

Developing a Heat Stress Model in Dairy Cows Using an Electric Heat Blanket (EHB)

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Summary and Implications

Heat stress (HS) is an annual environmental issue which negatively affects a variety of production parameters including milk yield and composition, growth, and reproduction. However, precisely studying HS typically requires expensive climate controlled facilities; infrastructure inaccessible to most researchers. Thus, study objectives were to explore the efficacy of an electric heat blanket (EHB) as an alternative method to study HS and to determine whether EHB-induced hyperthermia affects production parameters similar to natural HS. Utilizing the EHB increased body temperature indices (rectal temperatures and respiration rate) and reduced dry matter intake and milk yield. Our results indicate that employing the EHB affects production parameters similarly to natural HS and thus the EHB is an effective and inexpensive research tool to evaluate the biological consequences of HS in lactating dairy cows.

Introduction

Heat stress occurs when environmental variables such as ambient temperature, humidity, and air movement create a heat load that exceeds the upper limit of the thermoneutral zone. Dairy cows are more susceptible to HS than most farm animals due to the high metabolic heat production and low surface area to mass ratio. Traditionally, environmental chambers have been required to conduct and design well-controlled HS studies in lactating dairy cows. However, due to cost of construction and operation, many institutions lack such facilities and/or resources. Hence, our objectives were to explore the efficacy of an EHB as an alternative and cheaper method to study HS and to determine whether EHB-induced hyperthermia affects production parameters similar to natural HS. To our knowledge, this is the first proof of concept study examining the feasibility of an EHB to induce HS in lactating dairy cows. If effective, this alternative model would allow scientists to further investigate the precise effects of HS without needing environmental-controlled facilities.

Materials and Methods

Animals and Experimental Design: Lactating Holstein cows ($n=8$; 133 ± 3 DIM; 709 ± 31 kg BW; parity 2.6 ± 0.3) were housed in individual box-stalls at ISU Dairy and were allowed to acclimate for 3 d. The trial included 2 experimental periods (P). During P1 (3 d), cows were fed ad libitum and housed in thermoneutral (TN) conditions for collecting baseline body temperature indices and production parameters (hence, each animal served as its own control). During P2 (7 d) cows were fitted with an EHB (Fig. 4) consisting of 12 infrared heating pads as a heat source (Thermotex Therapy Systems Ltd. Calgary, AB, Canada). The blanket was powered by a 110v that connected to the EHB in an area between the lumbar and thoracic vertebrae. The power cord was hung from the center of the box stall in a mounted and retractable cord reel with auto rewind to facilitate unabated movement and natural behavior. Cows were exposed to thermoneutral conditions throughout the experimental period (TN; $7.5 \pm 0.8^\circ\text{C}$). All procedures were approved by the ISU Institutional Animal Care and Use Committee. Cows were individually fed a TMR once daily (0800 h) and orts were measured before the a.m. feeding. The TMR was formulated to meet or exceed the predicted requirements (NRC, 2001) of energy, protein, minerals, and vitamins. Cows were milked twice daily (0600 and 1800 h) with yields recorded at each milking. Milk samples from each cow were collected on d 2 and d 3 of P1 and on d 3 and d 7 of P2. Samples were stored at 4°C with a preservative (bronopol tablet; DandF Control System, San Ramon, CA) until analysis by Dairy Lab Services (Dubuque, IA) using AOAC approved infrared analysis equipment and procedures.

During both P1 and P2, rectal temperature (T_r), and respiration rate (RR) were obtained twice daily (0600 and 1800 h). During the first 48 h of P2, body temperature indices were obtained hourly in order to monitor cow health and ensure animal safety. Rectal temperatures were measured using a standard digital thermometer (GLA M700 Digital Thermometer, San Luis Obispo, CA). Respiration rates were determined by counting flank movements during 15 sec intervals and multiplying by four to obtain breaths per minute.

Blood samples were collected on d 3 of P1 and d 7 of P2 by coccygeal venipuncture (K3EDTA, EDTA and serum; BD® Vacutainers, Franklin Lakes, NJ). Blood plasma and serum were harvested following centrifugation at $1,500 \times g$ for 15 min at 4°C , and subsequently frozen at -20°C until analysis. Plasma glucose and NEFA concentrations were determined using commercially available kits validated for use in our laboratory (Wako

Chemicals USA Inc., Richmond, VA). These procedures were scaled down and conducted in 96 well microplates (Rainin Instrument LLC, Oakland, CA) and read using a microplate photometer (Biotek instruments, Winooski, Vermont). The intra-assay coefficients for glucose and NEFA were 1.9 and 4.8 %, respectively.

