Effect of Heat Stress on Minerals Concentration in Blood and Colostrum of Heifers Around Parturition

T. Toharmat[1] and S. Kume
Department of Animal Nutrition, National Institute of Animal Industry, Tsukuba 305, Japan

ABSTRACTS: Sixteen Holstein heifers were employed to study the effect of thermal stress on rectal temperature and mineral status of heifers around parturition during hot and cool weather. During the hot weather, rectal temperatures of the heifers measured at 08:30 and 15:30 h from 7 d prepartum to parturition were higher than those during the cool weather. Blood hematocrit and hemoglobin were not significantly different between the hot and cool weather, but at 2 and 1 wk prepartum, those during the hot weather were higher. Plasma Ca, inorganic P and Fe of the heifers during the hot weather were higher than those during the cool weather, but plasma Mg and Zn and serum alkaline phosphatase during the hot weather were lower. Colostral protein and Mg of heifers at parturition during the hot weather were lower than those during the cool weather, but colostral Ca, P, Fe and Zn were not affected by the weather.

(Key Words: Hot Weather, Cool Weather, Mineral, Heifers)

INTRODUCTION

Parity of dams is a factor responsible for the changes in the mineral status of cows and their newborn calves. Concentrations of plasma Ca, inorganic P, and Zn of dairy cows decreased around parturition because of their large transfer to colostrum, and older cows had a greather risk of developing milk fever (Kume and Tanabe, 1993). The shift of plasma Fe to blood Hb was accelerated in heifers due to the high Fe demand for growth, because blood hematocrit (Hct) and hemoglobin (Hb) in heifers were higher than those in mature cows (Kume, 1996). Kume and Tanabe (1993, 1994 and 1996) reported that calves born from primiparous cows developed low blood Hct and Hb at 1 d of age.

Environmental effects on the health status of cattle involved the complex interaction between environmental and cattle factors (Collier et al., 1982). Heat stress in summer reduced feed intake and milk yield of dairy cows and altered mineral needs in ruminants (Beede and Collier, 1986; Collier et al., 1982; Kume, 1991; Sanchez et al., 1994). Blood Hct and Hb of cows decreased under the hot environment, and the depression of blood Hct and Hb was related to the reduction in cellular oxygen resquirements to compensate for elevated environmental heat load (Shaffer et al., 1981). Blood Hct and Hb of the periparturient multiparous cows showed greater levels and their rectal temperatures were higher during the hot weather compared to the cool weather (Kume, 1996; Toharmat and Kume, 1996). However, it was not clear whether heat stress adversely affected mineral status and thermoregulation of periparturient heifers.

The objective of this study was to clarify the effect of thermal stress on thermoregulation and mineral status of Holstein heifers around parturition during hot and cool weather.

MATERIALS AND METHODS

Data from 16 Holstein heifers were collected at National Institute of Animal Industry (Tsukuba, Japan) during hot and cool weather from June 1995 to March 1996. Eight heifers which calved from June 6 to August 22 were termed as the hot group; 8 heifers which calved from November 16 to March 20 were termed as the cool group. The heifers were managed in individual tie stalls and in a paddock during the periparturient period. The heifers were fed 3 to 4 kg/d of concentrate and appropriate amounts of Italian ryegrass silage (table 1) in individual tie stalls to meet recommendations (AFFRCS, 1994) for TDN, protein and minerals before parturition.

Blood was sampled at 08:30 h at 2 wk, 1 wk and 2 d before expected calving date, assuming that the gestation length to be 280 d, and at parturition and 1 and 6 d after parturition. At parturition, blood samples were taken

[1] Faculty of Agriculture, Tokyo University of Agriculture, Setagaya-ku, Tokyo 156, Japan.
Address reprint requests to S. Kume.
Received August 22, 1996; Accepted November 20, 1996

within 12 h after birth. blood was collected via jugular vein puncture into heparinized and unheparinized vacuum tubes. Samples of colostrum were collected at parturition and 96 h after parturition. Blood and colostrum compositions were determined as previously described (Kume and Tanabe, 1993 and 1996; Toharmat and Kume, 1996).

