New Concepts in Ventilation to Keep Your Cows Comfortable

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Introduction

Annual losses to the US dairy industry due to heat stress exceed 900 million dollars. Reducing thermal stress is a key issue in efficient and profitable dairy production. Across the US there has been tremendous improvement in heat stress abatement for dairy cattle in the last two decades. However, heat abatement systems continue to evolve and develop, increasing the choices available to dairy producers. Systems today focus on providing adequate cooling while minimizing energy and water utilization. In addition, the benefits of cooling dry and pre-fresh cattle have also been addressed in several studies. The key benefits of effective cow cooling are increased milk production, increased feed intake and improved reproductive performance. Improvement in summertime milk production and reproductive performance has longer-lasting effects than just a few summer months. Effective heat abatement during the summer, which allows for normal pregnancy rates, reduces the slugs of pregnancies in the fall, which generally results in increased calving activity in the spring and early summer. The focus of this paper will be some of the newer options available to dairy producers for effectively cooling their dairy herds.

Determining Thermal Stress

Thermal stress in dairy cattle is most often defined by the Temperature Humidity Index (THI). Most recently, researchers at the University of Arizona have redefined this index with more current dairy genetics. This index combines the effects of temperature and humidity into a single estimate of thermal heat load. The data suggested that milk production losses began when the minimum daily THI exceeded 65 or when the average THI exceeded 68. In general, the industry has accepted that heat abatement should begin when the THI reaches 68; however, losses started at a THI of 65.

The effects of heat stress and mechanics of heat exchange were extensively studied at the Missouri experiment station in the 1940s and 1950s. Studies showed that at temperatures above 70°F, heat loss was primarily due to moisture evaporation from the skin and lungs. As temperatures exceeded 90°F, more than 85% of the total heat dissipation was due to vaporization of water from the body surface and lungs. Researchers suggested that at a temperature of 95°F, wetting the hair and skin greatly increased heat dissipation due to the hair increasing the surface area available for water vaporization.

Experimentally, respiration rate, body temperature and heart rate have been measured as indicators of increased thermal stress. There has been considerable interest in developing a system by which sentinel cows would be monitored and the data utilized to control heat abatement systems. While this would offer more precise control of the system, the concept has not been widely adopted in the industry due to issues of cost and reliability.

Methods to Reduce Thermal Stress

Lactating dairy cattle produce large amounts of heat due to digestion and metabolic processes, and this heat must be exchanged with the environment to maintain normal body temperature. Cattle exchange heat through the mechanisms of convection, conduction, evaporation and radiation. Cattle can either give or receive heat energy from the environment. Solar radiation increases heat load by increasing the surface temperature of cattle. Air temperature above the normal body temperature of cattle also increases the heat load. In addition to increasing heat load, heat exchange at the body surface is reduced. Protection from solar radiation by providing adequate shade is the first step in reducing heat stress in dairy cattle.

Increasing natural ventilation during the summer months by increasing sidewall openings, increasing roof pitch and providing an opening at the roof peak have been incorporated into building designs for many years. Many existing facilities have been modified in an effort to increase airflow over the animals. However, this does not effectively address the situations where thermal stress exceeds the natural ability of the cow to exchange heat with the environment. For the months of May-September, this can be a huge challenge for Midwest dairy producers.

Feedline Soaking

For the last couple of decades, the application of feedline soaking systems and supplemental airflow created by fans has been a popular method to reduce heat stress in dairy herds. By starting with increased air movement and then increasing the amount of water applied as heat stress increases, producers have been able to reduce the level of heat stress experienced by the herd. Wetting frequency and level of supplemental airflow have been shown to have a dramatic impact upon the heat exchange rate of dairy cattle. Systems have been shown to be effective in increasing summer milk production and have proven to be economical. However, in some cases water consumption and the efficiency of wetting have been a concern. In general, most systems will only utilize about 25% of the consumed water for cow wetting. Most of the rest will simply increase the volume of waste in the lagoon.

