Effects of Prepartum Energy Intake and Calving Season on Blood Composition of Periparturient Cows

T. Toharmat[1], I. Nonaka, M. Shimizu[2], K. K. Batajoo and S. Kume[3]
Department of Animal Nutrition, National Institute of Animal Industry, Tsukuba 305, Japan

ABSTRACT : Sixteen periparturient Holstein cows calving during summer and autumn were fed to meet maintenance plus last 2 month of gestation level of TDN (MP) and 1.2 time of MP level (HMP). Dry matter intake of cows fed at HMP level during summer and autumn decreased by 1 and 2% of the offered feed in 1 week prepartum, respectively, and cows fed at MP level consumed all of the offered feed. Rectal temperatures at 08:30 h of cows fed at HMP level were higher than those of cows fed at MP level. Blood hematocrit and hemoglobin of cows increased during summer and were higher for cows fed at HMP level. Plasma total protein and glucose of cows during summer were higher than those during autumn, and the increased feed intake elevated plasma total protein and glucose. Plasma urea-N of cows fed at MP level was higher than that of cows fed at HMP level during autumn. The increased feed intake decreased plasma nonesterified fatty acid of cows during summer and autumn. These results suggest that blood components of periparturient cows are altered by calving season and feeding level.
(Key Words: Feed Intake, Heat Stress, Blood Composition, Periparturient Cows)

INTRODUCTION

The transition period from nonlactation to lactation imposes enormous stress on the dairy cows and may impair dry matter intake, milk production, and herd health (Grant and Albright, 1995). Late-pregnant cows are characterized by moderately increased mobilization of NEFA from adipose tissue and increased hepatic gluconeogenesis (Bell, 1995). Reduced feed intake during late gestation is a factor that influences mobilization of fat from adipose tissue and glycogen from the liver (Grummer, 1995).

Health status of cattle involves the complex interaction between environmental and cattle factors (Collier et al., 1982). Blood hematocrit (Hct) and hemoglobin (Hb) of cows decreased under the hot environment, and the depression of blood Hct and Hb was related to the reduction in cellular oxygen requirements to compensate for elevated environmental heat load (Shaffer et al., 1981). Blood Hct and Hb as well as rectal temperatures were higher in periparturient cows fed at maintenance level of TDN than in cows fed at maintenance plus last 2 months of gestation level of TDN during hot weather, but the blood Hct and Hb in cows fed at maintenance level were lower during cool weather (Toharmat and Kume, 1996 and 1997). However, it was not clear whether heat stress adversely affected blood metabolites and thermoregulation of periparturient cows.

The objective of this study was to clarify the relationship between feed intake, rectal temperature and blood composition of periparturient cows during summer and autumn.

MATERIALS AND METHODS

Sixteen multiparous Holstein cows which calved from July to December 1996 at National Institute of Animal Industry were used. Eight cows calving from July 29 to September 22 were termed as the summer group; 8 cows calving from October 9 to December 7 were termed as the autumn group. The cows were kept in individual tie stalls and in a paddock. Air cooling system was employed to blow the cool air for about 8 h during the hot summer days.

Feeding level was designed to meet maintenance plus last 2 months of gestation requirement of TDN (MP) or 1.2 times of MP level (HMP) (AFFRCS, 1994). The cows were fed at 08:30 and 15:30 h in equal amounts for 4

[1] Bogor Agricultural University, Indonesia.
[2] Fukui Prefectural Animal Experiment Station, Japan.
[3] Address reprint requests to S. Kume. Hokkaido National Agricultural Experiment Station, Sapporo 062, Japan.
Received December 4, 1997; Accepted May 11, 1998

wk before the expected calving date, assuming that the gestation length to be 280 d. Diet consisted of 70% Italian ryegrass silage and 30% concentrate on a DM basis (table 1). The concentrate almost consisted of barley, corn, milo and wheat bran. Nutrient content of feed met the recommendations (AFFRCS, 1994) for protein of pregnant cows. Feed intake was measured every day from 4 wk prepartum to parturition.