Table 1. Chemical composition of feedstuff during hot and cool weather

	Hot		Cool	
	Concen-trate	Italian ryegrass silage	Concen-trate	Italian ryegrass silage
	.... (%)			
DM	86.9	40.9	88.1	41.6
CP	16.7	12.6	16.6	13.0
NDF	16.0	63.4	17.1	62.9
ADF	9.3	40.0	10.0	39.0
Ca	0.81	0.49	0.82	0.45
P	0.62	0.28	0.61	0.34
Mg	0.29	0.22	0.30	0.32
	.... (ppm)			
Fe	250	1,819	156	1,038
Zn	82.3	30.3	83.8	27.2

[1]All values expressed on a DM basis except for DM.

Daily temperature and relative humidity were recorded at the Division of Agrometeorology, National Institute of Agro-environmental Sciences (Tsukuba, Japan), which was located approximately 1 km from the experimental barn. Rectal temperature was measured by a clinical thermometer and recorded daily at 08:30 and 15:30 h from 7 d before expected calving date until parturition.

The general linear models procedure of SAS (SAS, 1988) was used to analyze the effect of weather on gestation length, calf birth weight, colostrum yield, and colostrum composition.

Data of rectal temperature and blood components were analyzed by least squares ANOVA using the general linear models procedure of SAS (SAS, 1988), and the differences were tested by least significant difference. Significance was declared at $p < 0.05$ unless otherwise noted.

RESULTS AND DISCUSSION

The upper critical temperature for dry and pregnant cows has been defined as 25℃ and relative humidity higher than 80% indirectly affected the upper critical temperature (Collier et al., 1982; NRC, 1981). Significant changes in various physiological processes of cows will not usually occur within the range of 5 to 25℃ (Collier et al., 1982). The mean temperature and relative humidity in August were above 25℃ and 80%, and those in July were relatively high. The monthly mean temperatures during the cool weather ranged from 2.8 to 9.1℃ and those from December to February were slightly lower than 5℃ (table 2).

Table 2. Monthly temperatures and relative humidities during hot and cool weather

	Hot			Cool				
	Jun.	Jul.	Aug.	Nov.	Dec.	Jan.	Feb.	Mar.
Maximum temperature (℃)	22.5	28.7	32.9	15.8	10.9	9.2	8.6	12.2
Mean temperature (℃)	18.8	24.5	27.2	9.1	4.0	3.3	2.8	7.0
Minimum temperature (℃)	16.1	21.4	23.2	2.7	−2.1	−2.4	−2.3	2.2
Mean relative humidity (%)	89.0	89.4	82.9	69.5	59.2	61.7	65.0	66.2
Minimum relative humidity (%)	74.1	74.4	59.6	41.6	31.5	38.3	38.3	40.2

Body weight of the heifers during the hot weather tended to be lower ($p < 0.10$) than that of the heifers during the cool weather, but birth weight of their calves was not significantly different between the weather groups. Rectal temperatures at 08:30 h ($p < 0.01$) and 15:30 h ($p < 0.01$) from 7 d perpartum to parturition in the heifers during the hot weather were higher than those of heifers during the cool weather (figure 1.) The result agreed with the previous experiments (Kume, 1996), which had showed that rectal temperatures of periparturient multiparous cows and heifers were higher during the hot weather than those during the cool weather.

For periparturient cows, prediction of parturition time was important to prevent the dystocia, and rectal temperatures were often utilized for estimating the onset of parturition (Fujimoto et al., 1988; Kume, 1996;

Toharmat and Kume, 1996). Rectal temperature below 39℃ or the depression of the rectal temperature by 0.5℃ in the evening within 2 d before parturition were useful for the prediction of parturition time (Fujimoto et al., 1988). The rectal temperatures of cows fed at maintenance level of TDN in both hot and cool weather were not suitable for the prediction of parturition time, although the rectal temperatures during hot weather were higher than those during cool weather (Kume, 1996). In the present experiment, the rectal temperatures of the heifers during hot weather may not be available for the perdiction of parturition time, because the declines in rectal temperature at 15:30 h during 2 d prepartum were 0.3 and 0.8℃, respectively during the hot and cool weather. These results suggested that thermoregulation of periparturient heifers might be adversely affected by the heat stress, although similar feed was offered to the heifers throughout the experimental period.

