Effect of Parity on Mineral Concentration in Milk and Plasma of Holstein Cows During Early Lactation

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ABSTRACT : Plasma and milk samples of 24 periparturient Holstein cows were collected from 1 week prepartum to 10 week postpartum to measure the effects of parity on mineral status in periparturient cows. Cows were fed mainly mixed ration with the concentrate supplement during the experimental period to meet nutrient requirement of dairy cattle for TDN, protein, and minerals. Plasma Ca of cows decreased as parity increased, but plasma Mg, K, Fe and Zn were lowest in the first lactation cows. Plasma inorganic P, Na, and alkaline phosphatase were not affected by the parity. Plasma Ca, Fe and Zn of cows decreased at parturition, but plasma Mg increased. Plasma Ca of the first, second and third and more lactation cows at parturition were 9.65, 8.96, and 8.92 mg/dl, respectively. Colostral Ca, P, Mg, Na, and Zn were highest in the first lactation cows, although colostrum yield was lower. Milk yield from 1 to 10 weeks postpartum was lowest in the first lactation cows, but mineral concentrations in milk were not affected by the parity.
(**Key Words:** Parity, Mineral, Postpartum Cows, Colostrum)

INTRODUCTION

Mineral status of dairy cows varies with a number of factors. Parity is a factor responsible for the changes in the mineral status of periparturient cows and newborn calves (Kume, 1996; Kume and Tanabe, 1993). Colostral Ca, P and Mg at parturition decreases as parity increases and stabilizes after the third lactation (Kume and Tanabe, 1993). The shift of plasma Fe to blood Hb is accelerated in heifers due to the high Fe demand for growth (Kume, 1996; Kume and Tanabe, 1996). Kume and Tanabe (1993, 1994, 1996) reported that calves born from primiparous cows developed low blood hematocrit and hemoglobin on the first day after birth.

The transition period from nonlactation to lactation imposes physiological and nutritonal stress on the dairy cows (Grant and Albright, 1995). Disturbance of mineral metabolism, such as milk fever and grass tetany, are often observed during the periparturent period, because dairy cows secrete large quantities of minerals into milk (NRC, 1988). In particular, plasma Ca and inorganic P (Pi) concentration of dairy cows decrease at parturition because of the large transfer of Ca and P to colostrum, and milk fever usually occurs in their third or greater lactations (Horst et al., 1994). Because milk fever is an economically important disease in high producing dairy cows, significant advances have been made during the past several years in the understanding of the pathogenesis of milk fever (Horst et al., 1997). Also, the deficiencies of Ca and P impair the reproductive function in cattle (Hurley and Doane, 1989). However, the metabolism of the other minerals in dairy cows has not been well clarified during the periparturient and early lactation periods.

Production and composition of colostrum or milk varies with the uptake of nutrients by the mammary gland, and this is influenced by mammary blood flow and utilization of nutrients by mammary gland (Kume and Tanabe, 1993). In high producing cows, the understanding of the relationship between mineral removal in milk and plasma mineral status is important to maintain the health status during the periparturient and early lactation periods.

The objective of this study is to investigate the effect of parity on the concentration of 7 minerals, such as Ca, P, Mg, Na, K, Fe and Zn, in the milk and plasma of Holstein cows from 1 week prepartum to 10 weeks postpartum.

MATERIALS AND METHODS

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Data from 24 periparturient Holstein cows (10 first lactation, 6 second lactation, and 8 third and more lactation) kept at Koibuchi College of Agriculture (Uchihara, Japan) were collected from November 1995 to July 1996. Cows were fed mainly mixed rations (table 1) in addition to a concentrate supplement from 1 week prepartum to 10 weeks postpartum to meet nutrient requirements (AFFRCS, 1994) of dairy cattle for TDN, protein, and minerals.

