EFFECT OF ENVIRONMENTAL TEMPERATURES ON HEAT PRODUCTION IN DAIRY HEIFERS DIFFERING IN FEED INTAKE LEVEL

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Summary

A study using dairy heifers was conducted to determine the effect of environmental temperature on heat production differing in feed intake level. The design consisted of three levels of feed intake (low, medium and high) and two environmental chamber temperature (15 and 30℃) with four replications in each treatment. Rectal temperature (RT), respiration rate (RR), heart rate (HR) and heat production (HP) were then measured. At the both environmental temperature, RT, RR and HR increased with the increase in feed intake level. The RT and RR also increased with the elevation of environmental temperature. The HP of 30℃ was significantly higher (4.8-8.9%) than 15℃. The estimated metabolizable energy requirement for maintenance (MEm) was higher ($p < 0.05$) at 30℃ (554.7 kJ/kg$^{0.75}$ d) than 15℃ (464.9 kJ/kgd). It was suggested that the decreasing in productive efficiency under hot environmental conditions partly associated with the increase in HP, which associated with the change in heat loss mechanism from sensible path to evaporative path.

(Key Words: Dairy Heifer, Environmental Temperature, Heat Production, Metabolizable Energy, Physiological Responses)

Introduction

Rectal temperature of dairy heifers increased when they were exposed to 30℃ for a week compared with the exposure to 20 or 10℃ (Purwanto et al., 1991). The exposure to hot environmental conditions decreased sensible heat loss, conversely, evaporative heat loss was increased. Therefore, in this condition, the heifers will attempt to increase evaporative heat loss. Consequently, metabolic heat production may change due to the activities or responses of thermoregulation.

Kurihara et al. (1991) showed that heat production as a percent of energy intake in non-lactating dairy cows was greater under hot environmental conditions (32℃) than under cool conditions (18℃). Thus energetic efficiency was reduced (Shibata and Mukai, 1982), which may be associated with increased energy requirement for maintenance. Wilks et al. (1990) suggested that under heat stress a proportion of the energy requirement for maintenance of dairy cows may be increased, which implies that availability of metabolizable energy for milk production would decrease. A study by McDowell et al. (1969) showed clearly that the energy requirement for maintenance of lactating dairy cows increased when they were exposed to hot environmental temperatures.

The present study was carried out to determine the effect of heat exposure on heat production and estimated metabolizable energy requirement for maintenance of dairy heifers in relation to their thermoregulation processes.

Materials and Methods

Animal management

Two Holstein heifers with initial body weight of 217.5 kg, were housed in a pen (120 × 190 cm) and were exposed to two levels of constant ambient temperature (15 and 30℃). They were fed a commercial mixed concentrate (68.0% TDN and 13.0% DCP) and Italian ryegrass (*Lolium multiflorum*, 56.6% TDN and 6.2% DCP) hay at three levels of TDN intake (low, medium and high levels) for 7 day periods. The first 5 days were used for adjustment to the experimental

conditions and the last two days for data collection and calorimetric measurement.

The high (H) level of TDN intake was defined as the ration which would maintain the animals and permit growth of 0.6 kg per day according to the Japanese Feeding Standard (National Reasearch Council of Agriculture, Forestry and Fisheries, 1987). The low (L) and medium (M) TDN levels were equal to 60 and 80% of the H level. The ME content of the diets was estimated according to the Japanese Feeding Standard.

Measurements

Dry and wet bulb temperatures (DBT and WBT) of the climatic chamber were recorded every hour during the test periods using thermocouples.

Rectal temperature (RT) was recorded using a thermocouple inserted 15 cm into the rectum at 10 min before heat production (HP) measurement. At the same time, respiration rate (RR) was measured by counting the number of flank movements using a heart girth typed carbon pick up (Nihon Kohden, TR-601G) and a bioelectric amplifier (Nihon Kohden, AB-621G), which recorded on a polygraphs recorder (Nihon Kohden, WI-641G). Heart rate (HR) and HP were measured every 2 h intervals as described previously by Purwanto et al. (1990), except the head cage was ventilated at 260 l/min.