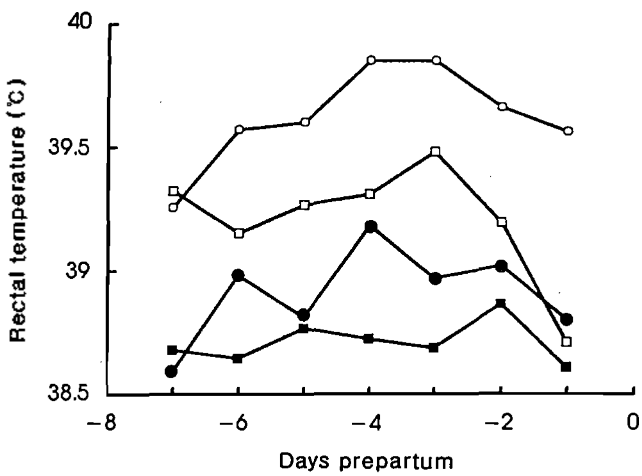

Figure 1. Rectal temperature of heifers at 08:30 h (●) and 15:30 h (○) during hot weather, and rectal temperature of heifers at 08:30 h (■) and 15:30 h (□) during cool weather.

Blood Hct and Hb were not significantly different between the weather groups (table 3), but blood Hct and Hb at 2 wk and 1 wk perpartum during the hot weather were higher than those during the cool weather (figures 2 and 3). Plasma Fe was significantly higher during the hot weather than that during the cool weather.

Shaffer et al. (1981) reported that blood Hct and Hb of cows decreased under the hot weather to compensate for elevated environmental heat load. However, blood Hct and Hb as well as rectal temperature of periparturient multiparous cows were higher during hot weather than those during cool weather (Kume, 1996). Thus, the higher rectal temperatures of periparturient cows and heifers in a hot environment may be partly due to the imbalance of erythropoiesis.

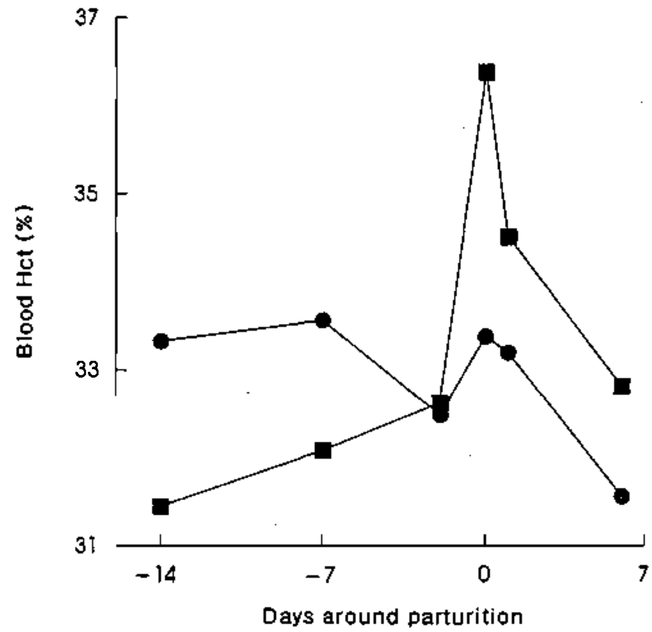

Figure 2. Blood hematocrit (Hct) of heifers calving during hot weather (●) and heifers calving during cool weather (■).

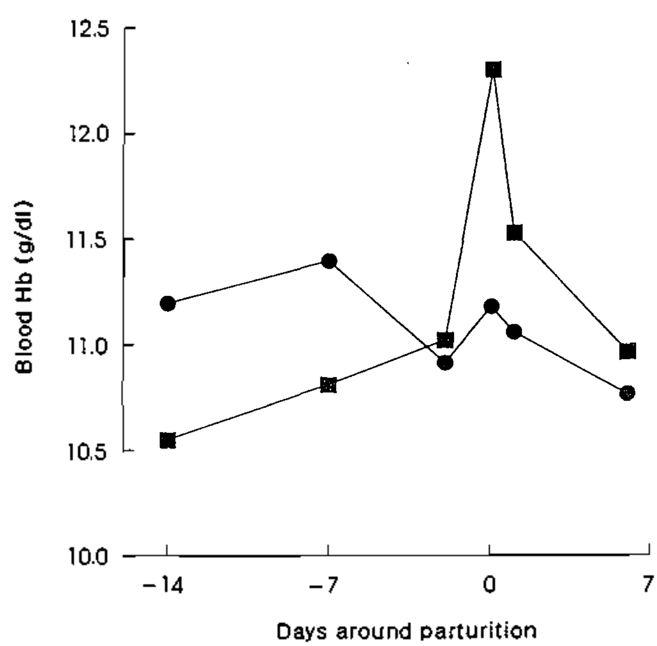

Figure 3. Blood hemoglobin (Hb) of heifers calving during hot weather (●) and heifers calving during cool weather (■).

