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Effect of *Ascophyllum nodosum*[1] on alleviation of heat stress in dairy cows

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ABSTRACT

A study was conducted to evaluate the effect of Tasco (Ascophyllum nodosum; Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada) on alleviation of heat stress in dairy cows. Thirty-two cows were randomly assigned (randomized complete block design) to 4 treatments: control-1 (C-1); control for period 2 and 0.50% Tasco for period 3 (C-.5T); 0.25% Tasco (0.25T); 0.50% Tasco (0.5T). The study was divided into 3 periods: period 1 (7 d; adaptation to Calan Gate system); period 2 [28 d; C-1 and C-.5T representing the control (CON)]; period 3 (28 d; C-.5T was changed to 0.50% Tasco to evaluate duration of feeding Tasco and other groups remained unchanged). Respiration rate and rump and ear skin temperatures were measured at 0700, 1600, and 1900 h. Core body temperature was recorded every 20 min with telemetric temperature transmitters in the reticulum. Tasco had no effect ($P > 0.10$) on milk production, but DMI was occasionally less ($P < 0.05$) for 0.25T cows than for CON cows in period 2. The rump skin temperature of 0.25T cows was reduced ($P < 0.05$) for some hours in period 2 and for some days in period 3. Linear regression of core body temperature and rump skin temperature versus ambient temperature in period 3 revealed less ($P < 0.05$) increase for 0.25T than for the control as ambient temperature increased. These results suggest that inclusion of 0.25% Tasco reduced body temperature response to increasing ambient temperature and sustained milk production, even with reduced DMI. No benefit of 0.50% Tasco was seen when fed for 28 or 56 d. Limited benefits of Tasco were observed in this study.

Key words: *Ascophyllum nodosum*, dairy cow, heat stress

INTRODUCTION

Heat stress is one of the main causes of economic losses in livestock production in the United States, caused by decreased performance (production, efficiency, and reproduction), health, and well-being, and increased mortality of animals. St-Pierre et al. (2003) estimated losses of $2.4 billion per year for the livestock industry, with the dairy industry contributing $1.5 billion. Dairy cattle are one of the most affected animals because of excessive heat production associated with lactation (Kadzere et al., 2002); when exposed to a hot environment, the animal has difficulty dissipating body heat, which results in hyperthermia (West, 2003). Several approaches have been used to alleviate heat stress in dairy cows, including management and feeding strategies. Although no feed additives have effectively reduced heat stress, some evidence exists that brown seaweed (*Ascophyllum nodosum*) may decrease core body temperature ($\mathbf{T}_{core}$) for the short term (Spiers et al., 2004; Archer et al., 2007) and improve immune function during heat stress, without affecting performance (Allen et al., 2001; Fike et al., 2001; Saker et al., 2001). *Ascophyllum nodosum* is processed in a meal form from brown seaweed and marketed as Tasco (Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada). Previous work (Spiers et al., 2004; Williams et al., 2009) showed that Tasco-14 fed at 1% of diet DM had a short-term effect in reducing T_{core} of beef steers exposed to heat stress. With limited studies conducted with dairy cows, the objective was to evaluate the ability of Tasco to alleviate the effects of heat stress under fluctuating ambient temperature ($\mathbf{T}_a$) and humidity conditions.

[1] Tasco is the trade name for *Ascophyllum nodosum* marketed by Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada.
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MATERIALS AND METHODS

Animals and Dietary Treatments

Thirty-two Holstein dairy cows (milk production = 33.6 ± 4.8 kg/d) were assigned to a randomized block design during summer 2008 for 63 d. Animals were housed in a free-stall barn at the University of Missouri Foremost Dairy Research Center (Columbia, MO). The Animal Care and Use Committee at the University of Missouri approved the protocol for conducting this study. Cows were blocked according to parity (2.7 ± 1.5) and DIM (138 ± 43 d) and assigned to 1 of 4 treatments, with 8 cows per treatment. The study was divided into 3 periods based on treatment times. Period 1 (June 2 to June 8, 7 d) was an adjustment period to a Calan Gate system (Growsafe Systems, Airdrie, Canada) and no treatments were fed. In period 2 (June 9 to July 6, 28 d), cows started dietary treatments, and in period 3 (July 7 to August 3, 28 d) one treatment was changed. In periods 2 and 3, treatments were as follows: control-1 (**C-1**); initial control-1 in period 2, followed by 0.50% Tasco in period 3 (**C-.5T**); 0.25% Tasco (**0.25T**); 0.50% Tasco (**0.5T**). In period 2, C-1 and C-.5T represented control groups; in period 3, C-1 was the only control and C-.5T became a second treatment of 0.50% Tasco. Level of Tasco fed was based on previous work (Cvetkovic et al., 2005; Kellogg et al., 2006) demonstrating a milk production response in cows exposed to heat stress. The intent in using the higher level (i.e., 0.50% Tasco) was to evaluate the duration of feeding Tasco to dairy cows for 28 versus 56 d. Tasco was mixed with 100 g of dried distillers grain and top-dressed onto the morning TMR, which consisted of corn (*Zea mays*) silage and alfalfa (*Medicago sativa*) haylage and corn, along with other feed ingredients, vitamins, and minerals (Table 1). In period 2, 0.25T and 0.5T cows consumed daily an average of 63.0 and 131.9 g of Tasco, respectively, and in period 3, C-.5T, 0.25T, and 0.5T cows received daily an average of 114.9, 55.7, and 117.4 g of Tasco, respectively.

