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Timothy hays differing in dietary cation-anion difference affect the capability of dairy cows to maintain their calcium homeostasis

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ABSTRACT

Forages low in dietary cation-anion difference (DCAD) can be used to decrease the DCAD in prepartum diet but the extent to which DCAD needs to be reduced is of recent interest. The objective of this study was to evaluate the effectiveness of timothy hays differing in DCAD at maintaining Ca homeostasis. Six nonlactating and nonpregnant multiparous Holstein cows were fed diets containing timothy (*Phleum pratense* L.) hay with DCAD values of 4.1 ± 3.6 (LOW), 14.1 ± 3.0 (MED), or 25.1 ± 2.5 (HIGH) mEq per 100 g of DM in a duplicated 3 × 3 Latin square design with 14-d experimental periods. The LOW and MED hays were produced by fertilizing established timothy fields at a rate of 224 kg $CaCl_2$ per ha, and HIGH hay was obtained from the same field where LOW hay was produced, but from a section not fertilized with $CaCl_2$. Experimental diets, containing LOW, MED, or HIGH timothy hay at 71% of dietary DM, had DCAD values of 0.7, 7.3, and 14.4 mEq per 100 g of DM, respectively. Animals were fed at 6% of metabolic body weight, which provided 108% of their daily energy requirement. For each period, after a 12 d diet adaptation, cows were subjected to an EDTA challenge (3 cows each on d 13 and 14). Infusion of EDTA solution into the jugular vein decreases the concentration of blood ionized Ca, and the EDTA challenge protocol determined the resistance time and recovery time: the time required for the blood ionized Ca concentration to decrease to 60%, and the time required to recover to 90% of the prechallenge concentrations, respectively. Urine pH was lower when cows were fed LOW compared with HIGH diet (6.88 vs. 7.83), but urine pH when cows were fed MED diet (7.15) did not differ from that when cows received the LOW or HIGH diet. However, immediately before the EDTA challenge, blood pH was lower when cows were fed LOW or MED compared with HIGH diet (7.44 vs. 7.47). Although the resistance time was not affected by treatments, the recovery time was shorter when cows were fed the LOW compared with MED or HIGH diet (185 vs. 248 and 263 min, respectively). Blood pH decreased when cows were fed the LOW or MED diet, but the capability to maintain Ca homeostasis was enhanced only when cows received the LOW diet, in which the DCAD value was decreased to 1 mEq per 100 g of DM.
Key words: EDTA challenge, dietary cation-anion difference, timothy hay, hypocalcemia

INTRODUCTION

Parturient paresis is a metabolic disorder that negatively affects productivity of lactating dairy cows. This metabolic disorder potentially reduces the productive lifetime of a dairy cow by 3.4 yr and may increase the risk of other metabolic disorders such as mastitis or uterine prolapse after calving (Horst et al., 1997). Supplementation of anionic salts to decrease DCAD was proposed as a management tool to decrease the occurrence and severity of milk fever in dairy cows (Horst et al., 1997). Greater dietary anion intake is expected to decrease blood pH and increase blood ionized Ca (**iCa**) concentration by actions of parathyroid hormone (**PTH**) and 1,25-dihydroxyvitamin D [**1,25(OH)$_2$ D**; Goff et al., 1991]. The PTH acts synergistically with 1,25(OH)$_2$ D to increase osteoclast activity mobilizing bone Ca (Yarrington et al., 1977; Goff et al., 1991; Block, 1994). However, feeding anionic salts or acidifying agents during the dry period often decreases DMI (Charbonneau et al., 2006), increasing the risk of other metabolic disorders.

Feeding low-DCAD forages is another management approach to decrease the severity of hypocalcemia (Charbonneau et al., 2008; Penner et al., 2008). Timothy (*Phleum pratense* L.) is low in potassium concentration and DCAD value, calculated as $Na^+ + K^+ - Cl^- - S^{2-}$ (Ender et al., 1971), compared with other cool-season grasses (Tremblay et al., 2006), and its DCAD can be further decreased with chloride fertilization (Oba et al., 2007; Pelletier et al., 2007, 2008). Penner et al. (2008) fed prepartum dry cows with low- or high-DCAD timothy hay (1.2 vs. 21.6 mEq per 100 g of DM), and re-

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Table 1. Nutrient composition of the low-, medium-, and high-DCAD timothy hays (n = 3 for each hay)