Increasing Airflow
There has been considerable research completed to address the speed and where airflow should be increased in a dairy barn. The first place would be the milking parlor holding pen. Generally, an air speed of 7 to 8 MPH is sufficient for effective cow cooling. However, in areas such as the milking parlor holding pen, it is important to introduce fresh air into the space as well. Some designs do not effectively introduce fresh air and only circulate the existing air. When trying to evaporate water from the backs of cattle, it is important to provide for adequate air exchange as well as air speed. Opening the sidewalls and including a roof peak opening will help with air exchange. However, this may not be adequate. Newer designs incorporating mechanical ventilation are addressed later in the paper.

Air Exchange Rate
Providing adequate air exchange is very important. During the wintertime, an air exchange 4 times per hour is considered adequate. However, during the summer, some systems may have exchange rates as great as once per minute or 60 times per hour. Generally, the ventilation rate has been increased to this level to increase the airflow over the animals and not because the ventilation rate needs to be once per minute. When ventilation rates are this high, it may be difficult to effectively use evaporative cooling to cool the air to reduce the heat stress in the building due to the volume of air that must be cooled at greater ventilation rates.

Increases in Fan Efficiency
New fan motor and fan blade designs have resulted in improvement in fan efficiency as determined by electrical usage per unit of air moved. In many cases, fans today are 25 to 30% more efficient than older standard basket fans. While these fans are more expensive, they are also more energy efficient and can help reduce operational cost in new and remodeled dairy facilities. In many regions, rebates from electrical supplies may help offset the additional cost of energy-efficient fans. Dairy producers are encouraged to carefully review the energy efficiency data when choosing fans. There are many choices available today, so make sure you understand the efficiency of the fan being purchased.

Adoption of Variable Speed Drives
Traditionally, fans were either on or off. Increasing the amount of airflow was simply a matter of increasing the number of fans running at a given time. Today, each fan can be equipped with a variable speed drive which allows for various fan speeds and also the ability to reverse the direction of rotation for winter time ventilation or mixing of the air in a facility. These drives can be utilized on fans operating on the intake and exhaust, and for air mixing within the buildings. Fans can be controlled to gradually increase airflow and air exchanges as heat stress increases to create a more uniform air flow across the building. This should improve air quality as well as more effectively reducing heat stress. This can also greatly increase the efficiency of electrical usages as the watts consumed per unit of air moved improves when the fan is turning at less than 100% of motor capacity. The cost of operating more fans at a lower speed may be less than operating a few fans at full capacity. Operating more fans at a lower speed will also improve the uniformity of the airflow across the building.

Changes in Sensors
One of the most exciting changes in cow cooling is from the standpoint of sensors for relative humidity. For many years, there has been a struggle to find relative humidity sensors which would work in the dusty and humid environments found in dairy facilities. Temperature sensors were generally reliable and durable. Humidity sensors required frequent maintenance and calibration to function correctly. The changes in humidity sensor design has greatly improved accuracy and durability. Now, relative humidity can be used efficiently and effectively to determine the level of heat stress experienced by cattle and to operate cooling systems to cool cows more effectively. This is especially important when using high-pressure misting or evaporative cooling to cool the air of the housing environment.

Changes in Cooling Controls
Significant advances have been made with cooling system controls. With the availability of improved humidity sensors, combining measurement of temperature and relative humidity into cooling system operation functions is becoming more commonplace.

This is especially true when using high-pressure misting for evaporative cooling of the air. The combination of sensors and advanced controls has allowed engineers to reduce the issues of creating a condensing environment, resulting in wet equipment and bedding when evaporative cooling is combined with increased air velocity.

