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Effects of High Potassium Intake from Alfalfa Silage on Mineral Status in Sheep and Periparturient Cows

S. KUME[a], T. TOHARMAT[b], M. RIDLA[b], K. NONAKA[a], T.OSHITA[a], M. NAKAMURA[a], Y. YAMADA[a] and J.H.TERNOUTH[c]

Abstract

Fifteen wethers were allocated to examine the effect of *ad libitum* intake and macerated treatment of alfalfa on mineral balance in Experiment 1. The K absorption rate in alfalfa silage was 95 to 97% for sheep, but plasma K was not affected by high K absorption. The K absorption rate of sheep fed large amounts of K was maintained at high level, although absorption rates of Ca and P decreased. Maceration improved Ca, P and Mg absorption in sheep. Sixteen multiparous Holstein cows were used, and four cows were assigned to an alfalfa silage diet or an orchardgrass silage diet in Experiment 2 and an alfalfa silage diet or an alfalfa plus corn silage diet in Experiment 3 from 4 weeks prepartum to 1 week postpartum to examine the effect of prepartum diet on the mineral status of periparturient cows. In the prepartum diet, the roughage to concentrate ratio was 70:30 of the total diet with alfalfa being 35% in Experiment 1 and 20% in Experiment 2, and dietary K contents ranged from 1.49 to 2.30% in each diet. Milk fever occurred in 2 cows fed the alfalfa diet in Experiment 2, and the occurrence of milk fever may be partly due to the impaired activity of PTH. Plasma Ca, inorganic P and hydroxyproline of the cows with milk fever decreased at parturition, although plasma PTH was not affected by the high K alfalfa diet. Plasma glucose and 1,25-dihydroxyvitamin D of the cows fed the alfalfa plus corn silage diet was higher in Experiment 3. These results suggest that the K absorption rate of ruminants fed alfalfa was high level, and alfalfa plus corn silage diet improve mineral status of periparturient cows because of the increased DM intake and decreased dietary K contents.

Key words: Alfalfa, High potassium, Mineral balance, Periparturient cows, Sheep

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a) National Agricultural Research Center for Hokkaido Region, Sapporo 062-8555, Japan
b) Bogor Agricultural University, Bogor, Indonesia
c) School of Animal Studies, The University of Queensland, Gatton, Qld 4343, Australia

Introduction

Alfalfa is suitable roughage for high producing cows because of the high protein content and high passage rate through the gut. The optimal CP content of alfalfa when fed in combination with corn silage should be 20% (Buxton, 1996). On the other hand, the K content of forages like in alfalfa is more important than the Ca content in predisposing cows to milk fever, and the incidence of milk fever was increased simply by increasing the K concentration in the prepartum diet from 1.1 to 2.1% (Goff and Horst, 1997a). Highly positive correlations were observed between CP and K in alfalfa, and alfalfa with 20% of CP contained 3.49, 3.31 and 2.88% of K in the first, second, and third cutting (Kume et al., 2001).

High producing cows in early lactation cannot consume sufficient DM to support maximal milk yield. As a result, body weight of cows decreases drastically immediately after parturition, and negative retention of N, Ca, P, Mg and K is due to the great secretion into milk (Kume et al., 2001). The metabolic alkalosis is an important factor in the occurrence of milk fever, and the use of high K diet in the transition diet of the dry cow should be limited to prevent the milk fever (Horst et al., 1997). In the previous study (Kume et al., 2001), low K alfalfa diet was found to stimulate PTH secretion of periparturient cows, and the increased PTH of cows enhanced bone resorption and Ca absorption from the gut immediately around parturition. However, the utilization of mature alfalfa might lower feed intake during the transition period due to its higher NDF content, although alfalfa harvested in a mature stage is lower in K concentration than alfalfa at a vegetative stage (Horst et al., 1997). Compared to alfalfa or grass silage, K contents in corn silage were low level (Kume et al., 2003a), and feeding corn silage for periparturient cows may be useful to prevent the milk fever and increase energy supply.

Because the annual increase in milk yield and composition is likely to continue in Japan, the improvement in the feeding regimen for high producing cows, especially during periparturient and early lactation period, is a main strategy to reduce the metabolic disorder and enhance milk production (Kume et al., 2002). However, it is not clear whether high K alfalfa affects mineral balance in ruminants or health status in periparturient cows. The present study was conducted to evaluate the effect of high K intake from alfalfa silage on the mineral balance of sheep and periparturient cows, and to clarify the effect of high K alfalfa on the DMI, milk yield, herd health and mineral status of periparturient Holstein cows.

