EFFECT OF ENVIRONMENTAL TEMPERATURE AND FEED INTAKE ON PLASMA CONCENTRATION OF THYROID HORMONES IN DAIRY HEIFERS

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Summary

A study was conducted to determine the effect of environmental temperature and level of food intake on plasma concentration of thyroid hormones. Three dairy heifers were used in an experiment which consisted of three levels of chamber temperature (10, 20 and 30℃) and three levels of food intake (100, 75 and 50% of recommended requirements). The analysis showed significant effects of environmental temperature on plasma triiodothyronine concentration, rectal temperature, respiration rate and heart rate but not on heat production. The range of plasma triiodothyronine was 2.51～1.79 ng/ml when the environmental temperature varied from 10 to 30℃. Effects of feed intake level were significant for heart rate and heat production. Heat production decreased from 25.9 to 20.0 $kJ/kg^{0.75} \cdot h$ when the TDN intake decreased from 66.3 to 35.1 $g/kg^{0.75} \cdot d$. There was no interactive effect of environmental temperature and feed intake level. Plasma triiodothyronine concentration decreased under high environmental temperature without any changes in heat production. The effects of environmental temperature and feed intake level on the physiological function of thyroid gland, as indicated by the relative circulating rate of thyroid hormones, were found to be clear.
(**Key Words**: Environmental Temperature, Feed Intake, Circulating Rate of Thyroid Hormones, Heat Production, Dairy Heifer)

Introduction

High environmental temperatures generally reduce feed intake (McDowell et al., 1976; Cavestany et al., 1985; Young, 1987), therefore, animal production is usually lowered under high environmental temperature. This situation could involve lowered heat production because of the lowered feed intake level, and also accompanied by reduced blood concentration of thyroid hormones.

There have been reported two factors which would influence plasma concentration of thyroid hormones in domestic animals, environmental temperature (Magdub et al., 1982; Pratt and Wettemann, 1986; Johnson, 1986) and level of feed intake (Christopherson et al., 1979; Dauncey et al., 1982; Glade et al. 1984; Youket et al., 1985; Pethes et al. 1985; Brendemuhl et al., 1987).

Magdub et al. (1982) and Johnson (1985) suggested that high environmental temperature would reduce the synthesis of thyroid hormones in the gland, and this was supported by declining plasma concentration of thyroid-stimulating hormone (TSH). Furthermore, it has been shown that fasting can alter thyroid hormones function resulting in lowered serum concentration of TSH (Burman et al., 1980).

It is generally accepted that there is no specific substrate to inactivate circulation of thyroid hormones, therefore plasma concentration of thyroid hormones are not changed. This suggests that the physiological effectiveness of thyroid hormones could be estimated not only by the plasma concentration, but also by some aspects of their dynamics (i.e. their relationship with general metabolism).

The level of general metabolism, heat production (HP), depends on the level of feed intake (i.e. Mount, 1979). Consequently, the changes in HP are followed by the changes in the plasma concentration of thyroid hormones. It means that to estimate the relationship between the plasma concentration of thyroid hormones and the level

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of general metabolism, HP should be considered.

The equation. $F = Q \div \triangle O_2$, is usually accepted to calculate the blood flow rate (F) using the measurements of oxygen consumption (Q) and oxygen arteriovenous different ($\triangle O_2$). Assuming changes in $\triangle O_2$ are negligible, then the Q is directly propotional to F: and by the measurements of HP, the level of F will be approximated.

The present study was undertaken to determine the effects of environmental temperature and level of food intake on plasma concentration of thyroid hormones using dairy heifers. We also measured the involvement of HP in the mechanism of decreasing the plasma concentration of thyroid hormones.

Materials and Methods

Experimental design

A 3 × 3 factorial design was used in this experiment. The design consisted of three levels of food intake (50, 75 and 100% of recommended total digestible nutrients (TDN) requirements) and three environmental chamber temperatures (10, 20 and 30℃) with nine replications in each treatment. TDN offered was calculated according to the Japan Feeding Standard (NRC Japan, 1987), where 100% of TDN was defined as the ration which would maintain daily body weight gain of 0.8 kg.

Animals

Three Holstein dairy heifers with an average initial body weight of 195 ± 1.2 kg were used in this experiment. They were kept in individual pens (120 × 190 cm^2) and offered a mixed concentrate pellet at 09:00 h each day. Brachiaria (*Brachiaria sp.*) hay was offered at 09:30 h and 15:00 h, and water was freely available.

The animals were exposed to 10, 20 and 30℃ for 7 day periods. The first 4 days of each period were used for adjustment to the experimental situations and the last 3 days for data collection.

Measurements

Heart rate (HR), respiration rate (RR) and rectal temperature (RT) were measured every day immediately before feeding in the morning.