Table 1. Chemical composition of feedstuff[1]

	Mixed ration	Concentrate
	(%)	
DM	53.1	87.1
CP	12.6	18.3
Crude Fat	3.52	3.75
NDF	40.4	17.4
ADF	27.8	9.6
Ca	0.78	0.79
P	0.48	0.72
Mg	0.26	0.29
Na	0.15	0.18
K	1.74	1.16
	(ppm)	
Fe	525	148
Zn	31.7	53.0

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

Each cow was milked immediately after parturition, and thereafter at 05:00 and 15:00 h postpartum. Milk weights were recorded daily. Colostrum samples were collected at parturition, and milk samples were collected at 1, 4, and 10 weeks postpartum. Milk analyzed was a composite sample of morning and evening milking. Blood samples were obtained by jugular puncture into heparinized vacuum tubes at 11:00 h 1 week before the expected calving date, at parturition, and 1, 4, and 10 weeks after parturition. Blood samples were obtained on the same day as milk collection after parturition and centrifuged immediately after collection. Plasma and milk samples were frozen at −20℃ and mineral composition in milk and plasma were determined as previously described (Kume and Tanabe, 1993, 1996).

The general linear models procedure of SAS (1988) was used to analyze the effect of parity on colostrum composition of cows. Data of milk and plasma composition of cows were analyzed by the least squares ANOVA using the general linear models procedure of SAS (1988). The model, which was similar to our previous studies (Kume and Tanabe, 1994; Kume et al., 1995), was as follows;

$$y_{ijk} = \mu + P_i + C_{(i)j} + T_k + PT_{ik} + e_{ijk}$$

where

μ = overall mean,
P_i = effect of parity,
$C_{(ij)k}$ = random variable cow nested in parity,
T_k = effect of sampling day,
PT_{ik} = interaction, and
e_{ijk} = residuals.

Significance was declared at ($p < 0.05$). An ANOVA was performed, and the differences among the parity or weeks around parturition were tested by least significant difference.

RESULTS

In the present experiment, no metabolic disorders occurred to the cows around parturition. Plasma Ca concentration of cows decreased ($p < 0.05$) as parity increased, but plasma Pi was not affected by parity (table 2). Plasma Ca decreased ($p < 0.001$) at parturition, and plasma Ca of the first, second and third and more lactation cows at parturition were 9.65, 8.96 and 8.92 mg/dl, respectively (figure 1). Plasma Pi was the same before and at the time at parturition (figure 2).

Table 2. Least squares means of mineral concentration in plasma of periparturient cows[1]

	Parity			SE
	1	2	≥3	
number of cows	10	6	8	
Age (mo.)	27.1[c]	44.7[d]	66.5[e]	1.7
Plasma				
Ca (mg/dl)	10.25[a]	10.20	9.99[b]	0.04
Pi[2] (mg/dl)	5.21	4.82	4.87	0.10
Mg (mg/dl)	2.05[d]	2.37[c]	2.29[c]	0.02
Na (mg/dl)	325	329	327	1
K (mg/dl)	16.4[b]	17.2[a]	17.7[a]	0.1
Fe (mg/l)	0.91[d]	1.23[c]	1.14[c]	0.03
Zn (mg/l)	0.73[d]	0.95[c]	0.92[c]	0.01
AP[3] (IU)	37.3	37.1	35.3	0.8

[a,b] Means within same row with different superscript letters differ ($p < 0.05$).
[c,d,e] Means within same row with different superscript letters differ ($p < 0.001$).
[1] Collected from 1 week prepartum to 10 week postpartum.
[2] Inorganic P.
[3] Alkaline phosphatase.

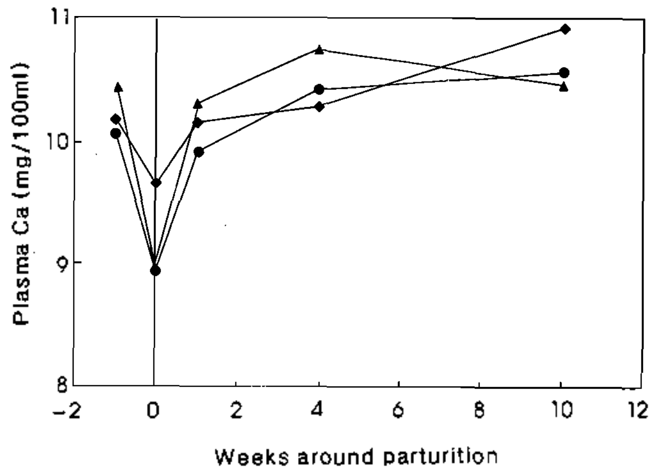

Figure 1. Plasma Ca of cows during the first (◆), second (▲) or third and more (●) lactations.