Materials and Methods

Experimental design in sheep

Second cutting alfalfa was harvested and ensiled in wrapped large round bales to examine the effect of *ad libitum* intake and macerated treatment of alfalfa on mineral balance of wethers in Experiment 1. Sixteen mature Corriedale wethers were utilized, and four wethers were allocated randomly to four treatments. The wethers were fed 1) the maintenance requirement of TDN (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1996) with conventional conditioning of alfalfa, 2) the maintenance requirement of TDN with macerated treatment of alfalfa, 3) *ad libitum* with conventional conditioning of alfalfa and 4) *ad libitum* with macerated treatment of alfalfa. Maceration was processed with a large-scale forage mat maker prior to wilting, and control conditioning was tedded and wilted (Nonaka et al., 2001). Wethers were placed in the digestion cages for 2 weeks, and balance trials were performed for 7 days of the second week. Silages were offered once daily and feed refusals were recorded every day. One wether fed maintenance level with macerated treatment was excluded due to the rapid decrease of feed intake during balance trial.

The chemical compositions of alfalfa in Experiment 1 were shown in Table 1. Feces and urine from each wether were separately collected daily during the balance trials. Blood was sampled via a jugular vein puncture into heparinized vacuum tubes prior to feeding in the last day of balance trial.

Experimental design in periparturient cows

Sixteen multiparous Holstein cows were used in Experiments 2 and 3. Eight multiparous cows in Experiment 2 consisted of three second, one third, three fourth and one sixth lactation cows, and 8 cows in Experiment 3 consisted of one second, five third and two sixth lactation cows. Four cows were assigned to an alfalfa silage (AS35) diet or an orchardgrass silage (OS) diet in Experiment 2 and an alfalfa silage (AS20) diet or an alfalfa plus corn silage (CS) diet in Experiment 3 from 4 weeks before the expected calving date to 1 week postpartum based on the parity and pre-milk yield. The gestation length was assumed to be of 280 days. The cows were fed as a TMR to meet 120% of TDN requirement for maintenance plus last 2 months of gestation (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1994) from 4 weeks prepartum to parturition. The TDN contents in the roughage and concentrates were estimated by the standard tables of feed composition in Japan (Agriculture, Forestry, and Fisheries Research Council Secretariat, 1995). The concentrate mix was formula feed, barley, corn, oat, soybean meal or fish meal. After parturition cows were fed ad libitum as a TMR.

In the prepartum and postpartum diet in Experiment 2, the roughage to concentrate ratio was 70:30 and 50:50, with alfalfa being 35 and 50% of the total diet, respectively (Table 2). In Experiment 3, roughage and concentrates were given in the ratio of 70:30 during the prepartum period with alfalfa or corn being 20% of the total diet. In the postpartum diet, roughage to concentrate ratio in the AS20 diet was 50:50, with alfalfa being 30% and orchardgrass being 20% of the total diet. Also, roughage to concentrate ratio in the CS diet was 60:40 with alfalfa, corn and orchardgrass being 20% of the total diet. Chemical composition of each diet was shown in Table 1, and dietary cation-anion difference (DCAD) was calculated as milliequivalent of (Na+K) − (Cl+S) per kgDM.

In Experiment 2, alfalfa silage contained 15.3% of CP, 54.8% of NDF, 0.92% of Ca, 0.22% of P, 0.21% of Mg and 3.26% of K, and orchardgrass silage contained 13.1% of CP, 62.8% of NDF, 0.53 % of Ca, 0.23% of P, 0.22% of Mg and 2.13% of K. In Experiment 3, corn silage contained 8.0% of CP, 34.7% of NDF, 0.18% of Ca, 0.16% of P, 0.11% of Mg and 1.07% of K. Also, alfalfa silage contained 16.7% of CP, 44.8% of NDF, 1.38% of Ca, 0.30% of P, 0.21% of Mg and 3.34% of K, and orchardgrass silage contained 13.0% of CP, 64.2% of NDF, 0.52% of Ca, 0.25% of P, 0.19% of Mg and 2.23% of K.

The cows were managed in individual tie stalls and a paddock. The cows were fed equal amounts at 08.30 and 16.30 h, and feed refusals were recorded every day. The body weights of cows were measured each week in prepartum period, and 1 and 6 days after parturition. In Experiment 2, balance studies were performed for 4 cows within 8 cows, and 4 cows were housed in the metabolic chamber during 7 days in the 2nd week before the expected calving date. The metabolic chamber was maintained at 20 C and 60% relative humidity. Feces and urine from each cow were separately collected daily during the balance trials.

The cows were milked twice daily, and milk weights were recorded. Colostrum samples were taken within 12 h after birth. Blood was sampled via a jugular vein puncture into heparinized vacuum tubes prior to feeding at 08.30 h at 2 and 1 weeks before and 2 days before the expected calving date, at the parturition, and 1 and 6 days after parturition for the determination of plasma composition. At parturition, blood samples were taken within 12 h after birth.

Analytical method

Samples of feces, feed and feed refusals were oven-dried for 48 h at 60 C and ground to pass a 1-mm screen. The contents of DM, OM, CP, ADF, NDF, ether extract and minerals of feed, feed refusal and feces or N and mineral contents in urine were determined as previously described (Kume et. al., 2001). The solids, fat, protein, lactose and minerals in colostrum and plasma minerals, hydroxyproline and PTH were determined as previously described (Kume et. al., 2001). Plasma glucose and nonesterified fatty acid (NEFA) were determined by an Automatic analyzer (7250, Hitachi, Co. Ltd.), and plasma 1,25-dihydroxyvitamin D (1,25-$(OH)_2$D) was determined by the immunoassay (Fraser et al., 1997).

