**ARIZONA AND NEW MEXICO
DAIRY NEWSLETTER**

**COOPERATIVE EXTENSION
The University of Arizona
New Mexico State University**

SEPTEMBER 2007

THIS MONTH'S ARTICLE:

The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows

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(Reprinted from the Journal of Dairy Science Vol. 90 No. 4, 2007)

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Don't Forget!

6th Annual Arizona Dairy Production Conference will be on Thursday, October 11.

Discussions about high feed costs, raising Holstein steers, immigration reform, and methane digestion. See inside for details.

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J. Dairy Sci. 90:1674–1682
doi:10.3168/jds.2006-634

The Effect of Heat Stress and Lameness on Time Budgets of Lactating Dairy Cows

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ABSTRACT

Time budgets for 14 cows housed in a 3-row freestall pen were obtained for 4 filming sessions timed to capture different climatic conditions, with a range in mean pen temperature-humidity index from 56.2 to 73.8. Mean lying time decreased from 10.9 to 7.9 h/d from the coolest to the hottest session filmed. This change in behavior occurred predominantly between 0600 h and 1800 h. Time spent standing in the alley increased from 2.6 to 4.5 h/d from the coolest to the hottest session filmed, with changes occurring between 1200 h and 1800 h. There was a negative effect of increasing locomotion score over the summer with higher locomotion scores associated with less time spent standing up in the alley. Time spent drinking increased from 0.3 to 0.5 h/d across the range in temperature-humidity index. Filming session alone did not affect time spent standing in the stall, but the effect of locomotion score was significant, with score 2 and score 3 cows standing in the stall longer than score 1 cows (4.0 and 4.4 compared with 2.9 h/d respectively). Behavioral changes observed and traditionally associated with heat stress were confounded by changes in locomotion score. Increases in claw horn lesion development reported in the late summer may be associated with an increase in total standing time per day. The changes in behavior described were because of mild to moderate heat stress. The finding that activity shifts occur around a temperature-humidity index of 68 supports the use of more aggressive heat-abatement strategies implemented at an activation temperature of around 21°C.
Key words: heat stress, lameness, time budget

INTRODUCTION

The dramatic impact of heat stress on dairy cow milk production has been the primary focus of climate research in recent years (West, 2003). Under conditions of heat stress, dairy cattle develop respiratory alkalosis as a consequence of thermal panting and attempts to use evaporative heat loss (Benjamin, 1981). Dry matter intake is reduced; thus, blood flow to the mammary gland and the portal plasma flow are lowered, which in turn reduce milk yield (McGuire et al., 1989; Lough et al., 1990). In addition, heat stress affects reproductive performance through reduced viability of the spermatozoa and ova, via a negative effect on the intensity and duration of estrus, and through delayed or inhibited ovulation (Ravagnolo and Misztal, 2002).

The temperature-humidity index (**THI**) has been commonly used to estimate the effect of heat stress on production and reproduction (Ravagnolo et al., 2000; West et al., 2003). There is general agreement that significant effects are observed at a mean daily THI of around 72 (Johnson, 1987; Igono et al., 1992; Armstrong, 1994). Such combinations of temperature and humidity are seen during the summer across North America and in many other parts of the world. Most heat stress research has focused on conditions of sustained moderate to severe heat stress in locations such as the southeastern and southwestern United States, whereas information on the effects of episodic mild to moderate heat stress typical of the upper Midwest has not been readily available (Ominski et al., 2002). Episodic periods of heat stress may present the cow with greater challenges in the short-term because physiological homeorhetic adaptations take weeks rather than days to occur (Beede and Collier, 1986; Collier et al., 2006).

There has been little work on behavioral adaptations to sustained or episodic heat stress. Shultz (1984) studied cow responses to weather types in corrals in the southwestern United States. An almost linear relationship between ambient temperature and the proportion of cows standing was demonstrated. More recently, Overton et al. (2002) documented temporal cyclicity in lying behavior in a freestall pen and noted an inverse relationship between the proportion of cows lying down and ambient temperature. This association, however, was confounded by time after milking. In a study con-

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Received October 5, 2006.
Accepted December 13, 2006.
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ducted in 4 Swiss dairy herds, lying behavior of sentinel animals was tracked under different climatic conditions (Zahner et al., 2004). The authors noted that the duration of lying behavior decreased during the day with increasing THI, but lying duration during the night was unaffected. Although it is generally accepted that cows stand more in alleys and stalls during periods of heat stress, no previous study has followed a group of cows through different climatic conditions and reported changes in daily time budgets for lying, standing, drinking, milking, and feeding activity.

Claw horn lesions, such as sole ulcer, are believed to develop from increased pedal bone mobility induced by changes in the corium at calving (Lischer et al., 2002) and potentially from nutritional insults such as subacute ruminal acidosis (Cook et al., 2004a; Stone, 2004). Factors that contribute to an increase in time spent standing may exacerbate these changes by further compromising the structure of the claw. Reductions in lying activity per day have been associated with lameness in dairy cows (Leonard et al., 1996; Cook et al., 2004a). Poor stall design and excessively long milking times also have a negative effect on hoof health (Cook et al., 2004b; Espejo and Endres, 2007). Behavioral adaptations to heat stress may be another potential risk factor for reduced lying times and associated lameness. An increase in the rate of claw horn lesion associated lameness in the late summer has been reported and associated with periods of heat stress in Wisconsin dairy herds (Cook, 2004). This may be because of increased susceptibility to subacute ruminal acidosis or because of an increase in standing activity or a combination of the two.