	Low-DCAD Timothy		Medium-DCAD Timothy		High-DCAD Timothy	
Nutrient	Mean	SD	Mean	SD	Mean	SD
DM, %	92.7	0.7	93.1	0.1	93.1	0.2
CP, % of DM	8.1	1.12	10.6	0.8	8.2	0.87
ADF, % of DM	40.5	0.9	38.2	1.4	40.1	1.3
NDF, % of DM	64.5	1.7	59.0	1.9	63.5	1.4
Ash, % of DM	6.5	0.84	7.3	0.32	5.3	0.66
Ca, % of DM	0.36	0.07	0.40	0.03	0.31	0.06
P, % of DM	0.15	0.02	0.17	0.01	0.14	0.01
Mg, % of DM	0.12	0.02	0.15	0.01	0.13	0.01
Na, % of DM	0.01	0.00	0.01	0.00	0.01	0.00
K, % of DM	1.71	0.12	1.69	0.05	1.32	0.14
S, % of DM	0.11	0.01	0.14	0.01	0.11	0.02
Cl, % of DM	1.18	0.05	0.73	0.06	0.07	0.02
Fe, mg/kg	99.3	45.2	79.3	14.0	78.3	12.3
Mn, mg/kg	40.3	17.6	84.0	6.2	30.0	9.8
Zn, mg/kg	42.7	28.9	30.3	2.5	36.3	23.1
Cu, mg/kg	11.0	1.7	12.3	1.2	8.67	3.5
DCAD,[1] mEq per 100 g of DM	4.1	3.6	14.1	3.0	25.1	2.5

[1]Calculated as $Na^+ + K^+ - Cl^- - S^{2-}$ (Ender et al., 1971).

ported that the diet containing low-DCAD timothy hay at 63% of dietary DM improved Ca homeostasis during the periparturient periods without decreasing DMI.

It was suggested that the DCAD needs to be −5.0 to −10.0 mEq per 100 g of DM to prevent hypocalcemia (Horst et al., 1997), but diets with low but positive DCAD also can improve Ca homeostasis around parturition (Kurosaki et al., 2007; Penner et al., 2008). The optimal DCAD that accounts for both reducing the prevalence and severity of hypocalcemia and minimizing depression in DMI has not yet been established. The use of low-DCAD forages in place of anionic salts does not drastically decrease the DCAD in prepartum diets. Thus, it is of interest to determine the extent to which DCAD needs to be reduced to exert physiological responses to prevent hypocalcemia.

The objective of this study was to evaluate the effects of slightly positive DCAD diets containing timothy hays varying in DCAD on the capability to maintain Ca homeostasis in nonpregnant, nonlactating Holstein cows in response to an EDTA infusion challenge.

MATERIALS AND METHODS

This experiment was conducted from May to July 2007 at the Metabolic Unit of Edmonton Research Station of the University of Alberta (Edmonton, AB, Canada). Experimental procedures were approved by the Faculty Animal Policy and Welfare Committee and conducted according to the guidelines outlined by the Canadian Council of Animal Care (Ottawa, ON, Canada).

Experimental Design and Dietary Treatments

Three lots of timothy hay varying in DCAD were obtained from established timothy stands near Lethbridge, Alberta, Canada. Low-DCAD (**LOW**) and high-DCAD (**HIGH**) timothy were grown on the field under a pivot irrigation system. The soil K content at this site was 486 kg/ha, and the field was fertilized with 112 kg of N/ha as urea, and 39 kg of P/ha as monoammonium phosphate on April 15, 2006. In addition, anhydrous calcium chloride ($CaCl_2$) was applied using a fertilizer broadcaster to the area between the second and third pivot towers at a rate of 224 kg/ha (143 kg of Cl/ha) on April 15 to produce the LOW timothy hay. Control timothy hay (HIGH) was grown on the area between the fourth and fifth pivot towers of the same field. The medium-DCAD (**MED**) timothy was grown on another field with soil K content of 387 kg/ha. The field was fertilized with 134 kg of N/ha as urea, and 45 kg of P/ha as monoammonium phosphate, and 143 kg of Cl/ha as $CaCl_2$ using a fertilizer broadcaster. All hays were harvested on July 8 as small rectangular bales weighing approximately 27 kg each, transported to the University of Alberta (Edmonton, AB, Canada), and stored in a covered shelter. Chloride concentration was 0.07, 0.73, and 1.18% DM, and the DCAD, calculated as $Na^+ + K^+ - Cl^- + S^{2-}$ (Ender et al., 1971), was 25.1, 14.1, and 4.1 mEq per 100 g of DM for HIGH, MED, and LOW timothy hay, respectively (Table 1). Although the same protocol was used for $CaCl_2$ fertilization, the Cl concentration was less than expected for one lot of timothy hay, which was then used as MED timothy hay for the present study. The reasons why the same