Table 1. Chemical composition of feedstuff and experimental feed[1]

	Summer			Autumn		
	Concentrate[2]	Italian ryegrass silage[2]	Experimental feed[3]	Concentrate[2]	Italian ryegrass silage[2]	Experimental feed[3]
	(%)					
DM	86.5	42.4	50.1	87.0	44.2	51.1
OM	93.5	88.8	90.2	93.9	88.6	90.2
CP	16.3	11.2	12.7	16.6	9.9	11.9
EE	2.1	3.1	2.8	3.0	3.1	3.0
NDF	16.8	60.3	47.2	17.7	61.6	48.4
ADF	9.6	38.6	29.9	9.1	38.9	29.9

[1] All values expressed on a DM basis except for DM.
[2] Data were analyzed.
[3] Consisted of 70% Italian ryegrass silage and 30% concentrate on a DM basis.

Blood was sampled via jugular vein puncture into heparinized vacuum tubes prior to feeding at 08 : 30 h in 3 wk, 2 wk, 1 wk and 2 d before expected calving date, at parturition and 1 and 6 d after parturition. At parturition, blood samples were taken within 12 h after birth. Blood samples were immersed in ice, and analyzed for blood hematocrit (Hct) and hemoglobin (Hb) as previously described (Kume and Tanabe, 1993). Plasma total protein was determined using a refractometer (ATAGO SRR-T2, Atago Co. Ltd., Japan) and plasma NEFA, glucose and urea-N were determined using commercial kits (Wako Pure Chemical Industries Ltd., Japan).

Ambient temperature and humidity inside the experimental barn were recorded daily at 08 : 30 and 15 : 30 h using a thermorecorder (RS-10, Tabai Espec Corp, Japan). Daily environmental temperature and relative humidity were obtaind from National Institute of Agro-environmental Sciences (Tsukuba, Japan), which is located approximately 1 km from the barn. Rectal temperature was measured by a clinical thermometer before feeding for 3 consecutive days a week in 3 and 2 wk prepartum, and daily from 10 d before expected calving date until parturition.

The general linear models procedure of SAS (1988) was used to analyze the effect of season and TDN level on gestation length and calf birth weight. Rectal temperature and blood composition were analyzed by least squares ANOVA using the general linear models procedure of SAS (1988). The model was as follows:

$$Y_{ijk} = \mu + S_i + T_j + ST_{ij} + C_{(ij)k} + D_l + SD_{il} + TD_{jl} + STD_{ijl} + e_{ijkl}$$

μ = overall mean,
S_i = effect of season,
T_j = effect of TDN level,
$C_{(ij)k}$ = cows, nested in season and TDN level,
D_l = effect of sampling time,
ST_{ij}, SD_{il}, TD_{jl}, STD_{ijl} = interactions, and
e_{ijkl} = residuals.

An ANOVA was performed, 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 is 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 at the environmental temperature within the range of 5 to 25℃ (Collier et al., 1982). The mean environmental temperatures during summer were lower than 25℃

and that during autumn ranged from 5.0 to 15.6℃ (table 2).

There were no metabolic disorders in periparturient cows fed at MP or HMP level during summer and autumn, although one cow fed at HMP level during autumn had dystocia. Dry matter intake of cows fed at MP level of TDN during summer and winter decreased by 6 and 4% of the offered feed in 1 wk prepartum, respectively (Toharmat and Kume 1996; and 1997). In lactating cows, dry matter intake begins to decline at mean daily environmental temperatures of 25 to 27℃ (Beede and Collier, 1986). In the present experiment, the cows fed at MP consumed all the offered feed from 3 wk prepartum to parturition, but feed intake in 1 week prepartum decreased by 1 and 2% of the offered feed at HMP level during summer and autumn, respectively.

Although the interaction between season and diet on body weight was significant ($p < 0.001$), body weights of cows fed at HMP level were higher ($p < 0.001$) than those of cows fed at MP level during summer and autumn. Birth weight of their calves was not significantly different between treatments, although 3 cows fed at MP level during summer and one cow fed at MP level during autumn gave birth to twins. Rectal temperatures at 08:30 h of cows fed at HMP level during summer and autumn were higher ($p < 0.001$) than those of cows fed at MP level. Rectal temperatures at 15:30 h of cows fed at HMP level during autumn were higher ($p < 0.001$) than those of cows fed at MP level.

