

The Impact of Mild Heat Stress and Lameness on the Time Budgets of Dairy Cattle

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Abstract. Time budgets for 14 cows housed in a three-row free stall pen were obtained for four 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 h/d to 7.9 h/d from the coolest to the hottest session filmed. Time spent standing in the alley increased from 2.6 h/d to 4.5 h/d from the coolest to the hottest session filmed. There was a negative effect of increasing locomotion score over the summer with higher locomotion scores associated with less time spent standing 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 3 cows standing in the stall longer than score 1 cows (4.0 and 4.4 compared with 2.9 h/d respectively).

Keywords. Heat stress, lameness, time budgets.

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), while others have focused on the effects on reproductive performance, which appear to be mediated 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) and there is general agreement that significant effects are observed at and above 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 Southeast and Southwest 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. In a study conducted on four Swiss dairy herds, lying behavior of sentinel animals was tracked under different climatic conditions (Zahner et al., 2004). The authors noted the duration of lying behavior decreased during the day with increasing THI, but lying duration during the night was unaffected. Whereas it is generally accepted that during periods of heat stress, cows stand more in alleys and stalls, 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 sub-acute 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. Behavioral adaptations to heat stress may be a 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 sub-acute ruminal acidosis or because of an increase in standing activity or a combination of the two.

This study aims to document 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.

Materials and Methods

Cow Selection and Filming

Twenty multiparous Holstein cows were randomly selected from a subset of cows less than 150 days in milk (DIM), within a single pen of a commercial free stall housed dairy herd. Each cow was given a unique identification number with black hair dye, visible from both flanks and the head. Cows identified as clinically lame by the herdsman during the filming period were treated within 7 days.

Weather forecasts were used to predict local weather conditions with the aim of filming two sessions with a predicted maximum outside ambient temperature less than 23.9°C and two sessions with a predicted minimum outside ambient temperature greater than 18.3°C. The pen was filmed over a three day period when weather predictions were favorable. The dates of filming for each of four sessions (S1 to S4) were June 22-24, July 12-14, August 10-12, and August 25-27, 2004. 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 City, NY) were used to record one second of activity every 30 seconds on the long play setting. Activity was captured between 2:07 p.m. on day 1 and 7:00 a.m. on day 3, resulting in 40.9 continuous hours comparable across four sessions. Data analysis was performed on the 24h period in the middle of the filming session.

At a single milking during each filming session, the cows were locomotion scored on a flat and level surface when returning from milking using a 4-point scoring system (score 1-4) (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 side walls and three rows of free stalls bedded with sawdust on top of a rubber crumb-filled geotextile mattress. Group size was maintained between 100 and 105 cows with access to a total of 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). Heat abatement was provided by 3 x 1.22 m diameter circulation fans 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. Pen THI was monitored every minute using two calibrated temperature and humidity data loggers (Dickson TR320 Pro Series; Dickson, Addison, IL) located at the east and west end of the pen and taped to a pole protected from direct sunlight and slightly above cow level.

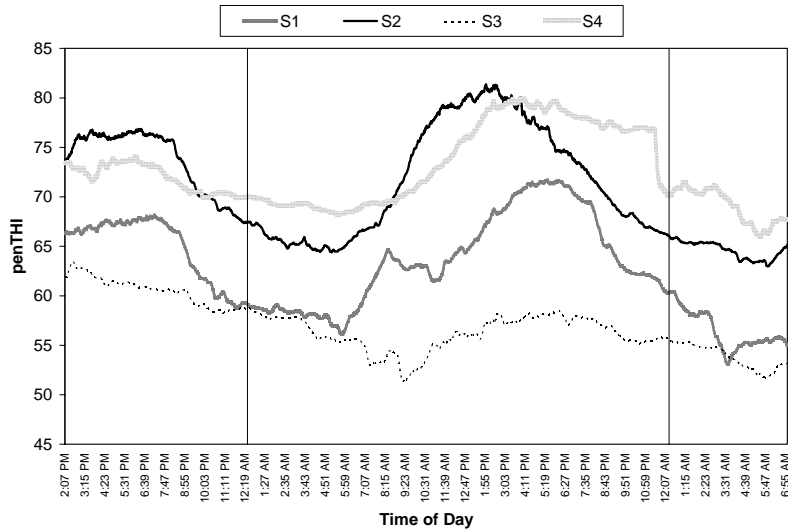
Statistical Analysis

Mixed effect models were created to investigate the differences in cow behavior (time spent lying 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. 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. Non-significant fixed effects ($P > 0.05$) were removed by the process of stepwise backwards elimination. Biologically plausible two-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 $P < 0.05$.