Statistical analysis: Effects of day and period were assessed separately using the MIXED procedure of SAS (version 9.4 Institute. Inc., Cary, NC). Dry matter intake, milk yield, body temperature indices and milk composition during P2 were analyzed using repeated measures with an autoregressive covariance structure and day as the repeated effect. In addition, the effects of period on DMI, milk yield, body temperature indices, milk composition, and blood metabolites were analyzed separately using the MIXED procedure of SAS with a diagonal covariance structure. Effects of day, hour, and their interaction on body temperature indices during the first two days of P2 were analyzed using repeated measures. P1 values for each variable were used as a covariate. Results are reported as LSmeans and were considered different when $P \leq 0.05$ and tend to differ if $P < 0.10$.

Results and Discussion

Body temperature indices: As expected, the EHB caused an immediate and safe increase in both Tr and RR during the first 48 h (Figure 1) and the magnitude of increase in both was characteristic of cows experiencing seasonal HS. Overall there was an increase in Tr and RR (1.0°C and 25 bpm, respectively $P < 0.01$; Figure 2 A, B) during P2 at 0600 h. Further, Tr and RR were increased (1.2°C and 29 bpm, respectively at 1800 h during P2; $P < 0.01$; Figure 2 C, D). Although the extent of increased body temperature indices was expected, little or no signs of “acclimation” occurred with time. In other words, we expected Tr and RR to peak between d 1-2 and then gradually decrease; changes indicative of “tolerance”. Reasons for the apparent lack of thermal acclimation are not clear, but are likely due to the fact that the blanket prevented

normal routes of heat dissipation that are presumably key aspects of heat acclimation.

Dry matter intake: Overall, dry matter intake progressively decreased during P2 compared to P1 ($P < 0.01$; Table 1). By the end of P2 DMI was decreased (25%; $P < 0.05$; Figure 3A). This severity of decrease in feed intake is certainly typical of HS normally observed in the US dairy industry.

Milk yield and milk composition: Milk production decreased during P2 compared to P1 ($P < 0.01$; Table 1) and the EHB decreased milk yield (21%; $P < 0.05$) by d 7. Milk protein percentage tended to decrease (4.4 %; $P = 0.07$) compared with P1. In contrast, milk urea nitrogen increased during P2 (33%; $P < 0.01$) relative to P1. No other differences were observed in milk fat, lactose, total solids, and somatic cell counts during P2 ($P > 0.10$; Table 1). The decrease in milk synthesis and changes in milk composition mirror that of cows experiencing natural HS.

Blood Metabolites: No differences in circulating glucose levels were observed during P2 ($P > 0.10$) when compared to P1. However, plasma NEFA concentrations tended to be increased in P2 compared to P1 (55%; $P = 0.09$, Table 1).

Overall Summary and Conclusion

Employing the EHB increased the body temperature indices (Tr and RR) and negatively affected production parameters similar to other HS models. Thus, utilizing the EHB is an unconventional but relatively cheap (while scientifically valuable) research technique to model HS in lactating dairy cows. Importantly, the EHB is not a good technique to study products whose mode of action are to facilitate heat dissipation via radiation, convection or evaporation (vasodilatation at the periphery or sweating) as the blanket markedly interferes with normal routes of heat loss. However, if experimental objectives are to study the biological consequences of HS or to test products whose activity is either within the GIT or via modifying metabolism then the EHB is a feasible strategy.