Statistic analyses

The general linear models procedure of SAS (1988) was used to analyze the effect of silage treatment and feeding level on mineral balance in Experiment 1. The general linear models procedure of SAS (1988) was used to analyze the effect of diet on colostrum composition, plasma composition and mineral balance in Experiments 2 and 3. Because milk fever occurred in 2 cows in Experiment 2, data from DMI, body weight, colostrum and blood samples in Experiment 2 were analyzed by the treatments in the cows fed OS, the normal cows fed AS35 (AS-N) and the cows with milk fever fed AS35 (AS-MF). The model was as follows:

$$Y_{ijk} = \mu + T_i + C_{(i)j} + D_k + TD_{ik} + e_{ijk}$$

where μ is the overall mean, T_i the effect of treatment, $C_{(i)j}$ the random variable caused by cow nested in treatment, D_k the effect of sampling day, TD_{ik} the interactions and e_{ijk} the residuals.

Significance was declared at $P<0.10$. The differences were tested by least significant differences.

Results and Discussion

High K intake on mineral status of sheep

Compared to the wethers fed at the maintenance level, DM intake of the wethers fed at *ad libitum* level with conventional and macerated alfalfa were 1.60 and 1.46 times higher (Table 3). Urine volume of wethers was not affected by the treatments, but the maceration enhanced ($P<0.001$) the urine pH. The decreased ($P<0.01$) digestibility of DM was observed in the wethers fed at *ad libitum* level, and the maceration decreased ($P<0.01$) digestibility of DM. Maceration increased the absorption and retention of Ca ($P<0.001$) and P ($P<0.001$), but Ca absorption and retention of wethers fed at *ad libitum* level with conventional conditioning of alfalfa was lower ($P<0.05$) than those fed at the maintenance level. Maceration increased Mg absorption ($P<0.05$) and retention ($P<0.001$), and Mg absorption of wethers fed at *ad libitum* level was higher ($P<0.001$). Maceration decreased ($P<0.05$) K retention of wethers, and K absorption of wethers fed at *ad libitum* level was higher ($P<0.001$). Plasma Ca, Pi, Mg and K of wethers were not affected by the silage treatment or feeding level.

The K absorption rate in alfalfa silage was very high, amounting to 95-97% for sheep in this experiment. In addition, K absorption rate of sheep fed large amounts of K from *ad libitum* intake of alfalfa silage was maintained at high level, although the absorption rates of Ca and P decreased at *ad libitum* intake. Most of the absorbed K from alfalfa was excreted in urine, but urine volume and plasma K was not affected by the high K absorption in sheep. It is known that the urine volume of cows was related positively to urinary K excretion (Bannink et al., 1999; Kume et al., 2003a; National Research Council, 2001). In the previous study (Kume et al., 2003a), K absorption rate of dry cows fed alfalfa silage was 88%. The highly positive correlations were observed between CP and K in the first and second cutting alfalfa, and K contents in alfalfa reduced with maturity (Kume et al., 2001). Thus, ruminants fed high K alfalfa at a vegetative stage or large amounts of alfalfa may absorb more K, but it is not clear whether high K absorption adversely affect Ca and P metabolism in sheep.

Maceration, a method of mechanical conditioning originally developed to increase field-drying rate, was also found to increase digestibility and net energy for lactation of alfalfa silage (Broderick et al., 1999). In this study, maceration improved Ca, P and Mg absorption in sheep and increased urinary K excretion, although the reason for the negative retention of Ca, P and Mg in the control conditioning was not clear. Rominger et al. (1975) reported that leaves of alfalfa contained higher concentrations of Ca, P, Mg and N than stems or roots, but stems contained more K. Because maceration intensifies the conditioning by crushing and shredding the stems and homogenizing the leaves and stems (Hintz et al., 1999), maceration may improve the utilization of minerals in the leaves and stems of alfalfa. However, further study is needed to utilize the macerated alfalfa for dairy cows, because maceration had no effect on digestibility and energy utilization (Nonaka et al., 2001) or mineral utilization (Kume et al., unpublished data) of dry cows in the previous experiment.

High K diet on mineral status of periparturient cows

Dry cow diets that are high in K or Na alkalinize the blood of cows and increase the susceptibility of milk fever (National Research Council, 2001). In the previous experiment (Kume et al., 2001), low K alfalfa diet was found to stimulate PTH secretion of periparturient cows and the increased PTH of cows enhances bone resorption and Ca absorption from the gut immediately around parturition. In Experiment 2, milk fever occurred in a third and a fourth lactation cows fed the AS diet at 1 day after parturition and these cows were unable to rise, but no metabolic disorders were detected in the other cows. After the appropriate therapy, including intravenous Ca infusion of the cows with milk fever, one cow was recovered, but the other cow was slaughtered because of the failure to recover within 1week after the therapy.