Table 3. Least squares means of age, gestation length, body weight (BW), blood hematocrit (Hct) and hemoglobin (Hb), plasma mineral, and serum alkaline phosphatase (AP) concentrations in heifers calving during hot and cool weather

	Hot	Cool	SEM
n	8	8	
Age[1] (mo)	28.5	27.6	0.9
Gestation length (d)	279	281	2
Calf BW[1] (kg)	39.5	37.6	1.5
BW[1] (kg)	487[b]	518[a]	11
Blood Hct[2] (%)	32.9	33.3	0.2
Blood Hb[2] (g/dl)	11.1	11.2	0.1
Plasma[2]			
Ca (mg/dl)	9.8[e]	9.6[f]	0.1
P_i (mg/dl)	5.6[e]	5.0[f]	0.1
Mg (mg/dl)	1.95[f]	2.20[e]	0.02
Fe (ppm)	1.20[c]	1.05[d]	0.05
Zn (ppm)	0.71[d]	0.76[c]	0.02
Serum[2]			
AP (IU)	43.5[f]	56.1[e]	1.4

[a,b] Means within same row with different superscript are significant at $p < 0.10$.
[c,d] Means within same row with different superscript are significant at $p < 0.05$.
[e,f] Means within same row with different superscript are significant at $p < 0.001$.
[1] At parturition.
[2] Means from 2 wk prepartum to 6 d postpartum.

The hot group heifers around parturition showed higher level of plasma Ca ($p < 0.001$) and P ($p < 0.001$) than those of the cool group ones, but lower level of plasma Mg ($p < 0.001$), Zn ($p < 0.05$) and serum alkaline phosphatase ($p < 0.001$) (figures 4 to 9). Colostral specific gravity, protein and Mg of heifers at parturition were lower during the hot weather than those during the cool weather (table 4), but there was no significant difference in colostral Ca, P, Fe and Zn between the hot and cool weather.

Kume (1996) reported that plasma Ca, Mg, and alkaline phosphatase of periparturient cows and heifers decreased during hot weather, but high plasma Ca, P_i, and alkaline phosphatase were observed in heifers. Heat stress in a hot environment also reduced Ca, P and Mg concentration in milk and serum of lactating cows (Kume, 1996). These results indicated that the adaptation for bone to meet Ca and P needs in heifers is active during gestation, and heat stress might have adversely altered Ca, P and Mg metabolism in periparturient and lactating cows. However, in the present study, plasma Ca and P_i of the periparturient heifers increased during hot weather, although plasma Mg, Zn, and serum alkaline phosphatase decreased. Zinc and alkaline phosphatase, an enzyme that contains Zn, can effectively stimulate bone growth and mineralization (Yamaguchi and Matsui, 1989). Thus, heat stress might adversely affect Mg and Zn metabolism in

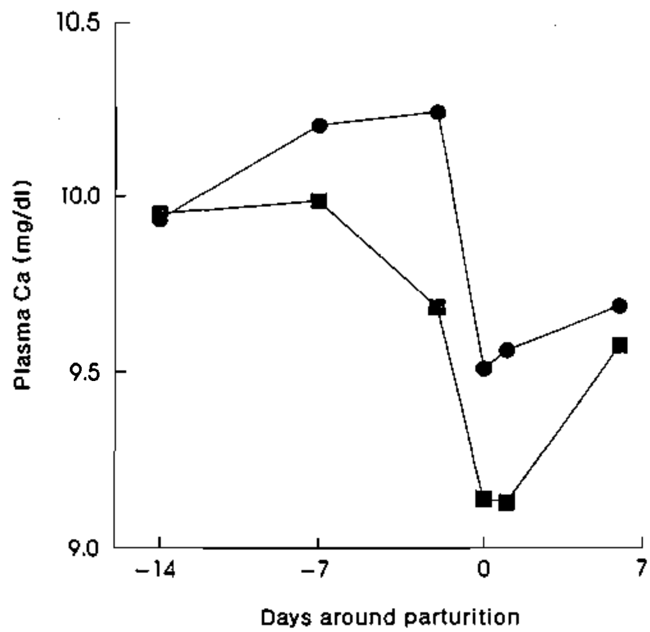

Figure 4. Plasma Ca of heifers calving during hot weather (●) and heifers calving during cool weather (■).