Table 1. Composition of the TMR

Item	% of DM
Feed ingredient	
Alfalfa hay	13.8
Alfalfa silage	13.8
Corn silage	18.1
Shelled corn	20.74
Soybean meal, 48%	3.8
Whole cottonseed	4.8
Roasted soybeans	4.0
Wet brewer's grains	7.2
Soybean hulls	11.7
Dicalcium phosphate	0.51
Limestone	0.62
Sodium bicarbonate	0.44
TM salt[1]	0.26
Vitamin ADE premix #1	0.09
Vitamin E premix	0.09
RTM[2]	0.05
Chemical analysis	
DM	52.1
CP	18.1
NDF	42.2
ADF	26.8

[1]Trace mineral salt, Morton salt, American Midwest, Kansas City, MO.

[2]Ruminant trace mineral, Nutrablend, Neosho, MO.

Twice daily (at 0500 and 1700 h) cows were moved to the parlor for milking and the procedures followed those recommended by the National Mastitis Council (2002). Milk production of each cow was recorded electronically at each milking (Metatron 12, Westfalia, Elk Grove Village, IL) and combined to obtain daily milk production. Cows were fed at 0800 and 1400 h and feed intake (fed minus refused) was recorded. Daily feed samples were analyzed for DM (official method 978.10; AOAC, 1995). Samples were combined by week, ground through a Wiley Mill (Thomas Scientific, Swedensboro, NJ) using a 2-mm screen, and analyzed in duplicate for NDF and ADF (Van Soest et al., 1991) and total nitrogen (LECO Instruments Inc., St. Joseph, MI; official method 990.03; AOAC, 1995).

Measurement of Thermal Status and Ambient Conditions

Skin temperatures and respiration rate (**RR**) were taken daily at 0700, 1600, and 1900 h. Skin temperature was measured using a calibrated infrared heat gun (Raytec, Everett, WA) at the rump ($\mathbf{T}_{rump}$) and outer ear ($\mathbf{T}_{ear}$) surfaces, which were previously shaved. Respiration rate was measured by enumeration of abdominal movements for 30 s. Core body temperature was recorded using calibrated telemetric temperature transmitters (Smart Stock, Pawnee, OK) inserted orally using a bolus gun before the study, to lodge in the reticulum of each cow. The transmitters were approved by the FDA and did not need to be removed. The telemetric system was composed of a bolus, antenna, barn receiver unit, base receiver unit, and a computer installed with the Smart Stock software program for logging the data and located inside a building about 30 m away from the free-stall barn. The antenna for transmitting data to the base receiver unit was located in the center of the barn where cows were housed, above the free-stalls, about 3 m above the floor. The telemetric bolus was programmed to record temperature every 20 min. A maximum T_{core} value per hour was obtained from the 3 recordings to eliminate the variation in reticulum temperature due to the influence of water consumed (Boehmer et al., 2009).

For the analysis of T_{core}, days were divided into night (from 0000 to 0600 h) and day (from 0700 to 1600 h) to represent the daily descent and rise of T_a, respectively (Figure 1). Comparisons between T_{core} and T_a were evaluated only during the day, because the night included milking hours, and T_a was not recorded in the parlor. Certain days were removed from the data set for T_{core} because of loss of data for an entire day or part of the day, attributed to power outage from electrical storms. A test for outliers was performed using quadratic regression of T_{core} versus T_a for each cow, and all T_{core} observations greater

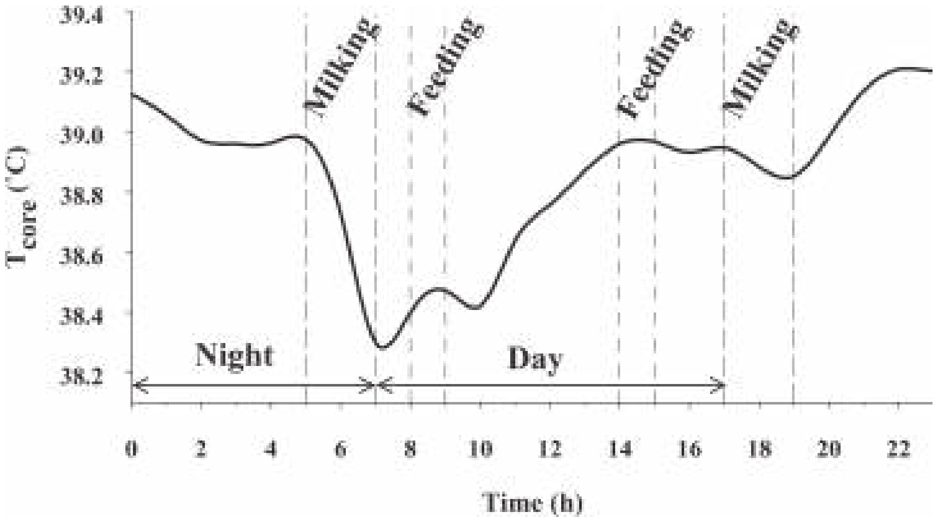

Figure 1. Average core body temperature (T_{core}) of all animals for the whole study throughout the night, day, and both milking and feeding periods.

than 2.5 SD from the predicted value were removed from the data set. After removal of outliers, the new data set was used for the T_{core} analyses. One cow from C-1 was removed from these analyses because the transmitter was inaccurate.

