

## Effect of rationalization of water consumption for evaporative cooling on productivity of dairy cattle

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Received: 17 October 2001; Accepted: 22 January 2003

### ABSTRACT

Holstein cows (20) were used to determine the effect of reducing amount of water use for evaporative cooling (WEC) system on animal productivity. The first group served as control and the other group was maintained under the same condition except that WEC system was timed for 5 min on and next 5 min off. A telemetry system was used to monitor core body temperature ( $T_{\text{core}}$ ) at 5 min intervals throughout the experiment. Core body temperature exhibited a circadian rhythm reaching maximum during middle of day and minimum in early morning. The 50% reduction in WEC resulted in a significant increase in daily average  $T_{\text{core}}$  that was not associated with a significant reduction in milk production. In conclusion, the 50% reduction on WEC did not have any adverse effect on animal productivity; therefore we strongly recommend applying a 5 min cycle system.

**Key words:** Animal productivity, Cattle, Circadian rhythm, Evaporative cooling, Heat stress, Management, Physiology

One of the major problems facing the dairy industries in Saudi Arabia is summer heat stress. The environmental temperature prevailing in the country remains above the thermoneutral temperature of lactating Holstein cattle (21°C) for at least 8 months of the year (Ali *et al.* 1999). As a result animal performance is affected negatively. Evaporative cooling is used extensively in the country with significant improvement in animal performance (El-Nouty *et al.* 1990). The use of water for evaporative cooling from early morning to evening will lead to depletion of the limited groundwater resources. Therefore, the objectives of this study were to determine the effect of reducing the amount of water use for evaporative cooling on temperature control and milk production.

### MATERIALS AND METHODS

Holstein cows (20), during the summer of 2000, were housed in an open barn and evaporative cooling system (ECS) was used daily from 0700 to 1900hr. The system consists of a sprinkler that included a timer; a 5 min cycle was used in the system. The sprinkler was on for 5 min and off for the next 5 min. The first group (10 cows) served as control and the other group was maintained under the same condition except that ECS timed for 5 min on and 5 min off. Two weeks prior to the initiation of the study, 5 cows from each group

were surgically implanted intraperitoneally with telemetric temperature transmitters for monitoring core body temperature at 5 min interval. Skin temperatures including shoulder (SK1), back (SK2), hip right (SK3) and hip left (SK4) were measured using infrared thermometer. Ambient ( $T_a$ ) temperature was monitored continuously using data logger. Temperature-humidity index (THI) was calculated according to West (1994).

Blood samples were collected from the jugular vein once a week. Blood was then analyzed shortly for red blood cell (RBC), packed-cell volume (PCV), haemoglobin (Hb), mean cell volume (MCV), mean cell haemoglobin (MCH), and mean cell haemoglobin concentration (MCHC) using the Coulter count. The concentrations of total serum thyroxin, and triiodothyronin, were determined using the enzyme-immunoassay kits.

This study lasted for 90 days, the first 45 days represented the first period and the second 45 days represent the second period. Data were subjected to statistical analysis of variance according to SAS (SAS 1985).

### RESULT AND DISCUSSION

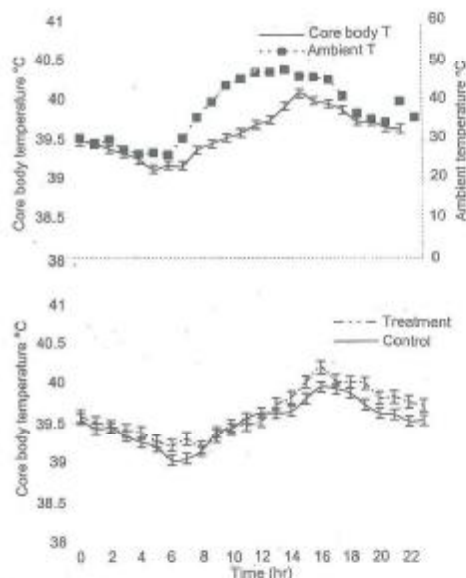
The ability of animals to dissipate heat is a function of many environmental variables besides ambient temperature, and relative humidity. One index has been used to incorporate the effect of humidity is the temperature humidity index (THI), a THI exceeding 72 indicated that cattle are heat-stressed

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(Ravagnolo *et al.* 2000). The THI in the present study was  $83.8 \pm 0.2$  which is above the normal, indicating that these animals were heat-stressed.

Milk production was not affected by reducing the amount of water used in evaporative cooling ( $P > 0.3$ ), the average milk production was  $20.9 \pm 0.29$  and  $21.3 \pm 0.29$  kg/day/cow for the control and treatment group respectively. However, lactation period had a significant effect ( $P < 0.001$ ) on milk production, the first period was significantly ( $P < 0.001$ ) higher than the second period ( $21.8$  and  $20.4 \pm 0.27$  kg/day/cow for the first period and the second period respectively). Reducing the amount of WEC did not result in a significant reduction in milk production that supports our hypothesis.