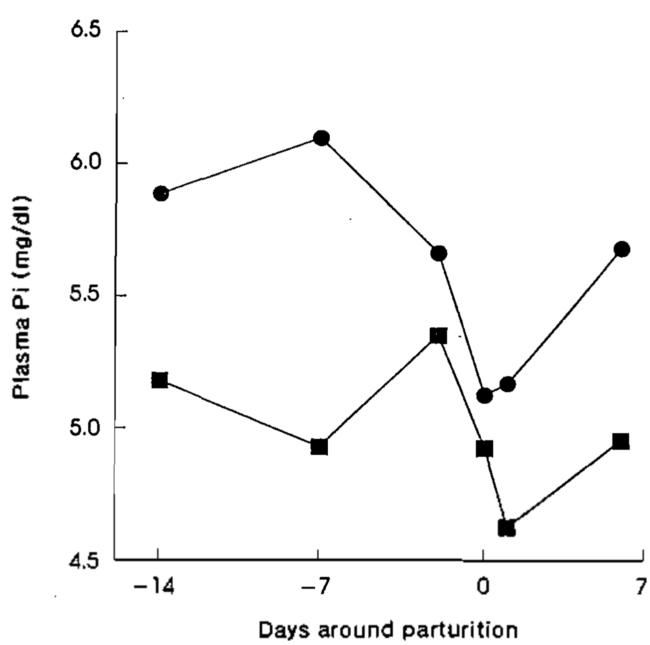

Figure 5. Plasma inorganic phosphorus (P_i) of heifers calving during hot weather (●) and heifers calving during cool weather (■).

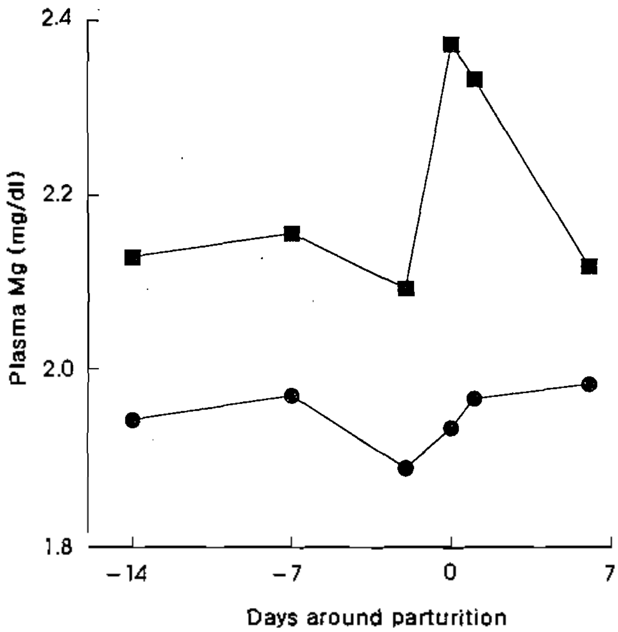

Figure 6. Plasma Mg of heifers calving during hot weather (●) and heifers calving during cool weather (■).

