Effect of Parity on Mineral and Vitamin Status of Holstein Cows during Early Lactation

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Abstract Milk and plasma samples from 4 primiparous and 4 multiparous Holstein cows were collected for 10 weeks after parturition to clarify the effects of parity on the mineral and vitamin status of dairy cows during the period of parturition to early lactation. Colostral Ca, P, vitamin A and β -carotene concentrations as well as those concentrations in plasma were higher in primiparous cows than in multiparous cows at parturition. Although colostral Zn concentration of primiparous cows was higher than that of multiparous cows, plasma Zn of primiparous cows was lower. There was a similar trend in plasma Ca, Fe, and Zn with parity at birth and early lactation, but there was a reverse trend for Ca and vitamin A in milk, and plasma vitamin A and β -carotene in primiparous and multiparous cows at birth and early lactation. There was no distinct trend in the change of plasma mineral concentrations during early lactation, while plasma vitamin A and β -carotene concentrations of multiparous cows increased drastically from parturition to early lactation.

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Dairy cattle secrete large quantities of minerals and vitamins into milk during the period of parturition to early lactation. As a result, disturbances in mineral and vitamin metabolism, such as milk fever and grass tetany, are often observed at early lactation¹⁰⁾. Also, some metabolic and reproductive disorders are related to the imbalances of minerals and vitamins in dairy cows around parturition to early lactation^{2, 4, 5, 9, 10)}.

Mineral and vitamin status of dairy cows varies with a number of factors. Lactation number is a factor responsible for the changes in the mineral and vitamin concentration of colostrum or milk and their nutritional status

in postpartum cows^{3, 7, 8)}. However, the relationship between mineral and vitamin removal in colostrum or milk and their status in plasma after parturition has not been well clarified in primiparous and multiparous cows. The objective of this study is to investigate the effects of parity on the mineral and vitamin status of dairy cows during the period of parturition to early lactation.

Materials and Methods

Data from 4 primiparous and 4 multiparous Holstein cows kept at Koibuchi College of Agriculture were collected for 10 weeks after parturition from November 1993 to March 1994.

Cows were managed under similar conditions during the experimental period to meet nutrient requirement of daily cattle¹⁾ for TDN, protein, and minerals. Cows were fed 3 kg of concentrate, 10 kg of corn silage, and oat hay for ad libitum intake during the dry period (Table 1). During the period of parturition to early lactation, cows were fed mainly mixed rations, which consisted of 20% of concentrate, 10% of beet pulp, 3% of cottonseed, 4% of Lucerne hay, 17% of Sudangrass hay, and 40% of corn silage. Vitamin A and β -carotene concentrations in feed were not determined, but approximately 10,000 IU/kg of vitamin A was added in mixed rations from vitamin premix.

Each cow was milked immediately after parturition and at 0500 and 1500 h postpartum. Milk weights were recorded daily. Colostrum samples were collected at parturition and milk samples were collected at equal intervals of 7 days from 1 to 10 weeks postpartum. Milk was a composite sample of morning and evening milking. Blood samples were obtained by jugular puncture into heparinized vacuum tubes at 1100 h on the same day as milk collection and centrifuged immediately after collection. Plasma and milk samples were frozen at -20°C until they were analyzed for minerals

and vitamins.

Colostrum composition and the concentrations of plasma Ca, inorganic P (Pi), Mg, vitamin A, and β -carotene were determined as described previously^{7,8)}. The concentrations of plasma Fe, Zn, and Cu were determined by atomic absorption spectrophotometry after dilution with distilled water.

The general linear models procedure of SAS¹¹⁾ was used to analyze the effect of parity on blood and colostrum composition of cows at parturition. Data from 1 to 10 weeks postpartum were analyzed by least squares ANOVA using the general linear models procedure of SAS¹¹⁾. The model was as follows ;

$$Y_{ijk} = \mu + P_i + C_{(ij)} + T_k + PT_{ik} + e_{ijk}$$

where

μ = overall mean,

P_i = effect of parity,

$C_{(ij)}$ = cows, random variable nested in parity,

T_k = effect of sampling time,

PT_{ik} = interactions, and

e_{ijk} = residuals.

Significance was declared at $P < 0.05$ unless otherwise noted.

Results

There were no metabolic and reproductive

Table 1. Chemical composition of feedstuff

	Mixed ration	Concentrate	Corn silage	Oat hay
	(%, DM basis)			
DM	59.90	87.04	19.94	89.26
CP	15.94	20.47	7.72	11.05
Crude fat	4.70	3.52	3.15	1.42
NDF	40.44	17.47	61.93	68.82
ADF	27.24	11.24	39.78	39.51
Ca	0.65	0.91	0.22	0.35
P	0.39	0.74	0.25	0.28
Mg	0.27	0.33	0.13	0.13
	(ppm, DM basis)			
Fe	167	123	336	3,105
Zn	29.6	51.2	18.5	20.0
Cu	8.2	12.2	8.6	11.4

disorders in primiparous and multiparous cows during 10 weeks after parturition. However, at 4 months postpartum, abortion was observed in a primiparous cow and another primiparous cow died due to kidney disorder.

