



Dietary Ca concentration to minimize the risk of hypocalcaemia in dairy cows is affected by the dietary cation–anion difference

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ABSTRACT

The objective of this study was to determine whether dietary Ca concentration affects the ability to maintain Ca homeostasis in non-lactating non-pregnant dairy cows fed diets differing in dietary cation–anion difference (DCAD). Eight non-lactating non-pregnant multiparous Holstein cows (594 ± 80.3 kg body weight; 34.5 ± 11.4 month old) were fed diets Low or High in DCAD (-64 vs. 82 mequiv./kg dry matter, respectively) in combinations with Low or High dietary Ca concentration (3.0 vs. 9.1 g/kg of dry matter, respectively) in a duplicated 4×4 Latin square design with 14-d periods. On d 14 of each period, cows were subjected to an EDTA challenge that consists of an intra-jugular infusion of EDTA solution to decrease blood Ca concentration. In this protocol, the time required to recover to 90% of the pre-challenge blood Ca concentration was determined as recovery time. During the EDTA challenge, mean blood bicarbonate concentration was lower for cows fed Low-DCAD diets although mean blood pH was not affected by treatment, indicating that cows fed Low-DCAD diets had mild compensated metabolic acidosis. Feeding High-Ca diet shortened the recovery time (106 vs. 134 min; $P=0.04$) when DCAD was low, while Low-Ca diet shortened the recovery time (125 vs. 159 min; $P=0.02$) when DCAD was high. These results suggest that the optimum dietary Ca concentration to minimize the risk of hypocalcaemia in dairy cows is likely different depending on the DCAD value.

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1. Introduction

Hypocalcaemia is a metabolic disorder that affects longevity of dairy cows and profitability of dairy operations (Horst et al., 1997). Clinical cases of hypocalcaemia typically occur within 24 h after calving, and it is related to higher incidence of dystocia, retained placenta, displaced abomasum, metritis, mastitis, and ketosis (Curtis et al., 1983). In the past, excess dietary Ca intake prior to calving was considered as the primary cause of hypocalcaemia after calving, and it was recommended to reduce the Ca concentration in prepartum diets (Goings et al., 1974). Feeding Low-Ca diets is effective at stimulating the release of parathyroid hormone (Yarrington et al., 1977), increasing Ca resorption and absorption, and decreasing Ca excretion (Horst et al., 1997), but it is difficult to limit dietary Ca intake below the animal requirement with the use of conventional feedstuffs. Goff and Horst (1997) showed that high dietary cation–anion difference (DCAD), not high dietary Ca intake, is the primary cause of hypocalcaemia. Feeding anionic salts in the 3 weeks prior to calving has been recommended

Abbreviations: aNDF, omneutal detergent fiber; CP, crude protein; DCAD, dietary cation–anion difference; DM, dry matter.

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to reduce the DCAD of the prepartum diets and induce mild metabolic acidosis, which increases the tissue responses to the parathyroid hormone and decreases the incidence of hypocalcaemia (Goff et al., 1991; Horst et al., 1997).

Optimal Ca concentration in the prepartum diets has been debated. According to meta-analyses, the risk of milk fever in dairy cows peaks when prepartum diets contain Ca at 11.6 g/kg (Oetzel, 1991) or 13.5 g/kg (Lean et al., 2006) of diet dry matter (DM). However, Oetzel (2000) recommended that Low-DCAD diets should contain Ca at 11–15 g/kg of DM, and some nutritionists in the field formulate prepartum diets for high Ca concentration regardless of DCAD value. The current confusion is in part attributed to the lack of data. Although individual effects of dietary Ca concentration and DCAD on the susceptibility to hypocalcaemia have been extensively studied, their interaction effects have not been clearly assessed. We had hypothesized that optimal dietary Ca concentration differs depending on the DCAD values.

The objective of the present study was to determine whether dietary Ca concentration affects the ability to maintain Ca homeostasis in non-lactating non-pregnant Holstein cows fed diets differing in DCAD.

