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Heat Abatement Programs for Midwest Dairies

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Heat stress is not isolated to the southern United States. The negative effects of heat stress on milk yield, milk composition, reproduction, and cow health occur every year in the Upper Midwest. These negative effects on the dairy's profitability can linger long after the hot weather has passed. A cow is most comfortable within her thermal neutral zone of 45-65 degrees F. Cows begin to experience heat stress when the temperature-humidity index (THI) reaches seventy-two degrees F.

$$THI = T_{db} - (0.55 - 0.55 \times RH/100) \times (T_{db} - 58)$$

Where: T_{db} is outdoor air temperature (F)
RH is relative humidity (%)
When: RH = 100 % then THI = T_{db}

Protecting the cow from excessive heat gain and supporting her natural ability to physiologically regulate her body temperature are keys to increasing cow comfort, performance and profitability.

The heat abatement program for any individual dairy must take into account the environmental challenges of the area, the type of facility, the level of management, and realistic economic benefits. A clear understanding of when heat stress occurs, what factors contribute to it, how a cow responds to this stress, and the ability of the cow to dissipate her body heat are necessary to design an effective heat abatement program.

Heat stress occurs when the sum of the cow's own physical heat production plus the environmental heat load becomes greater than her ability to lose heat. It is this combination that overloads the cow's ability to maintain normal metabolism. A series of physiological events occurs to increase the cow's maintenance requirements and cause behavioral alterations. These changes ultimately lead to reduced production, poor reproduction, and sub-optimal cow health.

A cow's own physical heat production is a combination of internal and external factors. Internal heat load comes from basic body functions such as respiration, digestion, and other daily maintenance requirements. These factors will be influenced by stage of lactation, production, and diet (feed quantity, quality, and type). External physical heat loads arise from management and environmental factors affecting physical activity and performance. Cow comfort, layout of facilities, stocking densities, and fly control can all impact the cow's external physical heat load.

Environmental heat is a combination of the direct effects of temperature and solar radiation and the indirect effects of humidity and air movement reducing the cow's ability to dissipate this heat load Heat load will increase as temperature, humidity and solar radiation increase and air movement decreases. All four of these factors must be controlled if a cow is to remain in her thermal neutral zone.

Cows react to heat stress behaviorally as well as physiologically. The purpose of a heat abatement system is to simply assist the cow in reducing her body's heat load and to prevent these behavioral and physiological changes. Behavioral changes will occur long before physiological ones such as panting and sweating. A cow's first response to heat stress is to stand. She will then seek shade and wind. Her next behavioral change is to decrease her dry matter intake to lower her internal heat production. She will also increase her water intake to meet an increase in maintenance requirements. Temperature sensitive neurons provide information to the hypothalamus that controls both the physiological and the behavioral responses. The hypothalamus signals the cow to increase peripheral blood flow. Coupled with the behavioral response of standing, the cow's increased surface area leads to a more rapid dissipation of heat.

During heat stress the cow will increase its respiratory rate, leading to a respiratory alkalosis as a result of rapid loss of CO_2. The cow compensates by increasing urinary output of bicarbonate (HCO_3). A simultaneous decrease in the saliva bicarbonate occurs due to drooling and panting. This decrease in saliva bicarbonate leads to lower rumen pH. Rates of gut and rumen motility are also reduced, thus slowing passage of feed through the GI tract. As peripheral blood flow increases, blood flow to the internal organs decreases and nutrient uptake is decreased.

In summary, the impact of heat stress on performance is in part due to specific behavioral responses leading to reduction in dry matter intake and in part due to physiological responses. These responses lead to a decreased blood flow to the internal organs, to decreased nutrient uptake, and to an increase in maintenance requirements.

Cows can dissipate body heat by either evaporative or non-evaporative means. Physiologically the cow's most important way to dissipate body heat is by evaporative means. Once the temperature exceeds eight-five degrees nearly eighty percent of the heat is dissipated through evaporation. The cow's two major natural means of evaporative cooling are sweating and panting. The primary obstacle to evaporative cooling is high humidity. Humid air is more saturated with water vapor and therefore reduces the vapor gradient driving evaporative cooling. Air movement helps overcome this barrier.