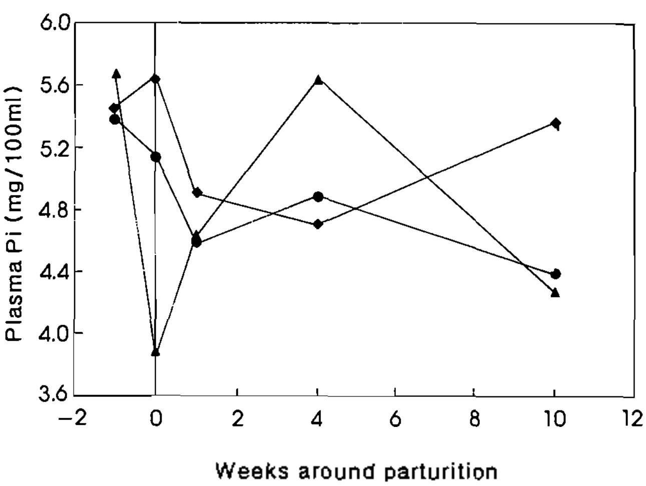

Figure 2. Plasma Pi of cows during the first (◆), second (▲) or third and more (●) lactions.

Colostral Ca and P concentration were highest ($p < 0.05$) in the first lactation cows, although colostrum yield of the first lactation cows was lower ($p < 0.05$) than that of the third and more lactation cows (table 3). The concentrations of Ca and P in milk were not affected by parity, but milk yield from 1 to 10 weeks postpartum was lowest ($p < 0.001$) in the first lactation cows (table 4). Milk yield was higher ($p < 0.001$) at 4 and 10 weeks postpartum than at week 1, but Ca ($p < 0.01$) and P ($p < 0.001$) concentrations in milk decreased at 4 weeks postpartum, compared to week 1.

Plasma Mg ($p < 0.001$), K ($p < 0.05$), Fe ($p < 0.001$) and Zn ($p < 0.001$) concentrations were lowest in the first lactation cows, but plasma Na and alkaline phosphatase were not affected by parity (table 2). Plasma Mg

Table 3. Least squares means of mineral concentration in colostrum of cows at parturition

	Parity			SE
	1	2	≧3	
Milk yield (kg/d)	6.4^b	6.5	8.6^a	0.4
Composition				
Protein (%)	12.8	11.5	11.7	0.7
Ca (mg/dl)	255^a	221	203^b	8
P (mg/dl)	224^a	205^a	169^b	5
Mg (mg/dl)	37.1^a	38.6^a	26.2^b	1.7
Na (mg/dl)	69.7^a	37.3^b	49.5	4.8
K (mg/dl)	164	194	179	5
Fe (mg/l)	1.7	1.4	1.5	0.1
Zn (mg/l)	23.1^a	18.8	13.5^b	1.5

a,b Means within same row with different superscript letters differ ($p < 0.05$).

Table 4. Least squares means of mineral concentration in milk of cows

	Weeks postpartum	Parity 1	Parity 2	Parity ≧3	SE
Milk yield (kg/d)	1	20.8^d	30.4^c	29.0^c	1.0
	4	24.6^d	37.2^c	37.6^c	1.0
	10	25.5^b	33.5^a	35.3^a	1.0
Composition					
Protein (%)	1	3.47	3.44	3.70	0.10
	4	2.77	2.74	2.85	0.11
	10	2.95	2.71	2.98	0.10
Ca (mg/dl)	1	128	129	139	3
	4	117	118	121	3
	10	130	115	124	3
P (mg/dl)	1	110	106	107	2
	4	96	94	89	2
	10	93	92	90	2
Mg (mg/dl)	1	11.0	12.3	12.0	0.3
	4	10.4	11.1	11.1	0.3
	10	10.4	9.7	10.2	0.3
Na (mg/dl)	1	33.5	29.1	33.7	0.8
	4	30.9	27.6	32.5	0.9
	10	31.6	33.7	31.3	0.8
K (mg/dl)	1	160	169	170	3
	4	165	165	165	4
	10	168	156	163	3
Fe (mg/l)	1	0.76	0.62	0.83	0.03
	4	0.67	0.72	0.66	0.04
	10	0.52	0.58	0.60	0.04
Zn (mg/l)	1	5.4	5.0	5.4	0.2
	4	4.3	4.2	4.5	0.2
	10	4.2	4.0	4.4	0.2

