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 ($\text{THI} \geq 72$). 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 al., 2001; West, 2003). However, little information is

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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)

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

²THI = temperature–humidity index.

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

posture changed, final CBT was considered the CBT at which the bout ended, and average CBT was considered the CBT average of the entire bout including the initial and final CBT. Temperature–humidity index intervals were derived from Zimbelman et al. (2009) and Zimbelman and Collier (2011), in which the authors derived heat-stress levels according to physiological changes (respiration rate, heart rate, and so on) in lactating dairy cows.

Statistical Analysis

All data were standardized to 5-min intervals for CBT and leg angle or 15-min intervals for ambient conditions. For all 3 trials, cattle were fed twice daily immediately following milking. Therefore, 2 h of data, which included 1 h for time spent in the milking parlor and 1 h spent feeding immediately after milking, were removed for each milking period to eliminate human interference and subsequent feeding following milking.

All data were analyzed as a complete randomized design for overall comparison or as a completely randomized block design when distinguishing differences across location or treatment. General analyses were performed using the MIXED or GLIMMIX procedures in SAS (SAS Institute Inc., Cary, NC) with the LSMEANS and PDIF options to compare means and SEM across potential behavioral factors. These factors included CBT, hour of day, period of day (0 to 0559, 0600 to 1159, 1200 to 1759, and 1800 to 2359 h), temperature, RH, and THI. Each factor was modeled separately or in combination with other appropriate factors to check for interaction. Cow was considered the experimental unit. Hour-of-day analyses included the REPEATED option, with hour as the repeated measure. The REG procedure was used to determine linear or nonlinear correlation between standing behavior and CBT or environment parameters. In all analyses, cow was used as a random variable. Ambient conditions and THI data for the California trial were not included in the analyses.

Bout parameters, including minimum, maximum, average, initial, and final CBT, were analyzed using the MIXED procedure with the LSMEANS and PDIF options. Independent variables included in the statistical model as possible interactions included period of day and CBT. Bouts that were interrupted because of or immediately after a milking period were removed from bout-duration analyses. Bouts beginning in one period of day and ending in another period were included in the period in which the bout began.

Two subsets of bout parameters were used: the first contained all bouts, the second contained only bouts that were at least 20 min in length. These subsets were

analyzed separately to describe overall bout characteristics with and without record restrictions. Others have reported that data sets with 5-min intervals for behavior are more accurate when shorter bouts remain in the analyzed data (Ledgerwood et al., 2010). Although useful with respect to bout duration, a 20-min bout threshold was chosen, because a bout lasting 20 min contained four 5-min interval records, allowing for more accurate statistical analysis for calculating CBT parameters. Bouts lasting less than 20 min only contained 1, 2, or 3 interval records, which could alter overall analysis when calculating least-standard means and SEM for changes and extremes of CBT.

RESULTS

A total of 229,860 five-minute interval records were used in the CBT data analyses. However, because of the 15-min interval for ambient conditions and 2 of 3 trials with ambient records, only 63,384 fifteen-minute interval records were used for the ambient-conditions data analyses. A total of 20,024 bouts were analyzed, with 9,994 lying and 10,030 standing bouts. When shorter bouts were removed, there remained 14,239 bouts analyzed, with 7,963 lying and 6,276 standing bouts.

Production data for all cows in the analyses were not available. However, general housing, cooling, and trial data were recorded (Table 1). Microenvironment data within building or under shade structure were not available for all trials. However, according to ambient conditions, cows in Arizona were subject to potential constant heat stress according to THI levels ($\text{THI} \geq 72$; Bohmanova et al., 2007), and cows in Minnesota and California were subject to heat-stress levels during part of the trial period. Relative humidity reached highest levels in Minnesota and lowest levels in Arizona.

Arizona cows spent a greater ($P < 0.04$) amount of time standing during a 24-h period compared with cows in Minnesota and California (12.6 vs. 11.4 and 11.3 ± 0.54 h/d, respectively). However, Minnesota numerically had the least variation between respective treatments, with less than 1% difference (not reported).

