Managing Heat Stress In Dairy Facilities

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Abstract

Heat stress can have a dramatic impact on milk production and reproduction on commercial dairies. The impact of heat stress can be minimized by improving water availability, providing shade in the housing areas and holding pen, reducing walking distance, reducing time in the holding pen, improving holding pen ventilation, adding holding pen cooling and exit lane cooling, improving ventilation in cow housing areas (freestalls), cooling close-up cows (3 weeks prior to calving), cooling fresh cows and early lactation cows, and cooling mid and late lactation cows. Dairy cattle can be cooled by providing a cooler environment (cooling the air) or by soaking the cows and evaporating water off her skin surface (cooling the cow). Using evaporative cooling to cool the air works in climates with low relative humidity. Evaporating water off the skin surface of the cow to cool the cow will be beneficial in all climates.

Effects of Heat Stress

Heat stress reduces intake, milk production, health and reproduction of dairy cows. Spain *et al* [17] showed that lactating cows under heat stress decreased intake 6-16% as compared to thermal neutral conditions. Holter *et al*[10] reported heat stress depressed intake of cows more than heifers. Other studies have reported similar results. In addition to a reduction in feed intake, there is also a 30 to 50% reduction in the efficiency of energy utilization for milk production[12]. In many parts of the US, milk production and reproductive performance drastically decline during periods of heat stress. The dairy cow can be cooled to minimize the impact of heat stress. Listed below are the priorities for reducing heat stress in dairy facilities:

1. Improve water availability
2. Providing shade in the housing areas and holding pen
3. Reduce walking distance
4. Reduce time in the holding pen
5. Improve holding pen ventilation
6. Add holding pen cooling and exit lane cooling
7. Improve ventilation in cow housing areas (freestalls)
8. Cool close-up cows (3 weeks prior to calving)
9. Cool fresh cows and early lactation cows
10. Cool mid and late lactation cows.

The method used to cool cows will be different depending on the type of climate (humid vs arid). For example using evaporative cooling to lower environmental Temperature Heat Index (THI) is difficult in humid climates.

Water Availability

Recommendations concerning access to water vary greatly. Current recommendations suggest a range of 1.2 to 3.6 linear inches (3 – 9 linear cm) per cow[16]. In the Midwest, the typical rule is one waterer or 2 linear ft (61 cm) of space for every 10 to 20 cows. In the Southwest, the recommendation is 3.6 linear inches (9 cm) of space for every cow in the pen. Typically, water is provided at each crossover in 4- and 6-row freestall barns, and generally a 4- and 6-row freestall have the same number of crossovers. Thus, water access in a 6-row barn is reduced by 37.5% as compared to a 4-row barn (Table 1). When overcrowding is considered (Table 2), water access is greatly reduced and the magnitude of reduction is greater in 6-row barns. Milk is 87% water and water intake is critical for peak dry matter intake. When building 6-row barns or overcrowding either 4-row or 6-row barns it is important to consider the amount of water space available based on actual stocking density rather than the number of stalls. In warmer climates, 3.6 linear in (9 linear cm) of waterer space per cow should be provided.

Table 1. Average pen dimensions, stalls, cows and allotted space per animal.

Barn style	Pen width ft (m)	Pen length ft (m)	Stall per pen	Cows per pen	Per Cow: Area ft² (m²)	Per Cow: Feedline space in (cm)	Per Cow: Linear water space in (cm)
4-row	39 (11.9)	240 (73.2)	100	100	94 (8.5)	29 (73.7)	3.6 (9.1)
6-row	47 (14.3)	240 (73.2)	160	160	71 (6.5)	18 (45.7)	2.25 (5.7)
2-row	39 (11.9)	240 (73.2)	100	100	94 (8.5)	29 (73.7)	3.6 (9.1)
3-row	47 (14.3)	240 (73.2)	160	160	71 (6.5)	18 (45.7)	2.25 (5.7)

Adapted from Smith, JF *et al, 2000.*

Table 2. Effect of stocking rate on space per cow for area, feed and water in 4 and 6-row barns.

