulf and kill mastitis-causing bacteria, making the cow more prone to udder infections during periods of environmental stress.

Other factors influencing heat stress on cows.

Wind velocity, ventilation, solar radiation, animal health, crowding and insect pests also influence heat stress on dairy cows. Similarly, breed, geographic location (latitude) and coat color can influence how cows are affected by their environment. For example, *Bos taurus* breeds, which originated in the Northern Hemisphere, are more susceptible to stress than *Bos indicus* breeds, which originated at latitudes near the equator. Likewise, cows with dark hair coats are more susceptible to heat stress than animals with lighter coats because dark hair absorbs more solar radiation and these animals radiate less body heat.

Fortunately, cows have developed mechanisms of their own for losing body heat, making them more comfortable during times of heat stress. When feeling the heat, an animal will seek air currents (wind). Through the process of convection, body heat is removed from the immediate surface of the cow by the air currents. Cows will also lie in moist, cool earth (mud) and conduct heat from their bodies into the ground. By the process of radiation, the cow's blood vessels will dilate, a process referred to as vasodilation, which helps to dissipate heat from the surface of the cow's body to the atmosphere. Additionally, by increasing her respiration rate (panting), hot, moist air from her lungs is vaporized; thus, heat is lost via evaporation. Likewise, by sweating, the moisture on her skin absorbs the heat from her body and evaporates, making her cooler. However, as heat and humidity in her environment increase, heat loss from the cow through the above mechanisms decreases.

Alleviating heat stress to make cows more comfortable.

One of the best practices to reduce heat stress is to provide adequate fresh, cool, clean drinking water. Other methods of cooling include shade, commercial coolers, tunnel ventilation, shower/fanning stations, fans, cooling ponds and center pivots.

Shade is probably the easiest and least expensive option to help cows cool themselves. For small operations, simple pasture shade trees work well; however, a high-cow density will kill trees in a matter of months due to the toxic effect of urine pH and excess nitrogen on root systems. Permanent shade structures in pastures work well but must be mounded periodically, otherwise, cows will dig out holes under shades and wet, muddy areas conducive to environmental mastitis will develop. Portable shades on skids are better, as they can bring shade to the cows and can be relocated to other areas of pasture as mud and manure accumulate. Permanent dry lot shades provide relief from the sun; however, it is important to keep shade structures away from feed bunks because cows tend to defecate and urinate where they eat. If there is shade provided over the bunk, they will lay down in feces and urine, which is a prime environment for mastitis-causing bacteria. Shade alone will reduce a cow's respiration rate by 30%, and adding sprinklers will reduce the respiration rate by 67%. Both methods of cooling will also lower rectal temperatures. Use of shade plus fans and sprinklers has an additive effect.

Use of fans is important, especially in confined structures, because fans help to move warm air from cows' bodies. Cows generate approximately 20% of their gross energy as body heat, which is released to the surrounding air, making them feel hot, especially under heat stress conditions. Fans remove this body heat via convection, thereby cooling down the surface of the animal. Sprinklers are used to soak the cow's hair coat to the skin with water, allowing the loss of body heat via conduction (e.g., heat is conducted through the water to the atmosphere). Fans plus sprinklers allow for conduction and evaporative cooling, as the fans help to vaporize the water that has been warmed by the release of body heat. Figure 3 illustrates the added effect of sprinklers on cooling cows with fans. Under the conditions of this study, heat-stressed animals were respiring at approximately 100 breaths per minute. The addition of fans resulted in some relief by decreasing respiration to almost 90 breaths per minute within 95 minutes. However, marked relief was observed by the use of fans plus sprinklers, which reduced respiration by 50% to 50 breaths per minute by 95 minutes into the trial.

Tunnel ventilation provides air movement and air exchange through a series of fans placed in one gable end wall of a freestall barn. Fans create a negative pressure in the barn, causing air to be drawn into the opposite end wall opening. Fresh, cool air flows longitudinally at a speed of 400-600 cubic feet per minute over the cows from the intake wall opening through the barn and is exhausted by the tunnel fans. The intake wall opening commonly contains a series of cooling cells, which removes heat from the incoming outside air by water evaporation. The temperature may be up to 8° C cooler inside vs. outside the barn, which lowers the cows' body temperature up to 1.2 °C, enhances cow comfort, and may result in an increase in milk production of 5-6 pounds/day.

