Metabolic Heat Production and Rectal Temperature of Newborn Calves

C. M. Mundia and S. Yamamoto
Department of Animal Science, Hiroshima University, Higashi-hiroshima 739, Japan

ABSTRACT: Rectal temperature (Tr), skin surface temperatures (Ts), and heart rate (HR) were measured continuously from birth (day 1) till day 7, while resting heat production (HP) was measured in a chamber on days 1, 3, 5 and 7, in order to study the characteristic variation of Tr in newborn calves by heat balance methods. Despite constant levels of milk being given to the newborn calves each day, daily mean resting HP was lowest on the day of birth, then increased to peak on day 3 and then decreased slightly thereafter. Daily mean HR was higher on days 2, 3 and 4, than on other days. Tr exhibited diurnal rhythms and daily mean Tr was low on day 1, high on day 3, and then decreased slightly after day 3. Daily average mean skin temperature (mTs) was similar on all days. Mean body temperature (Tb) exhibited diurnal rhythms and had a similar range between days, suggesting that heat balance and thermoregulation were carried out effectively on each day. The variation of Tb appeared to be synchronized with that of HP and suggested that newborn calves might use variations in the levels of Tb to facilitate the body's required levels of heat loss.
(**Key Words:** Newborn Calf, Thermoregulation, Heat Production, Heat Balance, Mean Body Temperature)

INTRODUCTION

The change from intra-uterine to extra-uterine life is perhaps the most dramatic and challenging physiological event that mammals experience. Several major metabolic alterations occurred in the neonate due to abrupt changes in the source and supply of nutrients (Chand et al., 1981). Soon after birth, the need for energy to support thermoregulation, respiration and musclar activity is increased.

The Tr of newborn calves had been reported to be low soon after birth and increased to peak on the third day, then reduced thereafter (Thompson and Clough, 1970), while the basal metabolism of the calf rose after birth to peak between the second and fourth days of life, and fell quickly during the next 8 days (Roy et al., 1957; Gonzalez-Jimenez and Blaxter, 1962). However, the nature of the characteristic alteration in Tr and the relationship between HP and Tr during this 'neonatal adjustment period' (Chand et al., 1981), has not been investigated.

In this investigation, thermoregulation in newborn calves was studied by heat balance methods.

MATERIALS AND METHODS

Animals

Two Holstein and one Holstein × Japanese Black F_1 cross-bred newborn calves weighing 48.0, 48.5 and 40.0 kg respectively were used in the study. The range of ambient temperature (DBT) for the calves was 19 to 33℃. The calves were bucket fed 2-2.5 kg (10% of body weight) colostrum from their dam, pre-heated to 39-40℃, twice daily at 09:00 and 16:00 h. The calves were successively subjected to the experiment.

Measurements

Shortly after birth, the calves were taken to a chamber (95 × 147 × 120 cm, vol. about 1.68 m^3), cleaned of fetal fluids with a towel and fitted with a portable data logger (T.K.K. 1850a, Takei Instruments, Tokyo, Japan) to measure heart rate continuously at 1 min intervals. A thermocouple encased in a plastic tube was inserted 10 cm into the rectum to measure Tr. Ts was measured after Nakamasu et al., (1993) at four sites {upper shoulder (a), lower shoulder (b), upper leg (c), lower leg (d)}, Tr, Ts, and ambient temperature were measured by thermocouples, all measurements of which were at 5 min intervals by data logger (TR 2723, Advantest, Tokyo, Japan), continuously for 7 days. mTs and Tb were calculated according to Nakamasu et al., (1993) and McLean et al., (1983) respectively as follows;

$$mTs = 0.25\,(a + b) + 0.32c + 0.18d$$

$$Tb = 0.14mTs + 0.86Tr$$

Resting HP was measured on alternate days (day 1, 3,

Address reprint requests to S. Yamamoto.
Received to July 30, 1996; Accepted November 11, 1996

5 and 7). Measurements and calculations of HP were done as described previously (Purwanto et al., 1990) at 3 h intervals by shutting the door of the chamber for 30 min at 10, 13, 16, 19, 22, 01, 04, and 07 h, with the volume of air drawn through the chamber at a rate of about 60 l/min. Measurements of HP were only carried out while the calf was calm and in lying position. If the calf happened to stand up during the 30 minute measurement period, that measurement was abandoned and carried out as soon as possible after the calf lay down. On other days (days 2, 4, and 6), the calf was kept in a pen next to the chamber, and except for HP, all other measurements continued.

Statistical analysis

Mean values of HP, Tr, Tb, mTs and HR at three hourly intervals for each calf were obtained and averaged. The data of the calves were analyzed by SAS (1985) for differences between days. The results are expressed as means and standard error.