Stocking rate (%)	Area per cow ft² (m²)		Linear feedline space per cow in (cm)		Linear water space per cow in (cm)	
	4-row	6-row	4-row	6-row	4-row	6-row
100	94 (8.5)	71 (6.5)	29 (73.7)	18 (45.7)	3.6 (9.1)	2.25 (5.7)
110	85.5 (7.8)	64.5 (5.9)	26 (66.0)	16 (40.6)	3.27 (8.3)	2.05 (5.2)
120	78.3 (7.1)	59.2 (5.4)	24 (61.0)	15 (38.1)	3.0 (7.6)	1.88 (4.8)
130	72.3 (6.6)	54.6 (5.0)	22 (55.9)	14 (35.6)	2.77 (7.0)	1.73 (4.4)
140	67.1 (6.1)	50.7 (4.6)	21 (53.3)	13 (33.0)	2.57 (6.5)	1.66 (4.2)

Shade

Providing shade in housing areas and the holding pen is the second step. Cows housed in dry-lot or pasture situations should be provided with solid shade. Research from Florida, California, Australia and Arizona indicates that when high-producing cows are exposed to direct sunlight and a THI exceeds 80 during daylight hours, shaded cows will produce approximately 4 to 9 lb (1.8 to 4.1 kg) of additional milk per day[1]. Natural shading provided by trees is effective, but most often shades are constructed from solid steel or aluminum. Using more porous materials such as shade cloth or snow fence is not as effective as solid shades. Table 3 lists the effectiveness of different shade materials in descending order[4,11]. Providing 50 ft² (4.5 m²) of solid shade per mature dairy cow is ideal to reduce solar radiation[18]. Shades should be constructed at a height of a least 14 ft (4.3 m) with a north-south orientation to prevent wet areas from developing under them.

Freestall Barn Orientation

The first freestall barn design criteria to be considered should be the orientation of the structure. Barns with a north-south orientation have greater solar radiation exposure than barns with an east-west orientation (Figures 1 and 2). Sunlight can directly enter north-south oriented barns both in the morning and afternoon. While the afternoon sun is the most detrimental, during hot summer weather morning sun can also modify cow behavior. Because cows seek shade during the summer, direct sunlight will reduce stall usage. Thus, utilization of stalls located on east and west outside walls of north-south oriented barns are greatly impacted when in the direct sunlight. It is also important to consider that with greater sidewall heights, afternoon sunlight can reach as much as the west half of the structure. Protection from direct sunlight is vital for effective heat stress abatement. A trial in California showed an increase in morning and afternoon respiration rates when barns were orientated north-south versus east-west[15]. Barns with an east-west orientation will provide greater protection from direct sunlight than north-south orientations. When working with a north-south oriented barn, shades can be utilized on the west wall to reduce the amount of sunlight entering the building. These curtains should be lowered about 1:00 pm each day and raised about 8:00 pm. The use of automatic curtains which slowly lower in the afternoon as required to provide shade may be the best choice. It is important to note that the curtain provides protection from direct sun, but it also blocks natural airflow. Therefore, the curtain should only be lowered during the time when pro-

Table 3. Shade material listed in descending order of effectiveness, as compared with new corrugated aluminum

Material	Description	Effectiveness
Hay	15 cm thick	1.203
Wood	Unpainted	1.060
Galvanized steel	Top white, bottom natural	1.053
Aluminum	Top white, bottom natural	1.049
Neoprene coated nylon	White, both sides	1.037
Aluminum	Standard	1.000
Galvanized steel	Standard	0.992
Asbestos board	Natural color	0.956
Shade cloth	90% solid	0.839
Shade cloth	80% solid	0.819
Slatted wood	5 cm solid – 5 cm open	0.589

Bond, *et al* [4]

tection from direct sunlight is required. The use of a minimum of 90% shade cloth or reflective curtain material is recommended for the curtain material.

Ventilation

Maintaining adequate air quality can be easily accomplished by taking advantage of natural ventilation techniques. Armstrong *et al*[2] reported that a 4/12 pitch roof with an open ridge resulted in lower afternoon cow respiration rate increases as compared to reduced roof pitch or covering the ridge. They also observed that eave heights of 14 ft (4.3 m) resulted in lower increases in cow respiration rates as compared to shorter eave heights. Designing freestall barns that allow for maximum natural airflow during the summer will reduce the effects of heat stress. Open sidewalls, open roof ridges, correct sidewall heights and the absence of buildings or natural features that reduce airflow increase natural airflow. During the winter months, it is necessary to allow adequate ventilation to maintain air quality while providing adequate protection from cold stress.