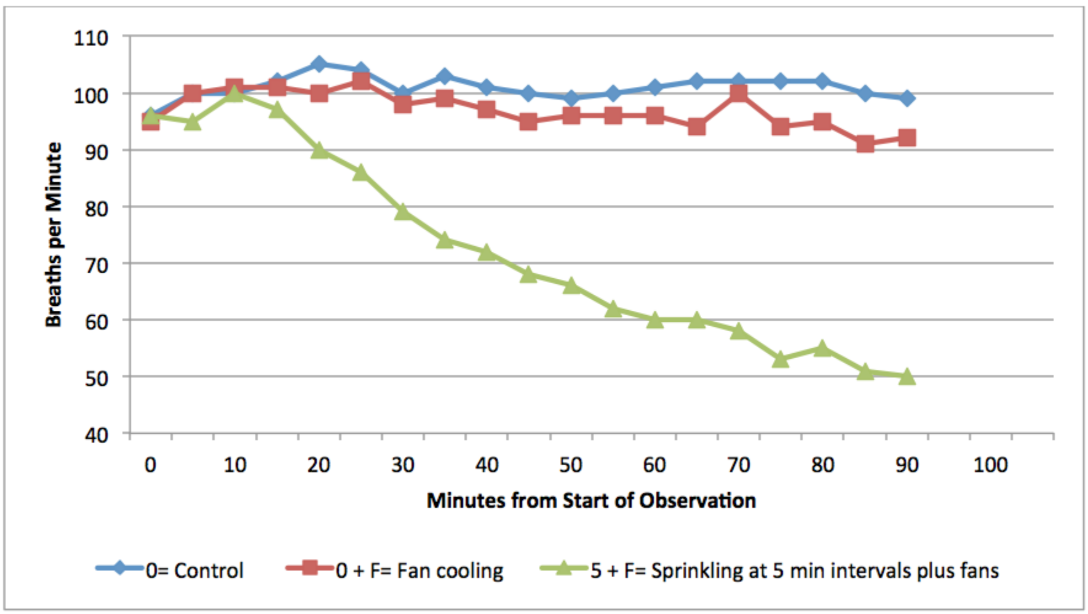

Figure 3. Impact of two cooling methods on cows exposed to heat stress.
0 = Control; 0 + F = Fan cooling; and 5 + F = Sprinkling at 5-minute intervals plus fans.

Commercial coolers combine air turbulence and high-pressure water injectors to lower the ambient temperature under shades. One study showed increased milk production (~10%), an increase in body weight of cooled cows (+49 lb) vs. uncooled cows (-54 lb), and a lower culling rate among cooled cows; however, these systems are expensive to operate. Mechanical refrigeration with evaporatively-cooled shades is another option, but they are also expensive and limited to areas with low relative humidity.

Cooling ponds have been used successfully in Florida to cool cows between milkings and just prior to entering the parlor. Such ponds are constructed either with a continuous flow or a circulating water supply system in which fresh water is provided; these are not stagnant ponds. *Prototheca zopfii*, a colorless algae, often grows in stagnant ponds, resulting in mastitis that cannot be cured with antibiotic therapy. Allowing cows access to such ponds should be avoided. Cows with access to properly designed cooling ponds exhibit less lying down in mud and manure, and less clinical mastitis.

Prior to milking, cows can be cooled in the holding pen with fans and sprinklers. The holding pen tends to be a hostile environment for cows during the summer due the combined stresses of crowding, body heat and elevated ambient temperature. To cool cows effectively, sprinklers are used to soak the hair coat to the skin, promoting body heat conduction to the surrounding air, and the fans remove this hot air surrounding the cows to the atmosphere by the process of convection. Cows must be allowed a drip/dry time of 10-15 minutes prior to entering the parlor; otherwise, water contaminated with bacteria runs down flanks and udders during milking and into the bulk tank, which increases the bacteria count. In addition, milking machine unit liner slips, vacuum fluctuations and faulty pulsation cycles in the presence of excess water on teats contaminates the claw and leads to machine-induced infections with environmental pathogens.