This study documented the degree of change in daily activity time budgets in a group of lactating dairy cows between filming sessions that targeted different THI on a commercial free-stall dairy farm. In addition, changes in activity during 4 specified periods of the day between filming sessions were recorded.

MATERIALS AND METHODS

Cow Selection

Twenty multiparous Holstein cows were randomly selected from a subset of cows less than 150 DIM, within a single pen of a commercial freestall-housed dairy herd. Each cow was given a unique identification number using black hair dye, visible from both flanks and the head. Three weeks before the start of filming, the feet of each cow were trimmed and balanced. Cows identified as clinically lame by the herdsman during the filming period were treated within 7 d.

The pen was monitored for a total of 4 filming sessions under different weather conditions. At a single milking during each filming session, the cows were scored for locomotion on a flat and level surface when returning from milking using a 4-point scoring system where 1 = nonlame, 2 = slightly lame, 3 = moderately lame, and 4 = severely lame (Nordlund et al., 2004). Parity, locomotion score, current DIM, and most recent DHIA-recorded daily milk weight at each filming session were used as covariates in the statistical modeling.

Animal Housing

Study animals were housed with a group of multiparous cows in an east–west oriented pen with curtain sidewalls and 3 rows of freestalls bedded with sawdust on top of a rubber crumb-filled geotextile mattress. Group size was maintained between 100 and 105 cows with access to 92 stalls that measured 1.19 m wide and 2.49 m long against the side wall (2.21 m long for the head-to-head stalls), 1.68 m from curb to brisket locator, with a neck rail 1.14 m above the stall surface and 1.68 m from the rear curb. Pen flooring was grooved concrete, with a 1.8-m wide rubber surface in the feed alley, adjacent to the feed bunk that consisted of 65- × 0.61-m wide headlocks. Water troughs were located at the ends of the pen and at the single cross alley in the middle of the pen.

Heat abatement was provided by 3 recirculation fans (1.22 m diameter) spaced at 12-m intervals and located over the feed bunk. No fans were located over the stalls. The fans were activated above a temperature of 21.1°C. In addition, water soakers were located along the feed bunk at 1.98-m intervals. The soaker cycle was activated above a temperature of 25.6°C and cycled through 1.5-min periods on and 11-min periods off.

Cows were milked 3 times daily. Fans and water soakers were present in the holding area. A TMR was fed once a day at approximately 0900 h and pushed up 6 times per day. Cows were added to and removed from the pen at weekly intervals. Filming was timed to avoid periods within 48 h of new pen additions.

Choice of Filming Times

Weather forecasts were used to predict local weather conditions for 4 filming sessions between early June and the beginning of September 2004. The aim was to film 2 sessions with a predicted maximum outside ambient temperature less than 23.9°C and 2 sessions with a predicted minimum outside ambient temperature greater than 18.3°C. The pen was filmed over a 3-d period when weather predictions were favorable. The dates of filming for each of 4 sessions (S1 to S4) were June 22 to 24, July 12 to 14, August 10 to 12, and August 25 to 27, 2004.

Climate Monitoring

Two calibrated temperature and humidity data loggers (Dickson TR320 Pro Series; Dickson, Addison, IL) were located at the east and west end of the pen and taped to a pole protected from direct sunlight and slightly above cow level. Temperature and relative humidity data were downloaded for each minute of each filming session and the THI was calculated for each location in the pen. A value for THI was obtained by averaging the data obtained from each end of the pen at each minute for the entire filming session and for distinct time periods within each session. The equation used to calculate THI was: $\mathrm{THI} = \mathrm{T} - (0.55 - 0.55 \times \mathrm{RH}) \times (\mathrm{T} - 58)$, where T is the pen ambient temperature in °F, and RH is relative humidity expressed as a decimal (NOAA, 1976).

Filming Methodology

Methodology for video capture and tracking of individual marked cows has been described (Cook et al., 2004b). Digital camcorders (Sony DCRTRV900 miniDV video cameras; Sony Corporation, New York, NY) were used to record 1 s of activity every 30 s on the long-play setting. Activity was captured between 1407 h on d 1 and 0700 h on d 3, resulting in 40.9 continuous hours comparable across 4 sessions.

Time spent feeding (head over the feed curb), drinking (head over the water trough), standing in an alley, standing in a stall (standing with all 4 feet in the stall or perching with front 2 feet in the stall), lying down in a stall, and time spent out of the pen while milking was recorded for each cow at each session. Time budgets were created for 4 periods during the middle 24 h of the filming of each session, where period A (**PA**) was from 00:00 (h:min elapsed) to 05:59, period B (**PB**) was from 06:00 to 11:59, period C (**PC**) was from 12:00 to 17:59, and period D (**PD**) was from 18:00 to 23:59. Period X (**PX**) was the combined total from 00:00 to 23:59 h (where PX = PA + PB + PC + PD), and period Y (**PY**) was the time budget for the whole 40.9-h period, converted to a 24-h day by proportion.