Results

Time budgets for the four filming sessions were obtained for 14 out of 20 cows with a mean parity of 2.6 (range 2 to 5) and are presented in Table 1. Between cows and sessions, DIM ranged from 53 to 195 and milk yield ranged from 22.8 to 52.5 kg/d. 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.

Figure 1. Variation in mean Temperature Humidity Index for the free stall pen (penTHI) by minute, for four filming sessions (S1-S4).



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) (Figure 1).

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 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 h/d 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 (\pm 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 (\pm 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 1. Least squares mean \pm SE lying time, time standing in the stall, time standing 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. *P*-values are for Type 3 tests of fixed effects from the mixed models for the effects of session and locomotion score (LMS)

Activity (h/d)	Filming Session				<i>P</i> -values	
	S1	S2	S3	S4	Session	LMS
Mean THI	63.6	71.6	56.3	73.8		
Lying time	8.65 ^a ± 0.48	9.12 ^b ± 0.48	10.93 ^{abc} ± 0.48	7.91 ^c ± 0.48	<0.001	NS ²
Time standing in stall	4.27 ± 0.42	3.47 ± 0.40	3.41 ± 0.37	3.95 ± 0.38	0.169	0.020
Time standing in alley	3.20 ^a ± 0.49	3.18 ^b ± 0.47	2.55 ^c ± 0.45	4.48 ^{abc} ± 0.45	<0.001	0.019
Time drinking	0.45 ^a ± 0.06	0.47 ^b ± 0.06	0.26 ^{abc} ± 0.06	0.50 ^c ± 0.06	0.004	NS
Time feeding	4.93 ± 0.25	5.22 ^a ± 0.25	4.64 ^a ± 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

¹S1-S4 denote each of four filming sessions targeted to capture different climatic conditions.

^{a-c} Means across rows with the same superscript were significantly different ($P < 0.05$) using Fisher's protected least significant difference.

²Not significant ($P > 0.05$).

Discussion

Healthy dairy cattle provided comfortable resting areas maintain 12 to 13 h/d lying time (Jensen et al., 2005; Cook et al., 2004b) and this amount of time is a target resting period for the high producing dairy cow housed in free stall barns. 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 other similar mattress free stall 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 score 3 cows were observed at the end of the summer in this study herd.

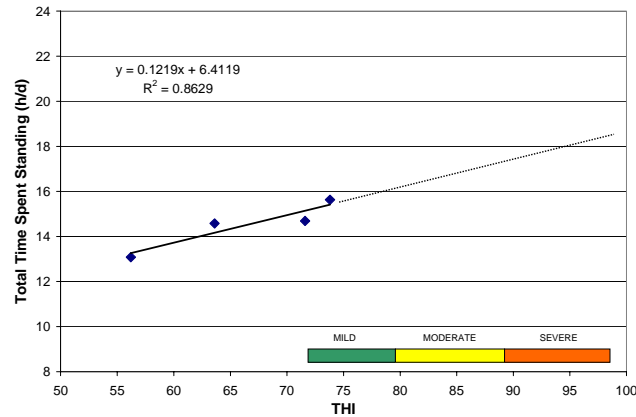
Time spent standing when the cow would rather be lying may stress the bond between the third phalanx and the claw horn capsule; a bond that is already weakened around calving (Tarlton et al., 2002) and by feeding disorders such as sub-acute ruminal acidosis (Thoenner et al., 2004).

The most significant behavioral changes across session were 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 suggest this observation may be only partly true. Increased time spent standing in stalls 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 (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 are seen standing in the stall. Increases in time spent in the alley are associated with increases in mean THI between sessions, but they are also influenced negatively by locomotion score – which tends to reduce time spent standing in the alley. Thus, it would appear that while non-lame 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 sub-acute 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.

Figure 2. A linear regression model comparing daily standing time with mean THI for each filming session, extrapolating data from sessions filmed under mild heat stress to consider the effect of severe heat stress.



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. Figure 2 assumes a linear relationship between the increasing effect of heat and standing time. Under conditions of severe heat stress, daily standing times may exceed 18h/d. Behavioral adaptations to severe heat stress should be the subject of future studies.

Conclusions

Conditions of mild heat stress increased daily standing times in mature Holstein cows by 3 h/d over the course of a typical Wisconsin summer. This increase was largely due to an increase in the time spent standing in the feed alley of a 3-row pen with fans and soakers over the feed bunk. Time spent standing in the stalls was affected more by lameness than by heat and increases in stall standing behavior over the course of the summer are probably due to the increase in lameness that is typically seen over this time. Increased loading of the claw and inadequate rest may contribute to this increase in lameness.

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