Another ventilation consideration is the width of the barn. Six-row barns are typically wider that 4-row barns. This additional width reduces natural ventilation. Chastain[7,8] indicated that summer ventilation rates were reduced 37% in 6-row barns as compared to 4-row barns. In hot and humid climates, barn choice may increase heat stress resulting in lower feed intake and milk production. A trial completed in northwest Iowa indicates that respiration rates are higher in 6-row versus 4-row barns[14].

Methods to Minimize Heat Stress

Heat stress can be reduced by providing a cooler environment (cooling the air) or by soaking the cow and evaporating water off her skin surface (cooling the cow).

Cow Cooling, Evaporating Water Off Her Skin Surface

The use of low pressure sprinkler/soaker and fan systems to effectively wet and dry the cows will increase heat loss from the cow. Dairy cows can be soaked in the

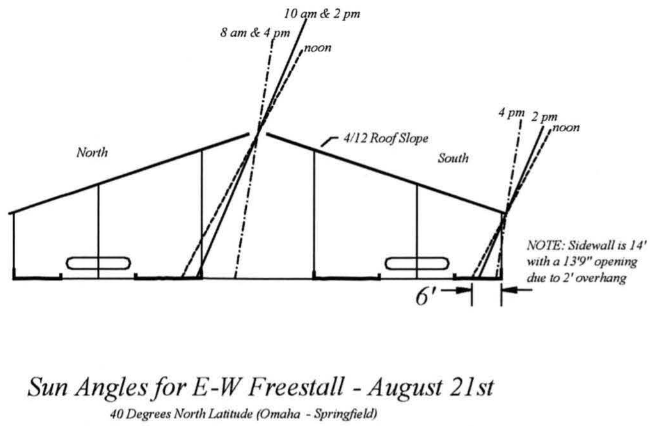

Figure 1. Sun angles of a east-west oriented freestall barn.

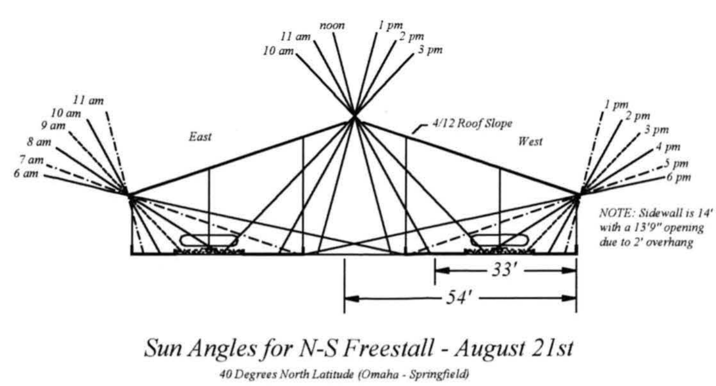

Figure 2. Sun angles of an north-south oriented freestall barn.

Table 4. Experimental treatments.

Treatment	Soaking frequency*	Supplemental airflow
0	None	None
0 + F	None	700 cfm
5	Every 5 minutes	None
5 + F	Every 5 minutes	700 cfm
10	Every 10 minutes	None
10 + F	Every 10 minutes	700 cfm
15	Every 15 minutes	None
15 + F	Every 15 minutes	700 cfm

*0.35 gallon/headlock applied in 1 minute

holding pen, exit lanes, and on feedlines. The goal should be to maximize the number of wet-dry cycles per hour. In the summer of 2001, a study was conducted at Kansas State University to determine the effects of soak frequency and airflow on respiration rates and skin temperature of heat stressed dairy cattle. Sixteen heat stressed lactating cows (8 primiparous and 8 multiparous) were arranged in a replicated 8x8 Latin Square design. Cattle were housed in freestall dairy barns and milked twice daily. During testing, cattle were moved to a tie-stall barn for a 2-hour period from either 1-3 pm or 3-5 pm on 8 different days in late August and early September. Afternoon temperatures ranged between 88 and 96°F (31.1 to 35.6°C), with a relative humidity between 75 to 85%. During the testing period, respiration rates were determined every five minutes by visual evaluation. Skin temperature of three sites was measured with an infrared thermometer and recorded every 5 minutes. Treatments (Table 4) were 4 different soaking frequencies with and without supplemental airflow. Soaking frequencies were control (no soaking), every 5 minutes,