Statistical Analysis

Mixed effect models were created to investigate the differences in cow behavior (time spent lying down in the stall, standing in the stall, standing in the alley, standing drinking, standing feeding, and standing milking) between different filming sessions (S1 to S4) at different mean THI. Plots of residuals were used to ensure an approximate normal distribution and determine whether transformations of the data were required. Where log transformations were used, back transformed values of the least squares mean along with 95% confidence limits are given in the data tables.

For the entire filming session, analysis of covariance was performed for each behavior using PROC MIXED in SAS version 9.1 (SAS Institute, Inc., Cary, NC), with filming session and locomotion score for each individual cow at each session forced into all models. Other covariates were parity, most recent DHIA-recorded milk yield, and DIM at each filming session. Session, parity, locomotion score, and cow identification were included in the class statement along with a random effect for cow. Nonsignificant fixed effects ($P > 0.05$) were removed by the process of stepwise backwards elimination. Biologically plausible 2-way interactions were examined from the resultant model and retained if $P < 0.05$. Differences recorded between least squares mean activities for each session were tested using Fisher's protected least significant difference with $P < 0.05$.

For the analysis of behavior by period (PA to PD) and between each session (S1 to S4), a repeated measures mixed model was used with cow as the repeated subject. The Akaike information criterion was used to test 2 different covariance structures. Compound symmetry provided the best model fit, compared with the first-order autoregressive covariance structure, suggesting that the correlation within a cow was relatively constant across periods, rather than becoming weaker over time. The compound symmetry covariance structure was identical to fitting cow as a random effect, as the random effect assumes equal correlation across periods (Littell et al., 1998). Fixed effects of session, period, and the interaction between session and period were forced into all models. Other covariates were parity, most recent DHIA recorded milk yield, locomotion score at each session, and DIM. Nonsignificant fixed effects ($P > 0.05$) were removed by the process of stepwise backwards elimination. Biologically plausible 2-way (other than session by period) and 3-way interactions were examined from the resultant model and retained if $P < 0.05$. Differences between least squares means activities for each period between sessions were tested using Fisher's protected least significant difference. Tukey's method was used to allow for multiple comparisons, with significance determined at $P < 0.05$.

RESULTS

Cow Background Information

Time budgets for the 4 filming sessions were obtained for 14 out of 20 cows with a mean parity of 2.6 (range 2 to 5). Three cows were removed from the pen during at least one of the filming sessions because of illness, and 3 cows could not be tracked because of indistinct coloring. Between cows and sessions, DIM ranged from

Table 1. Days in milk (mean ± SE), most recent DHIA-recorded milk yield, and locomotion score data for 14 individual cows at each filming session (S1 to S4)[1]

	Filming session			
Item	S1	S2	S3	S4
DIM	87.9 ± 7.1	106.9 ± 7.1	136.9 ± 7.1	151.9 ± 7.1
DHIA milk yield (kg)	37.1 ± 1.6	37.1 ± 1.8	42.4 ± 1.6	44.5 ± 1.5
Locomotion score[2] (mean ± SE)	1.6 ± 0.1	1.6 ± 0.2	1.8 ± 0.2	1.7 ± 0.2
Locomotion score (% 2 or more)	64.3	57.1	57.1	50.0
Locomotion score (% 3 or more)	0	7.1	21.4	21.4

[1] S1 to S4 denote 4 filming sessions targeted to capture different climatic conditions.

[2] Locomotion was scored using a 4-point scoring system where 1 = nonlame, 2 = slightly lame, 3 = moderately lame, and 4 = severely lame (Nordlund et al., 2004).

53 to 195 and milk yield ranged from 22.8 to 52.5 kg/d (Table 1). Mean locomotion score for the 14 cows filmed varied from 1.6 to 1.8 between sessions, with the proportion of cows scoring 3 or more (clinically lame) increasing to 21.4% for S3 and S4. The proportion of cows with a locomotion score of 2 or more was greatest for S1.

Climate Data

Mean THI for each filming session and period are shown in Table 2. Filming sessions were captured with mean THI ranging from 56.2 to 73.8. Two sessions captured periods when cows were under mild to moderate heat stress (THI >72 for more than 10 h/d; S2 and S4).

Changes in Behavior Between Filming Sessions

Comparisons between sessions for the entire filming period (PY) were similar to the sum of the 4 periods (PX). The data for PX, therefore, are presented in Table 3. The effect of filming session was significant for time lying in the stall, time standing in the alley, time drinking, and time feeding, but was not significant for time standing up in stall, and time milking. In addition, the effect of locomotion score was significant for time standing in the stall and time standing in the alley, with no interaction between locomotion score and session.

Time spent standing in the alley increased from 2.6 to 4.5 h/d from the coolest to the warmest session. The contrasts between S4 and all other sessions were significant. The effect of locomotion score was also significant with least squares mean (±SE) time standing in the alley at locomotion scores 1, 2, and 3 being 4.33 ± 0.44, 3.36 ± 0.43, and 2.36 ± 0.65 h/d, respectively. The contrasts between score 1 and 2 (P = 0.047), and between 1 and 3 (P = 0.007) were significant. The total differences in time spent standing in the alley observed across session, therefore, were explained partly by the effect of session and partly by the effect of locomotion score.