Methods of non-evaporative heat dissipation include conduction, convection, and radiation. These require a difference between the cow's body and the immediate environment, i.e., a thermal gradient. When this gradient is present, the cow's excessive body heat is readily transferred from its warmer body to the cooler environment.

Radiant energy is caused by the loading of thermal energy from a warmer surface to a cooler surface. High external temperatures narrow the thermal gradient between the cow's body and the surrounding air. Protecting the cow from solar radiation is of primary importance when designing a heat abatement program. Radiant energy can come not only from the sun, but from reflective surfaces also.

Conduction is the flow of heat from a warmer object to a cooler one. Anytime cool water is added to a cow via sprinklers, soakers, or when the cow seeks out mud holes or the alleys to lie in, conduction is being used to cool cows.
Convection is the exchange of heat with moving air. This is the major means by which fans provide cooling. To accomplish this, the air in immediate contact with skin must be replaced with cooler air. This will not be an effective means to cool cows if only hot air is blown since the thermal gradient needed for non-evaporative means of cooling will be minimized. Fans also

play a role in evaporative cooling by removing heat and water vapor surrounding the cow and replacing it with cooler, drier air.

Unfortunately, as summer temperatures rise, the temperature differences become too small for effective cooling by non-evaporative means without intervention. Without intervention, the cow must rely on her own evaporative cooling to maintain heat balance. This is a highly ineffective means to cool with the humidity typical in the Upper Midwest. The temperature threshold for sweating is about ninety degrees and panting slightly higher, both well outside a cow's thermal neutral zone. The behavioral changes of standing, seeking shade or wind, as well as decreasing dry matter intake, will occur before the physiological changes do and, without intervention, performance will suffer.

There are three interventions management can consider to reduce heat stress. These are genetic changes, nutritional strategies and environmental modifications. Genetically there are breed, color, and individual differences in susceptibility to heat stress. Unfortunately, to base a genetic program around a cow's susceptibility to heat stress is a tremendous step backward. Dairy cows are more prone to heat stress than other animals due to the genetic selection for high milk production having produced an animal with a high internal heat load. The profitability of using genetics to decrease production to manage heat stress is highly questionable.

Nutritional changes to control heat stress, although widely discussed and practiced, will have a relativity small impact on productivity. With few exceptions, the dietary changes are in response to the cow's behavioral and physiological reaction to heat stress. Increasing the energy density of the ration through the use of fats or adjustments to forage to concentrate levels, are reacting to the cow's behavioral response to decrease dry matter intake in an attempt to reduce her internal heat production. In response to physiological changes leading to panting, drooling, reduced rumen motility and altered rumen fermentation, microbial additives and buffer levels are often increased in an attempt to maintain rumen health. Increases in mineral levels are often a reflection of the changes in dry matter intake or simply an attempt to maintain physiological homeostasis. Potassium levels need to be increased as cows loose potassium in sweat rather than sodium.

The most commonly overlooked (yet most critical for production) nutrient is water. At eighty degrees F, a cow producing ninety pounds of milk will need in excess of three hundred pounds of water. The most common water bottlenecks are inadequate water trough space, lack of water pressure, lack of space surrounding waterers, waterers that are difficult to clean, or improperly located waterers.

