EFFECT OF STANDING AND LYING BEHAVIORS ON HEAT PRODUCTION OF DAIRY HEIFERS DIFFERING IN FEED INTAKE LEVELS

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Summary

Four Holstein heifers were used in the present study to investigate the effect of standing and lying behaviors on heat production and physiological responses under low (L), medium (M) and high (H) levels of TDN intake. Rectal temperature (RT), respiration rate (RR), heart rate (HR), heat production (HP) and animals behavior (standing time, ST) were measured continuously for 5 h (11:00-16:00) periods. There was a tendency for increased RT with TDN intake, and no difference in RT was observed between standing and lying. The RR, HR and HP during standing were significantly higher ($p < 0.05$) than during lying. The difference between standing and lying HP were 4.41, 4.68 and 5.37 kJ/kg$^{0.75}$ h for L, M and H of TDN intake, respectively. These values showed that standing HP was 18.6-20.9% higher than lying HP. A multiple regression analysis of HP (kJ/kg$^{0.75}$ h) on TDN intake (g/kg$^{0.75}$ d) and ST (min/h) was HP = 7.75 + 0.28 TDN intake + 0.12 ST (R = 0.84). This analysis showed that the total HP not only depend on feed intake levels, but also depends on animal behavior. It was suggested that the change in HP due to the change in feed intake and animal behavior would influence the level of heat loss which was indicated by the changes in the RR and HR.

(**Key Words**: Dairy Heifer, Feed Intake, Animal Behavior, Heat Production)

Introduction

The level of metabolic heat production (HP) in domestic animals depends on their feed intake and muscular activity (Blaxter, 1989). Purwanto et al. (1990) showed that the levels of HP in dairy cows fed with 54.9, 84.2 and 159.2 g/kg$^{0.75}$ d of TDN were 29.7, 37.8 and 44.1 kJ/kg$^{0.75}$ h, respectively. Other studies showed that the standing HP was higher than lying HP in cattle under fasting (Vercoe, 1973) or in sheep under feeding conditions (Ito et al., 1990).

On the other hand, many studies showed that dairy cattle reduced their feed intake during summer season or under high environmental temperature conditions (McDowell et al., 1976). In another study by Hayasaka and Yamagishi (1990) showed that dairy cattle also did an elongation of standing time during summer season.

Since the interaction effect of feed intake levels and animals behavior on HP has not been evaluated, the present study was carried out using dairy heifers in order to investigate the effect of standing time on increasing rates of metabolic HP under different level of feed intake.

Materials and Methods

Experimental design

The study was carried out the experimental farm of Hiroshima University during November 1991. The experiment consisted of three levels of feed intake (low, medium and high levels of TDN intake). Each level of feed intake was offered for a 3 d period. The first day of each period was used for adjustment to the intake level and data was collected during the last two days. The TDN intake was calculated according to the Japanese Feeding Standard for Dairy Cattle (National Research Council of Agriculture, Forestry and Fisheries, 1987). The high (H) level of TDN intake was defined as the ration which would give to the individual test animal a TDN intake of 72.5 g/kg$^{0.75}$ day. The low (L) and medium (M) levels of TDN intake were equal to 60 and 80% of the H level, respectively.

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Animals

Four Holstein dairy heifers with an average initial body weight of 280 ± 8 kg (11 months old) were used in this experiment. They were kept in individual stanchion stall and offered at 1.4, 2.8 and 4.2 kg commercial mixed concentrate pellet (70.0% TDN and 13.0% DCP) for L, M and H feed intake levels, respectively, and 3.5 kg Italian ryegrass (*Lolium multiflorum*. 56.6% TDN and 6.2% DCP) hay at 08:30 and 17:00 each day. After each 2 hour period any residual feed was removed and the actual amount of feed intake was calculated. Water and mineral salt were freely available during the feeding periods.

Measurements

Rectal temperature (RT), respiration rate (RR), heart rate (HR) and HP were measured continuously for 5 h started at 11:00. During the test periods (11:00 16:00) dry and wet bulb temperatures were measured using thermocouples.

