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Changing Dietary Cation-Anion Difference for Dairy Cows Fed with Two Contrasting Levels of Concentrate in Diets

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ABSTRACT

High-producing dairy cows are commonly fed diets containing a high proportion of rapidly degradable starch, which can cause subacute acidosis and reduce dry matter (DM) intake. Because of the properties of nonmetabolizable cations and anions, increasing the dietary cation-anion difference (DCAD = Na + K – Cl – S in mEq/kg of DM) may prevent a drop in DM intake. To test this hypothesis, 48 Holstein cows were blocked into 2 groups of 24 and assigned to two 3 × 3 Latin squares in a split-plot design. Each group received one level of concentrate at either 20% or 40% on a dry matter (DM) basis. The diet containing 20% concentrate was formulated to supply 4% rapidly degradable starch, whereas the diet containing 40% concentrate supplied 22% rapidly degradable starch. Diets in each square were formulated to provide a DCAD of 0, 150, or 300 mEq/kg of DM. The 3 values were obtained by manipulating Na and Cl contents. Intake, 4% fat-corrected milk yield, and milk fat percentage, as well as blood nonesterified fatty acids and β-hydroxybutyrate increased with DCAD, but only on the diet providing 40% concentrate. The yield of *trans*-10 $C_{18:1}$ and odd-chain fatty acids decreased with increasing DCAD, whereas *trans*-11 $C_{18:1}$ increased. Again, this occurred only with the diet providing 40% concentrate. Blood pH and HCO_3 concentration increased along with DCAD, irrespective of the concentrate level. A positive DCAD led to increasing DM intake and fat-corrected milk yield in dairy cows fed highly degradable diets. The mechanism involved may be a localized rumen buffering effect, together with the ability of positive DCAD to maintain blood acid-base status in cows faced with a massive acid input.

Key words: dietary cation-anion difference, performance, acid-base status, dairy cow

INTRODUCTION

High-producing dairy cows are commonly fed highly digestible diets containing a high proportion of rapidly degradable starch. Obvious drawbacks to this strategy are the subsequent decrease in ruminal pH, increase in the production of VFA, an increase in propionate production, and an alteration in rumen biohydrogenation of dietary polyunsaturated fatty acids, which, in turn, reduces milk fat synthesis (Doreau et al., 1999; Bauman and Griinari, 2003). Moreover, several experiments have reported changes in blood acid-base status that were correlated with changes in ruminal environment. Faverdin et al. (1999) showed that blood HCO_3 concentration and blood base excess were negatively correlated with the concentration of VFA in ruminal fluid when large amounts of rolled wheat were added into the rumen of dairy cows. This finding was accompanied by a transient reduction in DMI. Other studies have reported a marked decrease in blood HCO_3 concentration and base excess during subacute rumen acidosis in steers (Goad et al., 1998). Therefore, in agreement with Owens et al. (1998), we can assume that, with highly degradable diets, a higher proportion of HCO_3 can be derived from the blood, thus causing a decrease in blood base excess.

A large DCAD, defined as milliequivalents of (Na + K – Cl – S) per kilogram of DM (Tucker et al., 1991), should assist in preventing metabolic acidosis because the absorption of Na and K will increase blood HCO_3 concentration (Stewart, 1983). A large positive DCAD could also alter ruminal fermentation and increase ruminal pH, as suggested by Roche et al. (2005). There is some evidence that milk yield, fat yield, and DMI increase along with DCAD in early and mid-lactating dairy cows fed high-grain and low-roughage diets (Tucker et al., 1988; West et al., 1991).

The effect of increased DCAD on the cow's performance may differ according to the proportion and type of concentrate in the diet. Increasing DCAD could be more efficient when concentrates rich in rapidly degradable starch make up a high proportion of the diet offered to dairy cows, because of either direct ruminal

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buffering or a systemic buffering effect. Consequently, the target level of DCAD may depend on the concentrate-to-forage ratio of the diet. In the present study, we aimed to test this hypothesis by examining the effects of increasing DCAD from 0 to 300 mEq/kg of DM on DMI, milk production, and acid-base status in lactating dairy cows receiving diets with different roughage-to-concentrate ratios.