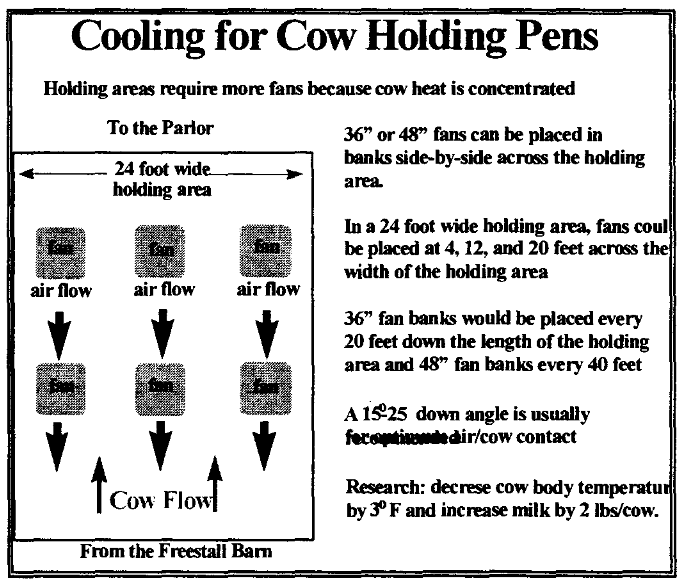
The appropriate investment in environmental modification to alleviate heat stress will depend on the climate and on current facilities. The more extensive the environmental modifications, the greater the potential for reduction of the detrimental effect of heat stress. Because air temperature and humidity are costly to modify, evaporative cooling systems have their limitations in humid regions of the country such as the Upper Midwest. Consequently, when we make interventions on the dairies in the Upper Midwest to alleviate heat stress, we need to be dealing with the non-evaporative means of cooling. To do this we must reduce the radiant heat through facilities or increase the thermal gradient. Increasing the thermal gradient can be accomplished using conductive means such as soakers or sprinklers, as well as convective means through natural or forced ventilation.

To prioritize the investment in cooling systems, start with the location where heat stress is the worst. Next, invest where you would like the cows to spend the most time, then finally where they already spend the most time. The holding pen tends to be the worst environment on the dairy from a heat stress concern. Wherever we pack a large number of animals in a small area, during time of environmental challenges, heat stress becomes a major concern. Without adequate cooling a cow's body temperature will increase three degrees within fifteen minutes, often exceeding 105 degrees.

Because holding pens in the Upper Midwest tend to be shaded, blocking the radiant heat is usually not an issue. However, ventilation can often be a challenge. When discussing ventilation (meaning moving air), there are a few basic principles to follow. Any effective ventilation system must have five basic components:

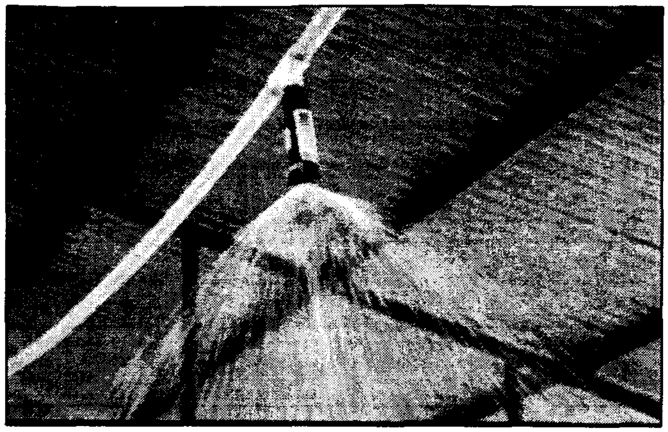
- an inlet
- a path
- an outlet
- a driving force (push or pull)
- a complete distribution

It is critical to have an outlet for the hot air to dissipate. Often ridge caps in the holding pen areas are quite restrictive to hot air rising and leaving. Recommendations for the ridge opening are at least 12 inches wide for the first 20 feet of width and then 2 inches for each additional 10 feet. This should allow adequate opening space such that thermal buoyancy can occur and natural ventilation can take place. Adequate openings for cross ventilation are also critical. Convection cooling can further be increased by forced airflow via fans.



To cool in a holding pen we strive to have 1,000 cfm per cow. If your pen size is 100 cows you will need 100,000 cfm's in the holding pen. As a rule three-foot fans provide 10,000 cfm per fan, while four foot fans provide approximately 20,000 cfm per fan. Therefore, in this 100 cow group example you would require ten, three-foot fans (100,000/10,000) or four, four-foot fans (100,000/20,000). Three-foot fans should be mounted 20 feet apart while four-foot fans can be mounted 40 feet apart. In the holding pen fans should be mounted in banks of two to four depending on width of the holding pen. The banks of fans should be spaced either 20 feet (for three foot fans) or 40 feet (for four foot fans) apart, being sure to cover the entire holding pen. Fans need to be mounted as low as possible, but at least 7.5-8.5 feet off the holding pen floor, being sure to clear the crowd gate. They should be tipped on a 15-25 degree angle. Attempts should be made to utilize prevailing winds. Fans must be kept clean. It only takes a small amount of dust on the blades or housing to reduce the efficiency of a fan up to 30 percent.

