Behavioral Responses to Heat Stress: Dairy Cows Tell the Story

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SUMMARY

- Heat stress causes production losses and can impair animal welfare
- Dairy cattle change their behavior in response to hot weather and these changes can provide insight into when to cool cows
- Both shade and sprinklers can effectively reduce heat stress

INTRODUCTION

Heat stress is an economic cost for US producers. It is estimated that hot weather costs dairy farmers $900 million/year in reduced milk production and reduced fertility. In addition, heat stress is an animal welfare issue. Severe heat stress can result in death. Animal behavior can provide insights into how and when to cool dairy cows. We will review the behavioral responses to heat stress and examine results from new studies looking at two common methods for cooling dairy cattle: shade and sprinklers.

BEHAVIORAL RESPONSES TO HEAT STRESS

Throughout this paper, we will discuss three measures of environmental conditions: ambient temperature (in F), solar radiation (W/m^2) and Temperature-Humidity Index (THI), which combines the effects of temperature and humidity. A THI of 72 is an ambient temperature of 77°F and 50% humidity.

Shade Seeking

Cows readily use shade when given access to it and the provision of shade can alleviate negative effects of increased heat load. Not surprisingly, there is evidence that dairy cattle are motivated to use shade in warm weather. For example, we have found that dairy cows choose to stand in shade instead of lying in warm conditions (air temperature > 86°F) even when they were deprived of lying for the previous 12 h (Schütz et al., 2008). Furthermore, shade use increase with increasing air temperature and solar radiation (Kendall et al., 2006). Indeed, there is evidence that cattle will engage in aggressive behavior to gain access to shade, especially when the heat load increases.

Reduced Feed Intake

One of the most discussed behavioral responses to heat load is reduced feed intake. For example, in one study, Ominiski and colleagues exposed cows to heat stress in an environmental chamber (90°F) and found that intake was reduced by 3.1 lbs/d, or approximately 5%/d. This change also resulted in a 3.8 lb reduction in milk yield (Ominski et al., 2002). Extensively managed cattle also change grazing times and patterns to cope with heat load. For example, Kendall and others (2006) found shaded cows used shade during the day and grazed more at the night compared to unshaded cows. In this experiment, THI averaged 63.

Increase in Time Spent Standing

A second, but less discussed, change in behavior associated with heat load is an increase in time spent standing (e.g. Overton et al., 2002). In a recent experiment, we found that time spent standing increased by 10% (13.8 h to 15.3 h/d) when heat load increased by 15% (THI= 60 -70, Tucker et al., 2008). We suggest that cows spend more time standing to increase heat loss by increasing the amount of skin exposed to air flow or wind. In the infrared photo below (Figure 1), we show that a considerable amount of heat is lost from the underside of the cow, illustrating one possible reason why standing may be an important behavioral response to heat load.

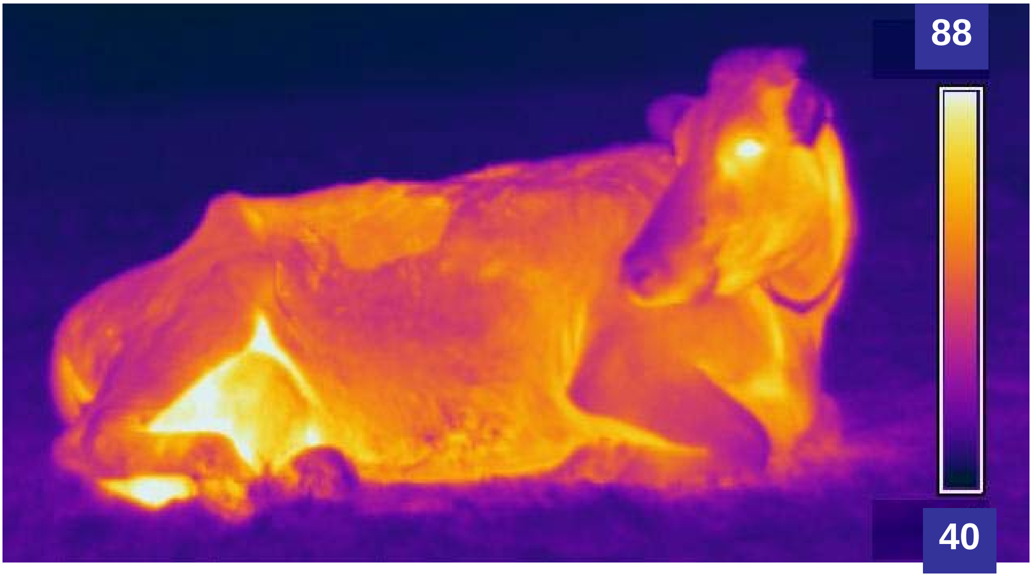

Figure 1. Infrared image of a dairy cow lying down at night. The scale represents temperature in F.