Kume (1996) showed that heat stress increased rectal temperatures of periparturient cows and heifers. The restricted feed intake of prepartum cows increased rectal temperatures during summer, but the restricted feed intake decreased rectal temperatures during winter (Toharmat and Kume, 1996; and 1997). In the present experiment, the increased feed intake elevated rectal temperatures of prepartum cows during summer and autumn, but rectal temperatures were not influenced by calving season.

Table 2. Mean temperature and relative humidity during experimental period

	Summer			Autumn		
	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Environment						
Temperature (℃)	24.3	24.3	20.4	15.6	10.5	5.0
Relative humidity (%)	86.1	84.0	87.1	86.2	81.8	73.9
Barn						
Temperature (℃)						
at 08:30 h	25.8	26.5	22.1	17.0	11.5	6.7
at 15:30 h	29.3	28.2	24.3	20.4	15.4	11.9
Relative humidity (%)						
at 08:30 h	80.8	76.4	76.9	77.0	77.8	67.0
at 15:30 h	66.7	63.0	67.9	63.0	64.1	49.1

Blood Hct and Hb of cows were higher ($p < 0.001$) during summer than those during autumn and those of cows fed at HMP level were higher ($p < 0.001$) than those of cows fed at MP level (table 3). Blood Hct ($p < 0.001$) and Hb ($p < 0.001$) of periparturient cows increased at parturition (figures 1 and 2).

The rise in blood Hct and Hb of periparturient cows during summer agreed with the previous report (Kume, 1996), which showed that blood Hct and Hb of cows during summer were higher than those during autumn and winter. The restricted feed intake increased blood Hct and Hb as well as rectal temperature of peripaturient cows during hot summer, but the restricted feed intake decreased blood Hct and Hb as well as rectal temperature during autumn and winter (Toharmat and Kume, 1996; and 1997). However, the increased feed intake increased blood Hct and Hb as well as rectal temperature of periparturient cows during summer and autumn in the present experiment, because the environmental temperatures during summer were relatively cool. The temporary increases in blood Hct and Hb at parturition during summer and autumn may be caused by rapid mobilization of red blood cells from storage sites in spleen and bone marrow (Furugouri et al., 1982). These results suggest that feed intake is a factor for increasing blood Hct and Hb, and hot environments during summer may alter mobilization of red blood cells and body water in periparturient cows.

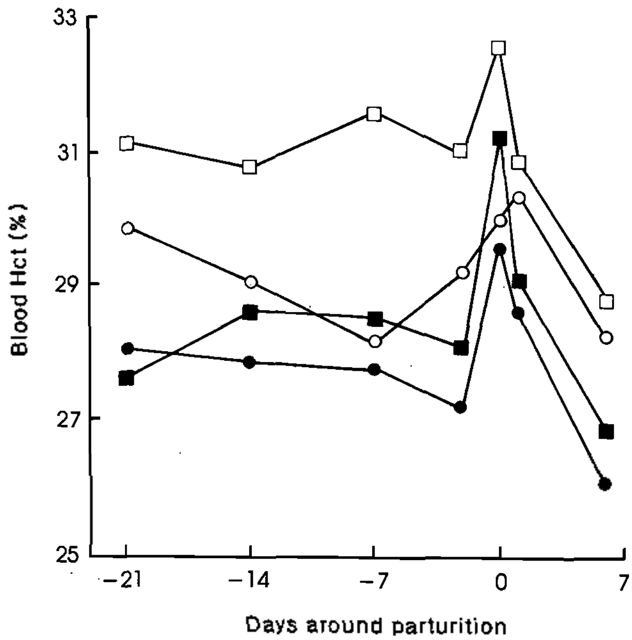

Figure 1. Blood hematocrit (Hct) of cows fed at MP (○) and HMP (□) levels during summer and blood Hct of cows fed at MP (●) and HMP (■) levels during autumn.