Prepartum DMI of the cows fed the AS35 diet ($P<0.05$) was higher than that of cows fed the OS diet in Experiment 2 and prepartum DMI of the cows fed the CS diet ($P<0.05$) was higher than that of cows fed the AS20 diet in Experiment 3, because the feed offered was different due to the BW of each cow (Table 2). The DMI of the cows with milk fever decreased drastically at parturition in Experiment 2. Except for the cows with milk fever, milk yield and DMI of each cow in Experiments 2 and 3 increased drastically immediately after parturition, and body weights decreased from 1 to 6 days after parturition (Figures 1 and 2). There were no significant differences in colostrum yield of cows between diets in Experiments 2 and 3, but colostrum yield of cows in Experiment 3 were 2 to 3 times higher than that in Experiment 2 (Table 2). Milk solid, fat, protein, lactose, Ca, P, Mg, Na and K in colostrum of cows were not affected by the diet in Experiments 2 and 3.

The large amounts of nutrients in the body were secreted into colostrum because of the high colostrum yield in Experiment 3. The average Ca secretions of cows at parturition were 7 and 16g in Experiments 2 and 3, respectively, and Ca secretion of cows with milk fever was 6.9g. In the previous experiment (Kume et al., 2003b), plasma Ca and Pi concentrations of the third and more lactation cows decreased drastically around parturition because of large transfer of Ca and P to colostrum. However, the occurrence of milk fever was not affected by the large Ca secretion in this study. Shappel et al. (1987) showed that hypocalcemia and the amounts of Ca secretion to colostrum were not correlated in multiparous dairy cows. Although the large transfer of Ca to colostrum was a factor for the development of low plasma Ca in multiparous cows (National Research Council, 2001), another factor may influence the occurrence of milk fever in this study.

In the balance study of Experiment 2, 2 cows in AS35 diet consisted of one normal cow and one cow with milk fever. Urine volume and pH of cows were not affected by the treatment (Table 4). The digestibility of ADF ($P<0.05$) and NDF ($P<0.10$) of cows fed the AS35 diet were higher than that of cows fed the OS diet, but the digestibility of DM and OM was not affected by the treatment. The Ca intake of cows fed the AS35 diet was higher ($P<0.10$) than that of cows fed the OS diet, but P absorption and retention were lower ($P<0.05$). The K intake and absorption of cows fed the AS35 diet were higher ($P<0.10$) than those of cows fed the OS diet, and the absorption rates of K in cows fed the AS35 and OS diets were 82.8 and 67.3%, respectively.

Plasma glucose of the cows with milk fever at parturition was higher ($P<0.05$) than that of the normal cows fed the AS35 diet and the cows fed the OS diet in Experiment 2 (Figure 1), and plasma NEFA of the cows with milk fever at 1 day after parturition was higher ($P<0.05$). Compared to the cows fed the OS diet and normal cows fed the AS35 diet, plasma Ca and Pi of the cows with milk fever decreased ($P<0.05$) drastically at parturition and 1 day after parturition, and the concentrations of plasma Ca and Pi at 1 day after parturition were 4.2 and 1.4mg/dl, respectively. Plasma PTH was not affected by the diet, but plasma hydroxyproline of the cows with milk fever and cows fed the OS diet were lower ($P<0.05$) than those of the normal cows fed the AS35 diet at parturition and 1 day after parturition. Plasma Mg, Na and K of cows were not affected by the diet.

In Experiment 3, plasma glucose of the cows fed the CS diet was higher ($P<0.01$) than that of the cows fed the AS20 diet (Figure 2), but plasma NEFA, Ca, and Pi were not affected by the diet. Plasma Ca and Pi decreased at parturition, and plasma Ca of the cows fed the AS20 and CS diets at parturition were 7.8 and 8.5mg/dl, respectively. Although plasma PTH and hydroxyproline were not affected by the diet, plasma 1,25-$(OH)_2$D of the cows fed the CS diet was higher ($P<0.05$) than that of the cows fed the AS20 diet. There were no significant differences in plasma Mg, Na and K of cows between diets.

Metabolic alkalosis is considered to prevent tight binding of PTH to its receptor so that bone resorption and production of 1,25-dihydroxyvitamin D are impaired reducing the ability to successfully adjust to the Ca demand of lactation (National Research Council, 2001). The low K alfalfa diets stimulates PTH secretion of cows immediately around parturition (Kume et al., 2001), but the response of plasma PTH of cows fed the high K alfalfa diet varied in Experiments 2 and 3. Although K concentration of cows fed AS35 diet in Experiment 2 was slightly lower than that of cows fed AS20 diet in Experiment 3, milk fever did not occur in Experiment 3. Because the cows developed milk fever had adequate plasma PTH and low plasma hydroxyproline, a biochemical marker of the resorption activity of bone collagen (Kume et al., 2001), the occurrence of milk fever may be partly due to the impaired activity of PTH in Experiment 2.