RESULTS

The calves remained healthy and consumed all their milk on each day. Mean resting HP, Tr, mTs, Tb and HR of the calves are shown in figures 1 and 2. The levels of resting HP varied with days during the measurement period, and on each day exhibited a rhythm with a maximum and a minimum (figure 1). Daily mean resting HP was significantly ($p < 0.05$) lower on day 1 and 7, and higher on day 3 and 5 (table 1). Tr exhibited a diurnal rhythm with a maximum and minimum on each day (figure 1), and daily mean Tr was lower on day 1, and significantly ($p < 0.05$) highest on day 3 (table 1).

mTs had a greater range of variation than Tr (figure 1), but was similar among the days (table 1). The response of Tb was similar to that of Tr, exhibiting a diurnal rhythm with a maximum and minimum on each day (figure 2) and daily mean Tb was significantly ($p < 0.05$) low on day 1 and highest on day 3, then reduced slightly thereafter (table 1). HR was more variable than other parameters and appeared to have a daily maximum and minimum (figure 2). The maximum values in thermoregulatory responses of Tr or Tb, mTs, HR and resting HP occurred at 16:00 h while the minimum values were in the early hours of the morning before feeding. Daily mean HR was higher on days 2, 3 and 4, compared to other days (table 1). The differences between the daily maximum Tb for calves A, B and C are shown in table 2. As may be observed, there were no significant differences among calves and the mean values between days are similar (table 2).

Table 1. Daily mean resting heat production (HP), rectal temperature (Tr), mean skin temperature (mTs), mean body temperature (Tb) and heart rate (HR) of the calves from the day of birth (day 1) to day 7. (The mean values of 3 calves (n = 3) and the results are expressed as means and standard error)

	Days of age							SE
	1	2	3	4	5	6	7	
HP (kJ/kg$^{0.75}$h)	20.3^{a}		27.5^{c}		25.7^{bc}		22.6^{ab}	0.98
Tr (℃)	38.9^{a}	39.2^{ab}	39.7^{c}	39.3^{b}	39.2^{ab}	39.2^{ab}	39.0^{ab}	0.09
mTs (℃)	34.6^{a}	35.1^{a}	35.3^{a}	35.2^{a}	35.0^{a}	35.3^{a}	35.1^{a}	0.29
Tb (℃)	38.3^{a}	38.6^{ab}	39.1^{c}	38.7^{b}	38.6^{ab}	38.6^{ab}	38.5^{ab}	0.11
HR (/min.)	115^{b}	124^{b}	126^{b}	125^{b}	115^{b}	116^{b}	99^{a}	3.59

^{abc}Values in the same row with different letters are significantly different ($p < 0.05$) from each other.

Table 2. Difference between the daily maximum and minimum mean body temperature (Tb) for calves A, B, C from day 1 to 7

		Days of age							Mean	SE
		1	2	3	4	5	6	7		
Calf	A	2.21	1.35	0.99	0.93	1.14	0.76	1.14	1.22^{a}	0.18
	B	1.39	0.64	1.56	1.36	1.31	1.46	1.36	1.30^{a}	0.11
	C	0.87	1.24	1.24	1.06	1.27	1.23	1.46	1.20^{a}	0.07
Mean		1.49	1.08	1.26	1.12	1.24	1.15	1.32	1.24	0.05

^{a}Values in the same column with similar superscripts are similar.