After milking, cows can be cooled down one more time using a shower and fanning station in the milking parlor exit lane. Spraying should cover only the top and sides of the cow so that the post-milking germicidal teat dip is not washed off. In this way, the cows are temporarily relieved from the sun, and instead of returning immediately to the shade, they follow their normal cool weather practice of eating and drinking after milking, which keeps them on their feet and allows time for teat duct closure before contact with soil, manure and bacteria that cause environmental mastitis.

In grazing operations, typical of New Zealand-style dairying, center pivots and travelling irrigators are used to cool cows during the summer, but require a close and reliable water source. The pivots both irrigate grass pastures to maintain plant growth and cool the milking herd, as shade is usually not provided to these animals. The grazing cows quickly learn that if they stand under the pivot's spray to graze or go off to graze elsewhere in the pasture after being cooled, the evaporative cooling effect helps to lower their body temperatures.

How to reduce exposure to environmental bacteria.

It is obvious that in most instances, the cooling of cows involves the use of water, which, when combined with warm temperatures, is favorable for growth of environmental mastitis pathogens in the cows' surroundings. These bacteria require only warm temperatures, nutrients, water and a proper pH in order to thrive, so hot and humid summer conditions are ideal for growth of these organisms. Environmental streps and coliforms can double their numbers every 20-30 minutes, thereby increasing the bacterial load on the udder skin and teats. Thus, dairymen must tighten herd management practices, including cow hygiene, bedding management and premilking udder prep practices to maintain excellent milk quality during periods of environmental stress.

The environmental streps include *Strep. uberis*, *Strep. dysgalactiae*, *Strep. parauberis* and *Strep. equinus*, while the coliforms include *E. coli*, *K. pneumoniae* and *Enterobacter*, *Citrobacter* and *Serratia* spp. Environmental bacteria counts in bedding materials are directly related to counts on teat ends, which can lead to IMI if bacterial numbers are excessive. Thus, IMI are directly related to the number of bacteria in bedding as well as on teat surfaces. In addition to providing clean bedding, soiled teats can be minimized by flaming and clipping of udders and frequent alley scraping. Also, areas where cows calve should be clean and dry; clean pasture areas for calving are preferred.

In addition to clean housing and surroundings, strict milking hygiene is critical for reducing environmental bacteria. When a cow enters the milking parlor, any remaining sprinkler water from the holding pen and organic matter on the udder surface must be removed because they contain numerous mastitis-causing bacteria. If left on the udder surface, these skin contaminants would be removed by the flow of milk through the milking cluster and into the bulk tank, resulting in an increase in the bacteria count. It should be noted that psychrophilic (cold-loving) bacteria from the environment can thrive at refrigerated bulk tank temperatures, increasing the bacteria count even more. Moreover, such bacteria may survive pasteurization and reduce the shelf-life of dairy products. The bacterial load present on teat ends when cows are being prepared for milking is best reduced by using teat germicides, a practice known as predipping. Premilking teat sanitization, whether accomplished by dipping teats in a germicidal solution or by using sanitized towels, foaming devices or spray, is 40-50% effective in preventing infections with environmental bacteria as long as these procedures are done correctly (Figure 4).

Figure 4. When a cow enters the milking stall, the usual recommendation is to fore-strip each quarter using the gloved hand (1). This is followed by predipping and allowing the germicide to remain in contact with the teat skin for 30 seconds (2). Next, the germicide and any remaining organic materials are removed using single-service paper or cloth towels (3). The teat orifice should then be examined to ensure it is clean (4), before attaching the milking unit (5).

Forestripping is important because it flushes environmental bacteria from the teat orifice, stimulates milk let-down and allows the machine operator to observe milk for any abnormalities. Milkers' hands can transmit bacteria to and among cows, and wearing gloves reduces this transfer because bacteria do not adhere to the rubber/plastic surfaces of gloves as strongly as they do to human skin. When a milker touches a teat contaminated with bacteria, these bacteria are transferred to the milker's hands, and when the milker touches the teats of another cow, these bacteria are transferred to those teats, which can result in new infections. Wearing gloves minimizes this potential microbial transfer.