Alfalfa plus corn silage diet stimulated 1,25-$(OH)_2$D secretion of cows in Experiment 3, although PTH secretion was not affected. Dry cow diets that are high in K or Na alkalinize the blood of cows and increase the susceptibility of milk fever (National Research Council, 2001). Goff and Horst (1997b) reported that the incidence of milk fever of cows was increased simply by increasing the K concentration in the prepartum diet from 1.1 to 2.1%. In the previous experiment (Kume et al., 2001), the increased PTH of cows fed low K alfalfa diet enhances bone resorption and Ca absorption from the gut immediately around parturition. In addition, the large transfer of Ca to colostrum in older cows may enhance the risk of milk fever, and the reducing severity and duration of negative energy balance is crucial in the prevention of fatty liver and ketosis (Kume and Tanabe, 1993; Kume et al., 2003b; National Research Council, 2001). In this experiment, body weight of each cow decreased drastically immediately after parturition, but the plasma glucose and prepartum DMI were higher in the cows fed the CS diet. Goff and Horst (1997b) showed that cows that have milk fever exhibit a greater decline in feed intake after calving and hypocalcemia prevents the secretion of insulin which limits tissue uptake of glucose. Joyce et al. (1997) reported that a diet based on alfalfa and supplemented with 5 eq of anionic salts is viable for prepartum dairy cows, because cows fed this diet had highest serum Ca and consumed most dry matter postpartum. Also, alfalfa plus corn silage diet may improve Ca status of periparturient cows, because corn silage is less likely to accumulate K and contain high energy.

Although alfalfa contained more K, cows fed alfalfa silage produced more milk than did cows fed grass silage due to the high DMI and high passage rate through the gut during early lactation (Kume, 2002). Because the improvement in the feeding regimen such as alfalfa plus corn silage diet for high producing cows during periparturient period is useful to reduce the metabolic disorder and enhance milk production, further study is needed to clarify the relationships among feeding regimen, milk production and health status in high producing cows.

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Table 1. Chemical composition of alfalfa treated with control conditioning (C) or maceration (M)[1] in Experiment 1.

	Experiment 1	
	C	M
Nutrient		
DM	69.1	50.3
CP	16.4	17.4
Ca	0.88	1.20
P	0.27	0.35
Mg	0.24	0.26
Na	0.03	0.04
K	2.20	2.37

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

Table 2. Ingredient and chemical composition of complete diets based on orchardgrass silage (OS), and alfalfa silage (AS35) in Experiment 2 and alfalfa silage (AS20) and alfalfa plus corn silage (CS)[1] in Experiment 3.

	Experiment 2		Experiment 3	
	OS	AS35	AS20	CS
Ingredient				
Orchardgrass silage	70.0	35.0	50.0	30.0
Alfalfa silage	--	35.0	20.0	20.0
Corn silage	--	--	--	20.0
Concentrate	30.0	30.0	30.0	30.0
Nutrient				
DM, %	43.1	54.0	46.0	49.7
OM, %	92.9	92.3	90.8	93.5
CP, %	16.7	16.5	16.0	14.1
ADF, %	32.6	33.9	30.9	26.4
NDF, %	53.8	47.4	46.6	40.6
Ether extract, %	4.1	4.0	4.1	3.9
Ca, %	0.49	0.67	0.73	0.62
P, %	0.39	0.41	0.32	0.31
Mg, %	0.17	0.18	0.20	0.19
Na, %	0.26	0.17	0.17	0.12
K, %	1.49	2.04	2.30	1.62
Cl, %	0.73	0.81	0.94	0.70
S, %	0.26	0.27	0.23	0.23
DCAD2, meq/kg	126	199	254	126

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

[2]Calculated as milliequivalents of (Na+K)−(Cl+S).

Table 3. Means of mineral balance and plasma composition of wethers fed maintenance or *ad libitum* level of alfalfa silage treated with control conditioning (C) or maceration (M) in Experiment 1.

	Maintenance		*ad libitum*			Effect(*P*)		
	C	M	C	M	SEM	Silage	Level	SxL[1]
Number of wethers	4	3	4	4				
BW , kg	80.9	77.8	79.5	75.3	6.2	NS	NS	NS
DM intake, kg/day	0.92	0.87	1.47	1.27	0.10	NS	***	NS
Urine								
Volume, kg/day	2.17	1.66	1.67	1.69	0.37	NS	NS	NS
pH	9.11	9.23	9.18	9.22	0.02	***	NS	NS
Digestibility , %								
DM	54.1	51.5	51.8	47.8	0.8	**	**	NS
Ca	−3.1	15.6	−7.3	13.2	0.7	***	*	NS
P	−9.7	15.1	−8.5	9.3	1.1	***	NS	NS
Mg	22.5	24.6	17.3	25.5	1.0	*	NS	NS
K	97.3	96.6	95.5	95.3	0.4	NS	NS	NS
Ca balance, mg/kgBW/day[2]								
Intake	100.2	131.7	164.0	203.9	11.2	**	***	NS
Apparent absorption	−3.1	20.6	−11.4	26.8	2.2	***	NS	**
Retention	−4.2	20.3	−12.2	26.0	2.2	***	NS	*
P balance, mg/kgBW/day								
Intake	30.6	41.6	50.1	64.3	3.5	**	***	NS
Apparent absorption	−3.0	6.3	−4.3	6.2	1.1	***	NS	NS
Retention	−3.8	5.5	−5.0	5.3	1.1	***	NS	NS
Mg balance, mg/kgBW/day								
Intake	26.9	28.7	44.1	44.3	2.6	NS	***	NS
Apparent absorption	6.1	7.1	7.6	11.3	0.8	*	**	NS
Retention	−1.7	1.8	−2.9	1.8	0.4	***	NS	NS
K balance, mg/kgBW/day								
Intake	249.6	260.8	408.6	403.6	23.8	NS	***	NS
Apparent absorption	242.8	251.8	390.8	384.3	23.2	NS	***	NS
Retention	71.4	−17.3	97.1	−47.2	46.4	*	NS	NS
Plasma Composition								
Ca, mg/dl	11.2	10.7	10.8	10.7	0.1	NS	NS	NS
Pi, mg/dl	5.6	6.8	6.4	5.8	0.2	NS	NS	NS
Mg, mg/dl	2.4	2.3	2.5	2.6	0.1	NS	NS	NS
K, mEq/l	5.0	4.6	4.8	4.7	0.1	NS	NS	NS