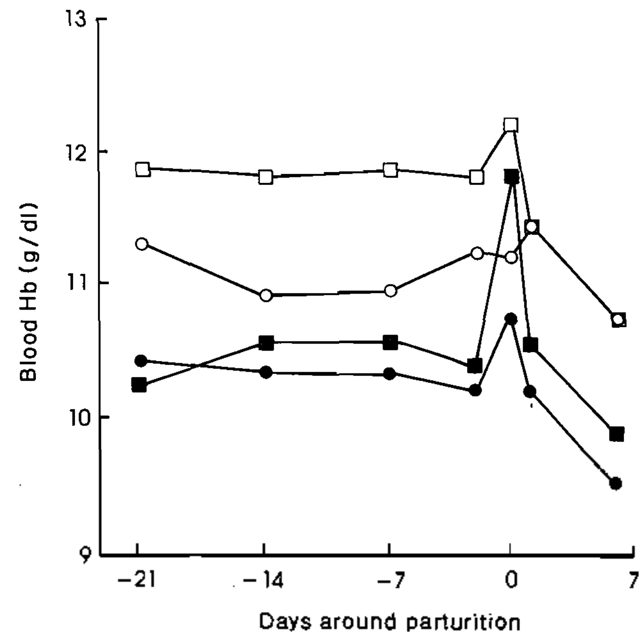

Figure 2. Blood hemoglobin (Hb) of cows fed at MP (○) and HMP (□) levels during summer and blood Hb of cows fed at MP (●) and HMP (■) levels during autumn.

Table 3. Least square means of rectal temperature, blood and plasma components of cows fed different dietary TDN levels prior to parturition during summer and autumn

	Summer		Autumn		SE	Effect (p)		
	MP[1]	HMP[2]	MP[1]	HMP[2]		Season	Diet	S × D[3]
n	4	4	4	4				
Age[4] (mo)	56.9	61.1	65.2	64.9	4.6	NS	NS	NS
Gestation length (d)	275	281	281	283	1	NS	NS	NS
Body weight (kg)								
Cow[5]	612	678	637	664	1	**	***	***
Calf at birth	60.3	43.9	53.2	48.3	3.0	NS	***	NS
DM intake[5] (kg/d)	8.38	10.35	8.44	10.31	0.02	NS	***	NS
Rectal temperature[5] (℃)								
at 08:30 h	38.66	38.74	38.68	38.81	0.01	NS	***	NS
at 15:30 h	39.22	39.23	39.20	39.43	0.02	**	***	**
Blood[6]								
Hct (%)	29.21	30.94	27.80	28.52	0.13	***	***	NS
Hb (g/dl)	11.10	11.68	10.25	10.57	0.06	***	***	NS
Plasma[6]								
Protein (g/dl)	7.14	7.60	6.50	6.98	0.04	***	***	NS
Urea-N (mg/dl)	9.17	9.93	12.08	9.70	0.21	**	NS	***
Glucose (mg/dl)	67.30	73.34	64.28	66.40	0.87	**	*	NS
NEFA (mEq/l)	0.57	0.43	0.51	0.42	0.02	NS	**	NS

[1,2] Dietary TDN level; MP = maintenance plus last 2 month of gestation and HMP = 1.2 × MP.
[3] Interaction between season and treatment.
[4] At parturition.
[5] Means from 3 wk before parturition to parturition.
[6] Means from 3 wk before to 6 d after parturition.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

Plasma total protein ($p < 0.001$) and glucose ($p < 0.01$) of cows during summer were higher than those during autumn (table 3). The plasma total protein ($p < 0.001$) and glucose were higher in cows fed at HMP level than those fed at MP level during summer and autumn.