Blood samples (3 to 5 ml) were collected by jugular vein puncture once each day before the morning feeding. Plasma concentration of total thyroxine (T_4) and total triiodothyronine (T_3) were determined using Enzyme Immuno-Assay kits (Boehringer Mannheim).

Heat production (HP) was measured before the calves were fed and just after the daily blood sampling. Heat production was determined by the head cage method as described previously by Purwanto et al. (1990) for animals standing in their pens. Oxygen concentration of inlet and outlet air from the head cage was measured over 5 to 8 min for each measurement. Heat production was then calculated according to McLean (1972) and the nitrogen calibration factor was determined according to Young et al. (1984).

Measurements of HP have been used to predict the blood flow rate at each environmental temperature. Blood flow rate was expressed using relative value as a ratio of HP on mean value of HP. The relative circulating rate of T_3 and T_4 were obtained by a multiplication of blood flow rate, its relative value, to plasma T_3 and T_4 concentration. In this case, we suggest that increasing blood flow rate will be followed by increasing thyroid hormone's circulation.

Comparisons with mean values of plasma concentration of thyroid hormones and other physiological responses among the treatments were analysed using least significant difference (Steel and Torrie, 1984).

Results

Mean values of environmental temperature and food intake are shown in table 1. The TDN intake per metabolic body size was successfully controlled and the calves gained weight at the expected levels. Mean values of physiological responses and HP measured during days 5 to 7 in each treatment are shown in table 2. There was no interactive effect of environmental temperature and food intake on any parameter.

The mean RT of 39.4 ± 0.5℃ environmental temperature at 30℃ was significantly higher ($p < 0.05$) than at 10 and 20℃, 38.9 ± 0.2 and 38.8 ± 0.2℃, respectively. No difference in rectal temperature was observed among feeding levels at 10 and 20℃, however, a significant difference,

TABLE 1. MEAN VALUES OF ENVIRONMENTAL TEMPERATURE AND ACTUAL TDN INTAKE IN EACH EXPERIMENTAL REGIME

	Temperature regime		
	10℃	20℃	30℃
Actual temperature (%)			
Dry bulb temperature	12.0 ± 1.9	20.5 ± 0.2	30.2 + 0.5
Wet-bulb temperature	10.0 ± 2.1	17.5 ± 0.8	24.2 ± 1.1
Relative humidity (%)	79.0 ± 5.0	75.0 ± 6.0	61.0 ± 5.0
Actual TDN intake ($g/kg^{0.75} \cdot d$)			
100% regime	66.4 ± 0.8	66.5 ± 2.4	64.9 ± 1.8
75% regime	50.8 ± 1.3	50.8 ± 0.3	51.5 ± 1.1
50% regime	35.4 ± 1.4	34.7 ± 1.3	35.2 ± 0.9

Each value indicates the mean ± SD of 7 day measurements.

TABLE 2. MEAN VALUES OF RECTAL TEMPERATURE (RT), RESPIRATION RATE (RR), HEART RATE (HR) AND HEAT PRODUCTION (HP) IN EACH EXPERIMENTAL REGIME

Temperature (℃)	TDN level[1] (%)	RT (℃)	RR (/min)	HR (beats/min)	HP ($kJ/kg^{0.75} \cdot h$)
10	100	$38.9^{2} \pm 0.1^{abc}$	30 ± 9^{a}	73 ± 8^{a}	25.7 ± 2.8^{a}
	75	39.0 ± 0.2^{d}	26 ± 6^{a}	61 ± 3^{b}	$22.7 + 3.2^{b}$
	50	38.7 ± 0.1^{a}	21 ± 12^{a}	53 ± 5^{c}	20.0 ± 2.4^{c}
20	100	38.8 ± 0.3^{a}	42 ± 7^{b}	71 ± 7^{a}	26.2 ± 1.8^{a}
	75	$38.7 + 0.2^{a}$	45 ± 11^{b}	63 ± 4^{bd}	23.2 ± 2.3^{b}
	50	38.8 ± 0.3^{ab}	39 ± 11^{b}	52 ± 2^{c}	20.5 ± 1.6^{c}
30	100	39.7 ± 0.5^{e}	96 ± 16^{c}	76 ± 2^{e}	25.7 ± 1.9^{a}
	75	39.3 ± 0.4^{d}	87 ± 17^{c}	66 ± 6^{d}	22.3 ± 0.9^{b}
	50	39.1 ± 0.4^{cd}	$74 + 24^{d}$	59 ± 5^{b}	19.5 ± 2.7^{c}

[1]For details of TDN level, see materials and method.

[2]Each value indicate the mean of 9 observations using 3 heifers.

[3a,b,c,d,e] Mean within a column with different superscripts differ ($p < 0.05$).

($p < 0.05$), was observed between 75 and 100% TDN intake at 30℃.