The addition of a conductive cooling system allows for maximum cow comfort and productivity. From a heat abatement standpoint, this is critical. This should be a soaker system, not a mister system. Mister systems tend to be high-pressure systems attempting to cool by evaporative means. Soaker systems are low-pressure systems that are cooling by conduction, or non-evaporative means. Our goal is to thoroughly wet the cow, using a large water droplet size, in a very rapid fashion, but to avoid water running on the cow's udder.



Fog and mist systems spray small water droplets into the air and cool air as droplets evaporate. Cows inhale cool air and they can exchange heat with air and remove heat from the body. There are several disadvantages to fogs and mists. First, they can be blown away easily under windy conditions. If mist or fog builds up on the cow's hair coats, it can trap a layer of air between the skin and water that can act as insulation and build up heat load. Respiratory problems also can arise from fog and mist systems if proper ventilation is not provided. Using sprinklers or soakers instead of foggers or misters can avoid many of these problems. This method does not rely on cooling air but uses a large water droplet size to wet the hair coat and skin of cows, allowing conductive cooling. If humidity is present this is the fastest, most effective way to cool cows. The addition of fans makes this system even more efficient How long to run the soaker system will depend on water pressure, line size, and holding pen size. Automation allows this to be standardized and set based on management's decision. If we are truly lowering basal body temperature, a high percentage of cows will begin to chew their cud in 12-15 minutes. If they are not, evaluate the time the soakers are running, the amount of CFMs the fans are producing, and the number of air changes that are occurring.

The second general area on the dairy that needs to be addressed in a heat abatement program is where we wish the cows to be located. The question is what is going to give maximum cooling leading to the maximum amount of dry matter intake but not interfere with cow comfort. From a cow comfort standpoint, our goal is to have the cow either eating or lying down. A cow will eat for four to six hours a day and prefers to lie down for eleven to fourteen hours a day. Behaviorally, a cow's responses to heat stress are to first stand up and then seek wind. This will occur long before physiological changes (panting and sweating for evaporative cooling) occur. If we concentrate all our cooling efforts on the feed lane we may encourage eating, but we can inadvertently diminish cow comfort in that our cows will stand along the feed lane and not lie down. This will lead to a diminish blood flow to the udder as well as increasing maintenance requirements. Consequently, even though dry matter intake may be maintained, production will decrease. Furthermore, by encouraging cows to stand we can have a detrimental effect on cow health. Studies have shown that there is a direct relationship between the amount of time a cow stands and her foot health.

To minimize this concern, a soaker system can be installed above the feedlane and fans over the beds. Research is showing that for heat stress fans alone, although effective, can be tremendously improved with the addition of soaker systems. A soaker system over the feedlane will allow you to cool the cows by conduction. By having this over the feedlane we will accomplish our goal of encouraging dry matter intake. We can then further our cooling by mounting fans over the beds, encourage the cow to lie down and cool by convection as well as aid evaporation. At the same time, we are promoting cow comfort by encouraging our cows to lie down, leading to increase blood flow to the mammary gland, and reducing maintenance requirements.

Fans should first be mounted over the center row of stalls. Mounting fans over the stalls as well as the feedlane has been shown to be beneficial. Fans should be 7.5-8.5 ft above the beds and tilted on a 15-25 degree angle. Use the prevailing winds to your advantage. Another advantage of mounting the fans over the beds is that if prevailing winds do shift perpendicular to the fans, then airflow will still be on the cows. A soaker system should be installed over the feedlane. The components of a soaker system include a timer, thermostat, a solenoid valve, pressure reducer, piping, and sprinkler nozzles. They can be on a timer or controlled manually.

Do not forget the dry cows or the maternity pen. All the above principles for heat abatement in lactating cows apply to dry cows as well. The potentially large economic benefits from effectively managing dry cows should not be underestimated. In fact, after the holding pen, the close up dry cows and the maternity pen are the next areas on which you should focus. The lingering effects of heat stress in the dry period can have major impact for the entire next lactation.

Environmental modification to protect the cow from excessive heat load and supporting her natural cooling ability are keys to optimizing milk production, reproduction and cow health during periods of heat stress.

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