Although predipping is sometimes performed first followed by forestripping, the sequence of forestripping followed by predipping is preferred because by forestripping first, bacteria already present on the teat skin as well as from milkers' hands via forestripping are subsequently killed by the germicide in the predip. The 30-second contact time is important because the active germicidal component (e.g., iodine or chlorine) needs this amount of time to penetrate the nooks and crannies of the teat skin to contact and kill the streptococci, coliforms and staphylococci that are colonizing these areas. The practice of premilking teat sanitization has been shown to be 40-50% effective in preventing new infections caused by *E. coli*, *Klebsiella*, *Enterobacter*, *Citrobacter*, *Serratia*, *Strep. uberis*, *Strep. dysgalactiae* and *Staph. aureus*. When predipping, it is important to cover the entire surface of the teat that will be in contact with the teat cup liner, thereby killing the maximum number of mastitis-causing bacteria.

After predipping and allowing the 30-second contact time, the germicide and any remaining organic materials are removed using single-service paper or cloth towels. The teat orifice should be examined to ensure it is clean before attaching the milking unit. During milking, teat surfaces become contaminated with mastitis-causing bacteria, both from the previous cow that may have had mastitis as well as from the cow being milked. This results in bacteria being deposited in the milk film present on the teat cup liner and teat surface. After the milking unit is removed, the film of milk remaining on the teat surface can support the growth of these organisms. However, postmilking teat disinfection (postdipping) replaces this milk film with a germicide that kills the majority of these bacteria, and this process has been shown to be 50-95% effective in preventing new IMI. As with predipping, when applying a postdip, it is important to cover the entire surface of the teat that was in contact with the contaminated teat cup liner.

When the cow leaves the milking parlor, it is recommended to offer her feed so that that she remains standing for approximately 1 hour and does not lay down in mud and manure. During this time, her teat canals remain dilated from the machine milking process, and this provides easy access to the interior of the gland by environmental bacteria. After 1 hour, the teat sphincter muscle has contracted around the teat canal keratin and formed a seal against bacterial penetration.

Nutritional aspects of heat stress management.

Water, the most important nutrient for the dairy cow, must be readily available, clean and cool to encourage consumption. Cows will drink 50% more water when the ambient temperature is 80°F compared with 40°F, so instead of consuming the average 30 gallons per day, their intake may increase to 45 gallons or more. The water consumed is used to cool cows' bodies via respired moisture and sweating as discussed above. The chilling of drinking water to 50°F alleviates heat stress as evidenced by decreased respiration and rectal temperature, resulting in increased feed intake, rumen motility and milk yield. It is important to provide at least 2 inches of trough space per animal in confinement barns to maximize access to water. It should be noted that excessive lowering of rumen temperatures by offering very cold water may suppress microbial activity and slow the fermentation process, subsequently requiring more feed energy and heat production, which is very inefficient.

Adjustments to cows' diets during heat stress may include changes in bunk management, feeding schedules and ration composition such as increased energy density and use of feed additives (buffers, potassium carbonate, yeast, etc.). Use of high-quality forages can reduce the heat generated through the digestion and assimilating processes, making cows more comfortable. For example, whole-plant corn silage and second harvests of hay are higher in energy and digestibility than first-cutting forages. Also, neutral detergent fiber (NDF) levels should be at least 28-30% of the DMI to maintain production and a normal fat test. Additional water can be added to the ration if the DMI drops significantly. It may be necessary to increase levels of certain mineral supplements to compensate for higher losses from the body during heat stress. It is recommended that the total ration dry matter include 1.5% potassium, 0.30% magnesium and 0.55% sodium. Other supplements that have been shown to be effective include *Aspergillus oryzae*, yeast culture or dried brewer's yeast, niacin and the fat-soluble vitamins A, D and E.

To minimize heat generated, the greater part of the cows' ration should be fed during the cooler periods of the days (e.g., between 4:00 and 6:00 a.m. and 9:00 and 11:00 p.m.); smaller amounts of feed can be available during daytime hours to reduce intake. Feed silages more frequently to compensate for shorter bunk life during hot weather and to prevent heating of feed, thereby improving intake. If a reasonable DMI (90%+ of usual) cannot be maintained, feed a higher fat ration (up to 5-7% of the total dry matter).

Managing heat stress during dry periods.

Dry cows typically exhibit far less DMI relative to lactating cows, and are able to cope with heat stress more effectively. However, controlling heat stress during this time when milk-producing tissues are developing can dramatically impact the cows' transition into the subsequent lactation. Heat stress abatement during the entire dry period should be stressed, as cows cooled for only the final portion of the dry period may exhibit lower production compared with cows cooled for the entire dry period.