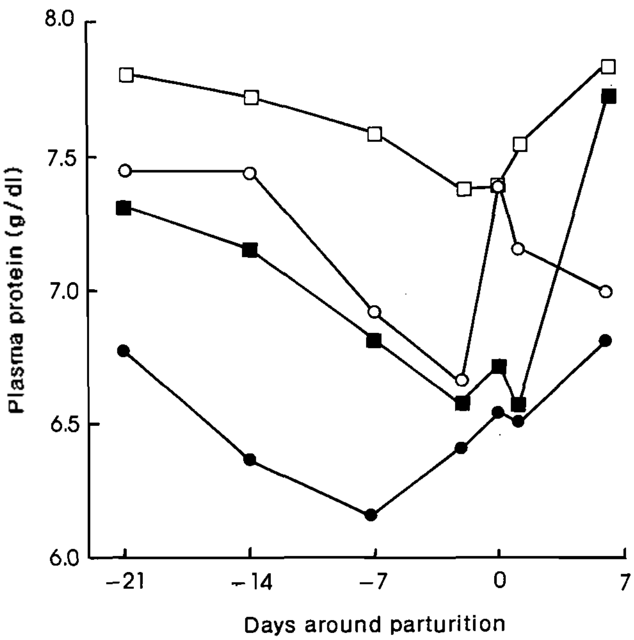

Figure 3. Plasma protein of cows fed at MP (○) and HMP (□) levels during summer and plasma protein of cows fed at MP (●) and HMP (■) levels during autumn.

Plasma urea-N of cows fed at MP level was higher ($p < 0.001$) than that of cows fed at HMP level during autumn. Cows fed at MP level during autumn showed low plasma protein, but showed high plasma uera-N (figures 3 and 4). Plasma glucose of cows increased ($p < 0.001$) dramatically at parturition (figure 5). Plasma NEFA of cows fed at HMP level was lower ($p < 0.01$) than that of cows fed at MP level during summer and autumn. Plasma NEFA of cows increased from 21 d prepartum to parturition (figure 6).

Plasma NEFA increased rapidly during the final days preceding parturition and plasma glucose decreases during the transition period except for the transient increase associated with calving (Grummer, 1995). The elevated blood NEFA and low blood glucose usually coincide with elevated ketone in blood, and blood NEFA concentration influences hepatic fatty acid uptake (Bell, 1995; Bertics et al., 1992; Grummer, 1995). Prepartum forced-feeding tended to reduce the magnitude of NEFA increase and increased plasma glucose of cows, and the dry matter intake prior to calving was correlated negatively with liver triglyceride immediately after calving (Bertics et al., 1992). Prepartum dry matter intake is positively correlated with postpartum dry matter intake, and the postpartum feed intake is more important in overconditioned cows which are susceptible to the incidence of fatty liver and ketosis (Grummer, 1995; NRC, 1988). In the present

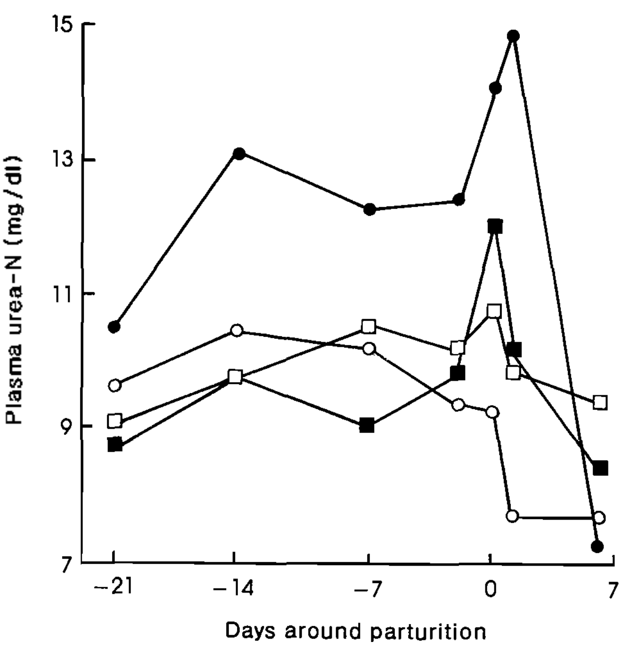

Figure 4. Plasma urea-N of cows fed at MP (○) and HMP (□) levels during summer and plasma urea-N of cows fed at MP (●) and HMP (■) levels during autumn.

