Improvement of Animal Production by Altering the Environment of the Animal

D. V. Armstrong

Department of Animal Sciences, University of Arizona, Tucson, 85721 USA.

خلاصة : يسبب الطقس الحار الاجهاد الحراري في أبقار الحليب. بالرغم من أن هذه الآثار واضحة في المناخات الحارة فإن أبقار الحليب في المناطق ذات الطقس المعتدل نسبياً تتعرض في فترات معينة للاجهاد الحراري. ويمكن تقليل التدني الناتج في إنتاج الحليب ومعدلات التناسل باعتماد برنامج يعتمد على التبريد من خلال التظليل والتهوية والرش واستخدام المراوح. كما يجب دراسة الفائدة الاقتصادية قبل الشروع في تركيب الأدوات لتخفيف آثار الاجهاد الحراري.

ABSTRACT: Hot weather causes heat stress in dairy cattle. The resultant decrease in milk production and reproductive efficiency can be offset by implementation of a program consisting of cooling through shades, ventilation, evaporative coolers and spray and fans. Corral shade would be consistent to be essential to reduce stress. Feed line shade will improve dry matter intake and milk production. Holding pen cooling with spray and fans is cost effective, even in moderate climates. Shade cooling using evaporative or spray and fans is cost effective, if milk price is competitive to world price. The economic benefit should be determined before installation of equipment to reduce heat stress.

Summer climates depress milk production and reproductive performance in dairy cattle in many areas of the world. Reducing 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,
4) solar radiation (Hahn, 1985).

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 (Bianca, 1962; Fuquay, 1981).

When the THI exceeds 72, high producing dairy cattle are affected adversely. Dr. Frank Wiersma of the University of Arizona developed a chart (Figure 1) to be used by dairy producers to estimate the severity of heat stress on a dairy cow. This chart utilizes ambient temperature and relative humidity which can be readily available to the dairy producer on a daily basis and indicates that dairy cattle can be subjected to slight to severe stress.

Dairy cows respond to heat stress in several ways:

1) reduced feed intake,
2) increased water intake,
3) changes in metabolic rate and maintenance requirements,
4) increased evaporated water loss,
5) increased respiration rate,
6) changes in blood hormone concentration,
7) increased body temperature.

Higher producing and multiparous cows are especially susceptible to heat stress.

Beede and Collier (1986) suggested three basic management schemes for reducing the effects of thermal stress:

1) physical modification of the environment,
2) genetic development of less heat sensitive breeds, and
3) nutritional management program.

This paper will deal with environmental modification methods, including shade and cooling to reduce the effect of heat stress on dairy cattle.

Shade

In hot climates shade is considered to be essential to reduce the loss in milk production and reproduction efficiency and can be necessary for animal survival. Although not essential, shade in many other moderate summer climates may be cost effective in reducing the effect of summer heat. Trees are the most effective shade producers because they combine protection from the sun with the radiation sink effect created by cool leaves evaporating moisture (Hahn, 1976; Welchert et al 1965). Wood or palm branches also are effective shading material. Corrugated sheet steel is the most popular shade material because of cost, length of life, and low maintenance requirements. For the most effective shade, the upper surface of metal roofs should be painted white. Placing about 2.5 cm of insulation directly beneath the metal roof reduces the radiation