Most studies that investigated the benefits of alleviating heat stress have placed dry cows in free stalls that provided shade, fans and sprinklers. Animals cooled with fans and sprinklers had lower rectal temperatures and respiration rates, longer dry periods, higher body condition scores, gave birth to heavier body weight calves and produced more milk (7-10 lb more) than those afforded only shaded freestalls. In addition, the immune function of heat-stressed cows was compromised, and their white blood cells exhibited a decreased capacity to kill disease-causing bacteria, such as those that cause mastitis.

Monitoring mastitis management practices during periods of heat stress.

To ensure that mastitis prevention techniques are working properly and to maximize milk quality, a milk monitoring system should be in place, especially during periods of environmental stress when milk quality will suffer. Monitoring may be as simple as the daily checking of milk pipeline filter socks and cowside screening for clinical mastitis, or more sophisticated by periodically collecting bulk tank and/or individual cow milk samples for SCC and bacteriology. Dairy producers who perform regular bulk tank milk quality monitoring are better able to keep SCC low during the hot, humid summer months. For example, Figure 5 shows the two-year monthly bulk tank SCC averages for several upper Midwest dairies, illustrating the seasonal variation between low and high bulk tank SCC herds. The low SCC herds experienced better overall herd management and more comprehensive bulk tank monitoring.