Increase in Time Around Water Trough

Unshaded cattle adopt other behavioral strategies to alleviate heat load, such as increasing time around the water trough (Figure 2). In a study by Mader and collegues the percentage of beef cattle around the water trough was 2 to 3 times greater for unshaded groups compared to groups that had > $3.5m^2$ shade/animal (1997), especially when heat load was at its peak. We do not fully understand why cows spend more time around the water trough, and there are several possible explanations. Cattle may reduce the effects of high heat load by increasing water consumption. Access to cool drinking water improved weight gain in feedlot cattle in summer

(Ittner and Kelly, 1951) and several studies have shown that cattle increase their water consumption in summer, particularly when there is no access to shade (e.g. Mader et al., 1997). There is also the possibility that cattle spend more time around the water trough because evaporation from the trough may create a cooler microclimate, compared the rest of the enclosure.

Figure 2. Cows without shade spend more time around the water trough (foreground), compared to cows with shade (background). Equal numbers of cows were present in each group (n=10 cows/group, Schütz et al., in preparation).

Increased Respiration

Respiration rate increases in response to heat load with little or no lag in time (Brown-Brandl et al., 2005). For example, in feedlot cattle, respiration rate increased from approximately 65 breaths/min when THI < 76 to 93 breaths/min when THI ≥ 84. Cows increase respiration rate in order to promote heat loss via evaporation. Respiration rate can be the most practical way to identify heat stress, as flank movements are easy to count.

BEHAVIORAL RESPONSES TO SHADE AND SPRINKLERS: WAYS TO ALLEVIATE HEAT LOAD

Shade

To date, it is clear that shade provides benefits for cattle in terms of behavior, physiological responses and production. There are many ways to provide shade, but little is known about the importance of various design features of shade (e.g. blockage of solar radiation, shade amount/animal, etc.). Our next challenge is to make recommendations about the best way to provide shade for animals. Animal behavior, in combination with measures of heat load, such as body temperature, can provide valuable insights into when and how to cool cows. In a series of recent experiments, we examined how a single design feature of shade, protection from solar radiation, influenced the behavioral and physiological responses of dairy cattle in summer.

In the first experiment, we compared the behavior and body temperature of dairy cattle when they had no access to shade, or free access to shade that blocked either 25, 50 or 99% of solar radiation (Tucker et al., 2008). Cows were kept in one of the four treatments in separate pastures and were observed all day. We found that use of the shade increased with higher levels of protection from solar radiation (total shade use, 25%: 1.3 h, 50%: 3.0 h, 99%: 3.3 h/15.5 day-time h, S.E.M.: 0.22 h). As average ambient solar radiation increased, total use of the shade structures increased (Figure 3). Cows with more protection from solar radiation had lower minimum body temperature (no shade, 25%, 50%: 100.2 °F, 99%: 99.8 °F), although the difference was relatively small.

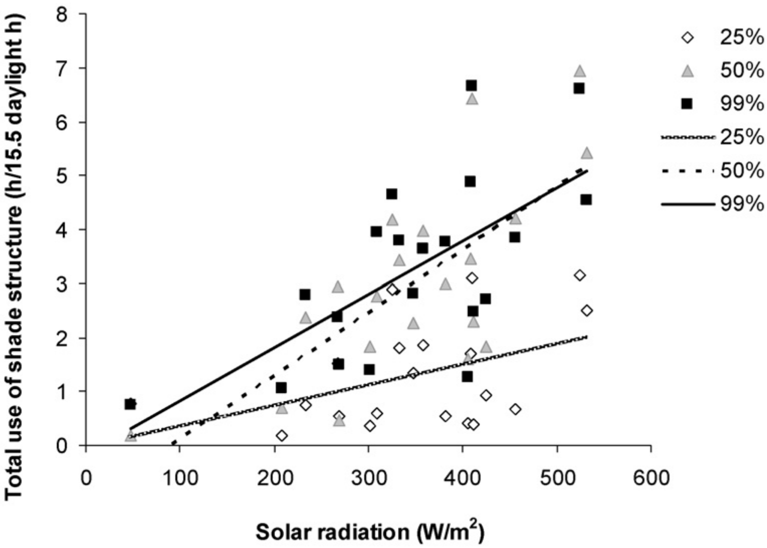

Figure 3. Relationship between daily average solar radiation and total use of the shade structures. The shade structures blocked 25, 50 or 99% of solar radiation and were freely available to dairy cattle (Tucker et al., 2008).