The RT, RR, HR and HP data and comparisons between the levels of feeding and the temperature treatments means were analyzed using

Student's t test (Steel and Torrie, 1984). A linear regression analysis was used to correlate the retained energy to metabolizable energy intake. Analysis of covariance was used to test the homogeneity of regression analysis between temperature treatments (Yoshida, 1978).

Results

Mean values of environmental temperatures, actual feed intake, RT, RR and HR are shown in table I. Dry and wet bulb temperatures were successfully controlled, but feed intake was decreased under 30°C, when the animals were fed at the H level of feed intake. It showed clearly that the animals were probably under heat stress. Daily variation of RT, HR and HP patterns at 15 and 30°C of environmental temperatures are shown in figure 1. Although the RT, HR and HP differed significantly among groups, all groups had similar daily pattern of RT, HR and HP.

The levels of RT and RR increased (p < 0.05) with the environmental temperature and the feed intake levels. Under exposure at 30°C, RR was not significantly different between M and H of feed intake levels. Although there was a tendency for increase of RR with the level of feed intake, the standard deviation was high and the observed trends were not statistically significant.

The HR increased (p < 0.05) with the increase in feed intake levels at the both environmental

TABLE I. MEAN VALUES OF ENVIRONMENTAL TEMPERATURES, TOTAL DIGESTIBLE NUTRIENTS (TDN) INTAKE AND PHYSIOLOGICAL RESPONSES IN EACH EXPERIMENTAL REGIME

	15°C			30°C		
	L*	M	H	L	M	H
Environmental temperature (°C)						
Dry bulb temperature	16.2 ± 1.9	15.9 ± 0.8	15.4 ± 0.8	30.4 + 0.3	30.6 ± 0.4	30.5 ± 0.3
Wet bulb temperature	13.4 ± 1.0	13.8 ± 1.2	11.7 ± 1.1	23.7 ± 0.3	23.7 ± 0.3	22.9 ± 0.4
TDN intake (g/kg$^{0.75}$ d)	36.1 ± 0.7	51.6 ± 0.6	62.1 ± 1.8	36.7 ± 0.7	51.6 ± 0.2	60.8 ± 0.4
Physiological responses :						
Rectal temperature (°C)	38.6 ± 0.3[a]	38.8 ± 0.2[b]	39.1 ± 0.4[c]	39.0 ± 0.2[c]	39.8 ± 0.2[d]	40.0 ± 0.3[e]
Respiration rate (beats/min)	20 ± 4[a]	31 ± 7[b]	39 ± 7[c]	53 ± 9[d]	75 ± 13[e]	80 ± 13[e]
Heart rate (beats/min)	47 ± 7[a]	64 ± 10[b]	75 ± 10[c]	53 ± 6[d]	67 ± 7[d]	74 ± 8[c]

* For details see materials and methods.

a,b,c,d,e Mean within a physiological response with different superscripts differ (p < 0.05).

temperatures. The HR of the animals fed at the L and M levels of feed intake at 30°C was higher than those at 15°C of environmental temperature. However, because of a reduction in feed intake at H level, the HR at 30°C was the same as at 15°C.