MATERIALS AND METHODS

Experimental Design

The trial was conducted using a split-plot design with 48 Holstein cows. Cows were assigned to 2 groups of 24 according to parity (6 primiparous and 18 multiparous animals), stage of lactation (105 ± 22 DIM), milk production (29.2 ± 4.0 kg/d), milk protein (3.16 ± 0.25%), fat content (4.23 ± 0.46%), and BW (624 ± 60 kg). Each group of cows received 1 of 2 levels of concentrate during the trial. Within each group, cows were assigned to 3 planned levels of DCAD. The cows were assigned to 4 blocks of 6 and within each block the cows received the 3 levels of DCAD according to a 3×3 balanced Latin square design. The trial included a 2-wk period of adaptation to the basal diet, followed by 3 measurement periods of 4 wk each.

Treatments and Feeding

Six diets were formulated with various different levels of concentrate and DCAD (Table 1). The low-concentrate diets (**LC**) consisted of 21% concentrate and minerals and 79% corn silage on a DM basis. The high-concentrate diets (**HC**) consisted of 41% concentrate and minerals and 59% corn silage. The 3 planned DCAD levels were 0 (**LD**), 150 (**MD**), and 300 (**HD**) mEq/kg of DM. The 6 experimental diets were 1) low concentrate with low DCAD (**LCLD**), 2) low concentrate with medium DCAD (**LCMD**), 3) low concentrate with high DCAD (**LCHD**), 4) high concentrate with low DCAD (**HCLD**), 5) high concentrate with medium DCAD (**HCMD**), and 6) high concentrate with high DCAD (**HCHD**).

Two energy concentrates were formulated to maximize the difference in rapidly degradable starch (wheat and barley) between the 2 groups of diets (Table 1). The centesimal compositions on a DM basis of the 2 concentrates are shown in Table 1. Because the DCAD of grain was approximately zero, dehydrated alfalfa and molasses were added to the concentrate in the HC diet to ensure similar DCAD for the 2 diets before adding the experimental mineral mixture. Finally, for the LC and HC diets, respectively, the proportions of highly fermentable cereals were 3.7 and 21.5% DM. The respective proportions of ADF were 18.6 and 16.2% DM, and the proportions of NDF were 35.7 and 31.4%. In the LD and HD diets, NDF originating from corn silage accounted for 30.4 and 22.7%, respectively.

Differences in DCAD values were obtained by manipulation of dietary Na and Cl. Two mineral mixtures were used to set the medium and high DCAD levels. The ingredients of the 2 mineral mixtures are shown in Table 1. Low DCAD was obtained by adding 0.8% NH_4Cl to the MD diets (Table 1). High DCAD was obtained by replacing $CaCO_3$ by $NaCO_3$ and Na_2PO_4. With increasing DCAD, Na content increased from 0.21 to 0.50% DM, whereas Cl content decreased from 1.05 to 0.45% DM (Table 1). The concentrations of other minerals were kept constant to ensure that the observed effects could be attributed to the manipulation of DCAD. The K, S, Ca, P, and Mg contents averaged 1.15, 0.12, 0.77, 0.33, and 0.19% DM, respectively. The S content was low because of the corn silage, which contained only 0.62 g of S/kg of DM.

The diets were formulated to supply similar amounts of NE_L (1.57 MCal/kg of DM), total CP content (14.5% DM), and digestible protein in the intestine (**PDI**, 95.6 g/kg of DM) to meet energy, protein, Ca, and P requirements (Institut National de la Recherche Agronomique, 1989). The diets were supplemented with urea to cover 105% of the microbial requirements of degradable N.

Corn silage, concentrate, and mineral supplements were mixed in 6 different TMR. The cows were fed individually to ensure ad libitum intake (allowing more than 10% orts) twice daily at 0900 and 1600 h (50:50). Cows were housed in free stalls. To control mineral supply, no straw or mineral blocks were provided. Cows were milked twice daily at 0700 and 1730 h and weighed once a week.

Sampling Schedule and Procedure

Feeds and Orts. Voluntary DMI was individually recorded daily during the experiment using an individual electronic gate. The DM content of corn silage was determined (80°C, 48 h) every 3 d to adjust the proportion of corn silage in the diets. Orts were collected and weighed daily before the morning feeding. To calculate DMI, the composition of orts was assumed similar to the offered diet. For chemical analyses, oven-dried samples of corn silage were pooled over each period, whereas concentrates and mineral mixtures were sampled weekly, and the samples were pooled over the whole experimental period. All samples were ground with a 3-blade knife mill through a 0.8-mm screen. Organic matter content was determined by ashing at