****P*<0.001, ***P*<0.01, **P*<0.05.

[1]Interaction between silage treatment and level.

[2]Apparent absorption = intake − fecal excretion; Retention = intake − (fecal excretion + urine excretion).

Table 4. Least squares means of colostrum composition of cows fed orchardgrass silage (OS), and alfalfa silage (AS35) in Experiment 2 and alfalfa silage (AS20) and alfalfa plus corn silage (CS) in Experiment 3 at parturition.

	Experiment 2			Experiment 3		
	GS	AS35	SEM	AS20	CS	SEM
n	4	4		4	4	
Age, mo	56.4	54.5	9.5	63.6	60.3	10.8
Gestation length, day	282	280	3	283	279	2
Calf birth weight, kg	47.6	44.4	3.5	46.8	46.3	2.2
BW[1], kg	727	782	36	735	798	38
DMI[1], kg/day	9.7[b]	11.5[a]	0.3	9.8[b]	10.8[a]	0.3
DMI/BW[1], %	1.34	1.47	0.09	1.34	1.37	0.08
Milk production						
Milk yield, kg	2.9	2.4	0.3	7.5	5.9	1.2
Total solid, %	29.1	30.7	2.9	25.0	26.2	2.4
Protein, %	16.9	17.7	1.7	14.7	14.6	1.0
Fat, %	5.5	5.3	0.9	4.4	5.4	1.6
Lactose, %	2.5	2.8	0.2	2.4	2.9	0.2
Ca, mg/100g	243	295	36	212	273	22
P, mg/100g	198	246	24	184	227	20
Mg, mg/100g	48.9	57.0	8.1	39.1	41.2	6.1
Na, mg/100g	61.5	54.7	5.2	65.8	57.5	3.3
K, mg/100g	152	145	9	149	160	7

[a,b] $P<0.05$

[1]Data from 14 to 1 day prepartum.

Table 5. Means(SD) of prepartum digestibility, energy intake, N and mineral balance of cows based on orchardgrass silage (OS) and alfalfa silage (AS35) diet in Experiment 2.

	OS	AS35	SEM
Number of cows	2	2	
BW, kg	738	784	80
DM intake, kg/day	8.4	10.2	0.5
Water intake, kg/day	20.7	25.0	8.4
Urine			
Volume, kg/day	11.6	12.9	4.0
pH	8.22	8.30	0.10
Digestibility, %			
DM	68.6	67.0	1.7
ADF	65.3[c]	56.8[d]	1.3
NDF	66.7[a]	57.4[b]	1.6
N balance, g/day[1]			
Intake	243	274	13
Apparent absorption	164	188	19
Retention	−14	25	53
Ca balance, g/day			
Intake	42.4[b]	68.6[a]	5.0
Apparent absorption	13.2	11.3	2.8
Retention	9.6	9.6	1.9
P balance, g/day			
Intake	35.5	42.8	2.6
Apparent absorption	8.5[c]	5.4[d]	0.3
Retention	7.4[c]	4.3[d]	0.3
Mg balance, g/day			
Intake	14.9	18.4	1.0
Apparent absorption	3.6	1.9	1.2
Retention	0.9	0.2	1.4
K balance, g/day			
Intake	123.2[b]	200.5[a]	15.1
Apparent absorption	83.0[b]	166.3[a]	14.6
Retention	−38.7	−10.2	33.4

[a, b] $P<0.10$, [c,d] $P<0.05$

[1]Apparent absorption = intake − fecal excretion;

Retention = intake − (fecal excretion + urine excretion).