The results of calorimetric measurement are shown in table 2. The HP under 30°C were 8.9 and 8.0% higher than that at 15°C of environmental temperature for the L and M feed intake levels, respectively. These increases was almost clearly observed during the night time, after feeding in the afternoon to 02:00 A.M. (figure 1). However, because of a reduction in feed
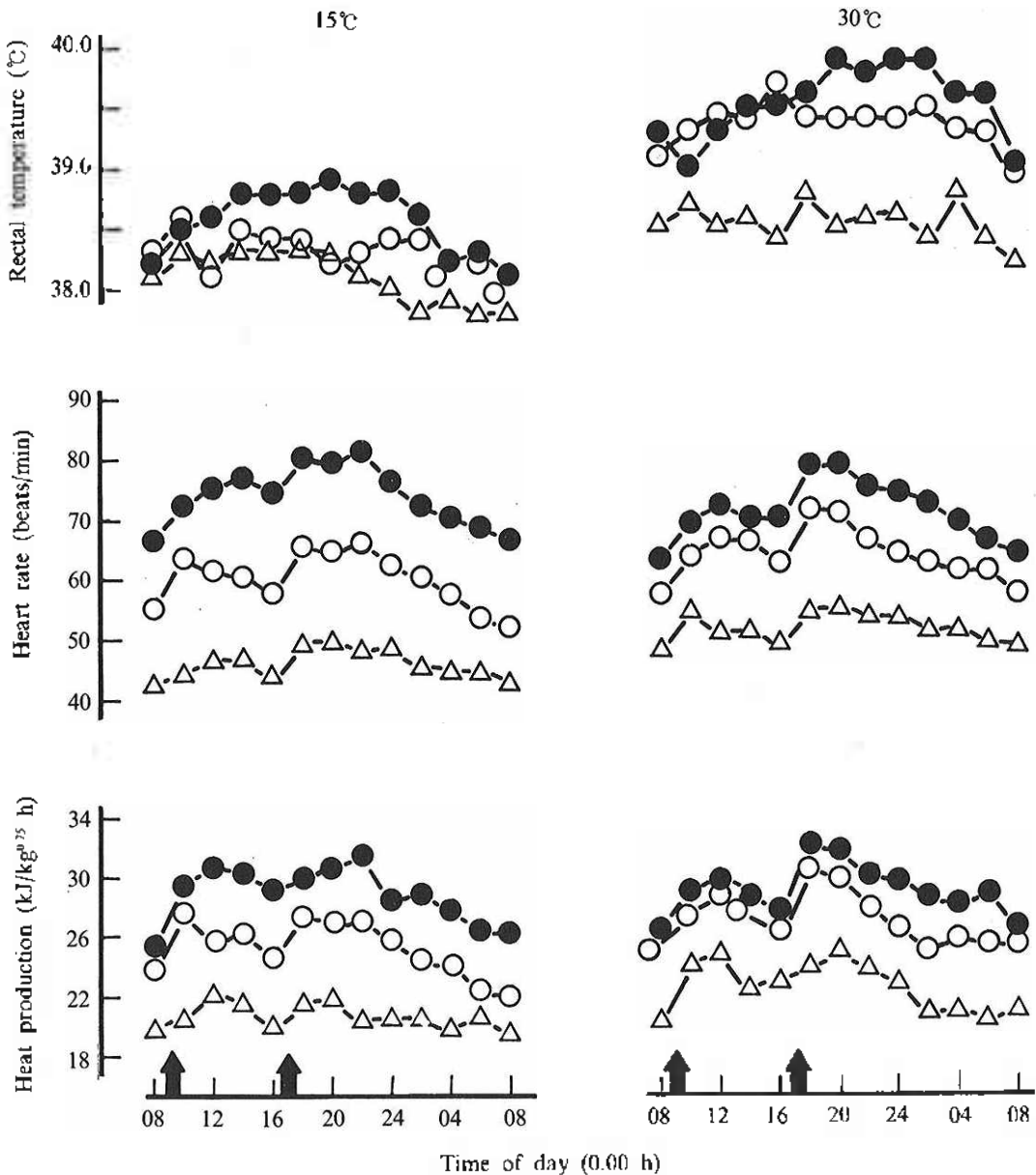

Figure 1. Daily rectal temperature, heart rate and heat production patterns in dairy heifers with low (△), medium (○) and high (●) of feed intake levels under 15°C and 30°C of environmental temperatures. The arrows indicate the time of feeding.

intake at H level, the HP at 30°C was the same as at 15°C. A relationship of retained energy and metabolizable energy intake are shown in figure 2. The estimated metabolizable energy requirement for maintenance under 30°C (554.7 kJ/kg$^{0.75}$ d) was higher (p < 0.05) than under 15°C (464.9 kJ/kg$^{0.75}$ d) and the efficiency of ME utilization was 0.49 and 0.53 for 15 and 30°C, respectively.