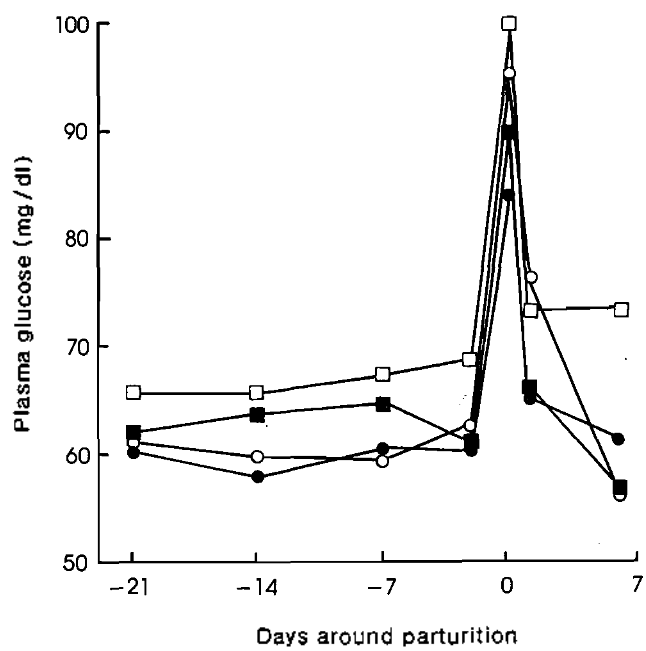

Figure 5. Plasma glucose of cows fed at MP (○) and HMP (□) levels during summer and plasma glucose of cows fed at MP (●) and HMP (■) levels during autumn.

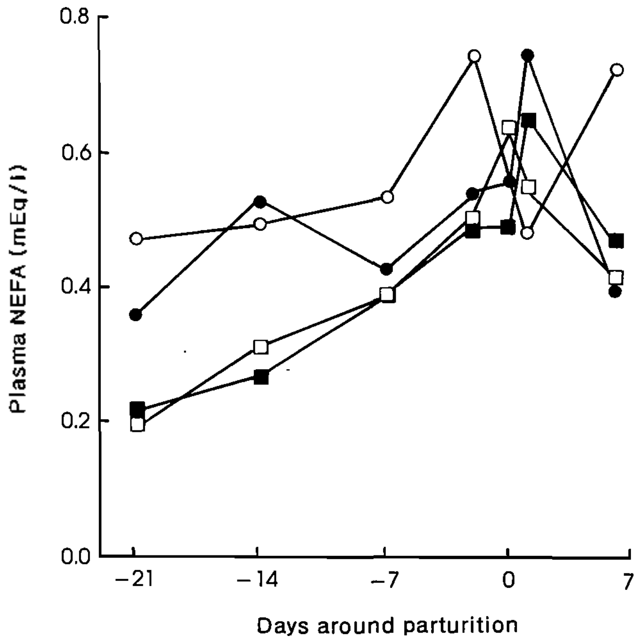

Figure 6. Plasma NEFA of cows fed at MP (○) and HMP (□) levels during summer and plasma NEFA of cows fed at MP (●) and HMP (■) levels during autumn.

experiment, the increased feed intake improved blood metabolites, because plasma glucose of periparturient cows were elevated and plasma NEFA was depressed.

Thermal stress alters dietary protein utilization and body protein metabolism (Collier et al., 1982). The increase in total protein during temperature-season progression was related to globulin or albumin fraction (Lee et al., 1976 and Shaffer et al., 1981). Albumin and blood Hb increases have been suggested to indicate an improved protein status resulting from an increase in the availability of nutrients for the synthesis of protein (Hassan and Roussel, 1975; Rowlands et al., 1974). In the present experiment, the increased environmental temperatures during the summer elevated blood Hct, Hb, and plasma protein, and the increased feed intake during summer enhance blood Hct, Hb and plasma protein of periparturient cows. The results suggests that periparturient cows may utilize dietary protein more efficiently during the cool summer.

