SYMPOSIUM: NUTRITION AND HEAT STRESS

Heat Stress Interaction with Shade and Cooling

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ABSTRACT

Hot weather causes heat stress in dairy cattle. Although effects are more severe in hot climates, dairy cattle in areas with relatively moderate climates also are exposed to periods of heat stress. The resultant decrease in milk production and reproductive efficiency can be offset by implementation of a program consisting of cooling through shades, ventilation and spray, and fans. The economic benefit should be determined before installation of equipment to reduce heat stress.

(Key words: cattle cooling, heat stress, shade)

Abbreviation key: THI = temperature-humidity index.

INTRODUCTION

Summer climates depress milk production and reproductive performance of dairy cattle in many areas of the United States. Southwestern and southeastern areas are especially affected by hot summer climates (8, 18, 20, 21, 34, 37, 39, 41, 49). Reduction of heat stress can reduce or even eliminate these losses. Heat stress occurs when any combination of environmental conditions cause the effective temperature of the environment to be higher than the animal's thermoneutral (comfort) zone.

Four environmental factors influence effective temperature: 1) air temperature, 2) relative humidity, 3) air movement, and 4) solar radiation (16). When the temperature exceeds 27°C, even with low humidity the effective temperature is above the comfort zone for high producing dairy cows. The temperature-humidity index (THI) commonly is used to indicate the degree of stress on dairy cattle (10, 20, 22). When the THI exceeds 72, high producing dairy cows are affected adversely. Frank Wiersma developed a chart (Figure 1) to be used by dairy producers to estimate the severity of heat stress of a dairy cow. This chart utilizes ambient temperature and relative humidity, which are readily available to the dairy producer on a daily basis and indicate from slight to severe heat stress of dairy cattle.

Dairy cows respond to heat stress in several ways: 1) reduced feed intake, 2) increased water intake, 3) changed metabolic rate and maintenance requirements, 4) increased evaporated water loss, 5) increased respiration rate, 6) changed blood hormone concentration, and 7) increased body temperature. Higher producing and multiparous cows are especially susceptible to heat stress (15).

Beede and Collier (9) suggested three basic management schemes for reducing the effects of thermal stress: 1) physical modification of the environment, 2) genetic development of breeds that are less sensitive to heat, and 3) nutritional management. This paper deals with environmental modification methods, including shade and cooling, to reduce the effect of heat stress on dairy cattle.

SHADE

In hotter climates of the southern United States, shade is considered to be essential to maintain the efficiency of milk production and reproduction and can be necessary for survival. Although not essential, shade in many moderate summer climates may be cost effective for reducing the effect of summer heat. Trees are the most effective shade producers; they combine protection from the sun with the radiation sink effect created by cool leaves evaporating moisture (23, 43). Wood or palm branches also are effective shading materials. Corrugated sheet steel is the most popular shade material because of cost, duration, and low maintenance requirements. For the most effective shade, the
Figure 1. Temperature-humidity index table for dairy producer to estimate heat stress for dairy cows. Deg = Degrees. Relative humidity expressed as percentage. (From Frank Wiersma, 1990, Department of Agricultural Engineering, The University of Arizona, Tucson.)

upper surface of metal roofs should be painted white. Placing about 2.5 cm of insulation directly beneath the metal roof reduces the radiation heat load on the cow (12). Protection directly beneath the metal roof reduces the initial peak load, but does not provide as much protection (12) and has a shorter life span.

Slatted shades are less effective than solid shades. Kelly and Bond (28) found that slatted shade with 50% shade, snow fencing with approximately 50% shade. Shade cloth is less expensive than solid roofing material but does not provide as much protection (12) and has a shorter life span.

The design and management of shade for dairy cattle vary in different areas and climates. The recommended shade area in drier climates such as the southwestern United States and in open lot corrals in the plains states is 3.5 to 4.5 m² per lactating cow (43). Less area can result in udder injury as cows crowd together. Excess shade over 4.5 m² has little or no benefit because cows tend to group together under the shade. Shades should be 3.5 to 4.5 m high to minimize radiation from the shade roof to the cow.

Orientation of the shade structure represents a compromise between most effective shading for the cow and maintenance of dry ground surface conditions under the shade. An orientation with the long axis north and south will expose the area under the shade to the morning and afternoon sun and assist in keeping it dry. Under an extremely hot, low rainfall (10 to 12 cm) climate, an east-west orientation may be preferable as the ground under the shade will be cooler and the ability to dry the area is not as relevant, but this orientation requires additional ground maintenance. In either case, shade should be located in the center of the corral or pen to help in distribution of manure. It also is important to drag wet material from under the shade and to replace it regularly with dry material to keep cows dry and clean.