2. Materials and methods

2.1. Animal use approval

The experiment was conducted at the Metabolic Unit of the Edmonton Research Station of the University of Alberta (Edmonton, AB, Canada) from May to July 2008. The experimental procedures were approved by the Faculty Animal Policy and Welfare Committee of the Faculty of Agricultural, Life, and Environmental Sciences of the University of Alberta and conducted according to the guidelines outlined by Canadian Council of Animal Care (Ottawa, ON, Canada).

2.2. Experimental design

Eight non-pregnant and non-lactating multiparous Holstein cows (594 ± 80.3 kg body weight; 34.5 ± 11.4 month old) with no history of parturient paresis were assigned randomly to replicated 4×4 Latin squares balanced for carryover effects with a 2×2 factorial arrangement of treatments. Treatments were DCAD (Low vs. High) and dietary Ca concentration (Low vs. High). Treatment periods were 14 d with the last 2 d of each period used to collect data and samples.

2.3. Timothy hay and diet

Two lots of timothy hay of either High- or Low-DCAD values were obtained from established timothy stands near Lethbridge Alberta Canada. To produce the Low-DCAD timothy hay, anhydrous calcium chloride (CaCl_2) was applied using a fertilizer broadcaster at a rate of 224 kg/ha (143 kg of Cl/ha; Penner et al., 2008). Both Low- and High-DCAD hays were grown under a pivot irrigation system, and the hays were harvested as small rectangular bales, transported to the University of Alberta (Edmonton, AB, Canada), and stored in a covered shelter. Samples of Low- and High-DCAD timothy hays and Low- and High-Ca concentrate mixes were collected every period during the animal study ($n = 4$ for each feed), and oven-dried at 60°C for 48 h and ground through a 1-mm screen with a Wiley mill (Thomas-Wiley, Philadelphia, PA). The samples were sent to Cumberland Valley Analytical Service (Hagerstown, MD) to determine concentrations of aNDFom (with the use of α -amylase, without the use sodium sulfite, and exclusion of residual ash; Van Soest et al., 1991), crude protein (AOAC, 2000; method 990.03), Ca, P, Na, K, and Mg (14; method 985.01). The concentrations of S and Cl were determined using a Leco S-144DR Sulfur Combustion Analyzer (Leco, St. Joseph, MI) and a Corning 925 Chloride Analyzer (Ciba Corning Diagnostics, Medfield, MA), respectively. The DCAD (mequiv./kg of DM) was calculated as $\text{Na}^+ + \text{K}^+ - \text{Cl}^- - \text{S}^{2-}$ (Ender et al., 1971). The Cl concentration was 11.2 and 1.2 g/kg of DM, and the DCAD, calculated as $\text{Na}^+ + \text{K}^+ - \text{Cl}^- - \text{S}^{2-}$ (Ender et al., 1971), was 24 and 231 mequiv./kg of DM for Low- and High-DCAD timothy hays, respectively (Table 1).

Experimental diets contained either the Low- or High-DCAD timothy hay at 690 g/kg of dietary DM and Low- or High-Ca concentrate mix at 310 g/kg of dietary DM (Table 2). The DCAD values were –64 and 82 mequiv./kg of DM for Low- and High-DCAD diets, respectively, and dietary Ca concentration was 3.0 and 9.1 g/kg of DM for Low- and High-Ca diets, respectively.

The cows were weighed on 2 consecutive d immediately before the start of the first period and on the last 2 d of each period at 0730 h prior to feeding. Then, animals were fed experimental diets at 60 g of DM/kg of metabolic body weight (DM intake: 7.2 ± 0.7 kg/d throughout the study), which provided 108% of their maintenance energy requirement. Experimental diets were also formulated to meet metabolizable protein requirement for maintenance using dairy NRC (2001). Timothy hay and the concentrate mix were fed separately once daily at 0800 h. Animals were housed in individual pens bedded with wood shavings and had free access to water.

2.4. Urine sampling

Urine was sampled (30 mL) on d 13 of each period by manual stimulating micturition from each cow at 5 h after feeding. A portable pH meter (model Accumet AP61; Fisher Scientific, Pittsburgh, PA) was used to measure urine pH immediately after sample collection.

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