Average standing CBT was 0.07°C greater ($P < 0.01$) than average lying CBT for all cows (38.91 vs. $38.84 \pm 0.001^\circ\text{C}$, respectively). Also, cows switching from a lying to standing position were warmest ($P < 0.01$) compared with continuing to stand or lie as well as switching from a standing to lying (Figure 1). A decrease ($P < 0.01$) in CBT after initially standing occurred in all locations and treatments, but an increase ($P < 0.01$) in CBT after initially lying was observed in all cows except those exposed to the greatest heat-stress levels (treatment 1). These CBT differences across posture

Figure 1. Core body temperature in relation to posture in lactating dairy cows across location and treatment. Initial standing is representative of the period in which the animal transitioned from a lying to standing posture; continuance of standing is representative of the period after the animal initially stood. Initial lying is representative of the period in which the animal transitioned from a standing to lying posture; continuance of lying is representative of the period after the animal initially lay. Treatments are designated as follows: 1 = Arizona with adjustable fans and misters under drylot shade; 2 = Arizona with fixed fans and misters under drylot shade; 3 = Minnesota within a cross-ventilated building; 4 = Minnesota within a cross-ventilated building with evaporative pads; 5 = California with feed-line soakers and fans; and 6 = California with hydrothermally cooled freestalls without feed-line soaking or fans. A treatment effect was observed ($P < 0.0001$). Columns within treatment with different letter designations (a–d) differ ($P < 0.01$).

were also observed in 3 of the 4 time periods, with the exception of the 0600 to 1159 h period (Figure 2).

Hour of day affected ($P < 0.01$) CBT as well as proportion of cows standing (Figure 3). A diurnal effect of proportion of cows standing was also observed ($P < 0.01$), with proportion of cows standing peaking at 0800 and 1900 h. A drop in CBT in standing and lying cows occurred at 1000 and 1100 h (Figure 4). Also CBT of lying and standing cows followed similar variation across a 24-h period, with lying cows staying cooler ($P < 0.01$) than standing cows for most of the day except for around 0700, 1500, and 1600 h.

All environmental factors differed ($P < 0.01$) across cow behavior for the 2 locations that had ambient conditions recorded (Table 2). Conditions were similar across specific posture types except for continuance of lying, which occurred at a greater ($P < 0.01$) THI, lesser ($P < 0.01$) RH, and greater ($P < 0.01$) ambient temperature than cows initially standing, initially lying, or continuing to lie. Overall, cows stood at a THI 2 points greater, a RH 2% wetter, or an ambient temperature 0.8°C greater compared with lying cows.

Once proportion of standing cows was separated into different THI groups, percentage of cows standing

peaked ($P < 0.01$) when exposed to THI values between 80 and 89, and the percentage of cows standing was lowest at THI values below 68 (Table 3). Although a quadratic relationship to standing proportion can be distinguished from the THI group separation, all regression model attempts failed to be accurate ($R^2 < 0.15$; not reported). Regression models including ambient temperature, RH, THI, or a combination of the 3 were also not predictive ($R^2 < 0.15$; not reported).

However, the correlation of CBT to percentage of cows standing versus lying produced greater ($P < 0.01$) accuracy with a quadratic relationship (Figure 5). Standing and lying interval patterns were sigmoidal, reaching peak counts with cows at a CBT of 38.97 and 38.81°C, respectively. Specifically, a 50% likelihood of a cow standing was met at a CBT of 38.93°C ($P < 0.01$).

Standing-bout durations peaked ($P < 0.01$) and lying-bout durations decreased ($P < 0.01$) during h 1200 to 1759 (Figure 6). Throughout all periods, average minimum standing and lying bout CBT were similar ($P > 0.10$), whereas average maximum standing and lying bout CBT differed ($P < 0.01$); Figure 7). Differences between maximum and minimum CBT were 0.37°C for standing bouts and 0.30°C for lying bouts.