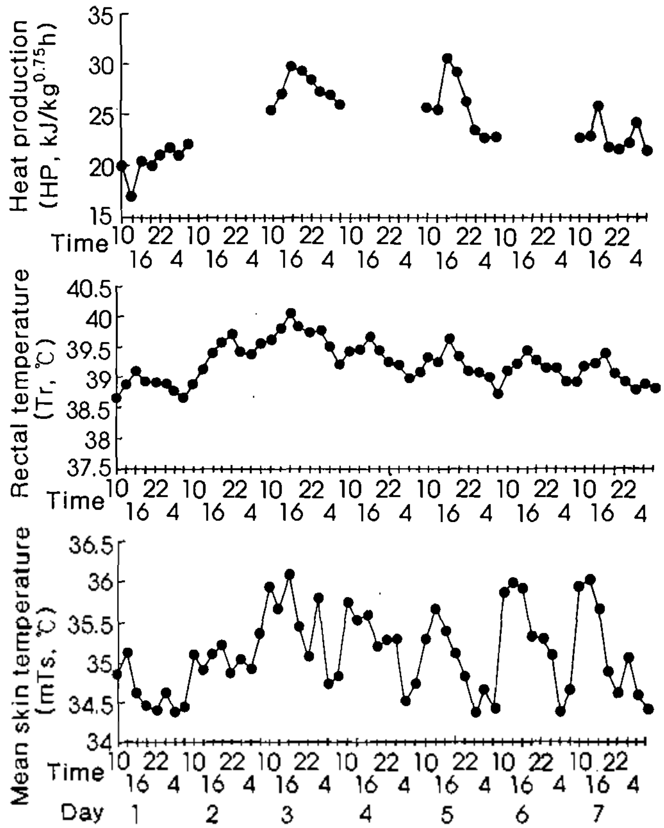

Figure 1. The average resting heat production (HP), rectal temperature (Tr) and mean skin temperature (mTs) of the calves at 3 hour intervals. Milk was given twice daily at 09:00 and 16:00 h.

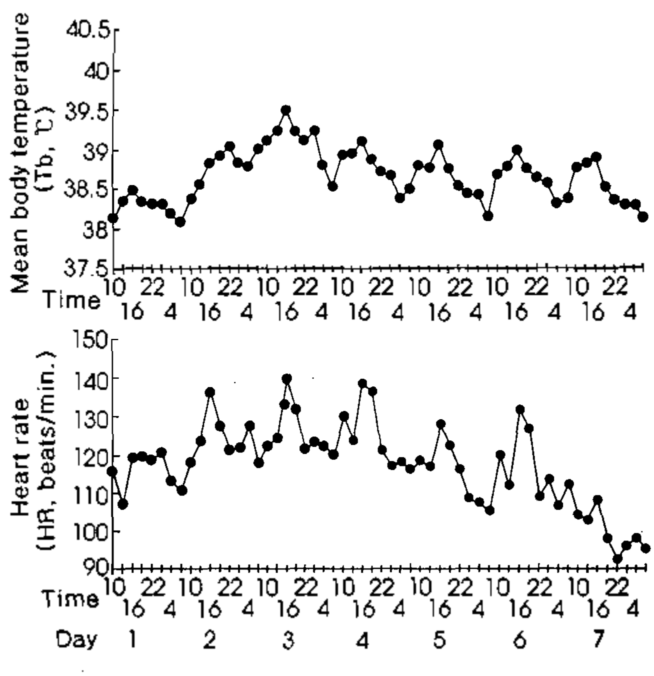

Figure 2. The mean body temperature (Tb) and heart rate (HR) of the calves at 3 hour intervals. Milk was given twice daily at 09:00 and 16:00 h.

DISCUSSION

Metabolic adjustments occuring in response to the transition from an intrauterine to an extrauterine environment were known to exist (Stanko et al., 1991) and calves that were 1 day old maintained normal body temperatures in either cold (5℃) or warm (25℃) environmental treatments (Stanko et al., 1992).

A diurnal variation in environmental temperature, with lowest temperatures early in the morning and highest temperatures in the afternoon, was observed. The daily variation of Tb or Tr, mTs, HR and HP appeared to be synchronized with that of environmental temperature. However, the level of responses, especially Tr, Tb, HP and HR were low on day 1, high on day 3 then low again on day 7. In contrast to this, the range of variation of environmental temperature was similar from day 1 to 7. Therefore, the range of the diurnal variation of Tr, Tb, HR and HP occurred independent of the range of variation of environmental temperature.

In the present study, a deliberate effort to keep metabolism at similar levels was made by providing a constant amount of milk daily, and carrying out measurements of HP only when the calf was calm and lying recumbent. Despite this, the daily average HP of newborn, colostrum-fed calves varied with days of age, and was low on day 1 and 7, and high on day 3 to 5. This agreed with previous reports (Roy et al., 1957; Gonzalez-Jimenez and Blaxter, 1962) and the HP values of the newborn calves in the present study are similar to previously reported values for dairy calves (Okamoto et al., 1986; Robinson and Young, 1988; Roy et al., 1957). The low HP on day 1 may be related to the low metabolic rate of the body due to inadequate metabolism of milk. It appeared that the elevated HP on day related to the development of digestive function and a proliferation of micro-organisms in the digestive tract of the calves. The dry matter content is considerably higher in colostrum, primarily due to the great increase in whey proteins namely albumins and globulins (Jacobson, 1970), and although the higher energy content of colostrum than of milk may be necessary to cover the high energy requirement of the calf over the first few days of life (Roy et al., 1957), the increased HP was probably not directly related to feed intake levels as the amount of milk given was kept constant. This is in agreement with earlier observations (Okamoto et al., 1986), where the feeding of colostrum 30 min prior to cold exposure was not beneficial in improving the apparent resistance of calves to hypothermia. Diurnal rhythms in HP are known to exist (Aschoff et al., 1970), and in this study similar variations in HP were observed.