Percent relative humidity (**RH**) and T_a were automatically recorded every 15 min using data loggers (Hobo, Onset Computer Corp., Bourne, MA). Two loggers were placed above the free-stalls, and one was placed in the midpoint above the Calan Gate feeding system (all positioned approximately 3 m above the floor). An average T_a per hour in the barn was obtained from the 3 loggers. Two loggers presented errors in the measurement of RH, so only one was used to represent the humidity.

Statistical Analysis

The data were analyzed as a complete block design with repeated measurements over time (Littell et al., 1998), for each period of the study, and included RR, T_{ear}, T_{rump}, T_{core}, DMI, and milk production as influenced by Tasco. Within each period, main effects for all the parameters, as well as 2- and 3-way interactions, were analyzed using MIXED procedure of SAS (SAS Institute Inc., Cary, NC), and mean differences were determined using Fischer's least significant difference. The linear model contained the main plot effects of Tasco, time, and the interaction of Tasco × time. Animal was the experimental unit, and $P < 0.05$ was used for establishing significant differences. Six cows with mastitis (4 from C-.5T, 1 from 0.25T, and 1 from 0.5T) were removed for certain days for recovery. After they recovered, all except one cow were placed back on the study.

The influence of Tasco on the increase in core body and surface temperatures as T_a increased during the day was analyzed using PROC REG of SAS, with linear or quadratic function. Linear slopes were obtained for each treatment and compared by PROC GLM of SAS to determine differences. Only T_a was used to express ambient conditions because T_a and the temperature–humidity index were highly correlated for all the periods ($R^2 = 0.97$ for period 1 and 0.94 for periods 2 and 3). Although there are regions of the United States where RH is a significant and often independent contribution to heat stress, this is seldom the case in the mid-Missouri area. In general, T_a increases during the day and RH decreases, with the reverse occurring at night. The linear regression of T_{rump} and T_{ear} with T_a was preferred over the quadratic to describe the relationship. For T_{core} versus T_a, an average T_{core} for each cow was obtained for the same value of T_a, regardless of hour and day, to get one mean T_{core} for each cow, for each value of T_a. The relationship between T_{core} and T_a was quadratic; however, only the linear portion of the quadratic regression was used because this represents either the point where T_a produces an increase in T_{core} and is a stressor or the daily rise in T_{core} associated with a circadian shift in T_{core}.

RESULTS AND DISCUSSION

Period 1 – Acclimation (No Treatments Fed)

The average daily values in period 1 for maximum, mean, and minimum T_a were 29.6, 26.0, and 21.7°C, respectively, and the maximum, mean, and minimum RH were 91.8, 79.0, and 66.1%, respectively. A T_a of 25°C can be considered as a threshold for heat stress in lactating dairy cows (Berman et al., 1985). The elevated T_a for period 1 may have caused some heat stress for the cows during this baseline period; however, no differences ($P > 0.10$) in DMI, milk production, RR, T_{rump}, and T_{ear} for main effects or interactions were found between preassigned treatments. For T_{core} during the day (from 0700 to 1600 h), a treatment × day interaction existed ($P < 0.05$), with 0.5T cows having greater T_{core} than that of C-1 cows on d 2 (39.06 vs. 38.61°C) and greater T_{core} than that of C-.5T cows on d 4 (39.11 vs. 38.77°C). These findings indicate that during the pretreatment phase, the 0.5T group had an occasionally greater T_{core} than cows assigned to C-1 and C-.5T. However, these differences did not exist for the last 3 d before dietary treatment. For this reason, it was assumed that there were no group differences immediately before treatment and cows had adjusted to the test facilities as anticipated.

Period 2 – Beginning of Dietary Treatments

Ambient Conditions and Performance Parameters. In period 2, C-1 and C-.5T represented control treatments. Because no differences ($P > 0.10$) existed between them for any parameters, they were pooled and called control (**CON**). The average daily values for maximum, mean, and minimum T_a were 28.0, 23.2, and 18.5°C, respectively (Figure 2A), and maximum, mean, and minimum RH were 94.6, 76.8, and 56.7%, respectively. Cows definitely had sufficient time to adapt to heat stress during this period, because maximum T_a remained above 25°C for all except 3 d. The highest T_a was 32.6°C on d 35.