Shade requirements for hot, humid climates are somewhat different. Based on studies conducted in Florida (17), each cow should be provided 4.2 to 5.6 m² of shade. The larger space allotments provide more open area for ventilation, which is a critical factor in hot, humid climates. If earthen floors are used, they should be in a well-drained location, preferably on a mound. Although cows prefer to stand and lie on a dirt surface, concrete floors may be necessary to prevent mud holes. A concrete floor should be at least 10-cm thick and grooved to provide firm footing (15). The slab should be larger than the roof area to accommodate the full shade pattern, which varies with the season. If concrete floors are used, then there is no preference as to shade orientation.

If cattle are housed in a large open pasture, portable shades can be provided. Management of the area under the shade to prevent destroying the pasture grass and to keep the cows clean requires the ability to move the shade every 1 or 2 d.

COOLING OF HOLDING PENS

The holding pen adjacent to the milking parlor is, on most dairy farms, the most stressful area for dairy cows. When a cow is confined in the holding pen for 15 to 60 min two or three times daily, stress can occur even under moderate ambient temperatures. Most holding pen areas add to the summer heat stress because they lack ventilation.

In warm climates in which cows are washed from below in a wash or spray pen, the area becomes very hot and humid. To improve this environment, the holding pen roof should be a minimum of 4.5 m above the cows at eave height. Open sides should be encouraged if winter weather will permit that design. Ventilation can be improved by air movement from thermal buoyancy when the roof is steep and has an adequate ridge vent. A roof slope of 33% (4 in 12) is adequate with a ridge opening equal to 5 cm/3 m of structure width but never less than 20 cm (11). Roofs over the holding area should never be flat.

To improve the holding pen environment, overhead sprinklers (not foggers) and large fans were provided and tested in an Arizona trial (44); 1.2-m diameter fans were mounted overhead at a 30° angle from vertical so that the air blew downward and around the cows at ap-
proximately 28 m³ per cow. The sprinklers in front of the fans sprayed continuously at approximately 18 L/h per fan. Cow body temperatures were 1.7°C lower for the cows cooled in the holding pen than for cows with no holding pen cooling and resulted in milk production that was .79-kg/d higher during the summer months when daily high temperatures were 27 to 46°C. The estimated payback for most dairy farms in southwestern United States is less than 1 yr. Results of a research trial in Israel (48) using holding pen cooling five times daily increased milk production 2.4 kg/d over that of uncooled cows.

In most present holding pen installations, fans with .61 and .91 m diameter are used because of their common availability. The majority of present installations have installed the fan system to blow air away from the parlor although a few installations blow toward the milking area. If the air movement is away from the parlor, use of these fans, even without water spray, is beneficial when the ambient temperature is moderately warm. To improve the holding pen environment, fans should be considered by dairy producers even in moderate climates.

**EXIT LANE COOLING**

To prolong the cooling period at milking time, a system to wet the hair coat of cows automatically as they exit the parlor was developed in Arizona (4). Three nozzles that delivered approximately 30 L/min at 300 to 400 kPa of pressure automatically wet the skin and hair coat without interfering with postmilking teat dip. Moisture from the wet hair coat evaporated as the cow returned to the corral, providing 12 to 18 min of additional cooling. Exit sprinkler cost approximately $400 to $600 per exit lane and are activated with electric eye or wand switches. Financial data are not available for this additional postmilking cooling period.

**SHADE COOLING**

Refrigerated air-conditioning has been used experimentally to increase milk production and fertility (6, 25, 27, 38, 46), but the results have been less favorable than those for evaporative cooling. Furthermore, refrigeration systems are too expensive to be cost effective.

Cooling cattle with evaporatively cooled air has been effective in areas of low humidity (3, 29, 33). Even in more humid areas, the daytime humidity often is low enough for beneficial cooling (13, 36).

In 1981, a Mesa, Arizona manufacturing company developed a low maintenance evaporative cooling system that injects a very fine fog into the air stream (2, 5, 29). Cooling systems of this type under a corral shade on a dirt surface require a very fine mist to prevent accumulation of water on the ground. The fine mist particles stay suspended in the air and evaporate before being deposited on the ground, thus cooling the surrounding air. Some small droplets may be deposited on the hair coat of the cattle. Hahn (24) reported that the presence of these droplets may increase the insulating characteristics of the haircoat, resulting in a greater heat buildup in the cow. However, as long as substantial air movement is provided by the fans, properly designed mist systems can effectively improve the environment for dairy cattle (1, 7, 29, 31). A weighted curtain on the prevailing wind side of the shade helps contain the cooled air in the area occupied by the cows. The curtain is rolled up automatically to eave height when the cooling system is off or in the presence of high wind. This system presently is being used in Arizona, Hawaii, Mexico, Saudi Arabia, and the United Arab Emirates.