Body temperature of cattle as monitored by calibrated telemetric transmitters showed monophasic variations with 1 peak and 1 trough (Fig. 1), reached maximum ( $40^\circ\text{C}$ ) during middle of the day (1400hr) and minimum ( $39.1^\circ\text{C}$ ) in the early morning (0500-0600hr) with amplitude of  $1.0^\circ\text{C}$ . Many investigators have reported that body temperature of cattle showed distinguish rhythm (Lefcourt *et al.* 1999, Al-Haidary 2001). Bligh and Lampkin (1965) showed that cattle under thermoneutral conditions exhibit a monophasic diurnal variation in body temperature, in agreement with the present



Figs 1-2. 1 The overall average of core body temperature and ambient temperature during the study. 2 Core body temperature of control and treatment cows during the first 45 days (period 1) and the second 45 days (period 2) of the study.

study. Peak  $T_{\text{core}}$  of cattle during heat challenge in the present study occurred between 1400 and 1600hr, and lowest point was at 0500 to 0600hr. Similar relative change in rectal temperature, with peak around 1800 and minimum in the middle of the day, occurs in dairy cattle during heat stress (Al-Haidary 2000). In contrast, there have been reports of maximum rectal temperature occurred in the middle of the night, and minimum at during middle of the day (Lefcourt *et al.* 1999). The discrepancy between studies may be due to the pattern of ambient temperature exposure (i.e., constant or cycling). In the present study,  $T_a$  was cycling and being high during day and dropped at night while in the other studies  $T_a$  was maintained constant.

There was a significant increase in daily average of core body temperature because of both treatment and lactation period. The 50% reduction in WEC resulted in a significant increase ( $P < 0.001$ ) in daily average of core body temperature ( $39.55$  and  $39.63 \pm 0.009^\circ\text{C}$  for the control and the treatment group respectively). Monitoring the 24hr core body temperature rhythm of both groups showed significant changes in the early morning (0500-0600hr) and during evening (1500-2200hr) between the control and treatment groups (Fig. 2). Ambient temperature also showed a circadian rhythm reaching maximum ( $47.7^\circ\text{C}$ ) in the middle of the day (1300-1400hr) and minimum ( $26.0^\circ\text{C}$ ) in the early morning (0400-0600hr), with large amplitude ( $21.7^\circ\text{C}$ ). There was no significant difference ( $P > 0.05$ ) between  $T_a$  in period 1 ( $37.18^\circ\text{C}$ ) and period 2 ( $37.25^\circ\text{C}$ ). Similar to the daily average of  $T_a$ , the 24hr  $T_a$  also did not show any statistical differences (Fig. 2).

The daily variation in  $T_{\text{core}}$  followed the same trend as the  $T_a$  rhythm (Fig. 1). In the early morning (0500-0600hr)  $T_{\text{core}}$  and  $T_a$  increased gradually reaching maximum around middle of the day, then both decreased gradually until they reached a nadir in the early morning. However, there was a 3-4 hr lag between the maximum body temperature and maximum ambient temperature.  $T_a$  peaked at 1100hr while  $T_{\text{core}}$  reached maximum at 1400hr (Fig. 1).

Treatment and lactation period did not have any significant affect on skin temperatures measurements in 4 different locations and rectal temperature. Similarly, rectal temperature did not show any significant changes with the treatment, although the average daily  $T_{\text{core}}$  was significantly ( $P < 0.0001$ ) higher for the treatment cows ( $39.63 \pm 0.006^\circ\text{C}$ ) compared to the control cows ( $39.50 \pm 0.006^\circ\text{C}$ ). Core body temperature measured by the telemetry showed that during 0900hr  $T_{\text{core}}$  of control cows were  $39.39^\circ\text{C}$  and of treatment animals  $39.34^\circ\text{C}$ , which indicated the importance of the time of measurement.

Rectal temperature measurement was conducted to determine the relationship between the temperature measurement from the rectum and the telemetry measurement. Our result showed that reducing the amount of water resulted in a significant increase in the average daily core body

temperature, while RT measurement did not detect any statistical differences. Moreover, when the  $T_{\text{rect}}$  at 0900hr, which was the time for the RT measurement, was statistically analyzed, these results were similar to the RT, and there was no statistical difference between the 2 groups. These findings emphasized the importance of the circadian rhythm rather than just single measurement, and the accurate determination of body temperature of dairy cattle can only be derived from several measurements at different phases of the daily cycle.