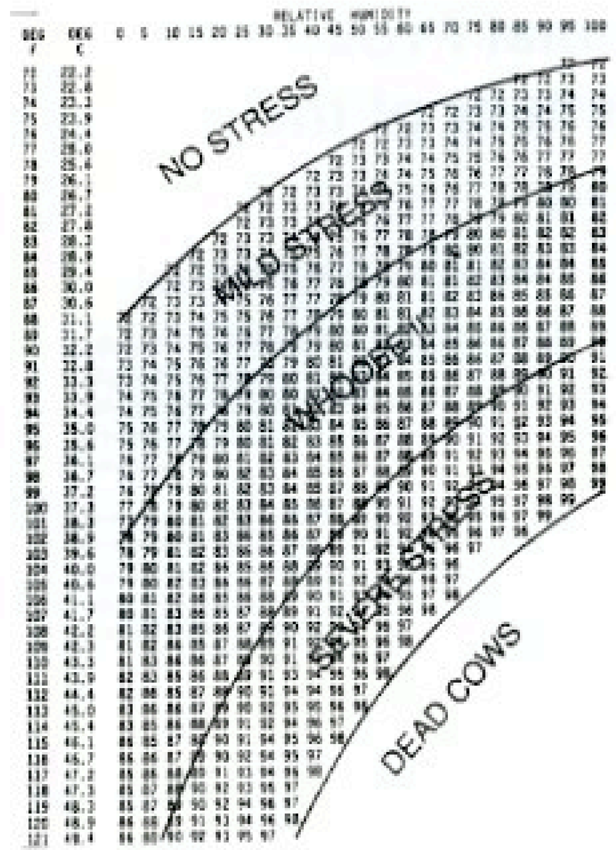

Figure 1. Temperature-humidity index table for dairy producers to estimate heat stress for dairy cows. Deg = Degrees Celsius. Relative humidity expressed as a percentage (from Frank Wiersma, 1990, Department of Agricultural Engineering, The University of Arizona, Tucson, USA).

heat load on the cow (Bond et al, 1961). Protecting the insulation material from birds may be necessary to prevent damage (Buffington, 1986).

Slatted shades are less effective than solid shades. Kelly and Bond (1958) found that slatted snow fencing with approximately 50% opening was only 59% as effective as new aluminum sheathing for shading the ground. In an Arizona study (Thatcher et al, 1974) comparing solid shade with slatted shade on dairy cows, daily milk production for cows with solid shade averaged 1.4 kg higher than for cows under slatted shade.

Shade cloth such as polypropylene fabric also has been used for shading dairy cattle. The most popular configuration is a fabric providing 80% shade. Shade cloth is less expensive initially than solid roofing material but does not provide as much protection[10] and has a shorter life span.

The recommended shade area in desert climates in open lot corrals in the plains states is 3.5 to 4.5 m^2 per lactating cow (Welchert et al 1965). Less area can result in udder injury as cows crowd together. Excess shade over 4.5 m^2 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 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 requires additional ground maintenance. In either case, shade should be located in the centre 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 with dry material on a regular basis to keep cows dry and clean.

Feed line shade has improved dry matter intake and milk production (Armstrong 1986). Fence line shade should never be the only shade available. It should be used only in corrals which have already provided sufficient shade for all animals in the corral. Cattle returning from the milking barn which has a holding pen cooling system (explained in the next section) will go directly to the feed manger and eat for a longer period of time than those cows which have not been provided feed line shade. Maximum benefit of feed line shade will be from corrals of cattle which are milked between 1100 and 1500 hours.

Extra cleaning of the concrete cow stand under the fence line shade is necessary. If this area becomes wet, cows will lie in the wet area, which increases the risk of mastitis and foot problems.

Cooling of Holding Pens

The holding pen adjacent to the milking parlour 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 2 or 3 times daily, stress can occur even under moderate ambient temperatures. Many holding pen areas add to the 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 4.5m 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. 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. Fans, 1.2m diameter, were mounted overhead at a 30° angle from vertical so that the air blew downward and around the cows at approximately 28 m^3/cow. The sprinklers in front of the fans spray continuously with 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 a 0.79 kg per day higher milk production 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 one year. Results of a research trial by Wolfenson et al (1988) using holding pen cooling five times daily increased milk production 2.4 kg per day over that of cows not cooled.

In most present holding pen installations, 0.91m and 1.2m diameter fans are used because of their common availability and need for the movement of large volumes of air. The majority of present installations have installed the fan system to blow air away from the parlour although a few installations blow toward the milking area. Blowing wet air toward the parlour will improve the environment for the operator, but may decrease the life of equipment, especially electrical equipment. If the air movement is away from the parlour, their use, even without water spray is beneficial when the ambient temperature is moderately warm. Fans to improve the holding pen environment should be considered by all dairy producers in warm or hot 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 parlour was developed in Arizona (Armstrong and Wiersma, 1986b). Three nozzles which would deliver approximately 30 L/min at 300 to 400 kpa pressure automatically wet the skin and hair coat without interfering with postmilking teat dip. Moisture from the wet hair coat evaporates as the cow returns to the corral, providing 12 to 18 min of additional cooling. Exit sprinkler is activated with electric eye or wand switches. Because of their low cost in hot climates, exit sprinklers should be considered for the additional postmilking cooling period benefits.

Shade Cooling

Refrigerated air-conditioning has been used experimentally to increase milk production and fertility (Armstrong, 1986c; Hahn 1985; Igono et al 1987; Taylor et al 1986; Wiersma and Armstrong, 1988), but the results have been less favourable than evaporative cooling (Armstrong 1986). Furthermore, refrigeration systems are very expensive to operate and in most parts of the world would not be cost effective.