Similarly, shade use peaked during the hottest part of the day, or when solar radiation was highest. To illustrate this effect, we plotted shade use during the day with the highest solar radiation in the study (Figure 4). Cows used the shade simultaneously during the middle of the day. These results highlight that cows need to be able to use shade simultaneously during periods of peak heat load. Having access to shade that blocked more solar radiation and being able to use this shade at the same time helped these cows maintain their body temperature.

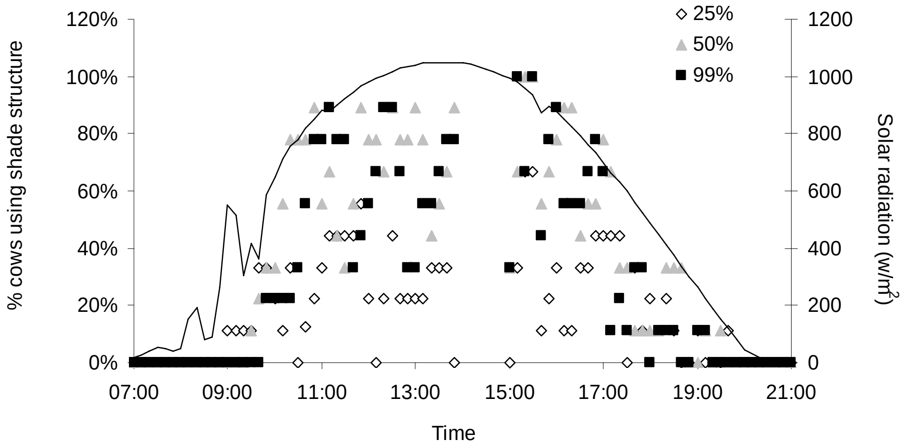

Figure 4. Percentage of cows using shade structures on the day with the highest average ambient solar radiation during the 20-day experiment. Dairy cows had access to shade structures that blocked 25, 50, or 99% of solar radiation in summer. Solar radiation (—) is plotted on the second y-axis. From (Tucker et al., 2008).

In a second experiment, we asked the cows for their opinion about the amount of solar radiation the shade blocked (Schütz et al., 2009). We let the cows choose between two different types of shade cloth that blocked: (1) 50 or 99%, (2) 25 or 50%, and (3) 25 or 99% of solar radiation. Each group of cows had access to four shade structures, and two structures of each type were provided to reduce competition. We monitored which shade cloth they chose to use by recording their location every 10 minutes during the hottest part of the day. We found that cows preferred shade cloth that blocked greater amounts of solar radiation in two of the combinations (99% versus 25%: 72.3% time spent in the 99% option, 50% versus 25%: 72.0% time spent in the 50% option), but showed no preference for shade cloth that blocked 50 or 99% of solar radiation when these two options were presented at the same time (49.8% time spent in the 99% option).

Together, these results demonstrate that the degree of protection from solar radiation is an important design feature of effective shade for dairy cattle. From the levels we tested, cows should be provided with shade that blocks at least 50% of the solar radiation. This example highlights how animal behavior and preferences can be used to evaluate design features of shade.

Cooling with Water: Sprinklers

Although shade is beneficial and readily used by cattle, cooling with water can provide more effective relief from heat. For example, in a recent experiment we found that sprinklers reduced respiration rate by 62% compared to a 30% reduction when cows were only provided with shade (Kendall et al., 2007). Indeed, others have found that the combination of shade and sprinklers provides the most marked reduction in respiration rate (Mitlöhner et al., 2001).

Indeed, there is extensive evidence that cooling with water, either as sprinklers or misters with or without fans, reduce respiration rate. Despite the overwhelming evidence that water is an effective way to cool cows, several questions remain unanswered. Namely, few researchers have explored if and when cattle will voluntarily use sprinklers. In most experiments, sprinklers are used over the feed bunk such that cows will get wet while they feed. There is some evidence that cattle may find sprinklers aversive. In previous work, we have found that body temperature will rise when sprinklers are used on cooler days (< 74°F), perhaps due to vasoconstriction in order to maintain core temperature (Figure 5 Kendall et al., 2007). In this experiment, cows were forced to get wet in the 90 minutes before afternoon milking and these results indicate that sprinklers may cause cold stress on days when ambient temperature was below 74°F. Others have also found that body temperature will rise shortly after sprinkling (Araki et al., 1985), but this has not been replicated by other researchers (e.g. Gaughan et al., 2004). It is likely that these differences between experiments can be explained by weather conditions, as we have shown that this short-term increase in body temperature only occurs on cooler days (Figure 5).