Figure 2. Effect of period of day on core body temperature in relation to posture of lactating dairy cows experiencing mild to moderate heat stress. A period-of-day effect, core-body-temperature effect, and an interaction between the 2 were observed ($P < 0.01$; SEM = 0.01°C).

Standing bouts increased ($P < 0.01$) to more than 60 min in length when initial CBT increased from below 37.75°C to above 40.50°C (Figure 8). In contrast, lying-bout duration decreased ($P < 0.01$) by approximately half the magnitude of standing bouts (30 min) as CBT increased from below 37.75°C to above 40.50°C.

Differences are also observed between initial and final CBT for standing and lying bouts (Figure 9). Standing bouts averaged a 0.22°C decrease in CBT from initial to final interval record, whereas lying bouts averaged a 0.17°C increase in CBT. Standing and lying bout CBT changes were similar ($P > 0.10$; range = 0.17 ±

Figure 3. Core body temperature and percentage of cows standing across a 24-h period. Cows ($n = 157$) from 3 separate trials were exposed to mild to moderate heat stress. Solid line = core body temperature; dashed line = % of cows standing. An hour effect was observed for both parameters ($P < 0.01$).

Figure 4. Average core body temperature changes within posture across a 24-h period in lactating dairy cows. Cows ($n = 157$) were subjected to mild to moderate heat stress. An hour effect was observed ($P < 0.01$; SEM = 0.01°C) for both postures, as well as an hour × core body temperature interaction ($P < 0.01$).

Table 2. Effect of environmental parameters on posture of lactating dairy cows experiencing mild to moderate heat stress¹

Item	Variable posture				SEM	Overall posture		
	Initial standing	Continuance of standing	Initial lying	Continuance of lying		Standing	Lying	SEM
THI ²	76.3 ^a	78.8 ^b	77.1 ^a	76.7 ^a	0.30	78.5 ^a	76.7 ^b	0.09
Relative humidity, %	68.1 ^a	65.4 ^b	66.9 ^a	67.7 ^a	0.43	65.7 ^a	67.6 ^b	0.13
Temperature, °C	24.1 ^a	25.0 ^b	24.3 ^a	24.1 ^a	0.12	24.9 ^a	24.1 ^b	0.04

^{a,b}Numbers with differing superscripts within each row and posture group (variable or overall) differ ($P < 0.0001$).

¹Cows ($n = 120$).

²THI = temperature–humidity index.

0.018°C) across period of day; however, initial and final CBT differed ($P < 0.01$) across period of day, with an approximately 0.5°C greater difference during 0600 to 1159 h compared with the other 3 periods.

DISCUSSION

The fact that heat-stressed animals spend more time standing is critical when managing high-producing cows. Although the cow is attempting to improve heat abatement by taking advantage of increased sensible water loss, radiating surface, and air movement or convection by increasing its body surface area exposed to these effects (Silanikove, 2000; Berman, 2003; Maia et al., 2005), the effects of standing rather than lying down may work against efficient milk production. Standing anatomically limits blood flow to the udder as compared with a lying position in cows (Rulquin and Caudal, 1992). Longer standing episodes increase risk of lameness (Cook et al., 2004). West (2003) reported that increased physical activity (i.e., standing) increases energy expenditure, altering nutrient use and increasing maintenance requirements. This increase in maintenance costs compounded with high energy expenditure (and increased heat production) for high-producing cows negatively affects milk yield (Purwanto et al., 1990; Umphrey et al., 2001).

The amount of time an unstressed cow will spend lying down in a 24-h period can vary widely, with one group reporting a 9-h range (5.2 to 14.4 h/d; Ledgerwood et al., 2010). However, time spent lying down in the current study diminished as degree of heat-stress

conditions rose. Arizona cows in the current study, which were subjected to constant heat-stress conditions according to THI levels, lay down less than cows in Minnesota and California, which had at least some respite to heat-stress conditions. This idea of stress level and behavior has been reported elsewhere within single locations (Malechek and Smith, 1976; Frazzi et al., 2001; Provolo and Riva, 2009).