RT were measured using a thermocouple inserted 15 cm into the rectum, and the average of RT were recorded every minute. RR were measured by counting the number of flank movements using a heart girth typed carbon pick up (Nihon Kohden, TR-601T) and a bioelectric amplifier (Nihon Kohden, AB-621G), which then recorded on a polygraph recorder (Nihon Kohden, WI-641G). HR was measured as described previously by Purwanto et al. (1990), except the logging interval was 30 sec.

HP was measured continuously for 5 h using a head cage method as described previously by Purwanto et al. (1990). The head cage, 79 (W) × 64 (D) × 128 (H) cm was ventilated at 365 to 380 l/min. During the measurements of HP, standing time (ST) was recorded by means of an "on - off" switch (National, AM1701) which stretched above the animals using a string.

The RT, RR, HR and HP data, and comparisons between feeding treatments and animal posture were analyzed using the Student's t test (Steel and Torrie, 1984). A multiple regression analysis was used in order to relate HP, feed intake and standing time.

Results

Mean values of environmental temperatures, daily feed intake and animal responses are shown in table 1. The mean values of environmental temperatures showed that the experiment was within the thermoneutral zone for the dairy heifers. No significant difference in ST was observed among the feeding levels.

The RT were not significantly different between standing and lying. The mean RT at H level of TDN intake was the same with the M level, but was higher ($p < 0.05$) than the L level. However, no significant difference was observed between L and M feeding level.

At each level of TDN intake, RR during standing was more than that during lying. However, a significant difference ($p < 0.05$) between the RR during standing and lying was observed when the animal was fed at the H level. The mean RR at the H level was the same with the M level, but was higher ($p < 0.05$) than the L level and no significant difference was observed between L and M.

At each level of TDN intake, HR during standing was more than that during lying. However, a significant difference ($p < 0.05$) between the standing and lying HR was observed when the animal was fed at the H level. The HR significantly increased ($p < 0.05$) with the level of TDN intake.

At all level of TDN, the mean value of standing HP was higher ($p < 0.05$) than lying HP. The differences between standing and lying HP at L, M and H were 4.4, 4.7 and 5.4 kJ/kg$^{0.75}$ h, respectively. It can be shown that standing HP was 20.9, 18.2 and 18.7% higher than lying HP at L, M and H feed intake levels, respectively; and it showed that these relative values did not depend on the feed intake levels.

A multiple regression analysis of HP (kJ/kg$^{0.75}$ h) on TDN intake (FI, g/kg$^{0.75}$ d) and ST (min/h) was HP = 7.75 + 0.28 FI + 0.12 ST ($n = 24$, $R = 0.84$ and $R^2 = 71\%$). This result shows that the HP was significantly ($p < 0.01$) correlate with TDN intake level and ST. Using a factorial analysis, the interaction effect of TDN intake levels and animal behavior on HP was not observed.

Discussion

Effect of feed intake on physiological responses

Significant effects of feed intake levels on RT, RR and HR ($p < 0.05$) were observed. These

TABLE 1. ENVIRONMENTAL TEMPERATURES, BODY WEIGHT, FEED INTAKE, STANDING TIME AND PHYSIOLOGICAL RESPONSES TO FEEDING LEVEL TREATMENT DURING 5-HR MEASUREMENT PERIODS (MEAN ± S.D.)

	Feed intake level		
	L	M	H
Environmental temperature (℃):			
Dry bulb temperature	14.9 ± 1.3	16.4 ± 1.7	16.1 ± 2.4
Wet bulb temperature	10.4 ± 0.6	12.4 ± 2.6	12.4 ± 2.1
Body weight (kg)	280.9 ± 6.1	282.8 ± 6.7	282.8 ± 6.1
Total digestible nutrients ($g/kg^{0.75}$ per day)	43.6 ± 0.1	58.1 ± 0.1	72.7 ± 0.1
Standing time (min/hour)	31.6 ± 8.4	29.1 ± 6.3	24.3 ± 8.4
Physiological responses:			
Rectal temperature (℃)			
Standing	39.03 ± 0.23^a	39.10 ± 0.26^{ab}	39.20 ± 0.24^b
Lying	$38.93 + 0.23^a$	39.09 ± 0.21^{ab}	39.16 ± 0.22^b
Respiration rate (breaths/min)			
Standing	31.7 ± 6.6^{ab}	43.8 ± 11.5^b	58.1 ± 7.3^c
Lying	18.8 ± 6.8^a	34.4 ± 16.6^b	41.5 ± 12.1^b
Heart rate (beats/min)			
Standing	56.2 ± 4.8^{ab}	$68.6 + 7.9^{cd}$	85.8 ± 6.5^e
Lying	$50.7 + 3.0^a$	61.8 ± 7.7^{bc}	74.5 ± 4.4^d
Heat production ($kJ/kg^{0.75}$ h)			
Standing	25.48 ± 1.48^b	$29.87 + 2.87^c$	33.90 ± 2.05^d
Lying	$21.07 + 1.17^a$	25.19 ± 2.81^b	28.53 ± 1.77^c