Less expensive shade cooling systems (fans and water spray) with a lower pressure mist injected into the air stream of conventional fans suspended below the shade roof have been used successfully in arid and subtropical climates. Without the side curtain, these systems are less effective in the presence of natural air movement, which often blows the cooled air out from under the shade before it reaches the cattle. However, on hot, still days, cow comfort is enhanced substantially.

Where excess water on the floor surface can be accommodated, as in free-stall housing, cattle cooling systems using sprinklers and fans have a definite advantage over mist systems. The larger water droplets completely wet the hair coat, providing direct evaporative cooling on the cow surface rather than depending upon convection cooling with evaporatively cooled air. These systems are used in the feed area of free-stall barns; additional fans but no sprin-
kler are placed over the free-stall area. These systems are particularly effective in dry climates but also can be beneficial in semihumid areas (19, 32, 35, 40).

Table 1 presents the results of research trials (1, 2, 5, 6, 7, 29, 31, 33, 45, 46) and estimates of milk production response by cows of varying milk production to two cooling methods, evaporative and spray and fans, in a range of daily high temperatures in a dry climate. Estimates were used in some cases to complete the table so that it could be utilized by dairy producers.

The stage of lactation during which cooling of any type is the most effective has been a subject of a number of studies in both dry (1, 2, 7, 31) and subtropical climates (13, 15, 18, 27, 35, 39). Cooling dry cows also has been beneficial (45, 47).

**FEED LINE COOLING**

Misting systems over the corral feed line have been used with success in the western and southwestern United States. Schultz (30) reported that a spray line over the feed area improved both daily milk production and reproduction efficiency. Milk production response was more apparent with feed line spray when the area was shaded. Natural air currents provided the air exchange necessary for continued evaporation. However, except on still days, air movement often blew the mist away from the cattle or ineffectively over their backs. Excess water also can be a problem unless the feed platform is designed to collect and to drain the water without accumulating water on the dirt surfaces of the corral. These potential pitfalls necessitate careful design and management of feed line cooling systems.

Misting systems in the feed area without fans have had little success in improving feed intake or milk production in Florida (14). If used in a humid environment, fans may be necessary if any benefit is to be realized. In a Missouri study (26), milk production was increased when a mist was used in conjunction with fans.

**CONCLUSIONS**

Heat stress of dairy cattle can be alleviated by artificial cooling methods. The degree of improvement varies with the type of system provided, climate, and production of the cows. An analysis of the economic benefits of a

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**TABLE 1. Estimated milk production response for different types of cooling systems under cattle shades compared with no cooling, in semiarid climates with an average day time humidity less than 30%**.

<table>
<thead>
<tr>
<th>Production and daily high temperature</th>
<th>Evaporative cooling and fan</th>
<th>Daily increase in milk production (kg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>High (38.5 kg/d)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40.5°C</td>
<td>7.5</td>
<td>4.0</td>
</tr>
<tr>
<td>35 to 40°C</td>
<td>6.0</td>
<td>3.2</td>
</tr>
<tr>
<td>&lt;34.5°C</td>
<td>5.3</td>
<td>2.8</td>
</tr>
<tr>
<td>Medium (29.5 to 38.5 kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40.5°C</td>
<td>6.4</td>
<td>3.5</td>
</tr>
<tr>
<td>35 to 40°C</td>
<td>5.2</td>
<td>2.8</td>
</tr>
<tr>
<td>&lt;34.5°C</td>
<td>4.5</td>
<td>2.5</td>
</tr>
<tr>
<td>Low (29.5 kg)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40.5°C</td>
<td>5.6</td>
<td>3.2</td>
</tr>
<tr>
<td>35 to 40°C</td>
<td>4.5</td>
<td>2.6</td>
</tr>
<tr>
<td>&lt;34.5°C</td>
<td>3.9</td>
<td>2.3</td>
</tr>
<tr>
<td>Dry 1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>&gt;40.5°C</td>
<td>2.0 (240)</td>
<td>1.4 (168)</td>
</tr>
<tr>
<td>35 to 40°C</td>
<td>1.4 (168)</td>
<td>0.9 (108)</td>
</tr>
<tr>
<td>&lt;34.5°C</td>
<td>0.9 (108)</td>
<td>0.6 (72)</td>
</tr>
</tbody>
</table>

1 Based upon research projects in southwestern United States, Mexico, and Saudi Arabia (1, 2, 5, 6, 7, 29, 31, 33, 45, 46).

2 4.2 kW.

3 Milk production first 120 d of lactation.

particular system for a given situation should be made prior to the installation of any equipment.

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**REFERENCES**