There was no effect of session on time spent standing in the stall but the effect of locomotion score was significant (P = 0.02). Least squares mean (±SE) time standing in the stall at locomotion scores 1, 2, and 3 were 2.91 ± 0.35, 4.00 ± 0.34, and 4.41 ± 0.57 h/d, respectively, with the difference between scores 1 and 2 (P = 0.015) and 1 and 3 (P = 0.023) being significant.

Table 2. Temperature-humidity index (THI) characteristics by filming session[1] and filming period[2]

		THI			
Filming session	Filming period	Mean	Minimum	Maximum	Hours of THI ≥72
S1	PX	63.6	56.1	71.7	0
	PA	58.2	56.1	59.4	0
	PB	61.9	56.7	64.7	0
	PC	68.5	63.7	71.7	0
	PD	65.7	60.6	71.7	0
	PY	62.8	53.1	71.7	0
S2	PX	71.6	64.4	81.4	10.6
	PA	65.6	64.4	67.8	0
	PB	71.7	65.0	79.4	2.7
	PC	79.0	74.6	81.4	6.0
	PD	70.1	66.3	74.8	1.9
	PY	71.0	63.0	81.4	10.6
S3	PX	56.2	51.3	58.9	0
	PA	57.2	55.3	58.9	0
	PB	54.0	51.3	55.7	0
	PC	57.2	55.4	58.5	0
	PD	56.6	55.1	58.5	0
	PY	56.9	51.3	63.5	0
S4	PX	73.8	68.1	80.0	13.0
	PA	69.2	68.1	70.1	0
	PB	70.5	68.4	74.2	1.3
	PC	78.3	74.1	80.0	6.0
	PD	77.1	70.8	79.4	5.7
	PY	72.5	66.0	80.0	13.0

[1] S1 to S4 denote 4 filming sessions targeted to capture different climatic conditions.

[2] Filming periods within each session are denoted PX, PY, and PA to PD, where period A (PA) was from 00:00 to 05:59 (h:min elapsed), period B (PB) was from 06:00 to 11:59, period C (PC) was from 12:00 to 17:59, and period D (PD) was from 18:00 to 23:59. Period X (PX) was the combined total from 00:00 to 23:59 h (where PX = PA + PB + PC + PD), and period Y (PY) was the time budget for the whole 40.9-h period, converted to a 24-h day by proportion.

Table 3. Least squares mean (±SE) lying time, time standing up in the stall, time standing up in alley, time drinking, time feeding and time milking (h/d) for 14 cows for the entire filming period at four filming sessions (S1 to S4)[1]

	Filming session				P-values[2]	
Activity (h/d)	S1	S2	S3	S4	Session	Loco
Lying time	$8.65^{a} \pm 0.48$	$9.12^{b} \pm 0.48$	$10.93^{abc} \pm 0.48$	$7.91^{c} \pm 0.48$	<0.001	NS[3]
Time standing up in stall	4.27 ± 0.42	3.47 ± 0.40	3.41 ± 0.37	3.95 ± 0.38	0.169	0.020
Time standing up in alley	$3.20^{a} \pm 0.49$	$3.18^{b} \pm 0.47$	$2.55^{c} \pm 0.45$	$4.48^{abc} \pm 0.45$	<0.001	0.019
Time drinking	$0.45^{a} \pm 0.06$	$0.47^{b} \pm 0.06$	$0.26^{abc} \pm 0.06$	$0.50^{c} \pm 0.06$	0.004	NS
Time feeding	4.93 ± 0.25	$5.22^{a} \pm 0.25$	$4.64^{a} \pm 0.25$	4.86 ± 0.25	0.010	NS
Time milking	2.31 ± 0.14	2.40 ± 0.14	2.15 ± 0.14	2.24 ± 0.14	0.137	NS

[a–c] Means across rows with the same superscript were significantly different ($P < 0.05$) using Fisher's protected least significant difference.

[1] S1 to S4 denote 4 filming sessions targeted to capture different climatic conditions.

[2] P-values are for Type 3 tests of fixed effects from the mixed models for the effects of session and locomotion score (Loco).

[3] Not significant ($P > 0.05$).

Changes in Behavior Within Periods Between Filming Sessions

Session by period interactions were detected for time lying, time standing in the stall, time standing in the alley, time drinking, and time milking, but not for time feeding. The period effect on time milking was explained by the absence of milking in PB and was not examined further. Behavioral changes within periods and between sessions are shown in Table 4.

Time spent lying was affected by the interaction between session and period ($P = 0.006$). Contrasts were significant within PB and PC. Within PB, time spent lying decreased by over 1 h/d between S3 and S4, where mean THI changed from 54.0 to 70.5. Within PC, contrasts were significant between S1 and S3 (THI change from 57.2 to 68.5) and between S3 and S4 (THI change from 57.2 to 78.3). No effect of locomotion score was found.