Tasco inclusion in the diet at these levels had no effect ($P > 0.10$) on overall DMI, DMI per BW, or milk production. In contrast, Kellogg et al. (2006) found that Tasco supplemented at 0.25% of diet increased milk production of cows during heat stress; the average maximum T_a was higher than that observed in the current study, which may explain

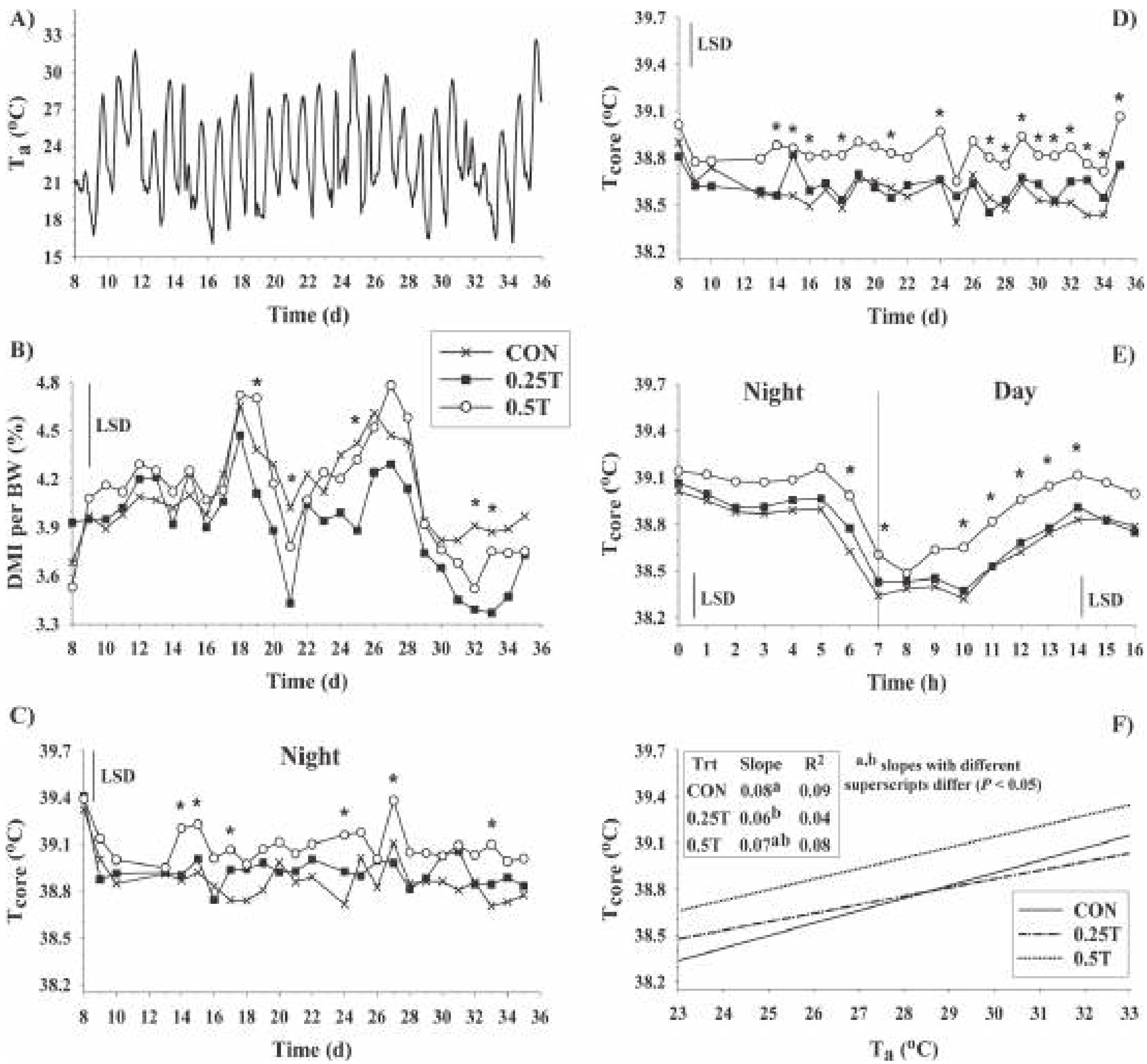

Figure 2. Results for period 2. (A) Ambient temperature (T_a) recorded hourly within the barn; (B) daily average DMI per BW; (C) daily average core body temperature (T_{core}) during the night (0000 to 0600 h); (D) daily average T_{core} during the day (0700 to 1600 h); (E) hourly average T_{core} during night and day; (F) change of T_{core} during the day as a function of T_a. LSD = least significant difference; Trt = treatment. *Days with differences at 5% between one or more treatments; see text for details. Treatments were as follows: control-1 (C-1); initial control-1 in period 2, followed by 0.50% Tasco (Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada) in period 3 (C-.5T); 0.25% Tasco (0.25T); 0.50% Tasco (0.5T). For period 2, C-1 and C-.5T have been combined and represent the control group (CON).

the more evident benefit of Tasco in reducing heat stress (Allen et al., 2001). Cvetkovic et al. (2005) found no differences in DMI but an increase in milk production (from 33.5 to 35.2 kg/d) for dairy cows fed 56.7 g/d of Tasco versus no Tasco during heat stress; however, no reference was made to the magnitude and duration of heat stress. In the present study, a tendency for a treatment × day interaction ($P < 0.10$) existed for DMI per BW (Figure 2B), with DMI per BW being less ($P < 0.05$) for 0.25T cows than for CON cows for 4 d and less than for 0.5T cows for 1 d. Most of these days with reduced DMI per BW for 0.25T cows followed a day with high T_a. According to Hahn (1999), cattle reduce feed intake during heat-stress periods in an attempt to reduce metabolic heat production and heat load. Reduced feed intake of animals consuming Tasco has been observed in other studies. Williams et al. (2009) found reduced feed intake of steers fed a diet based on cottonseed (*Gossypium*) hulls and corn supplemented with 1% Tasco as compared with controls during early exposure to heat in climatic chambers. Spiers et al. (2004) observed reduced feed intake of steers fed a diet supplemented with endophyte-infected tall fescue (*Festuca arundinacea* Schreb.) seed and 1% Tasco as compared with steers fed 0 or 0.50% Tasco diets, after 1 wk of heat exposure. This suggests that certain levels of Tasco supplementation affect feed intake. In the current study, the lower level of Tasco (i.e., 0.25%) caused some reduction in intake of dairy cows, whereas the 0.50% level had no effect compared with the control ($P > 0.10$).