One of our objectives was to determine the optimum time

Table 1. The average of red blood cell, packed cell volume, haemoglobin, mean cell volume, mean cell haemoglobin and mean cell haemoglobin concentration during the periods 1 and 2 of the study

	Period 1		Period 2	
	Control	Treatment	Control	Treatment
RBC( $\times 10^{12}/\mu\text{l}$ )	6.37 $\pm$ .09 <sup>a</sup>	6.06 $\pm$ .09 <sup>b</sup>	5.94 $\pm$ .09 <sup>b</sup>	6.16 $\pm$ .09 <sup>a</sup>
PCV (%)	30.1 $\pm$ .3 <sup>a</sup>	28.8 $\pm$ .3 <sup>b</sup>	29.6 $\pm$ .3 <sup>a</sup>	28.9 $\pm$ .3 <sup>b</sup>
HB (g/dl)	8.6 $\pm$ .12 <sup>a</sup>	8.3 $\pm$ .12 <sup>b</sup>	8.8 $\pm$ .12 <sup>a</sup>	8.1 $\pm$ .12 <sup>b</sup>
MCV ( $\mu\text{m}^3$ )	47.9 $\pm$ .7 <sup>a</sup>	48 $\pm$ .7 <sup>a</sup>	50.2 $\pm$ .7 <sup>a</sup>	47.1 $\pm$ .7 <sup>b</sup>
MCH (pg)	13.7 $\pm$ .27 <sup>b</sup>	13.9 $\pm$ .27 <sup>b</sup>	15.1 $\pm$ .27 <sup>a</sup>	13.3 $\pm$ .27 <sup>b</sup>
MCHC%	28.5 $\pm$ .35 <sup>b</sup>	28.9 $\pm$ .35 <sup>b</sup>	29.6 $\pm$ .35 <sup>a</sup>	28.2 $\pm$ .35 <sup>b</sup>

<sup>a,b</sup>Values in same row with different superscript differ ( $P < .05$ ).

of the day to use the evaporative cooling system, under these environmental conditions evaporative cooling system should be operated from early morning (0700hr) to late afternoon (1900hr) to minimize the adverse effect of high ambient temperature, however, it is very important to adjust the operating time according to the ambient temperature.

Skin temperature is a good indicator for blood vasomotor tone (Guyton 1991). Exposure to heat stress triggers vasodilatation and increased blood flow to the surface to facilitate heat dissipation, and exposure to cold stress, on the other hand, triggers vasoconstriction and reduction of heat loss. In this study there was no statistical differences between the control and treatment group, which indicated that these animals were equally heat-stressed, and the 50% reduction in WEC has no adverse effect on the control group. Many investigators showed that exposure to different environmental condition alters skin temperature (Di Costanzo *et al.* 1997; Al-Haidary 2000).

To understand the effect of the 50% reduction in WEC on the physiological status of the animal, the haematological

Table 2. Thyroid hormones, thyroxin ( $T_4$ ) and triiodothyronin ( $T_3$ ) concentrations during the periods 1 and 2 of the study

	Period 1		Period 2	
	Control	Treatment	Control	Treatment
$T_4$ (ng/ml)	1.95 $\pm$ 0.11	2.19 $\pm$ .11	2.19 $\pm$ .11	2.11 $\pm$ .11
$T_3$ ( $\mu\text{g/dl}$ )	6.52 $\pm$ .15	6.71 $\pm$ .15	6.61 $\pm$ .15	6.62 $\pm$ .15

Table 3. The average values of skin temperatures in four locations, rectal temperature average skin temperature and the calculated average body temperature during the periods 1 and 2 of the study

	Period 1		Period 2	
	Control	Treatment	Control	Treatment
Sk1	37.9 $\pm$ .15	37.8 $\pm$ .15	37.8 $\pm$ .15	37.8 $\pm$ .15
Sk2	37.7 $\pm$ .14	37.7 $\pm$ .14	37.7 $\pm$ .14	37.9 $\pm$ .14
Sk3	38.1 $\pm$ .14	37.8 $\pm$ .14	37.9 $\pm$ .14	37.9 $\pm$ .14
Sk4	38.2 $\pm$ .15	37.9 $\pm$ .15	38.0 $\pm$ .15	38.1 $\pm$ .15
Rt	39.1 $\pm$ .18	39.1 $\pm$ .18	38.7 $\pm$ .18	39.0 $\pm$ .18
Average SK	38.0 $\pm$ .13	37.8 $\pm$ .13	38.4 $\pm$ .13	38.7 $\pm$ .13

values were determined. The 50% reduction in WEC associated with lower haematological values (Table 1). Shaffer *et al.* (1981) reported similar result that exposure to heat stress decreased Hb and PCV. In the present study reduction in WEC induced depression of blood Hb, PCV, MCV, MCH without any significant alteration in circulating RBC. Shaffer *et al.* (1981) verified the depression in blood Hb and PCV of cattle that were subjected to elevate ambient temperature, and a haemodilution effect where more water is transported in the circulatory system for evaporative system. Thyroid hormones did not show any significant changes with the treatment or with location period (Table 2).

#### ACKNOWLEDGEMENTS

The authors thank Mr Almeman the general manager of the Alkharj dairy farm project, and Mr Al-Salboad and Al-Masoud for their valuable assistance throughout the study. The authors are grateful to A Al-Sheikhi for his assistance during data collections. This work was supported by King Abdulaziz City for Sciences and Technology grant number: LGP-3-43.

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