There was a session by period interaction for time spent standing up in a stall, but the only significant contrast was within PA between S3 and S4. Locomotion score was also significant alone ($P = 0.021$) and as part of a 3-way interaction with both session and period ($P = 0.046$). Effect of locomotion score within period followed a similar pattern to that described previously for the entire PX, with greater locomotion scores tending to increase time spent standing in the stall.

The session by period interaction was significant for time spent standing in the alley, with significant contrasts occurring within PC between S1 and S3 and between S3 and S4, with an increase of over 1 h/d standing between extremes of THI (57.2 to 78.3). There was also an effect of locomotion score alone ($P = 0.039$), but no interaction with session and period, with the trend of spending less time standing in the alley at higher locomotion scores mirroring that found for the entire PX.

DISCUSSION

Weather changes during the summer of 2004 enabled a comparison of behavioral time budgets in 14 high-yielding dairy cows housed in a single freestall pen between filming sessions with different THI. The mean THI was highest during PC and lowest for PA or PB for each filming session. The final range between filming sessions was typical of the variation observed over the summer in the upper Midwest, with relatively short episodes of mild to moderate heat stress.

The effect of filming session was complicated by the potential influences of change in DIM, milk yield, and locomotion score throughout the summer. The weather changes that occurred naturally in 2004 allowed for a "cool" session to be filmed in between 2 "hot" sessions. This created a switchback-like study design for the effect of session and THI on activity.

The covariates milk yield and DIM were not significant in our statistical models. Locomotion score of each individual cow at each session, however, was a significant covariate for time spent standing in the stall and time spent standing in the alley. The influence of locomotion score on stall use behavior has been previously described (Cook et al., 2004b). The finding that time spent standing in the stall increased and time standing in the alley decreased with increasing locomotion score complements the previous work. The importance of locomotion score in understanding the effects of heat stress in the current study lends support to the idea that behavioral studies on individual cows should include locomotion score as a covariate in statistical analyses (Cook et al., 2004b).

Changes in locomotion score during the summer influenced the change in behavior between sessions. Although the proportion of cows with a locomotion score of 3 increased toward the end of the summer, the propor-

Table 4. Least squares means (±SE) for activity (h/d) by filming period[1] within each filming session[2]

Activity	Filming session	Filming period PA	PB	PC	PD	SE or 95% CI range	*P*-value:[3] Session × period
Time lying	S1	2.53	2.71	1.42^{b}	1.99	0.21	0.006
	S2	2.43	2.75	2.19	1.75		
	S3	2.84	3.56^{a}	2.70^{bc}	1.84		
	S4	2.67	2.53^{a}	1.33^{c}	1.39		
Time standing up in stall	S1	1.23	1.13	1.06	0.87	0.15	0.026
	S2	1.14	0.62	0.69	1.02		
	S3	0.92^{a}	0.65	0.86	0.98		
	S4	1.48^{a}	0.84	0.66	0.96		
Time standing up in alley	S1	0.73	0.49	1.20^{a}	0.76	0.17	0.005
	S2	0.73	0.84	0.85	0.75		
	S3	0.82	0.42	0.46^{ab}	0.84		
	S4	0.74	0.92	1.49^{b}	1.33		
Time drinking[4]	S1	0.07	0.09	0.12^{a}	0.09	–1.34 to 1.56	0.040
	S2	0.07	0.11	0.09	0.13		
	S3	0.06	0.04	0.05^{ab}	0.09		
	S4	0.08	0.12	0.12^{b}	0.10		
Time feeding[4]	S1	0.62	1.24	1.30	1.45	–0.06 to 2.54	0.075
	S2	0.66	1.53	1.28	1.55		
	S3	0.59	1.13	1.20	1.42		
	S4	0.35	1.45	1.49	1.37		

[a–c] Means in columns with the same superscript were significantly different ($P < 0.05$) using Fisher's protected least significant difference and a Tukey-adjusted *P*-value.

[1] Period A (PA) was from 00:00 to 05:59 (h:min elapsed), period B (PB) was from 06:00 to 11:59, period C (PC) was from 12:00 to 17:59, and period D (PD) was from 18:00 to 23:59.

[2] S1 to S4 denote 4 filming sessions targeted to capture different climatic conditions.

[3] *P*-value for the interaction between session and period is the Type 3 test for fixed effects from the mixed model.

[4] For time drinking and time feeding, mixed models were created using log-transformed data. The activity values in the table are back transformations of the least squares means along with 95% confidence intervals (CI) rather than standard errors.

tion of abnormal scores (2 and 3) was highest during the first session filmed. This may have been related to the fact that all cows had their feet trimmed immediately before the study, which contributed to some of the differences observed between sessions and was accounted for in the modeling procedure.

Healthy dairy cattle maintain 12 to 13 h/d of lying time (Cook et al., 2004b; Jensen et al., 2005) and this amount of time is a target resting period for the high-producing dairy cow housed in a freestall barn. In the study herd, the maximum observed mean lying time was only 10.9 h/d during S3, the coolest session filmed. This resting time is typical of that found in similar mattress freestall herds under thermoneutral conditions (Cook et al., 2004b) and may be indicative of stall designs that have lunge obstructions, high brisket locators, and smaller resting areas than those currently recommended (Cook and Nordlund, 2005).