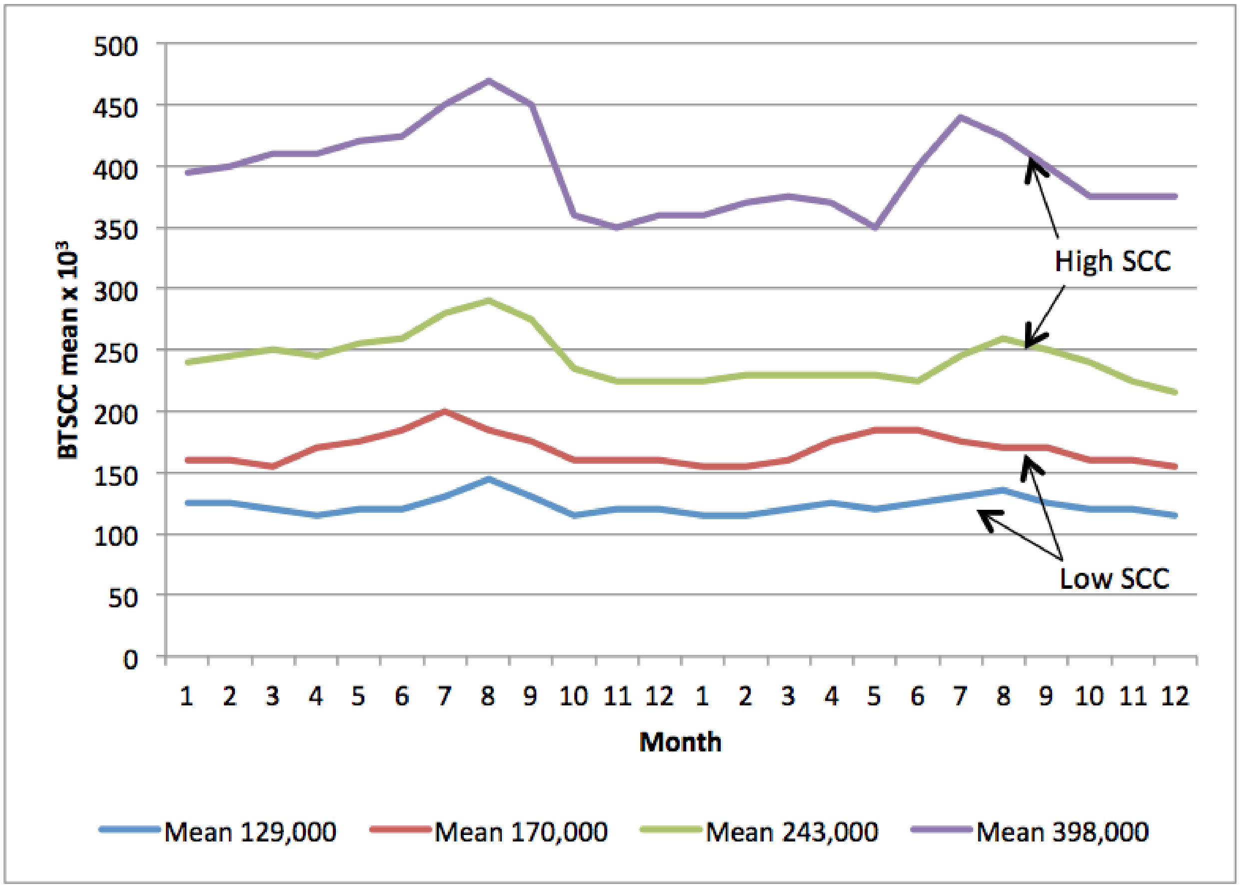

Figure 5. Two-year monthly bulk tank SCC averages for upper Midwest dairies illustrating high and low SCC herds.

From the figure, it can be observed that for years 1 and 2, the bulk tank SCC increases in months 7, 8 and 9 (July-August) were greater in the high SCC herds vs. the low SCC herds. It was concluded that the better bulk tank monitoring and udder health practices held the clinical mastitis level and bulk tank SCC in check over both years in the low SCC herds despite the hot and humid summertime conditions.

Managing heat stress in replacement heifers.

Dairy heifers also need relief from hot and humid environmental conditions. These young stock represent the future milking herd, so it is important that they remain healthy as calves and heifers and follow expected body growth patterns, reproductive cycles and mammary gland development to ensure maximum milk production in their first and subsequent lactations. Shaded areas in pastures and paddocks, and sprinklers and fans for housed animals, are necessary to counter heat stress and maximize animal comfort. Hot and humid environmental conditions are ideal for the proliferation of biting insect pest populations, such as the horn fly (*Haematobia irritans*). Horn flies irritate and cause stress to heifers by inserting their proboscis through the epidermis, mainly on the animals' backs, and sucking blood from capillaries near the skin surface. However, these flies will also attack the hairless teat skin, causing lesions that become infected with *S. aureus*. This places these mastitis-causing bacteria in an opportune position to enter the teat orifice, colonize the teat duct keratin and subsequently cause IMI. Heifer mastitis caused by *S. aureus* causes a chronic inflammation in the affected gland, preventing the milk-producing tissues from developing normally during the heifer's first pregnancy, which reduces milk production when the heifer calves.

Unfortunately, even when relief from heat stress is provided (shade, fans and sprinklers), a dense fly population will cause heifers to bunch together, which can disrupt cooling. However, stress due to horn flies can be managed by reducing contact between flies and animals through the application of insect repellents, such as pour-ons, sprays or ear tags, as well as by reducing fly populations through the incorporation of larvacides in feed additives. Such larvacides are consumed and pass through the animal's body into the feces. Adult horn flies lay eggs in feces that hatch into larvae (maggots), which consume the larvacides and perish, thus reducing the adult fly population and their subsequent procreation.

Summary

Stress is continually imposed upon dairy cows to produce more and more milk. To maximize yield, it is imperative to keep cows as comfortable as possible and maintain feed intake for conversion into milk. Heat stress negatively affects cow comfort, dry matter intake and, subsequently, milk yield; thus, management strategies must be applied to counter hot/humid environmental conditions that can lead to mastitis, increased SCC and reduced milk quality. Control is based on provision of fresh, cool, clean drinking water, and increased energy density of rations and use of feed additives, as well as the use of cooling mechanisms including shade, fans, sprinklers, tunnel ventilation, commercial coolers, cooling ponds, exit lane sprinklers and center pivots. Unfortunately, most cooling systems result in excess water in the cow's environment, which, along with warm temperatures, provides ideal conditions for the growth of mastitis-causing bacteria. Thus, the cows' surroundings must be kept as clean and dry as possible to reduce microbial growth. Additionally, the recommended premilking udder prep and milking time hygiene must be followed precisely to avoid new infections with environmental mammary gland pathogens. Bulk tank monitoring is critical during times of heat stress to ensure that mastitis control practices are indeed working and that maximum milk quality is maintained. Finally, heat stress control practices should also be applied to replacement heifers, as these animals constitute the future milking herd and their well-being must be considered in an overall herd health program.

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