Cooling cattle with evaporatively cooled air has been effective in areas of low humidity (Armstrong and Wiersma, 1986; Kelly and Bond, 1958; Smith et al, 1993). Even in more humid areas, the daytime humidity often is low enough for beneficial evaporative cooling (Brown et al, 1974; Stott et al, 1972).

In 1981, a Mesa Arizona manufacturing company developed a low maintenance evaporative cooling system that injects a very fine fog into the air stream (Armstrong et al, 1993; 1985; Kelly and Bond, 1958). Cooling systems of these types 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

TABLE I

Estimated milk production responses 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%.

Stage of lactation & daily high temperature	Daily increase in milk production	
	Evap. Cooling [1]	Spray & fan
High production 38.5 kg/d	----------Kg milk ----------	
> 40.5°C	7.5	4
35 to 40°C	6	3.2
< 34.5°C	5.3	2.8
Medium production 29.5 to 38.5 kg		
> 40.5°C	6.4	3.5
35 to 40°C	5.2	2.8
< 34.5°C	4.5	2.5
Low production 29.5 kg		
> 40.5°C	5.6	3.2
35 to 40°C	4.5	2.6
< 34.5°C	3.9	2.3
Dry cows[3]		
> 40.5°C	2.0 (240)	1.4 (168)
35 to 40°C	1.4 (168)	.9 (108)
< 34.5°C	.9 (108)	.6 (72)

[1] Based upon research projects in southwestern United States, Mexico, and Saudi Arabia (Armstrong et al 1993; 1993b; 1985; 1986; 1988; Ryan et al, 1992; Wiersma and Armstrong, 1988).
[2] Unit was 2.2 kw.
[3] Milk production first 120 d of lactation

on the hair coat of the cattle. Hahn (1982) reports that the presence of these droplets may increase the insulating characteristics of the haircoat resulting in a greater heat buildup in the animal. Substantial air movement provided by fans, in a properly designed mist systems can improve the environment for dairy cattle (Armstrong et al 1993, 1988; Kelly and Bond, 1958; Schultz 1988). A weighted curtain on the prevailing wind side of the shade helps contain the cooled air in the area occupied by the cattle. 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 (Armstrong et al, 1988; Shultz, 1988). 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, cattle comfort is enhanced substantially.

Table 1 presents the results of research trials 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 the table 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. Early lactation cooled cows have the greatest per-cent increase over non-cooled cows (Armstrong et al, 1993, 1993b, 1988; Shultz 1988). Cooling dry cows also has been shown to be beneficial (Wiersma and Armstrong, 1983; Wiersma andStott; 1966).

Feed Line Cooling

Misting systems over the open-lot corral feed line have been used with success in western and southwestern United States. Schultz (1988) reported that 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 is shaded. Natural air currents provide the air exchange necessary for continued evaporation. However, except on still days, air movement often blows the mist away from the cattle or ineffectively over their backs. In a Missouri study (Hahn et al, 1969), milk production was increased when a mist was used in conjunction with fans. Where excess water on the floor of the feed line surface can be accommodated, such as a feed line flush system, cattle cooling systems using sprinklers and fans, and using larger water droplets can be very effective. The larger water droplets completely wet the hair coat providing direct evaporative cooling on the animal surface rather than depending upon convection cooling with evaporatively cooled air. Excess water also can be a problem unless the feed platform is designed to collect and to drain the water. These potential pitfalls necessitate careful design and management of feed line cooling systems.

Dairy Design

Traditionally dairy design for hot-arid climates have been open lot corrals. Shade has been provided near the centre of their pen. Feed line shade has shown to be effective in improving feed intake. In the last five years a non-traditional design has been used with excellent success in hot arid climates. This design consists of combining the cow resting area shade with the feed line shade. When evaporative coolers were used over the cow lying area, and spray lines over the feed area, even on days with temperatures exceeding 49°c the inside temperature was below 35°C. Herd averages of milk sold per cow year have exceeded 12,000 litres of milk in the Arabic Peninsula. Individual cow milk production has exceeded 20,000 litres of milk per year. High milk production is possible in arid climates of the world, if environmental modifications are incorporated with excellent nutrition, management, and with dairy cattle of high genetic potential.

Conclusions

Heat stress in dairy cattle can be alleviated by artificial cooling methods. The degree of improvement will vary with the type of system provided, climate, and production of the cattle. An analysis of the economic benefits of a particular system for a given situation should be made prior to the installation of any equipment.

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