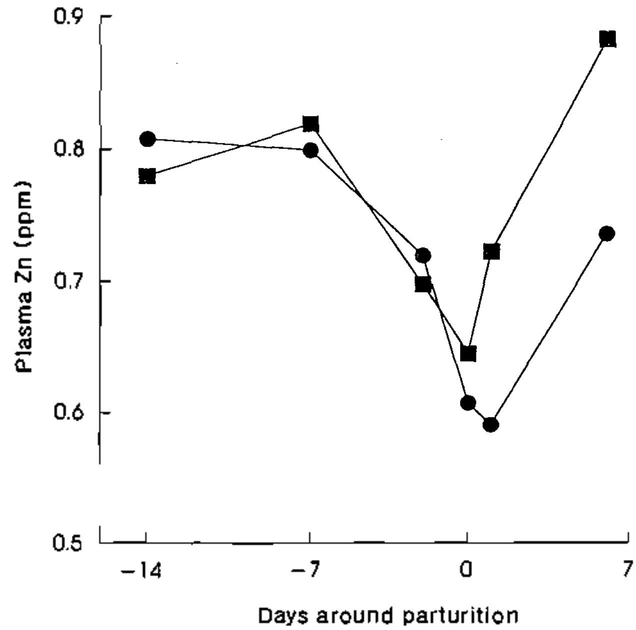

Figure 8. Plasma Zn of heifers calving during hot weather (●) and heifers calving during cool weather (■).

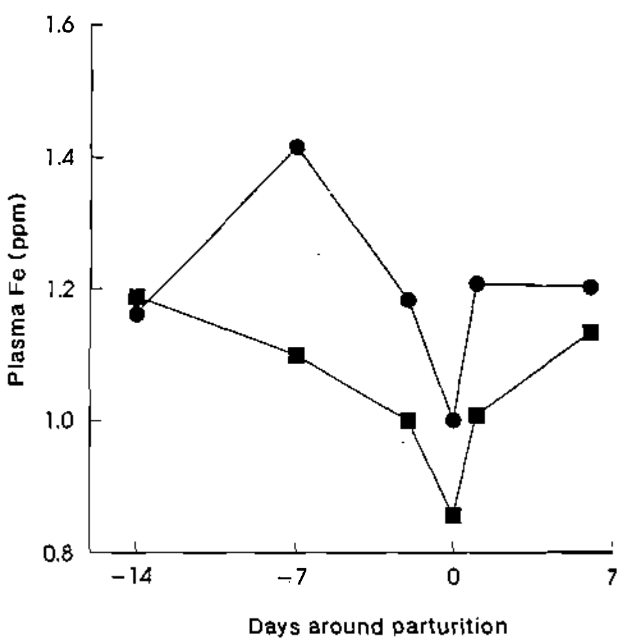

Figure 7. Plasma Fe of heifers calving during hot weather (●) and heifers calving during cool weather (■).

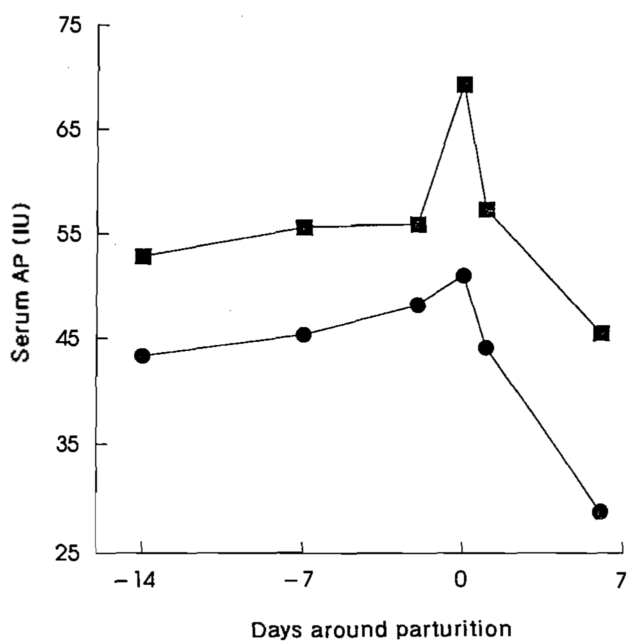

Figure 9. Serum alkaline phosphatase (AP) of heifers calving during hot weather (●) and heifers calving during cool weather (■).

periparturient heifers because of the retarded bone adaptation in the present experiment, but the reason for the increased plasma Ca and P_i during hot weather was not clear.

It was reported that blood Hct and Hb as well as plasma Ca and P_i in lactating cows decreased during hot weather (Kume, 1996; Shaffer et al., 1981), but the reverse relationships were observed in the periparturient cows (Kume, 1996) and heifers in the present experiment. Further study is needed to clarify optimal mineral status of periparturient heifers during hot and cool weather, because limited research has focused on the relationship between heat stress and mineral metabolism of the periparturient heifers.