a,b Means within same row with different superscript letters differ ($p < 0.01$).
c,d Means within same row with different superscript letters differ ($p < 0.001$).

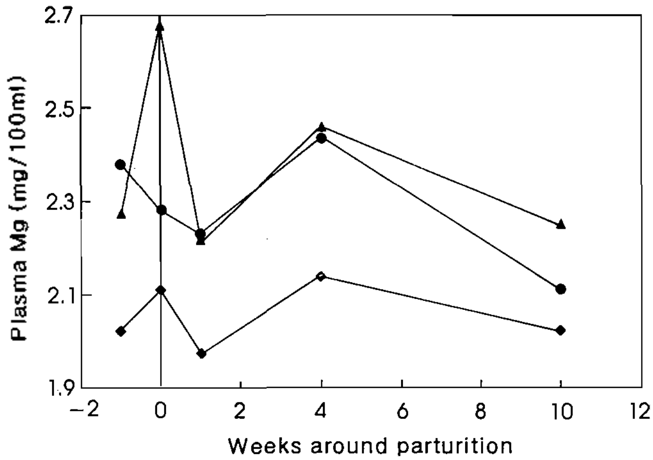

Figure 3. Plasma Mg of cows during the first (◆), second (▲) or third and more (●) lactations.

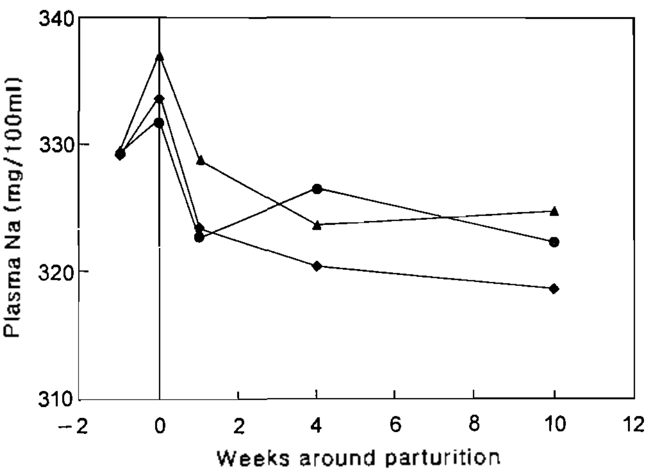

Figure 4. Plasma Na of cows during the first (◆), second (▲) or third and more (●) lactations.

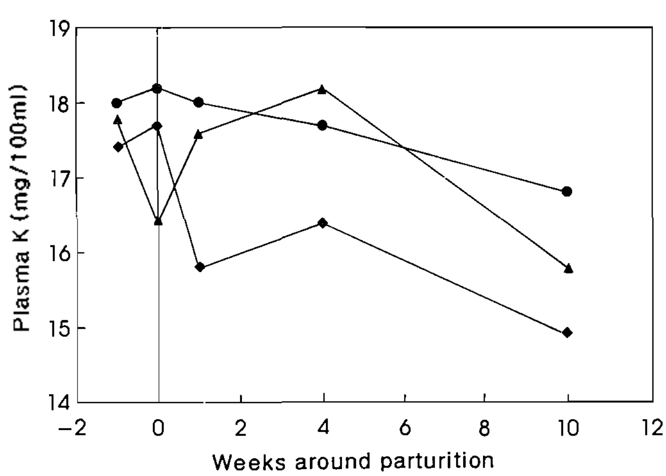

Figure 5. Plasma K of cows during the first (◆), second (▲) or third and more (●) lactations.