There was a reduction in lying time of 3 h/d over a range of mean THI from 56.2 to 73.8, resulting in resting times of less than 8 h/d for the warmest session filmed. Reduced lying time of this magnitude is a suggested risk factor for claw horn lesion development (Leonard et al., 1996) and may contribute to the increased rates of claw horn lesions observed in lactating dairy cows in Wisconsin in the late summer (Cook, 2004). Indeed, more cows with locomotion score 3 were observed at the end of the summer in this study herd.

Time spent standing when the cow would rather be lying down may stress the bond between the third phalanx and the claw horn capsule, a bond that is already weakened around calving (Tarlton et al., 2002) and by feeding disorders such as subacute ruminal acidosis (Thoefner et al., 2004). Heat stress behavior, poor stall design and comfort, overstocking, and prolonged milking times are the 4 major situations in modern dairy herds that cause this increase in daily standing time.

The behavioral component changes that result in changes in standing time across session (lowest to highest THI) are summarized in Figure 1. The most significant changes are increases in time spent standing in the alley and time spent standing in the stall, with a small but significant change in time spent drinking. The perception is that cows are standing in the stalls trying to cool off and spending time standing in the alleys beneath the water soakers and the fans. The data presented here suggest that this observation may be only partly true. Increased time spent standing in stalls

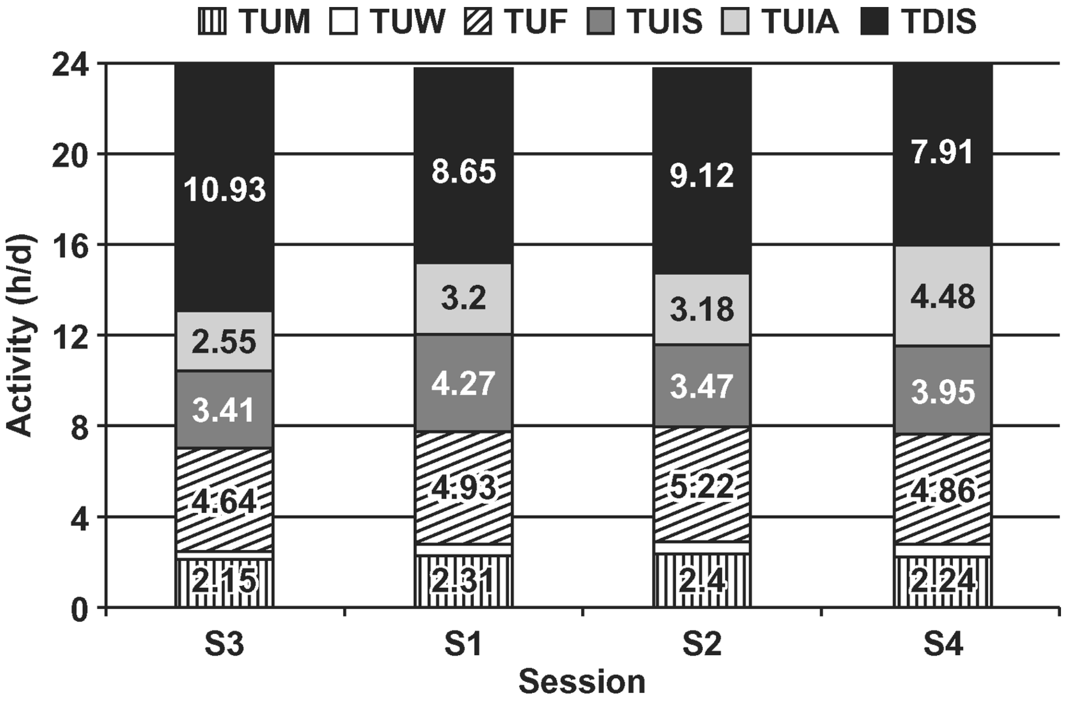

Figure 1. Time budgets (h/d) for 14 cows across 4 filming sessions (S1 to S4) in order of lowest (S3) to highest mean temperature-humidity index (S4) demonstrating the change in activity components that make up total daily standing time. Activity: TUM = time milking, TUW = time drinking, TUF = time feeding, TUIS = time standing up in the stall, TUIA = time standing up in the alley, and TDIS = time lying down in the stall.

was largely a result of changes in locomotion score rather than THI over the summer. Lame cows struggle to rise and lie down in mattress stalls and this leads to prolonged periods standing in the stall between periods of lying down (Cook et al., 2004b). There tend to be more lame cows at the end of the summer than at the start of the summer so more cows were seen standing in the stall. Increases in time spent in the alley are associated with increases in mean THI between sessions, but they were also influenced negatively by locomotion score, which tended to reduce time spent standing in the alley. Thus, it would appear that although nonlame cows attempt to cool off by standing beneath soakers and fans in the alley, lame cows may prefer to stand on the more cushioned surface of the stall and spend less time in the alley. This choice may compromise the ability of lame cows to cool when heat-stressed.

The influence of mean THI on feeding behavior in this study was not clear and perhaps confounded by changes in DIM, milk yield, and locomotion score between sessions. Dry matter intake is reduced during heat stress and feed meal behavior may change with increased "slug feeding" that makes subacute ruminal acidosis more likely (Stone, 2004). Feed meal behavior was not examined in this study but no consistent reduction in total feeding time was observed with increasing THI.