Regardless of heat-stress level, the difference in CBT related to the probability of whether the cow is standing or lying was quite narrow (0.07°C). Though this difference may be physiologically irrelevant, it may explain the behavioral change between whether the heat-stressed dairy cow perceives necessity either to stand or lie down. This CBT also varies by time of day, possibly because of the added effect of environmental conditions such as THI and cooling management. The diurnal standing behavior of the cows regardless of heat stress may also add to this variation (Provolo and Riva, 2009). Interestingly, cows were more willing to lie down at greater CBT during the hot part of day (1600 h), which coincides with greatest average daily CBT, than during cooler nighttime hours.

Regression analysis was successful and accounts for over 50% of the variability when predicting whether a cow is lying or standing according to CBT. Sigmoidal (S-curve) regression correlation for initial lying and standing data points according to CBT was also successful. Although specific 50% likelihood CBT for the current study is noted, this CBT may vary according to location and level of heat stress as mentioned earlier. Lee and Hillman (2007) reported Holstein cows

Table 3. Effect of temperature–humidity index (THI) on percentage of standing, lactating dairy cows experiencing mild to moderate heat stress¹

Item	THI ²						SEM	Overall <i>P</i> -value
	<68	68–71	72–79	80–89	90–98	>98		
% Cows standing	43.6 ^a	49.8 ^b	53.0 ^b	68.2 ^c	49.7 ^b	52.2 ^b	1.62	0.0001

^{a–c}Results without a common superscript differ ($P < 0.01$).

¹Cows ($n = 120$).

²THI intervals are indicative of different levels of heat stress defined by Zimbelman and Collier (2011).

Figure 5. Relationship of core body temperature (CBT) to (a) initial-standing and initial-lying data records and (b) proportion of cows standing. In (a), initial standing is representative of data records in which the cow transitioned from a lying to standing posture, and initial lying is representative of data records in which the animal transitioned from a standing to lying posture. A sigmoidal relation was observed for both positions ($P < 0.01$; $R^2 > 0.90$), with mean CBT for each equation noted. In (b), a quadratic correlation was observed ($P < 0.01$; $R^2 = 0.56$), with the CBT at the 50% mark and the equation noted.

were more likely to be standing than lying at a CBT of 38.89°C, which is approximately 0.1°C less than the 50% likelihood of the current study. This suggests that regression models may be unique to each operation. Also, we accept that although willingness of a cow to stand is affected by CBT, other influences may also

Figure 6. Change in standing- and lying-bout duration across a 24-h period of lactating dairy cows experiencing mild to moderate heat stress. ▲ = standing, bouts ≥ 20 min; ◆ = standing, all bouts; × = lying, bouts ≥ 20 min; ■ = lying, all bouts. A period effect was observed ($P < 0.01$; SEM = 1.6 min).

affect this willingness. Other than ambient condition changes, cows may change posture for a variety of other reasons that may include feeding episodes, tiredness from standing or lying down, pecking-order confrontations, unexpected laborer visits, and so on. This may explain the low accuracy of posture prediction according to CBT even with several hundred thousand observations used in the analysis.

Documented reports of changes in CBT from initial standing or lying through continuance of posture are limited. Furthermore, the authors could find no report on the changes within standing or lying bouts associated with CBT. The current study shows cows that initially stand or lie down will remain standing with their CBT approximately 0.17°C lesser than the initial CBT or will remain lying with their CBT approximately 0.17°C greater. This general pattern, although variable in initial CBT, is seen across all 4 periods of the day.