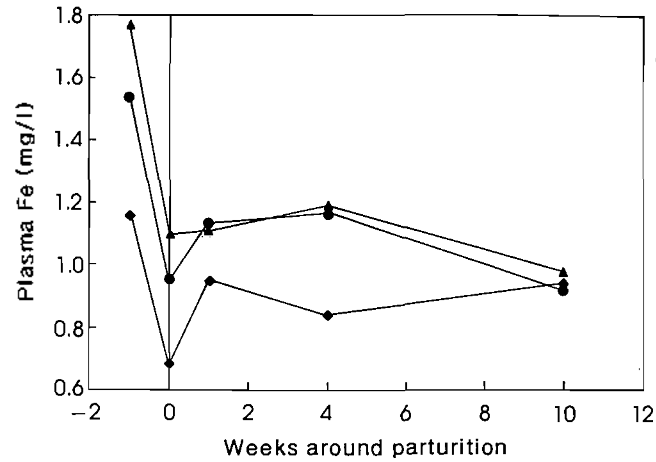

Figure 6. Plasma Fe of cows during the first (◆), second (▲) or third and more (●) lactations.

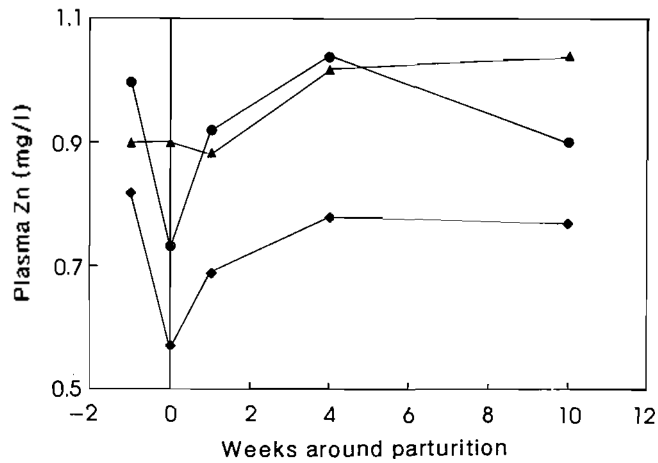

Figure 7. Plasma Zn of cows during the first (◆), second (▲) or third and more (●) lactations.

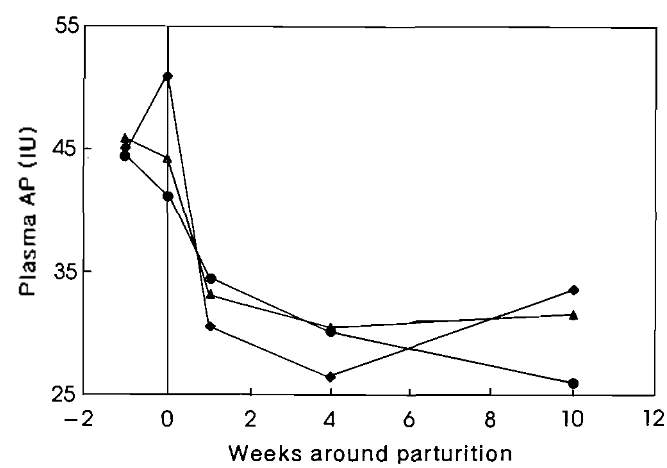

Figure 8. Plasma alkaline phosphatase (AP) of cows during the first (◆), second (▲) or third and more (●) lactations.

concentrations increased ($p < 0.05$) at parturition, and plasma Mg of the first, second and third and more lactation cows at parturition were 2.11, 2.68, and 2.28 mg/dl, respectively (figure 3). Plasama Na increased ($p < 0.05$) at parturition (figure 4), and plasma K decreased ($p < 0.01$) at 10 weeks postpartum than at week 1 and 4 (figure 5). Plasma Fe and Zn of cows decreased ($p < 0.001$) at parturition, and plasma Fe and Zn of the first lactation cows were lowest (figure 6 and 7). Plasma alkaline phosphatase decreased ($p < 0.001$) at 1 week postpartum and stabilized at 4 and 10 weeks postpartum (figure 8).