Comparison of activity during separate periods within a day and between filming sessions identified the specific times of the day during which cows were most affected by heat stress. There were differences observed between 0600 h and 1800 h. Lying time was reduced between 0600 h and 1200 h and between 1200 h and 1800 h between the extremes of THI (54.0 to 70.5). In addition, from 1200 h to 1800 h lying times were reduced for THI 57.2 to 68.5. A change in time standing in the alley between these periods was explained by the interaction between session and period.

There was no evidence for a shift in time of feeding in the study herd. This may have been because of the use of water soakers and fans over the feedbunk that allowed heat-stressed cows to maintain normal patterns of feeding behavior. The heat abatement strategies used may have persuaded cows to spend increased time feeding in one of the warmer filming sessions (S2).

Effects on production, reproduction, and bovine physiology are typically associated with a THI of 72 or greater (Johnson, 1987; Igono et al., 1992; Armstrong, 1994). In this behavioral study, we found subtle, but significant, changes in behavior at a THI of 68. To minimize the extent and impact of these changes, a more aggressive approach to cooling cattle, even under climates of only mild to moderate heat stress, may be necessary. The study herd was typical of many herds in the upper Midwest that activate recirculation fans at around 21°C and use water soakers at a temperature of 23.9 to 26.7°C. This study would lend support to the use of both fans and soakers at barn temperatures of around 21°C to limit heat-associated changes in behavior. The study herd did not have fans located over the stalls in the pen. Placing additional fans over the stalls may help further reduce the effects of heat stress but stall-standing behavior in this study was largely related to changes in locomotion score.

CONCLUSIONS

Dairy cows had a reduction in lying time of 3 h/d across the range of THI typically experienced in the upper Midwest during the summer. In addition, behavioral changes observed and traditionally associated with heat stress are confounded by changes in locomotion score that typically occur over the late summer months. Increases in claw horn lesion development in the late summer may be associated with the increase in total standing time per day. The changes in behavior described were due to mild to moderate heat stress (THI of 68). The use of more aggressive heat abatement strategies implemented at activation temperatures of around 21°C is recommended. The study did not measure the effects of the prolonged periods of moderate to severe heat stress seen elsewhere in North America. However, the findings may be useful in predicting behavioral outcomes in these more extreme environments.

ACKNOWLEDGMENTS

The authors would like to acknowledge the assistance of Tim Evert, the herd owner, for his patience and time. We would also like to thank Nicholas Keuler of the College of Agriculture and Life Sciences Statistical Consulting Service for advice on analyzing the data. This study was funded by the UW Cow Comfort and Well-being Consortium, which consists of Zinpro Performance Minerals, Pfizer Animal Health, Vitaplus Corporation, AgSource Cooperative Services, Promat Ltd., Artex Fabricators Ltd., and L and L, Inc., and a UW School of Veterinary Medicine Food Animal Grant. R. L. Mentink was funded by a Merck Merial Summer Training Scholarship in 2004.

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HIGH COW REPORT
AUGUST 2007

MILK

Arizona Owner	Barn#	Age	Milk	New Mexico Owner	Barn #	Age	Milk
Goldman Dairy	4510	03-08	40,320	*Providence Dairy	111	6-06	39,420
Stotz Dairy	18263	05-02	38,470	S.A.S. Dairy	7957	4-08	37,611
Stotz Dairy	18771	04-10	38,460	S.A.S. Dairy	8590	3-10	37,531
Zimmerman Dairy	1086	05-00	38,290	*Providence Dairy	860	5-08	36,140
Stotz Dairy	18949	04-09	38,150	*Providence Dairy	6178	4-09	35,640
Mike Pylman	1315	03-05	37,270	S.A.S. Dairy	8688	3-08	35,357
Goldman Dairy	8104	03-10	36,960	*Butterfield Dairy	1610	6-06	35,180
Mike Pylman	394	04-05	36,870	Mccatharn DAIRY	1396	4-02	35,113
Goldman Dairy	7223	06-00	36,850	*Providence Dairy	9492	6-09	34,940
Stotz Dairy	18250	05-02	36,840	*Wayne Palla Dairy	30215	3-02	34,940

FAT

* Stotz Dairy East	20527	04-03	1,931	Tee Vee Dairy	5248	8-06	1,540
* Stotz Dairy	18062	05-04	1,562	Dutch Valley Farms	4008	3-04	1,490
* Mike Pylman	20173	03-04	1,547	* Providence Dairy	5887	4-11	1,462
* Stotz Dairy	18771	04-10	1,526	* Rio Vista Dairy	1676	6-04	1,457
* Mike Pylman	20594	03-03	1,515	Pareo Dairy	4941	5-03	1,398
* Mike Pylman	21865	06-10	1,487	Tee Vee Dairy	1068	7-06	1,358
Parker Dairy	7883	07-08	1,484	Tee Vee Dairy	1517	5-06	1,312
* D & I Holstein	4525	03-01	1,478	* Providence Dairy	906	5-05	1,307
* Mike Pylman	20144	03-05	1,460	* Providence Dairy	5406	5-10	1,302
* Mike Pylman	21092	04-03	1,441	Pareo Dairy	4445	5-09	1,285