Changes in Barn Designs

Over the past couple of decades, we have moved from naturally ventilated barn designs toward tunnel-, cross- and positive-pressure designs for heat abatement in free stall barns, milking parlors and milking parlor holding pens. Tunnel- and cross-ventilation designs have been utilized to improve the airflow over the cattle beds. Cow behavior resulting in lying times of greater than 12 hours per day has been shown to increase milk production. Many barn designs contain a multitude of fans which control air entering the building, exiting the building and mixing within the building. By reducing the intake and exhaust airflow to the amount needed for fresh air exchange and then utilizing mixing fans internally to create the airflow over the beds, total energy utilization can be reduced as compared to simply increasing exhaust fans to create appropriate air velocity throughout the building. Utilizing positive pressure to introduce fresh air into the building also reduces the static pressure of exhaust fans. This also results in greater energy efficiency of the exhaust fans.

Advances in Evaporative Cooling

Soaking and then evaporating water from the surface of cattle represents the most efficient method to remove heat from cattle. However, when environmental temperature exceeds cow body temperature, evaporative cooling of the air may be necessary. Air conditioning would be the most effective by reducing air temperature and relative humidity. However, due to energy costs and system maintenance issues, it is not considered as a practical solution on commercial dairies.

A possible solution is evaporation of water into air as it enters the cow facility. Combinations of tunnel ventilation and evaporative cooling have been used in swine and poultry operations for many years to cool the environment. Recently, these systems have been installed in some Midwest dairy facilities. Many research reports have demonstrated that evaporative cooling can reduce the total hours of higher levels of THI in some environments. Evaporative cooling has been used very successfully to cool dairy cattle in hot arid climates. Under arid conditions and high environmental temperatures, the potential to reduce temperature and THI is improved. However, as relative humidity increases and or temperature decreases, effectiveness of evaporative cooling to modify the environment decreases. As relative humidity increases above 70%, the potential reduction in THI is less than 10%.

The improvement in controls, sensors and application of variable degrees of high-pressure misting have resulted in more robust systems that more effectively reduce the heat stress of dairy facilities. These improvements come with significant cost and are generally only effective in arid environments where several months of heat abatement is required.

Cooling the Bed

A newer concept of heat abatement involves cooling the freestall bed with various types of cooling systems. This creates a cooler surface for the cow when lying and helps to address the need to cool in the area of the barn where the cow will spend the largest portion of the day. It may also entice the cow to lay in the stall for a greater period of time. Systems have employed a variety of cooling lines and types of coolant. The depth and type of bedding seem to have major impacts on the degree of cow cooling. In very stressful environments, the heat balance may be positive and the cow's body temperature may rise to the point at which standing is more comfortable than reclining. In this case, an additional cooling system would need to be utilized to address the standing cattle.

Summary

Many changes have occurred in the last 10 years with the equipment and heat abatement systems available to dairy producers. While the changes are significant, the basic requirements of heat abatement are still the same. The goal should be to increase the amount of heat the cow can exchange with the environment. When thermal balance is no longer attainable, body temperature will increase resulting in many negative effects, most notably, losses of milk production and reproductive efficiency. Complex systems which control the environment of the cow through fresh air induction, air movement, evaporative cooling and exhaust ventilation and produce a more controlled environment for cattle can result in an improved environment for cattle. However, the cost of complex systems may be greater than the return in increased milk production. In additional to heat abatement, other factors of cow comfort and nutrition must be considered in order to get the maximum benefit from the system.

Considerations in Choosing Cooling Systems

1. Shade the cow from solar radiation. This should always be the first step in any cooling system.
2. Consider average temperature and relative hu-

midity of location during each hour of the day. Determine when during the day evaporative cooling would be effective. Even in humid environments, afternoon humidity may be low enough to benefit from evaporative cooling.

3. If environmental temperature is near or above normal cow body temperature for a significant portion of the summer, some form of evaporative cooling will likely benefit your operation.
4. Do not depend upon evaporative cooling alone, except in very arid environments. In most environments, feed line soaking will provide cooling over and above the evaporative system.
5. Consider all costs associated with evaporative cooling and feed line soaking. While additional benefits are realized by combination systems, additional milk production may not offset expenses.
6. When pricing and comparing different cooling systems, carefully consider all the options of the various cooling systems and make sure you are pricing comparing similar equipment.
7. Consider not only airflow, but also air exchange when selecting a cooling system for the entire year.

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