The mean RR, 26 ± 9/min at 10℃ significantly increased ($p < 0.05$) with the increase of environmental temperature, attaining 86 ± 21/min at 30℃. No difference was observed among feeding levels at 10 and 20℃, however, significant difference was observed between 50 and 75% TDN intake at 30℃ environmental temperature.

The mean HR, 67 ± 8 beats/min at 30℃ was significantly higher ($p < 0.05$) than at 10 and 20℃, 63 ± 10 and 62 ± 9 beats/min, respectively, and a difference in HR between 10 and 20℃ was not observed. HR significantly increased ($p < 0.05$) with the increased feeding level under each environmental temperature. Thus, the differences of HR between feeding levels in each environmental temperature were observed.

A difference in HP among the environmental temperatures was not observed, however, HP significantly increased ($p < 0.05$) with the increasing feeding level under each environmental temperature. The range of HP was 20.0 ± 2.4~25.9 ± 2.1 $kJ/kg^{0.75} \cdot h$ when the level of TDN intake varied from 50 to 100% of the recommended levels.

Data on plasma concentration of thyroid hormones are shown in figure 1 and 2. Plasma concentration of triiodothyronine (T_3) significantly decreased ($p < 0.05$) with the increase of environmental temperature. Thus, the range of T_3 was $2.51 \pm 0.51 \sim 1.79 \pm 0.46$ ng/ml when the environmental temperature varied from 10 to 30℃. The changes in plasma concentration of T_3 with increasing TDN intake were not significant. Also no statistical difference was observed in plasma concentration of thyroxine (T_4) among the treatments. Although there was a tendency for decrease of concentration with the increase of environmental temperature there was a high error

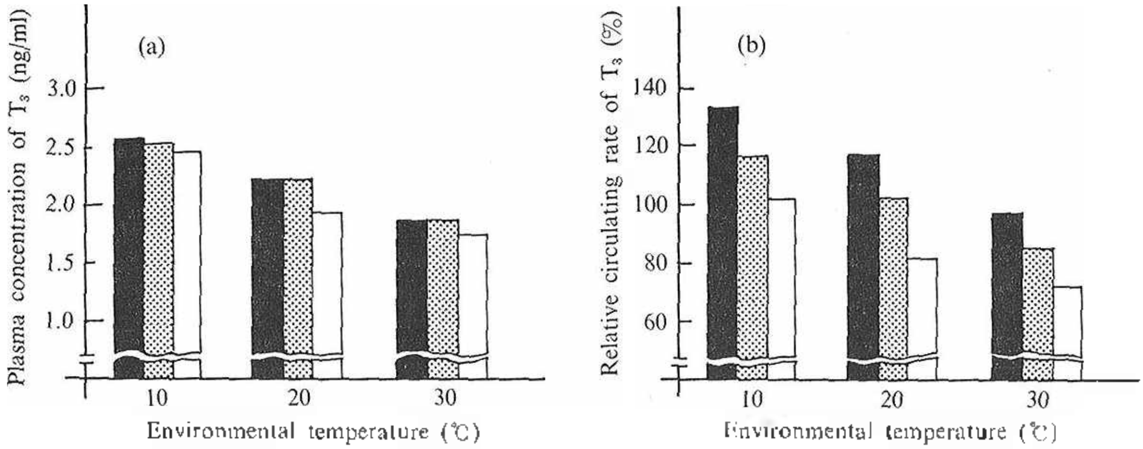

Figure 1. Effect of TDN intake (■ : 100%, ▒ : 75% and □ : 50%) on the (a) plasma concentration of T_3 and (b) relative circulating rate of T_3 in each environmental temperature. A 100% of relative circulating rate was calculated as a mean value of a multiplication between relative heat production and plasma T_3 concentration. Each value indicate the mean of 9 observations using 3 heifers.