TABLE 2. CALORIMETRIC MEASUREMENTS IN DAIRY HEIFERS EXPOSED TO 15 AND 30°C FED ON HIGH (H), INTERMEDIATE (M) AND LOW (L) LEVELS OF FEED INTAKE

Temperature* (°C)	Feeding level	ME intake	HP	Energy balance
		······································ (kJ/kg$^{0.75}$ d)··························		
15	H	939.71 ± 1.69	708.24 ± 24.44[a]	+ 231.47
	M	780.02 ± 11.30	618.84 ± 36.83[b]	+ 161.18
	L	547.73 ± 12.78	509.64 ± 32.07[c]	+ 38.09
30	H	881.38 ± 10.15	709.92 ± 5.43[a]	+ 171.46
	M	789.56 ± 11.60	668.04 ± 28.68[d]	+ 121.52
	L	550.49 + 7.04	554.76 ± 30.72[e]	− 4.27

* Actual environmental temperatures are shown table 1.
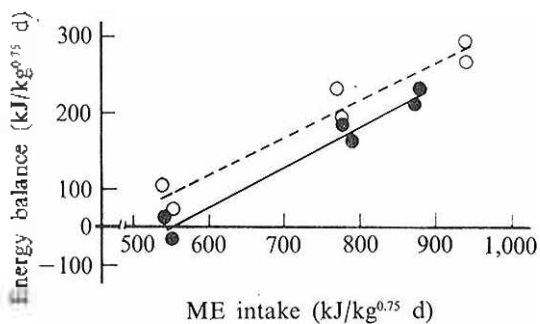[a,b,c,d,e] Mean within a column with different superscripts differ (p < 0.05).

Figure 2. Regression analysis of energy balance on metabolizable energy intake at 15°C (○, y = −222.8 + 0.49 x, r = 0.97) and 30°C (●, y = 294.0 + 0.53 x, r = 0.98).

Discussion

The increase in physiological responses with environmental temperature or feed intake level is in a agreement with the results of Shibata and Mukai (1977) and Purwanto et al. (1991).

The increases in RT, HR and RR under hot environmental condition are protective mechanism of homeothermic animals to maintain their heat balance by increasing the evaporative heat loss (eHL). The increase in RT at 30°C of environmental temperature means that the body heat sto-rage increased (McLean and Calvert, 1972) and the cutaneous vessels dilates and then the HR is increased to maintain blood pressure (Ganong, 1977). The increase in RT not only helps to increase or initiate eHL, but may also to maintain sensible heat loss (sHL), because the mean skin temperature was greatly increased at 30°C compared with 15°C (Nakamasu, 1991).

The increase in HR may also help in transporting body heat from internal organs to the body surface. Since, sHL has little impact under hot environmental conditions (Fuquay, 1981), the increase in RR at 30°C is part of the chain of increase in eHL through the respiratory passage (McLean and Calvert, 1972).

Mean values of HP were higher under 30°C than 15°C. These results are not in agreement with the previous studies by Johnson (1985) and Kurihara et al. (1991), who reported that the HP decreased when the environmental temperature increased. These differences in results may be due to the decreases in feed (energy) intake under high environmental temperatures in the previous studies.

The HP under 30°C were 8.9 and 8.0% higher than that at 15°C of environmental temperature for the L and M feed intake levels, respectively. Using a regression analysis of HP on ME intake, it was estimated that the HP at H feed intake level under 30°C increased by 4.8% compared

with at 15℃ of environmental temperature. These results are in agreement with Kurihara et al. (1990). As discussed previously, the increases in HP under 30℃ compared with under 15℃ may be associated with the change of HI mechanism from the sensible path to the evaporative path.

The estimated MEm was significantly higher ($p < 0.05$) at 30℃ (554.7 kJ/kg$^{0.75}$ d) than 15℃ (464.9 kJ/kg$^{0.24}$ d), with the efficiency of ME utilization were 0.49 and 0.53 for 15 and 30℃, respectively. These MEm are almost in the range of 488.3 (Moe et al., 1972) and 552.3 kJ/kg$^{0.75}$ d (Leahey et al., 1973). Therefore, a decrease in daily gain at 30℃ (0.33 vs 0.40 kg) may be associated with the increase in MEm.

From the present results, it was concluded that under the same feed intake level, the HP of dairy heifers at 30℃ were 4.8-8.9% higher than that at 15℃ of environmental temperature. This increase might be associated with the main path of heat loss, which had changed from sensible to evaporative paths. It was suggested that the decrease in productive efficiency under hot environmental conditions could be partly associated with the increase in HP.

Acknowledgements

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