RR and Skin Temperature. Tasco had no effect ($P > 0.10$) on RR. Also, Cvetkovic et al. (2005) found no differences in RR for cows supplemented with 56.7 g/d of Tasco during the summer. In contrast, Spiers et al. (2004) found a temporary reduction in RR of beef steers consuming an endophyte-infected tall fescue seed diet supplemented with 1% Tasco during heat stress as compared with no Tasco. The presence of another stressor (i.e., fescue toxicosis) may have contributed to the observed effect of Tasco. In another study (Williams et al., 2009), steers fed 1% Tasco at thermoneutrality for 36 d followed by heat exposure had lower maximum RR and a lower range of RR compared with the control treatment. It is possible that feeding Tasco for some period before the event of heat stress may improve its benefits. Because cows were exposed to elevated T_a during the first days of the study, acclimation to normal T_a did not occur in the current study. Moreover, the conflicting findings may be related to the different type of cattle (dairy vs. beef), due to the different level of metabolic heat production.

A trend ($P < 0.10$) for a treatment × hour interaction existed for T_{ear} (Table 2) to be less for 0.25T cows than for 0.5T cows at 1600 and 1900 h. Moreover, at 1600 h, a tendency ($P < 0.10$) existed for T_{ear} to be less for 0.25T cow than for CON cows. Average T_{rump} was less ($P < 0.05$) for 0.25T cows as compared with CON and 0.5T cows, which was attributed to reduced ($P < 0.01$) T_{rump} values for 0.25T cows than for CON and 0.5T cows at 1600 and 1900 h (Table 2). This daily relationship was due to the T_a being the highest for that time of day. Thus, cows on the 0.25% Tasco diet had reduced skin temperature during this period. In contrast, Cvetkovic et al. (2005) observed no effect on the temperature of rear udder skin from inclusion of 56.7 g/d of Tasco in the diet of dairy cows during the summer.

Table 2. Ear (T_{ear}) and rump (T_{rump}) skin temperatures of cows during period 2

	Treatment[1]				
Item	CON	0.25T	0.5T	SE_{pooled}	*P*-value
T_{ear} (°C)					
0700 h	34.16	34.12	34.06	0.10	
1600 h	34.88^{ab}	34.71^{b}	34.94^{a}	0.10	0.09
1900 h	34.62^{AB}	34.51^{B}	34.71^{A}	0.10	
Daily average	34.55	34.44	34.57	0.09	0.27
T_{rump} (°C)					
0700 h	33.82	33.68	33.67	0.10	
1600 h	34.86^{c}	34.54^{d}	34.88^{c}	0.10	0.004
1900 h	34.54^{c}	34.23^{d}	34.63^{c}	0.10	
Daily average	34.40^{a}	34.15^{b}	34.39^{a}	0.09	0.05

[a,b]Means with different superscripts within a row differ ($P < 0.05$).

[A,B]Means with different superscripts within a row differ ($P < 0.10$).

[c,d]Means with different superscripts within a row differ ($P < 0.01$).

[1]Treatments were as follows: control-1 (C-1); initial control-1 in period 2, followed by 0.50% Tasco (Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada) in period 3 (C-.5T); 0.25% Tasco (0.25T); 0.50% Tasco (0.5T). For period 2, C-1 and C-.5T have been combined and represent the control group (CON).

Core Body Temperature. No overall differences ($P > 0.10$) were observed among treatments for T_{core} during night or day, with hourly values for each cow used as averages across days over the entire period. In another study (Cvetkovic et al., 2005), no effects of Tasco were seen on rectal temperature of dairy cows supplemented with 56.7 g/d of Tasco for 5 weeks during heat stress. In contrast, lambs fed 2% Tasco and exposed to T_a reaching 32.0°C, during transportation in a trailer, had lower maximum and average ear canal temperatures (Archer et al., 2007).

A treatment × day interaction existed ($P < 0.05$) for T_{core}. During the night (Figure 2C), 0.5T cows had greater ($P < 0.05$) T_{core} than did

CON cows for 5 nights and greater T_{core} than 0.25T cows for 1 night. During the day (Figure 2D), T_{core} of 0.5T cows was greater ($P < 0.05$) than that of CON cows for 13 d and greater than that of 0.25T cows for 7 d. Thus, 0.5T cows had recurrent elevated T_{core}. In contrast, T_{core} of CON and 0.25T cows did not differ at any time, indicating that the lower level of Tasco did not have an effect on T_{core}. A lower regional skin temperature and potentially reduced heat loss, together with occasionally reduced DMI and possibly less heat production of 0.25T cows, might balance each other and explain the lack of a change in T_{core}.