There were no significant differences in colostrum yield and colostral protein at birth (Table 2). Colostral Ca ($P<0.01$) and P concentrations as well as plasma Ca ($P<0.01$) and Pi ($P<0.01$) were significantly higher in primiparous cows than in multiparous cows at parturition. Although colostral Zn concentration of primiparous cows was significantly ($P<0.01$) higher than that of multiparous cows, plasma Zn concentration of primiparous cows was lower. Plasma Fe concentration of multiparous cows was significantly higher than that of primiparous cows, but there were no significant differences in Mg and Cu concentrations in colostrum and plasma. The concentrations of colostral vitamin A ($P<0.001$) and β -carotene ($P<0.001$) as well as plasma vitamin A and β -carotene ($P<0.01$) of primiparous cows were significantly higher than those of multiparous

cows.

Milk yield ($P<0.001$) and milk protein of multiparous cows were significantly higher than those of primiparous cows during early lactation (Table 3). There was a similar trend in plasma Ca, Fe, and Zn with parity at birth and early lactation, but there was a reverse trend for Ca and vitamin A in milk, and plasma vitamin A and β -carotene in primiparous and multiparous cows at birth and early lactation. Additionally, colostral Mg ($P<0.001$) and Fe or plasma Mg concentrations of primiparous cows were significantly lower than those of multiparous cows during early lactation, but plasma Cu of primiparous cows was higher.

Protein, Ca, P, vitamin A and β -carotene concentrations in milk during early lactation decreased until 5 weeks postpartum and, then, tended to increase gradually, while the highest milk yields were observed at 4 weeks postpartum. There was no distinct trend in the change of Fe, Zn and Cu concentrations in milk and plasma mineral concentrations during early lactation, while there was a obvious trend

Table 2. Mineral and vitamin concentration of colostrum and plasma in primiparous and multiparous cows at parturition

	Colostrum		SEM	Plasma		SEM
	Primiparous	Multiparous		Primiparous	Multiparous	
n	4	4		4	4	
Age, mo.	25.8 ^d	48.1 ^c	2.9			
Milk yield, kg/d	2.0	2.8	0.9			
Protein, %	14.8	14.0	0.9			
Ca, mg/dl	284 ^c	234 ^d	7	10.9 ^c	8.9 ^d	0.3
P, mg/dl	234 ^a	217 ^b	4	6.1 ^{1,c}	4.1 ^{1,d}	0.3
Mg, mg/dl	44.5	40.5	1.3	2.18	2.29	0.07
Fe, ppm	1.3	1.2	0.1	0.52 ^b	1.28 ^a	0.15
Zn, ppm	25.7 ^c	17.5 ^d	1.4	0.32 ^d	0.57 ^c	0.04
Cu, ppm	0.30	0.34	0.02	0.81	1.02	0.09
vitamin A, μ g/dl	377 ^e	186 ^f	16	28.4 ^a	20.0 ^b	2.2
β -carotene, μ g/dl	135 ^e	65 ^f	7	234 ^c	98 ^d	19

^{a,b} Means within colostrum or plasma of same row with different superscript letters differ ($P<0.05$).

^{c,d} Means within colostrum or plasma of same row with different superscript letters differ ($P<0.01$).

^{e,f} Means within colostrum or plasma of same row with different superscript letters differ ($P<0.001$).

¹ Inorganic P.

Mineral and Vitamin Status of Cows

Table 3. Mineral and vitamin concentration of milk and plasma in primiparous and multiparous cows during 10 week after parturition

	Milk		SEM	Plasma		SEM
	Primiparous	Multiparous		Primiparous	Multiparous	
n	40	40		40	40	
Milk yield, kg/d	20.5 ^f	29.2 ^e	0.4			
Protein, %	3.0 ^b	3.4 ^a	0.1			
Ca, mg/dl	112 ^d	117 ^c	1	10.8 ^e	9.9 ^f	0.1
P, mg/dl	89	91	1	5.2 ¹	5.5 ¹	0.1
Mg, mg/dl	9.1 ^f	10.7 ^e	0.1	2.36 ^b	2.49 ^a	0.04
Fe, ppm	0.65 ^b	0.78 ^a	0.04	1.10 ^f	1.34 ^e	0.04
Zn, ppm	3.6	3.6	0.1	0.80 ^f	0.92 ^e	0.02
Cu, ppm	0.29	0.27	0.01	1.00 ^a	0.92 ^b	0.03
vitamin A, $\mu\text{g/dl}$	27.0 ^b	31.3 ^a	1.5	39.0 ^f	54.8 ^e	0.9
β -carotene, $\mu\text{g/dl}$	7.2	8.0	0.5	185 ^f	313 ^e	8

^{a,b} Means within milk or plasma of same row with different superscript letters differ ($P < 0.05$).

^{c,d} Means within milk or plasma of same row with different superscript letters differ ($P < 0.01$).

^{e,f} Means within milk or plasma of same row with different superscript letters differ ($P < 0.001$).

¹ Inorganic P.

Fig. 1. Plasma vitamin A concentration of primiparous (■) and multiparous (●) cows during 10 week after parturition (SEM=3.0).