The fall in Tr immediately after birth was probably due in part, to a fall in metabolic rate which occurred in the adjustment period when insufficient oxygen was available to support the aerobic metabolism of thermogenesis, (Chand et al., 1981) and in part due to high evaporative heat loss, (Thompson and Clough, 1970; Chand et al., 1981; Vernorel et al., 1989). In this study, Tr exhibited a daily maximum and minimum and daily mean Tr was low on the day of birth, but rose to peak on day 3, then decreased thereafter. This indicated the existence of a diurnal rhythm in Tr and that the level of Tr may vary with days of age.

Daily mean HR was found to be statistically similar on days 1 to 6 and did not show a close relationship with HP during this period. Similar results were obtained by Roy et al. (1957) and this could mean that the process of adjusting to the new environment was not complete during this neonatal period.

Although daily mean Tb was low on day 1, and highest on day 3, all the calves exhibited similar daily ranges of Tb from days 1 to 7. This suggested that thermoregulation and heat balance were carried out effectively on each day and in all calves. The variation of Tb appeared to be synchronized with that of HP and suggested that newborn calves may use variations in the levels of Tb to facilitate the body's required levels of heat loss.

REFERENCES

Aschoff, J. 1970. Circadian rhythm of activity and body temperature. In: Hardy, J. D. Gagge, A. P. and Stolwijk, J. A. (Editors) Physiological and behavioural temperature regulation Springfield: Charles C. Thomas. pp. 905-919.

Chand, D., G. C. Georgie., M. L. Madan and M. N. Razdan. 1981. Neonate physiological adjustments in winter and summer crossbred calves. Indian J. Dairy Sci. 34:2-10.

Gonzalez-Jimenez, E. and K. L. Blaxter. 1962. The metabolism and thermal regulation of calves in the first month of life. Brit. J. Nutr. 16:199-212.

Jacobson, N. L. 1970. The mammary gland and lactation. In:Swenson, M. J. (Editor) Duckes' physiology of Domestic Animals. 8 th Edition. Cornell University Press: London. pp. 1356-1382.

McLean, J. A., A. J. Dowine., C. D. R. Jones, D. P. Stombaugh and C. A. Glasbey. 1983. Thermal adjustments of steers (*Bos taurus*) to abrupt changes in environmental temperature. J. Agric. Sci., Camb. 100:305-314.

Nakamasu, F., B. P. Purwanto and S. Yamamoto. 1993. Effect of environmental temperature and heat production on mean body temperature in heifers. Anim. Sci. Technol. (Jpn.). 64:629-636.

Okamoto, M., J. B. Robinson., R. J. Christopherson and B. A. Young. 1986. Summit metabolism of newborn calves with and without colostrum feeding. Can J. Anim. Sci. 66:937-944.

Purwanto, B. P., Y. Abo, R. Sakamoto, F. Furumoto and S. Yamamoto. 1990. Diurnal patterns of heat production and heart rate under thermoneutral conditions in Holstein Fresian cows differing in milk production, J. Agric Sc. Camb. 114:139-143.

Robinson, J. B. and B. A. Young. 1988. Metabolic heat production of neonatal calves during hypothermia and recovery. J. Anim. Sci. 66:2538-2544.

Roy, J. H. B., C. E. Huffman and E. P. Reineke. 1957. The basal metabolism of the newborn calf. Brit. J. Nutr. 11:373-381.

SAS Institute. 1985. SAS User's Guide 5 th ed. (Cary, NC. SAS Institute, Inc).

Stanko, R. L., M. J. Guthrie, C. C. Chase and R. D. Randel. 1992. Effects of exogenous glucose or colostrum on body temperature, plasma glucose, and serum insulin in coldstressed, newborn Brahman calves. J. Anim. Sci. 70:3007-3013.

Stanko, R. L., M. J. Guthrie and R. D. Randel. 1991. Response to environmental temperatures in Brahman calves during the first compared to the second day after birth. J. Anim. Sci. 69:4419-4427.

Thompson, G. E. and D. P. Clough. 1970. Temperature regulation in the new-born ox. (*Bos taurus*). Biol. Neonate. 15:19-25.

Vermorel. M., J. Vernet, C. Dardillat, C. Siado, C. Demigne and Marie-Jeanne Davicco. 1989. Energy metabolism and thermoregulation in the newborn calf; effect of calving conditions. Can. J. Anim. Sci. 69:113-122.