Table. 4. Least squares means of colostrum yield and composition at parturition and 96 hours postpartum in heifers calving in hot and cool weather

	Hours postpartum	Weather		SEM
		Hot	Cool	
n		8	8	
Yield (kg)	0	1.4	1.3	0.2
	96	9.9	10.8	0.7
Specific gravity	0	1.053[d]	1.064[c]	0.003
	96	1.031	1.030	0.001
Composition:				
Protein (%)	0	13.4[b]	16.2[a]	1.0
	96	3.9	3.9	0.2
Ca (mg/dl)	0	193	227	15
	96	127	124	3
P (mg/dl)	0	177	206	14
	96	117	114	4
Mg (mg/dl)	0	29.2[d]	39.4[c]	3.3
	96	10.6	10.9	0.3
Fe (ppm)	0	2.0	1.6	0.2
	96	0.7	0.8	0.1
Zn (ppm)	0	20.5	21.7	2.8
	96	5.5	4.8	0.3

[a,b] Means within same row with different superscript are significant at $p < 0.10$.
[c,d] Means within same row with different superscript are significant at $p < 0.05$.

ACKNOWLEDGEMENTS

The authors wish to thank K. Kameoka for his helpful suggestions, the Division of Agrometeorology, National Institute of Agro-Environmental Sciences for the supply of environmental data, and T. Shimada and the staff at National Institute of Animal Industry for technical help.

REFERENCES

Agriculture, Forestry and Fisheries Research Council Secretariat. 1994. Japanese Feeding Standard for Dairy Cattle. Chuouchikusankai, Tokyo.

Beede, D. K. and R. J. Collier. 1986. Potential nutritional strategies for intensively managed cattle during thermal stress. J. Anim. Sci. 62:543-554.

Collier, R. J., D. K. Beede, W. W. Thatcher, L. A. Israel and C. J. Wilcox. 1982. Influences of environment and its modification on dairy animal health and production. J. Dairy Sci. 65:2213-2227.

Fujimoto, Y., E. Kimura, T. Sawada, M. Ishikawa, H. Matsunaga and J. Mori.. 1988. Changes in rectal temperature, and heart and respiration rates of dairy cows before parturition. Jpn. J. Zootech. Sci. 59:301-305.

Kume, S. 1991. Mineral requirement of dairy cows under high temperature conditions. Trop. Agric. Res. Ser. 25:199-207.

Kume, S. 1996. Thermal effect on mineral metabolism. Proc. 8th Animal Science Congress of AAAP. 1:579-587.

Kume, S. and S. Tanabe. 1993. Effect of parity on colostral mineral concentrations of Holstein cows and value of colostrum as a mineral source for newborn calves. J. Dairy Sci. 76:1654-1660.

Kume, S. and S. Tanabe. 1994. Effect of twinning and supplemental iron-saturated lactoferrin on iron status of newborn calves. J. Dairy Sci. 77:3118-3123.

Kume, S. and S. Tanabe. 1996. Effect of supplemental lactoferrin with ferrous iron on iron status of newborn calves. J. Dairy Sci. 79:459-464.

National Research Council. 1981. Effect of Environment on Nutrient Requirements of Domestic Animals. Natl. Acad. Sci. Washington, DC.

Sanchez, W. K., M. A. McGuire and D. K. Beede. 1994. Macromineral nutrition by heat stress interactions in dairy cattle: review and original research. J. Dairy Sci. 77:2051-2079.

SAS[R] User's Guide: Statistics, Version 6.03 Edition. 1988. SAS Inst., Inc., Cary, NC.

Shaffer, L., J. D. Roussel and K. L. Koonce. 1981. Effects of age, temperature-season, and breed on blood characteristics of dairy cattle. J. Dairy Sci. 64:62-70.

Toharmat, T. and S. Kume. 1996. Effect of reduced feed intake on mineral concentration in blood and colostrum of periparturient cows during a hot summer. Anim. Sci. Technol. (Jpn.). 67:686-692.

Yamaguchi, M. and R. Matsui. 1989. Effect of dipicolinate, a chelator of zinc, on bone protein synthesis in tissue culture. Biochem. Pharmacol. 38:4485-4489.