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Effect of core body temperature, time of day, and climate conditions on behavioral patterns of lactating dairy cows experiencing mild to moderate heat stress

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ABSTRACT

Cattle show several responses to heat load, including spending more time standing. Little is known about what benefit this may provide for the animals. Data from 3 separate cooling management trials were analyzed to investigate the relationship between behavioral patterns in lactating dairy cows experiencing mild to moderate heat stress and their body temperature. Cows (n = 157) were each fitted with a leg data logger that measured position and an intravaginal data logger that measures core body temperature (CBT). Ambient conditions were also collected. All data were standardized to 5-min intervals, and information was divided into several categories: when standing and lying bouts were initiated and the continuance of each bout (7,963 lying and 6,276 standing bouts). In one location, cows were continuously subjected to heat-stress levels according to temperature–humidity index (THI) range (THI ≥72). The THI range for the other 2 locations was below and above a heat-stress threshold of 72 THI. Overall and regardless of period of day, cows stood up at greater CBT compared with continuing to stand or switching to a lying position. In contrast, cows lay down at lower CBT compared with continuing to lie or switching to a standing position, and lying bouts lasted longer when cows had lower CBT. Standing bouts also lasted longer when cattle had greater CBT, and they were less likely to lie down (less than 50% of lying bouts initiated) when their body temperature was over 38.8°C. Also, cow standing behavior was affected once THI reached 68. Increasing CBT decreased lying duration and increased standing duration. A CBT of 38.93°C marked a 50% likelihood a cow would be standing. This is the first physiological evidence that standing may help cool cows and provides insight into a communally observed behavioral response to heat.

Key words: core body temperature, heat stress, lactating cow, standing behavior

INTRODUCTION

With an estimated annual production loss of more than $900 million to the US dairy herd (St-Pierre et al., 2003), heat stress has commanded considerable research attention within the past several decades. This interest in heat stress has coincided with the increase in energy expenditure due to a doubling of average production per cow (Hansen, 2000; Aharoni et al., 2005). Improvements in warm-weather dairy housing have provided more efficient technologies for cooling animals exposed to hot climates. However, heat stress remains an important environmental stressor on dairy cattle.

Heat stress directly and indirectly affects nutritional, productive, physiological, health, and behavioral parameters of cattle (Thatcher, 1974; Cook et al., 2007; Tucker et al., 2008; Rhoads et al., 2009). Increased ambient temperature increases standing times in heat-stressed cattle (Igono et al., 1987; Zahner et al., 2004), which further increases risk of lameness as well as possibly increasing maintenance requirements (Leonard et al., 1996; Cook et al., 2007). It is only recently that researchers have attempted to understand the correlation of one of the most documented outcomes (increased body temperature) to one of the emerging welfare concerns (time spent standing in a 24-h period) and its possible effect on bottom-line production.

Researchers have reported that an increase in standing time per day during hot periods increased lost production and disease prevalence (Cook et al., 2007) and that an increase in core body temperature (**CBT**) may be positively correlated to the amount of time cows stand during a 24-h period (Anderson et al., 2013). Also, increased heat-stress conditions, which are measured by calculating temperature–humidity index (**THI**) using relative humidity (**RH**) and temperature, have negative effects on CBT, standing behavior, and milk production (Johnson et al., 1963; Umphrey et

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Table 1. General parameters of trial conditions for data used

Item	Phoenix, AZ	Morris, MN	Tulare, CA
Cows, n	56	64	37
DIM	125	161	132
Milk production, kg/d	30.5	NA	NA
Milking periods/d	3	2 or 3	2
Stocking density, cows/head lock	0.96	1.1	NA
Housing style	Desert drylot	Freestall barn	Freestall barn
Cooling management	Shades with fans and misters, feed-line soakers	Cross-ventilated barns	Feed-line soakers, shaded barns
Trial treatments[1]	Fixed vs. adjustable fans	Evaporative cooling vs. without evaporative cooling	Conductive cooling without feed-line soakers vs. feed-line soaking with fans
Length of trial, d	5	9	7
Ambient conditions, range (mean)			
Temperature, °C	25.4–40.2 (32.7)	9.2–26.8 (20.9)	14.7–31.7 (22.8)
Relative humidity, %	16.9–75.3 (40.5)	46.0–96.5 (80.8)	29.1–82.6 (56.2)
THI[2]	76.3–84.4 (80.2)	51.4–79.9 (68.3)	58.3–76.7 (68.2)

[1]Cows were randomly and evenly distributed between treatments within trial location.

[2]THI = temperature–humidity index.

al., 2001; West, 2003). However, little information is available evaluating the effects of CBT, time of day, or ambient conditions on standing behavior of lactating dairy cows experiencing variable levels of heat stress. We hypothesize that cow behavior shifts according to changes within these parameters. Therefore, the objective of this study was to further define the effects of CBT or ambient conditions on standing behavior of lactating dairy cows.

MATERIALS AND METHODS

Cattle Trial Data

Data sets from 3 separate heat-stress trials were used for analysis. All studies were approved by the Institutional Animal Care and Use Committee of the respective university. Trials investigating differing forms of cooling management were conducted in Arizona (August 2011), California (September 2010), and Minnesota (August 2009; Table 1). In all trials, lactating dairy cows (n = 157) were intravaginally fitted with a stainless steel data logger (Hobo U12, Onset Computer Corp., Bourne, MA) attached to a blank controlled internal drug-releasing device (CIDR; Pfizer Animal Health, New York, NY) that recorded CBT. Cows were also fitted with a second data logger (Hobo Pendant G, Onset Computer Corp.) attached to the medial side of the cannon of either the right or left hind leg that recorded leg angle according to 3 different axes (Ledgerwood et al., 2010); leg angle can be used to determine the posture (lying or standing) of the animal. Both CBT and leg angle were measured simultaneously at 5-min intervals.

Ambient temperature and RH were recorded continuously at 15-min intervals during trial duration by Hobo U23 Pro v2 data loggers placed in solar radiation shields (Onset Computer Corp.) at 2 separate locations and outside of trial pens or barns on the Arizona farm and 4 locations for the Minnesota farm. Continuous ambient conditions were not recorded for the California trial; however, daily ambient conditions were collected with Hobo data loggers every 2 h beginning at 0600 to 1800 h during the trial period. Temperature–humidity indices were calculated using the following calculation:

$$T_{db} - [0.55 - (0.55 \times RH/100)] \times (T_{db} - 58),$$

where T_{db} is dry-bulb temperature (°F; Buffington et al., 1981).

Parameters for Analysis

Because the objective was to better describe behavioral patterns in heat-stressed cows, it was necessary to designate specific parameters to aid in describing statistical results. Although analyzed in other reports (Tucker et al., 2008; Anderson et al., 2013), a bout, either lying or standing, is defined as a period of time that begins once the animal changes posture and ends immediately before the animal changing back to the previous posture. Initial posture (lying or standing) is the first interval record at the beginning of each bout. Continuation of a posture bout (lying or standing) is any interval record during a bout that was not the initial posture. In regard to bout duration by period of day, initial CBT was considered the CBT at which the