A positive correlation between THI and time spent standing has been recorded by others (Zahner et al., 2004; De Palo et al., 2005; Provolo and Riva, 2009). The failure to produce a regression equation using THI, ambient temperature, RH, or a combination of the 3 in the current study may have been due to several factors. First, the ambient conditions may not be indicative of microenvironment conditions within building or under shade structure. Second, a limited number of ambient-condition interval records were available and were spaced 15 min apart, which may have masked short 5- to 10-min posture changes. Finally, others have reported that lying behavior in cows during nondaylight

Figure 7. Effect of period of day on average bout maximum and minimum core body temperatures (CBT) by posture in lactating dairy cows experiencing mild to moderate heat stress. Only bouts longer than 15 min were included. A period-of-day effect was observed ($P < 0.0001$). Columns within period of day with different letter designations (a–c) differ ($P < 0.01$; SEM = 0.014). SB = standing bouts; LB = lying bouts.

hours cannot be explained simply by THI (Zahner et al., 2004; Provolo and Riva, 2009). Zahner et al. (2004) explained that behavior during this period of day may be influenced more as an effect of time of day (diurnal pattern) as well as barn or lot environment (cooling management, bedding, and so on). In the current study, we observed a diurnal standing pattern regardless of THI, supporting this explanation. Regardless, peak standing within THI 80 to 89 rather than THI 90 to 98 or THI >98 may suggest that cows have already stood for some time in the THI 80 to 89 range before THI increased to greater heat-stress levels; therefore, their need to stand for cooling purposes may have been surpassed by the need to lie down due to fatigue from standing.

Despite incomplete THI correlation to standing behavior in the current study, ambient conditions still affected cow behavior. Provolo and Riva (2009) reported increased standing-bout durations and decreased lying-bout durations as THI increased. However, the current study extended the THI grouping beyond a 76 index reported by Provolo and Riva (2009) and found that this correlation was not linear, with less cows standing at severe THI (>89) than at moderate THI (80 to 89). Cows also increased standing proportion markedly once

Figure 8. Effect of initial core body temperature on standing- and lying-bout duration of lactating dairy cows experiencing mild to moderate heat stress. Solid line = standing bouts; dashed line = lying bouts. Cows ($n = 157$).

THI reached 68, a mark that has been suggested to be the new benchmark for heat stress in dairy cows (Zimbelman et al., 2009). It must be clarified that these THI marks were not the conditions under the cooling systems, so although THI may have exceeded 100, cows were not necessarily experiencing such an extreme level of heat stress.

Within the afternoon period, the hottest time of the day, lying and standing durations dramatically decreased and increased, respectively. Unstressed cows have been reported to have lying durations approximately 70 min in length (De Palo et al., 2005; Drissler et al., 2005; Ito et al., 2009). Other than the afternoon period, lying durations in the current study were similar, suggesting the afternoon period should be a crucial target for improving cow comfort.

De Palo et al. (2005) reported the negative correlation of THI to lying-bout duration. Because a positive correlation exists between ambient temperature and CBT (Wise et al., 1988), the current study shows the same negative correlation of CBT to lying-bout duration. Furthermore, we also show a positive correlation of CBT to standing-bout duration.

In conclusion, CBT and THI are correlated to cow behavior in terms of lying or standing. Without the influence of human interference, heat-stressed cows will respond to changes in CBT and shift posture accordingly. Cows with greater CBT will lie down for shorter and stand for longer durations. Research using micro-environment-conditions data are required to further

Figure 9. Effect of period of day on core-body-temperature measurements of standing and lying bouts of lactating dairy cows experiencing mild to moderate heat stress. ▲ = Standing, bouts >15 min; ◆ = standing, all bouts; × = lying, bouts >15 min; ■ = lying, all bouts. A difference ($0.17 \pm 0.018^{\circ}\text{C}$; $P < 0.01$) between initial and final CBT in all periods was observed. Initial and final CBT was least in period 0600 to 1159 h ($P < 0.01$). Core body temperature changes between initial and final segments did not differ ($P > 0.10$) across period of day.

understand the relationship between environmental conditions and cow behavior.

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