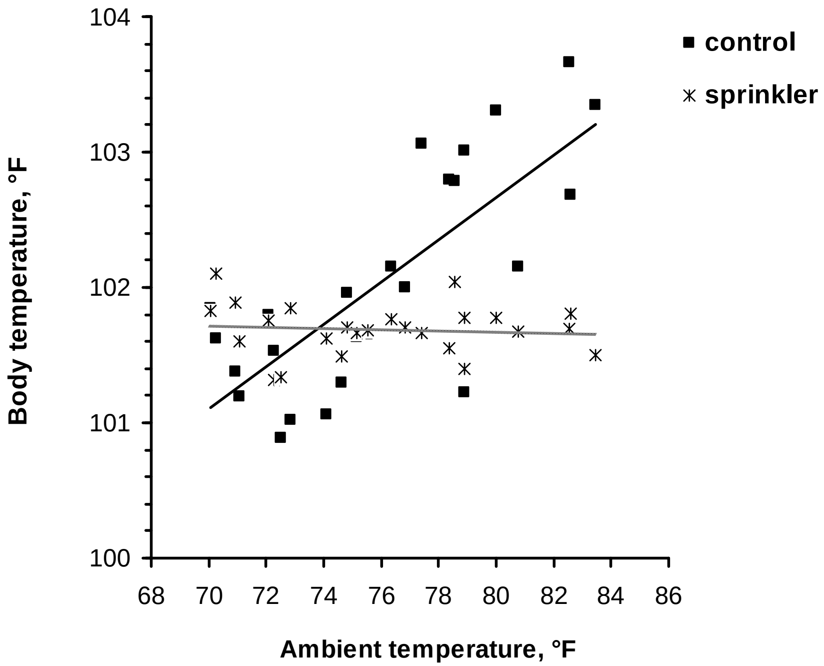

Figure 5. Relationship between body temperature and ambient temperature for cows that were provided no protection (control) or were sprinkled during the 90 minutes before afternoon milking. On cooler days (below 74°F), cows that were wet had higher body temperature.

There is only limited evidence about the behavioral response to sprinklers. In winter, cows seek shelter, particularly when it is raining (Vandenheede et al., 1995), and when exposed to wind and rain are five times more likely to stand with their head lowered compared to their sheltered counterparts (Tucker et al., 2007). When cows are unable to escape wetting by sprinklers because the water is applied to the entire pen or group, cows also spend more time with the head in a lower position, possibly in attempt to avoid getting water in sensitive areas like the ears, but also possibly because this is the only part of the body they can readily move away from the water (Kendall et al., 2007). Aversion is not directly measured by head position and only limited conclusions can be drawn from this behavior. Indeed, when given the choice in very warm conditions, cattle will stand under sprinklers (> 89.6°F, Seath and Miller, 1948, > 80.6°F, Igono et al., 1987).

In order to better understand how and when cows will cool with water, we built an idea first tested by in the 1940s and 50s (Kelly et al., 1955): cow showers. We built two showers that are activated by the cow stepping on the floor of the shower (Figure 6). Data analysis is still underway, but preliminary findings indicate that cows differ considerably from one another. For example, one cow spent, on average, 8 hrs/d in the shower, while another individual used the shower for only minutes each day. In addition to differences between individual cows, several external factors seem important. Cows use the shower more as the weather gets warmer. Secondly, cows primarily use the shower during the day. Together, these results, along with future studies, will help us better understand when to cool cows with water in order to maximize cow comfort and efficiently use resources.

Figure 6. A cow using a shower in a recent experiment. Cows could turn on the water by stepping on the floor of the shower.

CONCLUSIONS

In conclusion, dairy cattle change their behavior to reduce heat load in hot weather. Cows seek shade, reduce feed intake, spend more time standing, spend more time near the water trough and increase respiration rate as ambient conditions become warmer. These behavioral changes can provide insight into when and how to cool cows. Both shade and sprinklers can effectively reduce heat load. Animal behavior is a useful tool to understand how to best use and design shade and water cooling systems: cows will tell us about how to best cool them.

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