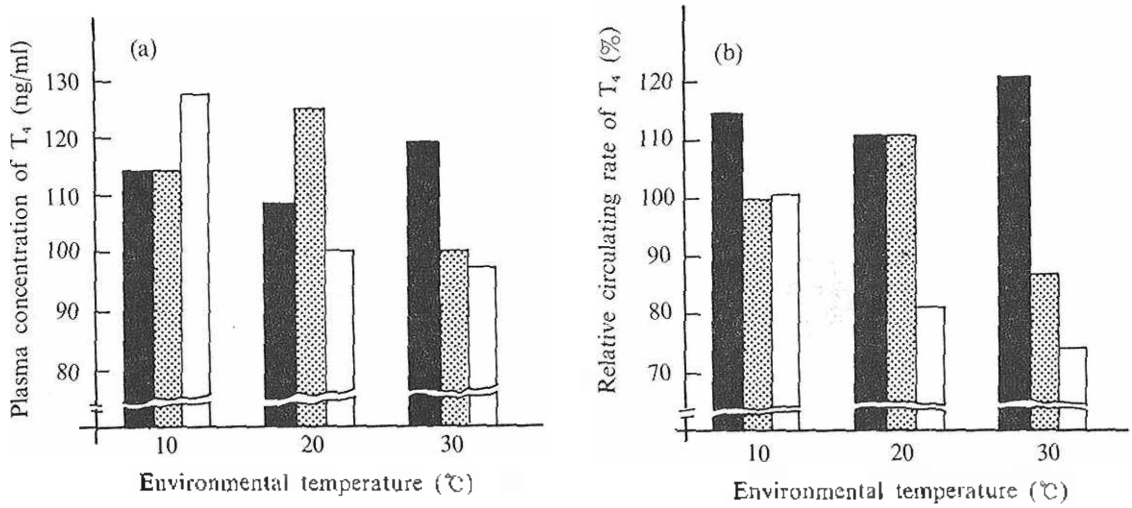

Figure 2. Effect of TDN intake (■ : 100%, ▒ : 75% and □ : 50%) on the (a) plasma concentration of T_4 and (b) relative circulating rate of T_4 in each environmental temperature. A 100% of relative circulating rate was calculated as a mean value of a multiplication between relative heat production and plasma T_4 concentration. Each value indicate the mean of 9 observations using 3 heifers.

variance and the observed trends were not statistically significant.

The relative circulating rate of T_3 and T_4 are shown in figure 1 and 2. The circulating rate of T_3 increased 15% ($p < 0.05$) when the feeding level increased 25% and decreased 17% ($p < 0.05$) when environmental temperature increased 10℃. However, the circulating rate of T_4 increased with the increased feeding level.

Discussion

Effect of environmental temperature on physiological responses and plasma concentration of thyroid hormones

RT was elevated only at the 30℃ environmental temperature, particularly when the animals were at the highest feeding level. This was also reflected in the RR. HR increased at the 30℃ environmental temperature compared with other temperature regimes. However, HP was not affected by the temperature regimes.

An increase in HR, RR and RT could be expected in the chain of physiological adjustments under high environmental temperature. With an increase in body temperature cutaneous vessels dilate, and the increase of HR would help maintain blood pressure. These effects of high environmental temperature was clearly observed in the present study.

Plasma concentration of T_3 decreased with no accompanying changes in HP when the environmental temperature was increased. A similar decrease of plasma concentration of T_3 was observed with increase ambient temperature by Magdub et al. (1982), Mohammed and Johnson (1985), Pratt and Wettemenn (1986) and Johnson (1986), but these authors did not report any HP values.

Effect of feeding level on physiological responses and plasma concentration of thyroid hormones

Significant effect of level of feed intake on HP and HP ($p < 0.01$) were observed. The effect of feeding level on general body metabolism was clearly evident and is in agreement with previous reports (Shibata and Mukai, 1977; Mount, 1979; Lobley et. al., 1987).

HR significantly decreased from $25.9 \pm 2.1 \sim 20.0 \pm 2.4$ $kJ/kg^{0.75} \cdot h$ when the level of feed intake was reduced from 100 to 50% in the present experiment. However, this significant decrease of HP was not reflected in the plasma concentration of T_3. Parallel published data on HP and blood concentration of T_3 on restricted feed cattle are not so available.

Christopherson et al. (1979) observed plasma concentration of thyroid hormones under several level of feed intake above maintenance in beef cattle, and showed no difference in the plasma concentration of T_3. Pethes et al. (1985) studied serum concentration of T_3 and T_4 in the cows fed 100% and 115 ~ 121% of NRC feeding standard at 20 and 14 days before, during and 4 and 28 days after the calving. These authors found a decrease of 8% in thyroid level 14 days before calving in the all groups.

Plasma concentration of T_3 decreased with not chages in HP when environmental temperature was increased. However, when the feed intake was decreased, significant decreases in HP were observed with no chages in T_3 concentration. It was supposed that a decrease of concentration of plasma thyroid hormones, as an indicator of food intake causing a decrease in HP. Considering the general relationship between the plasma level of T_3 and the level of general metabolism, the observed response in HP is important. This suggests that the physiological effectiveness of thyroid hormones can not be accounted for only by the level of plasma concentration, but probably also by some aspect of thyroid dynamics, e.g. circulating rate.

The increasing of relative circulating rate of T_3 and T_4, in the present study, with the increasing feed intake may be associated with the increasing in the oxygen consumption by tissue.

In conclusion, plasma concentration of T_3 is decreased by high environmental temperature. The decreases in plasma concentration of T_3 were not accompanied by any changes in HP under high environmental temperature. In this respect, the general relationship between plasma concentration of T_3 and HP was not confirmed. However, it was suggested that the level of relative circulating rate of T_3 might reflect the effect of both factors on the physiological function of thyroid gland.

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