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

results were clearly evident and are in agreement with previous studies of Shibata and Mukai (1977) and Purwanto et al. (1991a).

HP in the present study increased from 23.27 ± 2.62 to 31.21 ± 3.34 $kJ/kg^{0.75}$ h when the TDN intake was increased from 44 to 73 $g/kg^{0.75}$ d. The regression analysis of HP on TDN intake showed that the HP increased by 0.28 $kJ/kg^{0.75}$ h for each 1 $g/kg^{0.75}$ d increase in TDN intake. It was consistent with the results reported by Purwanto et al. (1991b), which was 0.30 $kJ/kg^{0.75}$ h, but it was higher compared with the results of other study in dairy cows (Purwanto et al., 1990). This difference may be due to the differences in physiological or production stage. Van Es and Boekholt (1987) showed that the efficiency of utilization of metabolizable energy intake depends on the kind of production, in the growing animals the energy retained as protein is superseded as fat in the mature animals.

The increase in HP was followed by the increase in RT, RR and HR. The increase in RR could be expected to help the animals increase their heat loss from respiratory passage. The increase in HR would help oxygen and nutrients transport to the tissue. At the same time the increase in HR also helps the transportation of metabolic heat to the body surface by which it could be expected that the skin surface temperature probably increased. Therefore, sensible and evaporative heat loss from the skin surface may be increased (Gatenby, 1986).

Effect of animal posture on the physiological responses

The mean standing HP (29.8 ± 4.1 $kJ/kg^{0.75}$ h) was higher ($p < 0.05$) than mean lying HP (24.9 + 3.7 $kJ/kg^{0.75}$ h). This difference, 4.9 $kJ/kg^{0.75}$ h or 0.08 $kJ/kg^{0.75}$ min, was higher compared to studies by Vercoe (1973) in fasting cattle and Ito et al. (1990) in sheep. Vercoe (1973) and Ito et al. (1990) found that the differences between standing and lying HP were 2.5 and 1.7 $kJ/kg^{0.75}$ h, respectively. The different results of the present study and the previous ones may be mainly due to the differences in feed intake levels. As shown in the present study, the difference between standing and lying HP was changed by the feed intake levels. However, when the results of the present study were expressed as ratio of standing and lying HP, the standing HP were 18.6-20.9% higher than lying HP. These values were almost the same with the previous studies. Vercoe (1973) and Ito et al. (1990) showed that standing HP in cattle and sheep were 18.6 and 16.0% higher than lying HP, respectively.

The increase in HP when the animals were standing caused an increase in RR and HR. The increase in these physiological responses is probably associated with the heat loss (HL) process. Watts et al. (1977) and McLean et al. (1982) showed that when the animals were standing the HP increased, and the body heat storage decreased because the HL was higher than the HP. Conversely, when the animals were Lying, the HP decreased, but the body heat storage increased because the HL was less than the HP. Therefore, the increase in RR when the animals were standing is not only because of the animals easy to do respiration, but also may be a mechanism to increase HL from respiratory passage. On the other hand, there are two possible additional reasons for the decrease in RR when the animals were lying. First, the tidal volume may be increased when the animals were lying, and secondly, it may be due to a temporary increase in conductive heat loss.

It can be concluded that the HP increased with the increase in TDN intake and the elongation of standing time. The change in HP due to the change in feed intake and ST would influence the level of heat loss which was indicated by the changes in the RT, RR and HR.

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