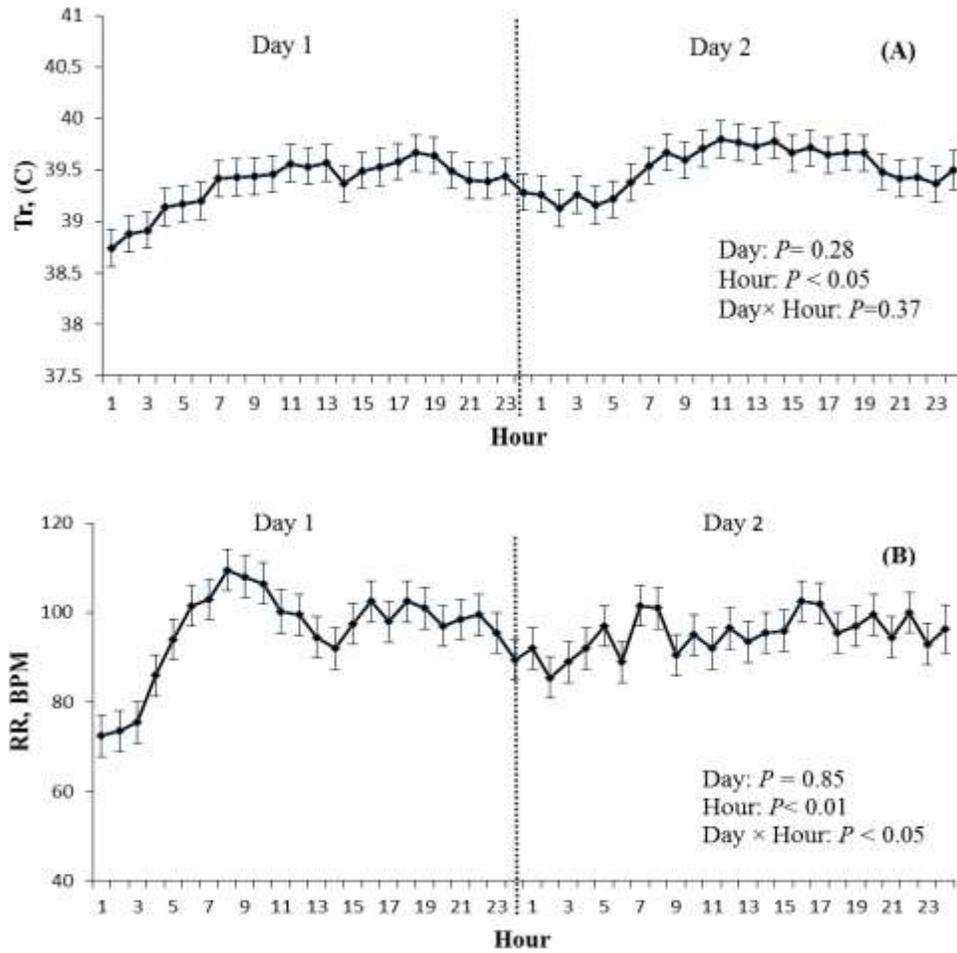


Figure 1. Effects of an electric heat blanket on body temperature indices in lactating dairy cows during the first 48 h of P2. A) Tr, and B) RR.