When the hourly average T_{core} of all days within the period was analyzed, a treatment × hour interaction existed ($P < 0.05$) during the night and day (Figure 2E). The pattern of T_{core} for all treatments was similar throughout the day. However, 0.5T cows had about 0.2°C greater T_{core} throughout the night compared with cows on other treatments, and this difference increased to about 0.3°C during most hours of the day. Minimum T_{core} occurred at 0800 h for 0.5T cows and at 1000 h for cows on other treatments. The 0.5T cows had a greater ($P < 0.05$) T_{core} than did CON cows at 0600 and 0700 h and from 1000 to1400 h and greater ($P < 0.05$) T_{core} than did 0.25T cows from 1000 to 1300 h. Thus, 0.5T cows had consistently greater T_{core} than did cows on other treatments. In contrast, rats fed a diet containing endophyte-infected tall fescue seed (i.e., fescue toxicosis) supplemented with 1% Tasco exhibited reduced T_{core} when exposed to heat stress (Eichen et al., 2001; Spiers et al., 2004). Moreover, steers grazing endophyte-infected tall fescue treated with Tasco-Forage (water-soluble extract produced by alkaline hydrolysis) had reduced rectal temperature compared with animals grazing untreated forage during summer (Saker et al., 2001); however, after animals were transported to a feedlot facility, steers consuming Tasco had a greater rectal temperature (Allen et al., 2001).

Even though no significant differences ($P > 0.10$) were observed for milk production, there was some evidence that cows on 0.5T had greater milk production than those in the other groups. This might have been due to a greater DMI resulting in a greater T_{core} for the 0.5T cows. High-producing dairy cows usually have greater feed intake and elevated metabolic rate and body heat production, resulting in elevated body temperature and higher vulnerability to heat stress (Kadzere et al., 2002). Cows in the 0.5T group had a greater ($P < 0.05$) T_{core} even during the pretreatment phase (period 1), suggesting that the differences in period 2 could be attributed to individual differences in T_{core} of the animals rather than treatment effect.

Regression of Body Temperature as a Function of Ambient Temperature. The linear relationship between T_{core} and T_a during the day (Figure 2F) revealed a lower ($P < 0.05$) slope for 0.25T cows than for CON animals. This indicates that the T_{core} of cows fed 0.25% Tasco increased less with the elevation in T_a compared with that of cows in the control treatment. Tasco had no influence ($P > 0.10$) on the slope for the relationships of T_{rump} or T_{ear} with T_a, suggesting skin temperature of animals responded similarly to the increase in T_a, regardless of treatment. Spiers et al. (2003) reported that steers grazing endophyte-infected tall fescue (i.e., fescue toxicosis) and previously fed 1% Tasco had 0.3°C reduced T_{core} during first exposure to heat stress, compared with animals not fed Tasco.

Period 3 – Insertion of a Second 0.50% Tasco Treatment

Ambient Conditions and Performance Parameters. The average daily values for maximum, mean, and minimum T_a were 31.0, 26.2, and 21.7°C, respectively (Figure 3A), and maximum, mean, and minimum RH were 95.2, 80.8, and 61.5%, respectively. The T_a exceeded 25°C every day during this period, except on d 59 (max T_a = 24.4°C). According to Roenfeldt (1998), the thermoneutral zone for lactating dairy cows ranges from 5 to 25°C, depending on breed, size, and level of production. In this period, the highest T_a was on d 49 (T_a = 34.9°C). No differences ($P > 0.10$) were found between treatments for DMI, DMI per BW, and milk production (data not shown).

RR and Skin Temperature. No differences ($P > 0.10$) were found for RR, T_{ear}, and T_{rump} for overall average or treatment × hour interaction during period 3 (data not shown). Supporting these findings, Cvetkovic et al. (2005) reported that supplementation of 56.7 g/d of Tasco during summer did not affect morning, afternoon, evening, and average daily temperatures of rear udder skin and RR of dairy cows. In the present study, a treatment × day interaction existed ($P < 0.05$) for T_{rump} (Figure 3B), with T_{rump} being less for 0.25T cows ($P < 0.05$) than for C-1 cows for 4 d and less than for C-.5T cows for 6 d. Cows on 0.5T had a reduced ($P < 0.05$) T_{rump} compared with C-1 cows for 2 d and compared with C-.5T cows for another 2 d. However, for 1 d, T_{rump} of 0.5T cows was greater ($P < 0.05$) than that of C-1 and C-.5T cows. The T_{rump} was reduced ($P < 0.05$) for C-.5T cows compared with C-1 cows only for 1 d, indicating that inclusion of 0.50% Tasco for a short length of time (i.e., 28 d) did not affect T_{rump} of cows. The inclusion of 0.25% Tasco in the diet reduced T_{rump} of cows on certain days; however, no effect on T_{ear} was observed. In general, 0.25T cows had reduced T_{rump} compared with cows on other treatments on days with high T_a (i.e., above 30°C). For period 2, 0.25T cows had reduced T_{rump} for the overall period and hourly averages compared with cows on other treatments. In period 3, this reduced T_{rump} of 0.25T cows was maintained, even though only the treatment × day interaction was significant, suggesting that the effect of the 0.25% Tasco in reducing T_{rump} lasted for most of the study.