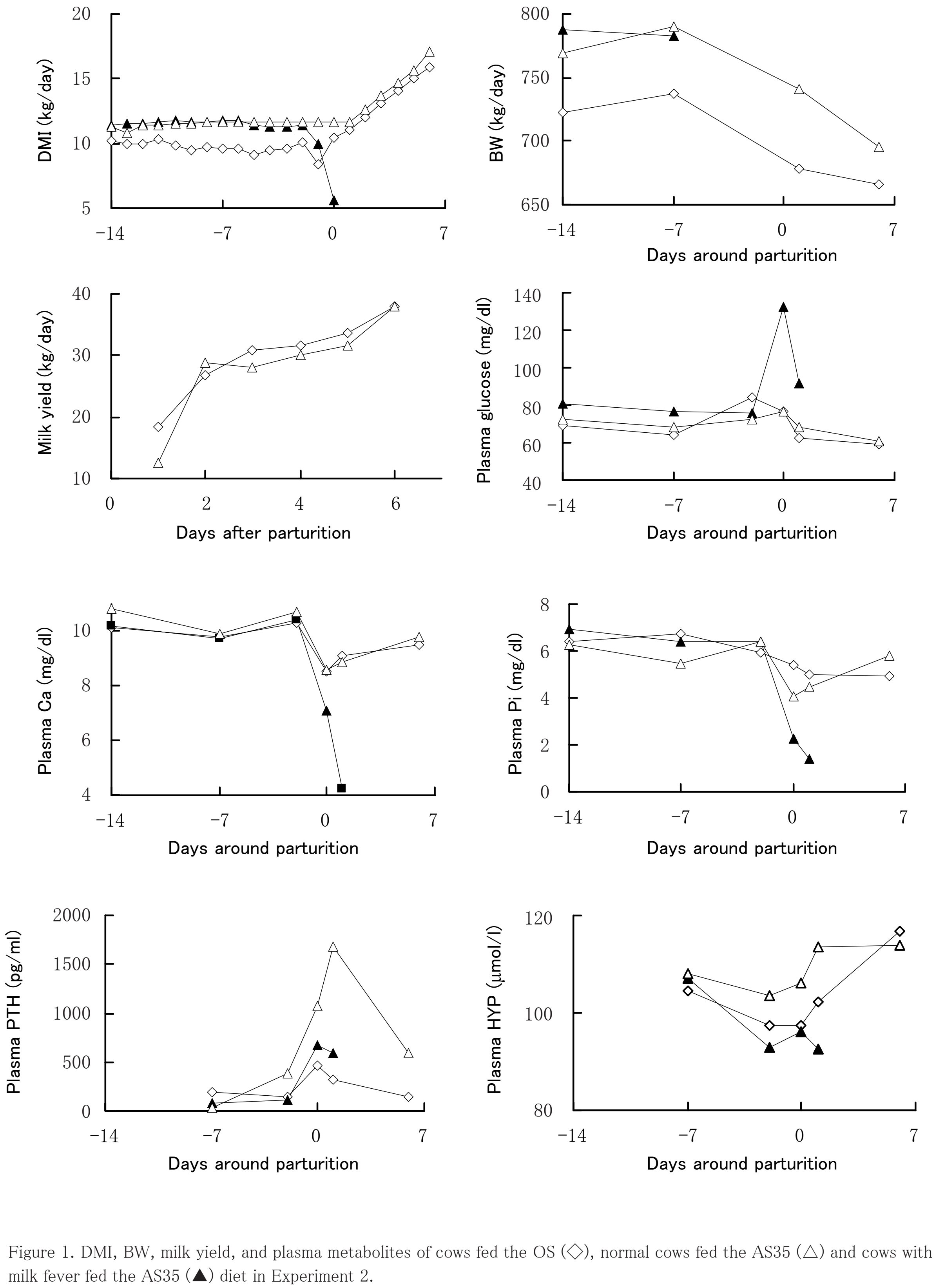

Figure 1. DMI, BW, milk yield, and plasma metabolites of cows fed the OS (◇), normal cows fed the AS35 (△) and cows with milk fever fed the AS35 (▲) diet in Experiment 2.