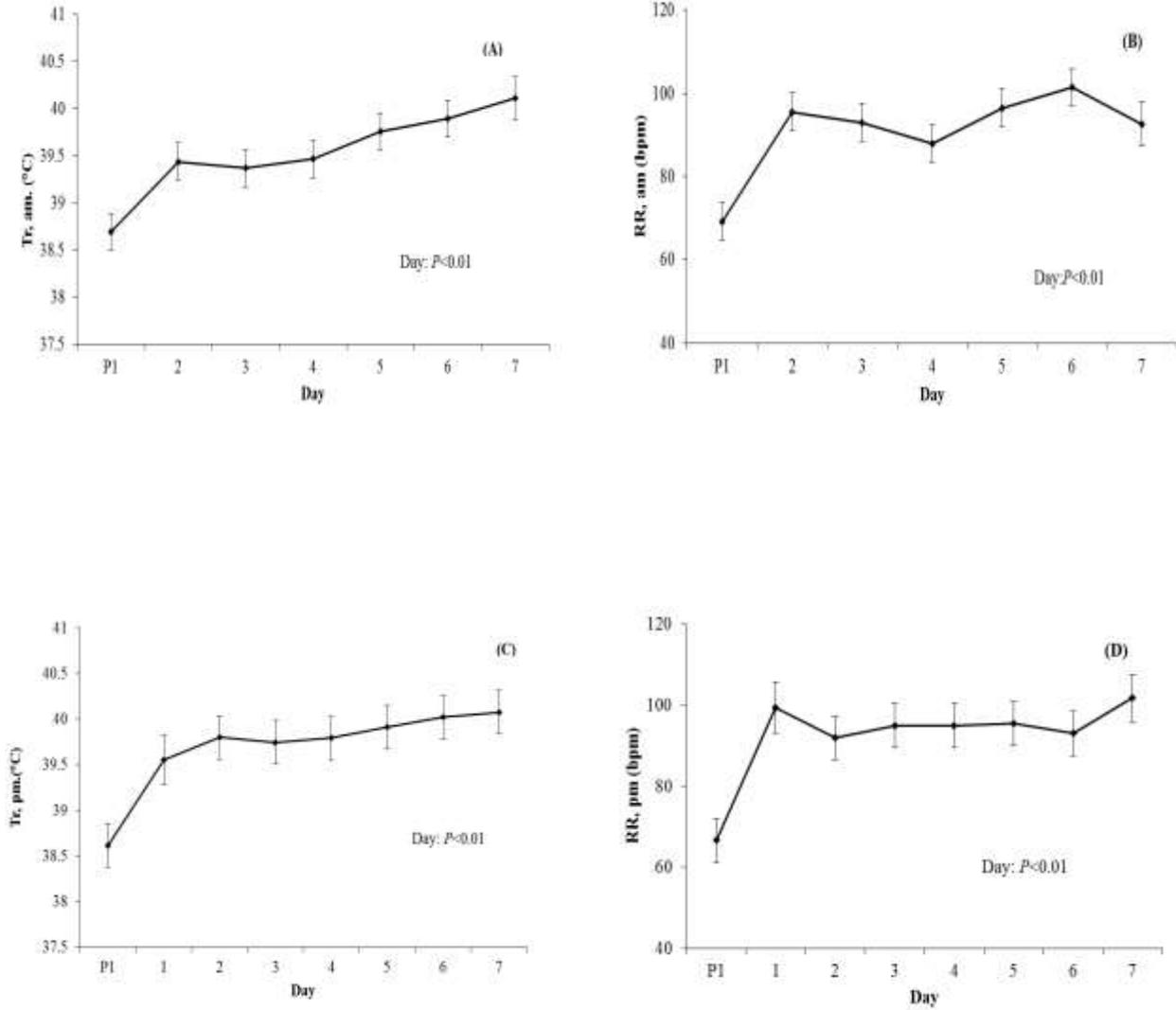


Figure 2. Effects of electric heat blanket on AM A) Tr, and B) RR and on PM C) Tr, and D) RR. The mean value from d 1 to 3 of P1 is represented by “P1” on the X-axis. The d 1 to 7 results are from P2 when cows were fitted with an electric heat blanket.

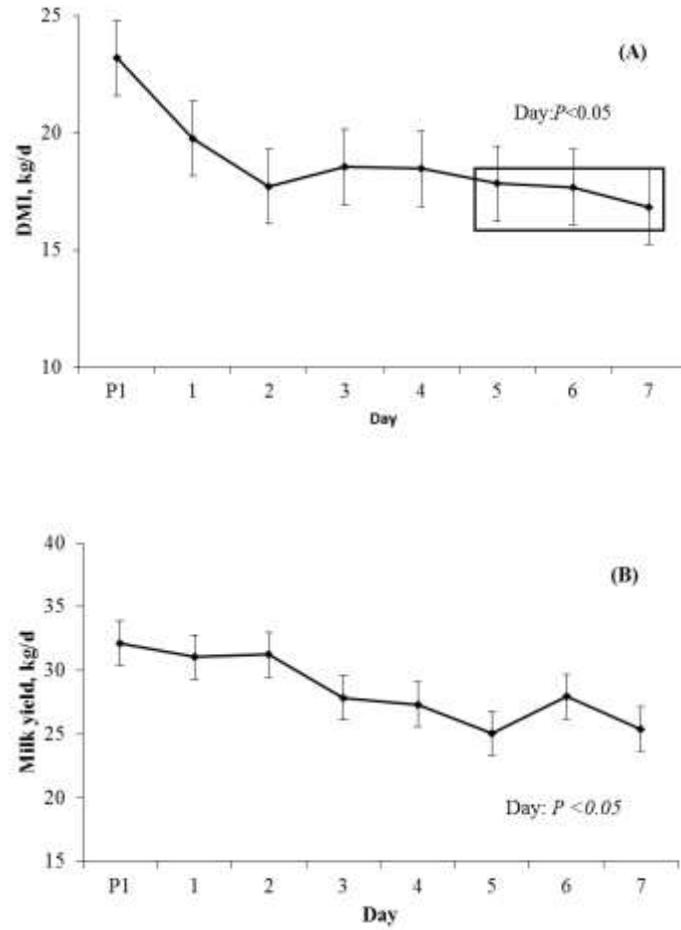


Figure 3. Effects of electric heat blanket on A) DMI and B) Milk yield. The mean value from d 1 to 3 of P1 is represented by P1 on the x-axis. The d 1 to 7 results are from P2 when cows exposed to HS via the electric blanket.

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Table 1. Effect of an electric heat blanket-induced heat stress on production and metabolism variables in lactating Holstein cows

Parameter	Period 1	Period 2	SEM	P-value
DMI, kg/d	23.0 ^a	18.0 ^b	0.8	<0.01
Milk yield, kg/d	32.2 ^a	28.0 ^b	0.9	<0.01
Milk components				
Fat, %	3.91	4.04	0.20	0.66
Protein, %	3.03	2.90	0.05	0.07
Lactose, %	4.81	4.80	0.02	0.89
Total solids, %	12.65	12.63	0.20	0.95
SCC, × 1000	90.6	105.6	24.2	0.66
MUN, mg/dL	12.8 ^b	17.0 ^a	0.6	<0.01
Glucose, mg/dL	73.3	69.4	1.9	0.17
NEFA, μEq/L	145	225	31	0.09

^{a,b} Values within columns of each variable with differing subscripts indicate $P < 0.05$.

Figure 4. Cow Pictures when the blanket was on