Core Body Temperature. No overall differences ($P > 0.10$) among

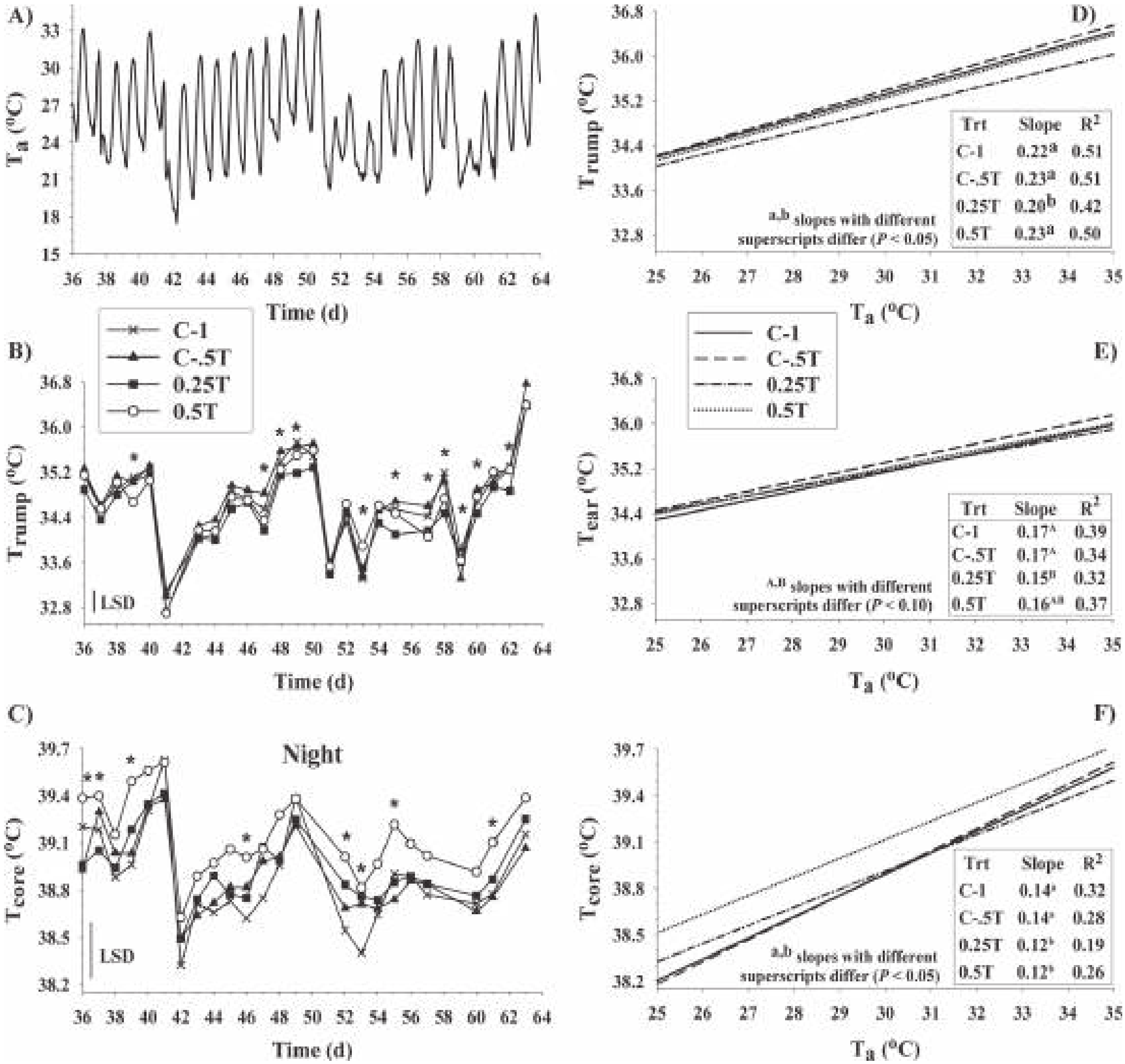

Figure 3. Results for period 3. (A) Ambient temperature (T_a) recorded hourly within the barn; (B) daily average rump skin temperature (T_{rump}); (C) daily average core body temperature (T_{core}) during the night (0000 to 0600 h); (D) change of T_{rump} as a function of T_a; (E) change of ear skin temperature (T_{ear}) as a function of T_a; (F) change of T_{core} during the day (0700 to 1600 h) as a function of T_a. LSD = least significant difference; Trt = treatment. *Days with differences at 5% between one or more treatments; see text for details. Treatments were as follows: control-1 (C-1); initial control-1 in period 2, followed by 0.50% Tasco (Acadian Seaplants Limited, Dartmouth, Nova Scotia, Canada) in period 3 (C-.5T); 0.25% Tasco (0.25T); 0.50% Tasco (0.5T).

treatments were found for T_{core} during night or day. In contrast, beef steers fed 1% Tasco and housed in climatic chambers had a lower range of rectal temperature during early exposure to heat (Williams et al., 2009). In the same study, however, steers exposed to heat after consuming Tasco for 36 d at thermoneutrality had greater rectal temperature and greater range of rectal temperature, suggesting that Tasco fed for extended periods had an opposite effect on T_{core} during heat stress (Williams et al., 2009).