Heat stress may exagerate the prepartum decline in dry matter intake and slow the rate of increase of dry matter postpartum (Grant and Albright, 1995). Heat stressed-cows might experience metabolic ketosis as energy input would not satisfy energy need and accelerate body fat catabolism (Collier et al., 1982). Cows had significantly lower plasma glucose and greater plasma NEFA during high environmental temperature (Lee et al., 1976; Shaffer et al., 1981; Skaar et al., 1989). In the present experiment, plasma glucose of periparturient cows increased during summer, but plasma NEFA was not influenced by calving season. Thus, the increased prepartum feed intake may improve nutritional status of periparturient cows during high environmental temperature, because the increase in feed intake during summer elevated plasma glucose and lowered plasma NEFA.

These results suggest that blood components of periparturient cows are altered by level of feed intake and calving season. Most metabolic disorders occur at or shortly after parturition and represent a failure of the cow to adjust to the rapid onset and stress of high milk production (NRC, 1988). Heat stress can represent sizable economic losses to producers of intensively managed dairy cattle (Beede and Collier, 1986). Further study is needed to clarify the effect of feed intake on blood metabolites to minimize heat stress in periparturient cows during hot weather.

ACKNOWLEDGEMENTS

The authors wish to thank the division of Agrometeorology, National Institute of Agroenvironmental Sciences for the supply of environmental data and T. Shimada and the dairy cattle barn staff at National Institute of Animal Industry for technical help during the experiment.

REFERENCES

Agriculture, Forestry and Fisheries Research Council Secretariat (AFFRCS). 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.

Bell, A. W. 1995. Regulation of organic nutrient metabolism during transition from late pregnancy to early lactation. J. Anim. Sci. 73:2804-2819.

Bertics, S. J., R. R. Grummer, C. Cadorniga-Valino and E. E. Stoddard. 1992. Effect of prepartum dry matter intake on liver triglyceride concentration and early lactation. J. Dairy Sci. 75:1914-1922.

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.

Furugouri, K., Y. Miyata and K. Shijimaya. 1982. Ferritin in blood serum of dairy cows. J. Dairy. Sci. 65:1529-1534.

Grant, R. J. and J. L. Albright. 1995. Feeding behavior and management factors during the transition period in dairy cattle. J. Anim. Sci. 73:2791-2803.

Grummer, R. R. 1995. Impact of changes in organic nutrient metabolism on feeding the transition dairy cows. J. Anim.

Sci. 73:2820-2833.

Hassan, A. and J. D. Roussel. 1975. Effect of protein concentration in the diet on blood composition and productivity of lactating Holstein cows under thermal stress. J. Agric. Sci. Camb. 85:409-415.

Kume, S. 1996. Thermal effect on mineral metabolism. Proc. the 8th AAAP Animal Science Congress, 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 newbom calves. J. Dairy Sci. 76:1654-1660.

Lee, J. A., J. D. Roussel and J. F. Beatty. 1976. Effect of temperature-season on bovine adrenal cortical function, blood cell profile, and milk production. J. Dairy Sci. 59:104-108.

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

National Research Council. 1988. Nutrient Requirements of Dairy Cattle. 6th. rev. ed. Natl. Acad. Sci. Washington, DC.

Rowlands, G. J., W. Little, R. Manston and S. M. Dew. 1974. The effect of season on the composition of the blood of lactating and non-lactating cows as revealed from repeated metabolic profile tests on 24 dairy herds. J. Agric. Sci. Camb. 83:27-35.

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.

Skaar, T. C., R. R. Grummer, M. R. Dentine and R. H. Stauffacher. 1989. Seasonal effects of prepartum and postpartum fat and niacin feeding on lactation performance and lipid metabolism. J. Dairy Sci. 72:2028-2038.

Tohamat, 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.). 67:586-692.

Tohamat, T. and S. Kume. 1997. Effect of restricted feed intake on mineral concentration in blood and colostrum of periparturient cows during autumn and winter. Anim. Sci. Technol. (Jpn.). 68:257-262.