Colostral Mg, Na, and Zn were highest ($p < 0.05$) in the first lactation cows, but mineral concentration in milk were not affected by the parity (table 3 and 4). Colostral and milk protein were not affected by the parity, and Mg ($p < 0.01$), Fe ($p < 0.01$) and Zn ($p < 0.001$) concentrations in milk decreased at 4 weeks postpartum.

DISCUSSION

The health status of high producing dairy cows is critical during periparturient and early lactation periods. Some metabolic disordes occur at or shortly after parturition and reflect a failure of the cow to adjust to the rapid onset and stress of high milk production (NRC, 1988). Mineral needs for lactating cows are increased after parturition because minerals are transferred to colostrum. Goff and Stable (1990) reported that plasma Zn as well as plasma Ca and Pi decreased at parturition because of large diversion to colostrum. In the present experiment, metabolic disorders were not observed at parturition, but plasma Ca, Fe and Zn decreased at parturition. The decreased plasma Fe at parturition may be due to the shift of plasma Fe to blood Hb, because blood Hb increased rapidly at parturition (Kume, 1996; Toharmat and Kume, 1996, 1997). Thus, the large amounts of transfer to colostrum mainly affects Ca, P and Zn metabolism of periparturient cows.

Although plasma Ca and Pi concentrations of dairy cows decrease around parturition, older cows have a greater risk of developing milk fever (Horst et al., 1994). Romo et al. (1991) showed that cows of higher parity had lower serum Ca and P around parturition. In the present experiment, plasma Ca as well as colostral Ca and P of older cows was lowest at parturition, which agree with the data in our previous experiments (Kume and Tanabe, 1993; Kume et al., 1995). The secretion of Ca and P in colostrum for 24 h after parturition were largest among minerals, whereas the decreased Ca and P secretion for older cows may be due to the reduced utilization from dam through mammary gland (Kume and Tanebe, 1993). Aging also results in a decline in the ability to mobilize Ca from bone stores and a decline in the active transport of Ca in the intestine (Horst et al., 1997). These results suggest that parity is a main factor for the development of milk fever due to the failure of rapid adaptation in Ca homeostasis.

Compared to the Ca and P, the reverse relationship was observed in plasma and colostral Mg and Zn. This means that colostral Mg and Zn was highest in the first lactation cows, but plasma Mg and Zn was lowest. Calcium, P and Mg are essential for bone formation in ruminants. Of the essential trace elements, Zn can effectively stimulate bone growth and mineralization, and a block of alkaline phosphatase synthesis attributable to the lack of Zn might lead to the retardation of bone growth (Yamaguchi et al., 1989). The lowest plasma Mg and Zn in the first lactation cows may affect bone metabolism at parturition, although plasma alkaline phosphatase was not affected by parity.

In the present experiment, plasma Mg, Fe and Zn in the first lactation cows was lowest from 1 week prepartum to 10 weeks postpartum, but Mg, Fe and Zn concentrations in milk were not affected by parity. Grass tetany is caused by inadequate Mg in extracellular fluids and older cows are more susceptible to grass tetany (NRC, 1988). An imbalance between production and safe disposal of reactive oxygen metabolites may contributes periparturient disorders in dairy cows, and immunity is reduced by inadequacies of antioxidant trace elements, incluing Fe and Zn (Miller et al., 1993). Thus, the increase of plasma Mg, Fe and Zn is needed for the first lactation cows to maintain the health status of high producing cows.

The reduced age at first calving offers management benefit in addition to the decreased feed costs. The reduced costs from a lower age at calving would be beneficial to the overall farm operation (Heinrichs, 1993; Thompson et al., 1983). According to the Japanese dairy herd improvement record (Livestock Improvement Association of Japan, 1996), the age at first calving was expected to be reduced to 24 months, but the average age at first calving in 1995 was 27 months. However, it is not clear whether the reduced age at calving adversely affects mineral status of periparturient cows, although the low plasmg Mg, Fe, and Zn concentrations were observed at frist parity. Further study is needed to clarify the optimal management in mineral status in periparturient cows for the reduced age at first calving.

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