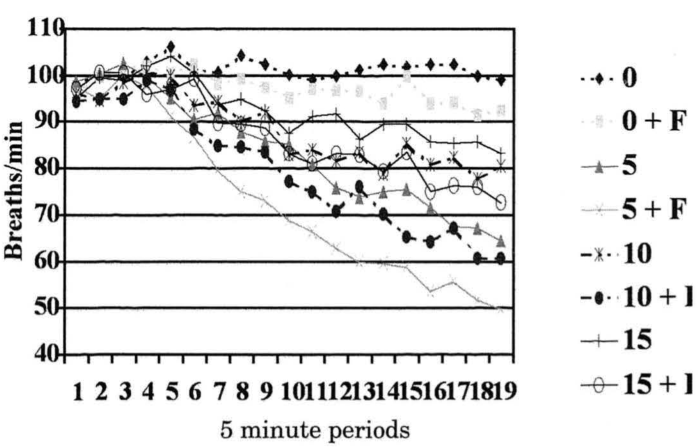

Figure 3. Effect of sprinkling frequency and airflow on respiration rate of heat stressed dairy cattle

every 10 or every 15 minutes. Supplemental airflow was either none or 700 cfm (0.33 m^3). Each wetting cycle provided similar amounts of water for all treatments. Initial data were collected for three initial 5-minute periods prior to the start of the treatments.

Cows soaked every 5 minutes with supplemental airflow (5+F) responded with the fastest and largest drop in respiration rate, reducing the initial respiration rate by 47% at the end of 90 minutes of treatment (Figure 3). Soaking cows every 5 minutes without airflow (5) resulted in a similar response as soaking cows every 10 minutes with airflow (10+F). Soaking cows every 15 minutes with airflow (15+F) and soaking cows every 10 minutes without airflow (10) resulted in similar responses until the last 30 minutes of the study. Supplemental airflow without soaking (0+F) resulted in little improvement over no soaking or airflow (0). Wetting had a greater effect on respiration rate than airflow. However, the combination of wetting and airflow had the greatest effect on the respiration rate. When cooling heat stressed dairy cattle, the most effective treatment included continuous supplemental airflow and wetting every 5 minutes.

This data suggests that different cooling strategies could be developed for different levels of heat stress. Under severe heat stress soaking every 5 minutes with fan cooling will be the most effective. Under periods of moderate stress soaking every 10 minutes with fan cooling may be adequate. Reducing soaking frequency when temperatures are lower could significantly reduce water usage. Data clearly indicate that the combination of soaking and supplemental fan cooling are superior to either single treatment. If used singularly, soaking cows would have more impact than the use of fans only for cow cooling. These data indicate that about one-third of the total reduction in cow respiration rates was due to airflow and the remainder due to soaking. Under periods of severe heat stress, soaking every 15 minutes with airflow is not adequate and soaking frequency must be increased.

Cow cooling with soaking and supplemental airflow is very effective in reducing respiration rate. Many systems may be ineffective because they do not deliver adequate water to soak the cow and/or have an inadequate soaking frequency.

Providing a Cooler Environment for the Cow

Evaporative cooling can be used to cool the air around the cow. On dairies producers have used tunnel ventilation with evaporative pads and combinations of fans and high pressure sprayers to cool the air around the cow. This method works well in arid climates. As water is evaporated into the air the temperature will drop and humidity will increase. The expected changes in THI using evaporative cooling and presented in Figures 4 and 5, as humidity increase it becomes more difficult to change the environment in which the cow is housed. Producers often try to break the laws of physics by installing these systems in humid climates. Many of these systems have been designed for use in the poultry and swine industry. It is important to be aware of the differences in the heat loads and the ability to dissipate heat of ruminants and monogastrics.

Cow Cooling in the Holding Pen

The holding pen should be cooled with fans and sprinkler systems and an exit lane sprinkler system may be beneficial in hot climates. Holding pen time should not exceed one hour. Soaker fans should move 1,000 cfm per cow. Most 30 and 36 in (76.2 – 91.4 cm) fans will move between 10,000 and 12,000 cfm (0.47 m^3) per fan. If one fan is installed per 10 cows or 150 ft^2 (13.5 m^2), adequate ventilation will be provided. If the holding pen is less than 24 ft (7.3 m) wide with 8-10 ft (2.4 to 3.0 m) sidewall openings, fans may be installed on 6-8 ft (1.8 – 2.4 m) centers along the sidewalls. For holding pens wider than 24 ft (7.3 m), fans are mounted parallel to the cow flow. Fans are spaced 6-8 ft (1.8 – 2.4 m) apart and in rows spaced either 20-30 ft (6.1 – 9.1 m) apart from 36 in (91.4 cm) fans or 30-40 ft (9.1 to 12.2 m) apart for 48 in (121.9 cm) fans[9]. In addition to the fans, a sprinkling system should deliver 0.03 gal water per ft^2 (1.25 l /m^2) of area. Cycle times are generally set to soak cows every 5-7 minutes.