Fig. 2. Plasma β -carotene concentration of primiparous (■) and multiparous (●) cows during 10 week after parturition (SEM=24).

in the plasma vitamin A and β -carotene with parity. Plasma vitamin A concentration of multiparous cows increased ($P < 0.001$) drastically from parturition to 4 weeks postpartum and remained constant, while the increase rate of plasma vitamin A of primiparous cows was small (Fig. 1). Plasma β -carotene

concentration of multiparous cows increased ($P < 0.001$) drastically from parturition to 10 weeks postpartum (Fig. 2). However, plasma β -carotene of primiparous cows decreased until 4 weeks postpartum and then increased ($P < 0.001$) drastically.

Discussion

Most metabolic disorders occur at shortly after parturition and reflect a failure of the cow to adjust to the rapid onset and stress of high milk production¹⁰. Mineral and vitamin needs for lactating cows were enhanced after parturition because of their transfer to colostrum or milk. KUME *et al.* reported that the lowest fat, protein, Ca, P, and Mg concentrations in milk were observed at 5 weeks postpartum in contrast with the increase of milk yield⁶, which agree with the results of present experiment, including the changes in vitamin A and β -carotene in milk.

Parity is a factor altering the mineral and vitamin status of dairy cows^{3,4,7,8}. Plasma Ca and Pi concentrations of dairy cows decreased around parturition because of the large transfer of Ca and P to colostrum, and older cows had a greater risk of developing milk fever⁴. However, we reported that Ca and P losses in colostrum at parturition tended to decrease after third lactation⁷. In the present experiment, plasma Ca and Pi of multiparous cows at parturition were lower than those of primiparous cows, and total Ca and P secretions in colostrum at parturition were slightly higher in multiparous cows. SHAPPELL *et al.*¹² reported that hypocalcemia and transfer of Ca to colostrum were not correlated. These results suggest that parity is the main factor for the development of milk fever due to the failure of rapid adaptation in Ca and P homeostasis, but further study is needed to clarify the relationship between Ca and P removal in colostrum and their status in plasma or bone at parturition.

Grass tetany is caused by inadequate Mg in critical extracellular fluids and older cows are more susceptible to grass tetany¹⁰. In the present experiment, however, plasma Mg of multiparous cows during early lactation was higher than that of primiparous cows, although Mg secretion into milk of multiparous

cows was greater. Also, plasma Fe and Zn of multiparous cows were higher than those of primiparous cows, while plasma Ca and Cu of multiparous cows were lower. Thus, although parity may be a factor altering mineral status of cows during early lactation, the relationship between mineral removal in milk and their status of cows were not well clarified in the present experiment.

The reverse relationships were observed for the concentrations of plasma vitamin A and β -carotene of primiparous and multiparous cows at parturition and early lactation, which coincided with the changes of those concentrations in milk. The biological function of β -carotene and other carotenoids is widely accepted to be independent of their provitamin A activity². In the present experiment, however, the similar trend was observed in vitamin A and β -carotene concentrations in plasma and milk of primiparous and multiparous cows, although dietary β -carotene level was not clarified. These results suggest that there is a close relationship between vitamin A and β -carotene status of cows during early lactation.

There were no metabolic and reproductive disorders in primiparous and multiparous cows during early lactation, but the abortion and death occurred in primiparous cows at 4 months postpartum. The reason for the abortion and death is not clear, but compared to multiparous cows, the concentrations of plasma Mg, Fe, Zn, vitamin A, and β -carotene of primiparous cows were lower. Immunity and animal health are impaired by inadequacies in some minerals and vitamins, including Fe, Zn, Cu, vitamin A and β -carotene, which are required for antioxidant defence⁹. Thus, it is possible that the health status of primiparous cows was adversely affected by the low plasma concentrations of Fe, Zn, vitamin A and β -carotene, but further study is needed to clarify the effect of mineral and vitamin status on the immunity of lactating cows.

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ホルスタイン種乳牛の泌乳前期におけるミネラル およびビタミン栄養に及ぼす産次の影響

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分娩直後から泌乳前期における乳牛のミネラルおよびビタミン栄養に及ぼす産次の影響を明らかにするために，初産牛4頭および経産牛4頭から乳および血漿を分娩後10週間採取した．分娩直後における初産牛の初乳および血漿中のCa，P，ビタミンAおよび β -カロテン濃度は，経産牛のそれらより高かった．分娩直後における初産牛の初乳中Zn含量は経産牛のそれより高かったが，血漿中のZn濃度は初産牛で低かった．産次間におけるミネラルおよびビタミン濃度を比較すると，血漿中のCa，FeおよびZn濃度は分娩直後と泌乳前期で同じ傾向が認められたのに対して，乳中のCaおよびビタミンA含量並びに血漿中のビタミンAおよび β -カロテン濃度は異なった傾向を示した．泌乳前期における血漿中のミネラル濃度の変動には明確な傾向は認められなかったが，経産牛の血漿中ビタミンAおよび β -カロテン濃度は分娩直後から泌乳前期にかけて急激に増加した．

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