PROTEIN

* Mike Pylman	20594	03-03	1,115	S.A.S. Dairy	6412	4-01	1,138
* Stotz Dairy	18650	04-11	1,115	S.A.S. Dairy	7882	4-07	1,093
* D & I Holstein	1871	06-08	1,109	S.A.S. Dairy	7570	4-11	1,093
* Stotz Dairy	18250	05-02	1,109	Pareo Dairy	505	5-01	1,093
* Mike Pylman	1569	04-02	1,100	* Providence Dairy	5887	4-11	1,090
* Goldman Dairy	4510	03-08	1,092	* Providence Dairy	6222	4-07	1,080
* D & I Holstein	4525	03-01	1,080	Caballo Dairy	9629	3-10	1,077
* Mike Pylman	1315	03-05	1,073	* Milagro Dairy	9955	7-06	1,075
* Goldman Dairy	9563	04-00	1,071	S.A.S. Dairy	4803	7-06	1,061
* Mike Pylman	20144	03-05	1,071	Pareo Dairy	5808	4-02	1,046
* Stotz Dairy	18771	04-10	1,071				

*all or part of lactation is 3X or 4X milking

ARIZONA - TOP 50% FOR F.C.M.[b]
AUGUST 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	DO
* Stotz Dairy West	2,229	27,021	996	27,829	207
* Red River Dairy	9,734	26,789	897	26,124	168
* Danzeisen Dairy, Inc.	1,557	24,481	899	25,158	146
* Goldman Dairy	2,379	24,227	845	24,173	162
* Zimmerman Dairy	1,245	23,945	845	24,051	154
* Stotz Dairy East	1,282	23,588	849	23,962	206
* Butler Dairy	616	23,754	832	23,758	174
* Mike Pylman	7,200	23,488	839	23,756	212
* Arizona Dairy Company	5,411	23,200	845	23,729	190
Parker Dairy	4,471	22,399	853	23,512	176
* Shamrock Farms	8,363	23,702	809	23,363	164
Paul Rovey Dairy	274	22,381	832	23,164	131
* Withrow Dairy	4,962	22,975	806	23,000	156
Lunts Dairy	652	21,574	800	22,297	137
* Saddle Mountain	3,026	21,227	782	21,855	147
* DC Dairy, LLC	1,128	21,396	754	21,474	148
* Yettem	3,719	17,835	818	20,972	137
Cliffs Dairy	324	20,736	737	20,913	187
* Mountain Shadow Dairy	1,287	17,647	801	20,615	122

NEW MEXICO - TOP 50% FOR F.C.M.[b]
AUGUST 2007

OWNERS NAME	Number of Cows	MILK	FAT	3.5 FCM	DIM
* Pareo 2	1,608	25,620	934	26,224	189
* Providence	2,957	25,387	903	25,620	195
* Do-Rene	2,301	24,687	883	24,993	189
* Hide Away	2,831	24,728	871	24,817	178
* SAS	1,964	24,997	850	24,592	180
* Milagro	3,481	23,801	874	24,464	193
Vaz 2	2,041	23,835	869	24,398	---
* Vaz	1,442	23,787	869	24,377	---
McCatharn	1,040	23,722	846	23,976	177
Caballo	3,646	23,443	843	23,807	---
* Butterfield	2,140	25,147	754	23,100	203
Tee Vee	1,049	21,631	815	22,569	212
* High Plains	1,407	21,702	790	22,195	---
Stark Everett	3,090	21,761	784	22,123	179
Ridgecrest	3,681	21,353	784	21,946	189

* all or part of lactation is 3X or 4X milking

[b] average milk and fat figure may be different from monthly herd summary; figures used are last day/month

ARIZONA AND NEW MEXICO HERD IMPROVEMENT SUMMARY FOR OFFICIAL HERDS TESTED AUGUST 2007

		ARIZONA	NEW MEXICO
1.	Number of Herds	37	31
2.	Total Cows in Herd	64,918	63,845
3.	Average Herd Size	1,755	2,060
4.	Percent in Milk	85	87
5.	Average Days in Milk	219	193
6.	Average Milk – All Cows Per Day	51.9	62.3
7.	Average Percent Fat – All Cows	3.6	3.6
8.	Total Cows in Milk	55,140	20,131
9.	Average Daily Milk for Milking Cows	61.2	71.6
10.	Average Days in Milk 1st Breeding	87	76
11.	Average Days Open	167	141
12.	Average Calving Interval	14.3	13.6
13.	Percent Somatic Cell – Low	84	87
14.	Percent Somatic Cell – Medium	11	7
15.	Percent Somatic Cell – High	6	5
16.	Average Previous Days Dry	61	63
17.	Percent Cows Leaving Herd	31	32
		STATE AVERAGES	
	Milk	22,663	22,687
	Percent butterfat	3.61	3.6
	Percent protein	2.94	3.0
	Pounds butterfat	820	865
	Pounds protein	660	683

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Arizona Dairy Production Conference

The 2007 Arizona Dairy Production Conference will be held on Thursday, October 11 at the Hilton Garden Inn Phoenix Airport. See the flyer and registration form inside this newsletter!