In period 3, there was no treatment × day interaction during the day ($P > 0.10$; data not shown). A treatment × day interaction existed ($P < 0.05$) during the night (Figure 3C), with 0.5T cows having greater T_{core} than C-1, C-.5T, and 0.25T cows for 4, 4, and 3 nights, respectively. As observed for period 2, 0.5T cows had elevated ($P < 0.05$) T_{core} compared with cows in other treatments for most nights in period 3. In contrast, during this period, C-.5T cows, which also received 0.50% of Tasco, did not exhibit elevated ($P > 0.10$) T_{core} compared with C-1 and 0.25T cows. The T_{core} of C-1, C-.5T, and 0.25T cows did not differ for most days, despite the reduced T_{rump} of cows on 0.25T on certain days, indicating that 0.25T, or 0.5T fed for a shorter period of time (i.e., 28 vs. 56 d), had no effect on T_{core} of dairy cows. The greater T_{core} for the 0.5T cows at night would suggest that their ability to dissipate heat during the night cooling phase had been reduced. It is uncertain at this time where the cooling problem is located. The lack of a large difference in T_{rump} across groups would indicate that there might be a greater difficulty in transferring heat from the core to the skin in the 0.5T cows. However, this remains to be studied in greater detail.

The 0.5T cows had a consistently greater T_{core} compared with other groups throughout the study. However, this effect was observed on certain days during period 1 under thermoneutral conditions, on days when T_a did not reach 25°C. From these observations, one may infer that cows assigned to 0.5T had a naturally greater T_{core} at thermoneutrality and that differences observed for 0.5T could likely be attributed to individual differences of the animals rather than a clear Tasco effect. Moreover, cows in C-.5T, which received the same level of Tasco (i.e., 0.50%) starting on the first day of period 3, did not have elevated T_{core}, despite the fact that Tasco is known to be more effective during early exposure to heat (Spiers et al., 2003; Williams et al., 2009). Thus, further research is necessary to identify true effects of the inclusion of 0.50% of Tasco on T_{core} of dairy cows.

During the study, T_a never reached 35°C, and peak T_a was above 30°C only for a few days. Thus, there were no extreme ambient conditions to evaluate the effect of Tasco on T_{core}, even though T_a was above the upper critical limit for dairy cows (Roenfeldt, 1998). In a previous study, no benefits were seen in the immune systems of steers grazing endophyte-free pasture and treated with Tasco (Saker et al., 2001), but after animals were exposed to the stress of transportation to the feedlot, the effect of Tasco on immune response was observed (Allen et al., 2001). The authors suggested that the effect of Tasco on immune function is dependent on the presence of a stressor. Thus, the lack of extremely hot days or prolonged heat stress situations in the current study may explain the little benefit of Tasco supplementation.

Regression of Body Temperature as a Function of Ambient Temperature. Linear regression of T_{rump} versus T_a (Figure 3D) demonstrated that 0.25T had a lower ($P < 0.05$) slope than all other groups. For T_{ear} versus T_a (Figure 3E), a trend ($P < 0.10$) existed for a lower slope for 0.25T as compared with C-1 and C-.5T. For T_{core} versus T_a during the day (Figure 3F), 0.25T and 0.5T had lower ($P < 0.05$) slopes than did C-1 and C-.5T; no differences ($P > 0.10$) were found between 0.25T and 0.5T or between C-1 and C-.5T. Thus, even though 0.5T cows had a greater T_{core} throughout the study compared with cows in other treatments, for period 3, the group had less of an increase in T_{core}, compared with the control, as T_a increased.

In this period, a lower slope of 0.25T for the increase in T_{rump}, T_{ear}, and T_{core} as a function of T_a indicates that cows fed 0.25% Tasco were better able to maintain a reduced body temperature with the increase in T_a during the day. Spiers and coworkers (2004) revealed that 1% Tasco in an endophyte-infected tall fescue seed diet reduced hyperthermia caused by fescue toxicosis. The steers also had reduced feed intake, suggesting that the lower energy intake may have reduced metabolic heat production and T_{core} (Spiers et al., 2004). In the current study, a lower dose of Tasco (i.e., 0.25%) was observed to cause a similar reduction in body temperature and feed intake for dairy cows.

It was noted that different responses were obtained for the relationship of body temperature and T_a during periods 2 and 3. In period 2, 0.25T had a lower slope for the relationship between T_{core} and T_a compared with other treatments, whereas no differences existed for T_{rump} and T_{ear} versus T_a. On the other hand, in period 3, 0.25T had a lower slope for T_{rump}, T_{ear}, and T_{core} versus T_a; in addition, 0.5T had a lower slope of T_{core} versus T_a as compared with C-1 and C-.5T. It was speculated that this variation in the response may be attributed to the greater level of heat stress in period 3, caused by the greater T_a. In period 2, T_a remained above 25°C for 33% of the time, whereas in period 3, it was increased to 57%, indicating the greater level of heat stress encountered during this last period.

IMPLICATIONS

Even though overall core body temperature was not affected, inclusion of 0.25% Tasco in the TMR reduced the increase in skin and core temperatures as ambient temperature increased. Feeding 0.50% Tasco for short or long periods had no beneficial influence on body surface temperature. Feeding 0.25% Tasco reduced DMI on certain days without any effect on milk production. The inclusion of Tasco at a 0.50% level in the feed for 28 d during period 3 did not have any effect on DMI, milk production, RR, or body core or surface temperatures.

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