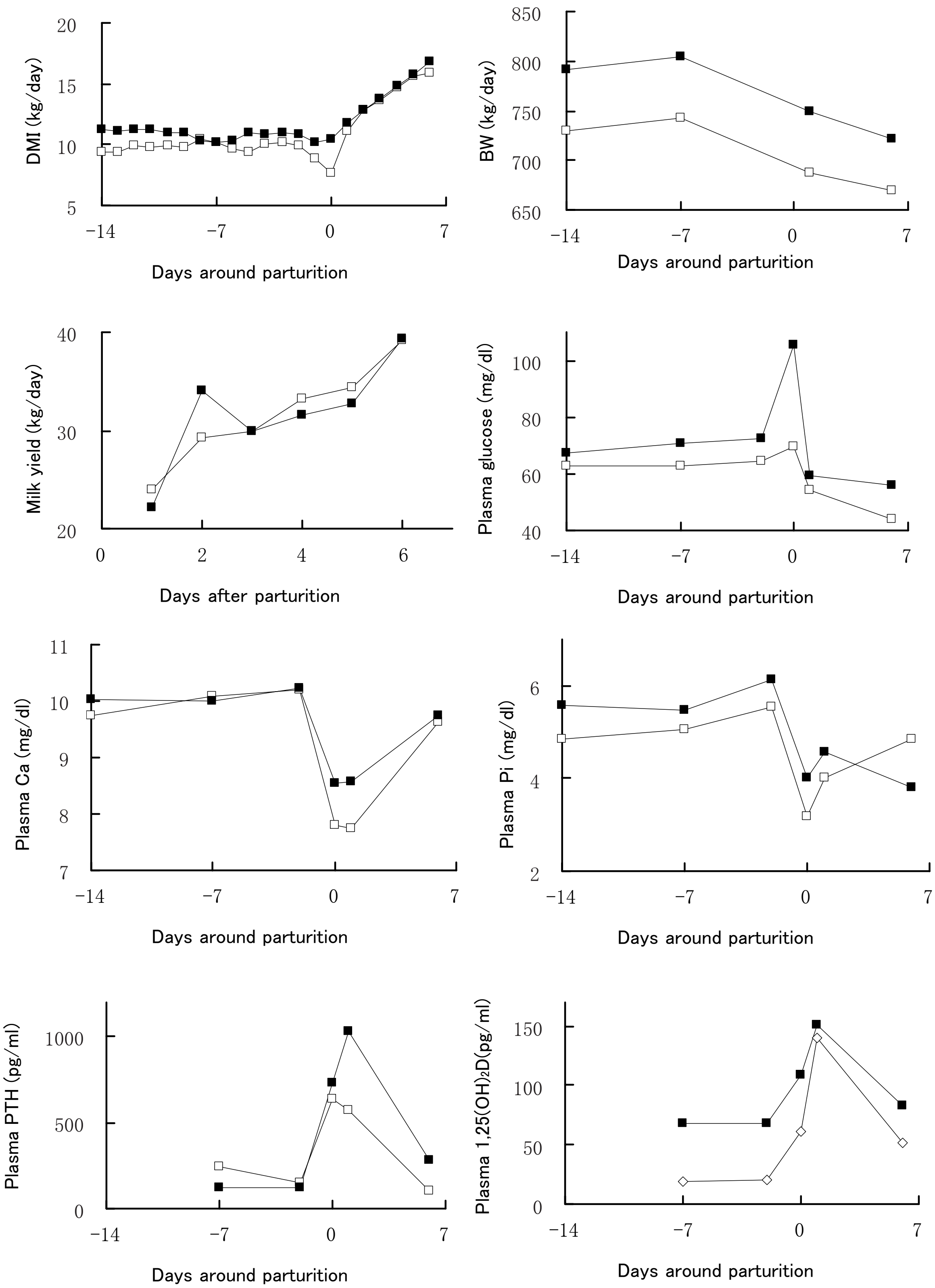

Figure 2. DMI, BW, milk yield, and plasma metabolites of cows fed the AS20 (□) and CS (■) diet in Experiment 3.

めん羊および妊娠牛のミネラル栄養に及ぼす アルファルファからのカリウム多量摂取の影響

久米　新一[1)]・T.トハルマット[2)]・M.リド[2)]・野中　和久[1)]・
大下　友子[1)]・中村　正斗[1)]・山田　　豊[1)]・J.H.ターノス[3)]

摘　　要

めん羊15頭を用いて、アルファルファの自由摂取と摩砕処理がミネラル出納に及ぼす影響を調べた（試験１）。アルファルファサイレージ給与時のめん羊のカリウム吸収率は95～97％と非常に高かったが、血漿中のカリウム濃度はカリウム吸収量が増加しても上昇しなかった。カルシウムとリン吸収率は摂取量が増加すると低下したが、カリウム吸収率は高レベルであった。摩砕処理はめん羊のカルシウム、リンおよびマグネシウム吸収量を改善した。経産牛16頭を用いて、分娩前のアルファルファあるいはオーチャードグラスサイレージ主体給与（試験２）およびアルファルファとアルファルファ＋トウモロコシサイレージ主体給与（試験３）が乳牛のミネラル栄養に及ぼす影響を調べた。分娩前の粗濃比は30:70とし、またアルファルファの給与比率は試験１では35％、試験２では20％に設定した。試験飼料のカリウム含量は1.49～2.30％の範囲内であった。試験２でアルファルファ給与牛２頭に乳熱が発生し、乳熱発生牛では分娩時に血漿中カルシウム、無機リンおよびハイドロキシプロリン濃度が急減した。しかし、血漿中副甲状腺ホルモン濃度は影響されなかったことから、副甲状腺ホルモンの働きを阻害されたことが乳熱発生の一因と思われた。試験３では、アルファルファ＋トウモロコシサイレージ給与牛の血漿中グルコースと活性型ビタミンＤ濃度が高かった。以上の結果から、アルファルファを給与した反芻動物のカリウム吸収率は非常に高いが、妊娠牛にアルファルファとトウモロコシサイレージを組み合わせて給与すると乾物摂取量の増加とカリウム摂取量の低下により、妊娠牛のミネラル栄養が改善すると推察された。

[1)] 北海道農業研究センター
[2)] ボゴール農科大学
[3)] クイーンズランド大学