Cooling Cows in 4-row Freestall Barns

A series of three trials were completed from 1998 to 2000 to determine fan placement in 4-row freestall barns (head to head configuration) with low pressure sprinklers on the feedline[5,6,12]. Based on these trials fans should be mounted above the cows on the feed line and above head-to-head freestalls in a 4-row freestall barn. If 36 in. (91.4 cm) fans are utilized, they should be located no more than 30 ft (9.1 m) apart. If 48 in (121.9 cm) fans are used, they should be located no more than 40 ft (12.2 m) apart and operate when the temperature reaches 70°F (21.1°C). Fans should be mounted as low as possible out of the reach of the cattle and in a manner that will not obstruct equipment movement. Fans should create airflow of 800-900 cfm per stall or headlock. Feedline sprinklers should be utilized in addition to the fans. Feedline sprinkling systems should be installed to soak cows. Cows should be soaked every 5-15 minutes, depending on the severity of heat stress. Application rate per cycle should be 0.04 inches/ft^2 (1.12cm/m^2) or 0.35 - 0.4 gal (1.3 – 1.5 l)/cow/cycle and sprinklers should operate when the temperature exceeds 70 to 75°F (21.1 to 23.9°C). In tail-to-tail 4-row barns additional fans may be need over the stalls located near the sidewalls.

Bottlenecks to Cow Cooling

Often producers do not plan to cool cows when they are building new dairy facilities. This creates serious

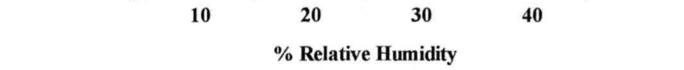

Figure 4. Potential THI change due to water evaporation at 100, 90,80 and 70°F in a low relative humidity environment.

Adapted from ASHRAE Handbook, 1993.

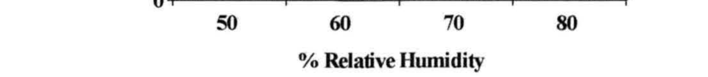

Figure 5. Potential THI change due to water evaporation at 100, 90,80 and 70°F in a high relative humidity environment.

Adapted from ASHRAE Handbook, 1993.

problems in cooling cows. Potential obstacles to minimizing heat stress include:

1. Undersized water supply lines
2. Failure to install supply lines to areas where cows will be soaked
3. Undersized sprinkler lines
4. Drift from sprinkler systems
5. Lagoon capacity to handle run off
6. Ability to control run off in areas where cows are soaked
7. Incorrect fan placement
8. Failure to install the electrical capacity for fans
9. Fan maintenance
10. Trying to use evaporative cooling to cool air in humid climates.

The biggest bottleneck is water availability to soak cows on the feedline in cow housing areas. Another problem is the lack of provisions to provide electricity for fans. It is much more economical to install the utilities necessary for fans and water systems during construction versus retrofitting these systems at a later date. The majority of the dairies being built today do not have water or electrical systems to meet the demands of cow cooling.

Conclusions: Management Opportunities to Reduce Heat Stress

Dairy producers have many opportunities to reduce heat stress on the dairy. Producers can follow the following list of priorities to reduce heat stress:

1. Improve water availability
2. Provide shade in housing areas and the holding pen
3. Reduce walking distance
4. Reduce time in the holding pen
5. Improve holding pen ventilation
6. Add holding pen cooling and exit lane cooling
7. Improve ventilation in cow housing areas (freestalls)
8. Cool close-up cows (3 weeks prior to calving)
9. Cool fresh cows and early lactation cows
10. Cool mid and late lactation cows

It is essential that the cooling system be designed for the climate where it will be operated. Many times a cooling system is selected based on data or results that were obtained in a different climate. An example of this would be trying to cool the air with evaporative cooling in a humid climate.

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