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Effects of the level and duration of maternal diets with negative dietary cation-anion differences prepartum on calf growth, immunity, and mineral and energy metabolism

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ABSTRACT

The objectives were to investigate the effects that maternal diets containing negative dietary cation-anion differences (DCAD) fed in the last 42 d of gestation may have on the acid–base status, hematology, mineral and energy metabolism, growth, and health of calves. The experiment was a randomized block design with a 2 × 2 factorial arrangement of 2 levels of negative DCAD (−70 or −180 mEq/kg) and 2 feeding durations (the last 21 d prepartum and the last 42 d prepartum). Bulls and heifers (n = 60) born to these dams were weighted at birth and fed 3.8 L of colostrum for their first feeding, and only heifers (n = 44, 9–12/treatment) were kept thereafter. Heifer body weight was also recorded at 21 d, 42 d, 62 d, 3 mo, and 6 mo of age. Blood was collected at birth, before colostrum feeding, and at 1, 2, 3, 21, and 42 d of age and assayed for minerals, metabolites, and cell counts. Heifers born to dams fed the last 42 d prepartum weighed 2.8 and 4.8 kg less at birth and 62 d, respectively, compared with calves born to dams fed the last 21 d prepartum; however, body weight at 3 and 6 mo of age was similar. Concentrations of ionized calcium did not differ among treatments at birth, but heifers born to −180 DCAD dams had increased blood concentrations at 3 d of age, whereas those born to −70 DCAD dams did not. At birth, heifers born to −180 DCAD dams experienced a subtle and transient metabolic acidosis (pH = 7.33 ± 0.02; pCO_2 = 53.0 ± 2.4 mmHg; HCO_3^- = 27.6 ± 0.7 mmol/L) compared with the more evident metabolic acidosis observed in those born to −70 DCAD cows (pH = 7.28 ± 0.02; pCO_2 = 59.3 ± 2.4 mmHg; HCO_3^- = 27.8 ± 0.7 mmol/L). Heifers born to −180 DCAD dams had reduced concentrations of β-hydroxybutric acid and nonesterified fatty acids compared with those born to −70 DCAD dams. Efficiency of IgG transfer from colostrum into blood and serum concentrations did not differ among treatments. There was no relationship between measures of metabolic acidosis and measures of efficiency of IgG absorption. Percentage of lymphocytes and neutrophils was altered by maternal treatments; however, treatments did not affect calf morbidity. Extending the duration of feeding up to 42 d or reducing the level of negative DCAD to −180 mEq/kg in maternal diets exerted a transient metabolic acidosis in the calves and slightly affected measures of mineral, energy metabolism, and growth.

Key words: acid–base balance, dairy calf, immunoglobulin G, maternal dietary cation-anion difference

INTRODUCTION

Approximately 25% of periparturient primiparous cows and 50% of periparturient multiparous cows on dairy farms in the United States suffer from subclinical hypocalcemia, and 5 to 7% of cows develop clinical hypocalcemia (Reinhardt et al., 2011). Hypocalcemia is a metabolic disorder that occurs when there are reduced circulating concentrations of calcium (Ca) in the blood. Risk factors for hypocalcemia in dairy cows include age and breed of cow and diets with high K and Na content, among others, which may lead to other metabolic disorders and diseases such as mastitis and reduced rumen and abomasal contractions (Huber et al., 1981; Curtis et al., 1983). Approximately 30% of dairy farms across the United States implement prepartum diets with negative DCAD to reduce the incidence of hypocalcemia at the onset of lactation (NAHMS, 2014). The typical recommendation is to feed a diet with negative DCAD, from −50 to −100 mEq/kg, during the last 21 d prepartum. In some situations dairy producers might prefer a single prepartum diet, which would result in feeding dairy cows a diet with a negative DCAD for more than 21 d prepartum. Although the optimum DCAD prepartum for cows remains unknown, even less is known about the effect on newborns. It is known that nutrient manipulations during the third trimester

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of gestation can influence fetal and postnatal development of the offspring (Corah et al., 1975; Du et al., 2010; Gao et al., 2012). A diet with a negative DCAD prepartum induces a compensated metabolic acidosis in dairy cows, which decreases the cows' blood pH and has been shown to increase blood Ca concentrations (Oetzel, 1988). However, the effects that acidogenic diets fed to dairy cows during late gestation may have on the developing offspring have been less studied.

Acidosis in neonates can occur as the result of dystocia and hypoxia during delivery (Quigley and Baum, 2004). Moreover, postnatal respiratory or metabolic acidosis has been linked to reduced colostral Ig absorption, leading to increased risk of mortality in dairy calves (Besser and Gay, 1994). It is possible that maternal metabolic acidosis induced by feeding acidogenic diets to dams prepartum could affect the neonate in utero because of the highly vascularized nutrient transfer system that occurs during the last trimester. Limited research has explored whether the induced maternal compensated metabolic acidosis might influence the physiology of the calf postnatally. Morrill et al. (2010) found that the efficiency of absorption and the concentrations of Ig in calves born to dams fed a diet with a DCAD of −100 mEq/kg did not differ from that of calves born to dams fed a diet with a DCAD of +77 mEq/kg during the last 21 d prepartum. Weich et al. (2013) reported that reducing the DCAD from +120 to −160 mEq/kg or extending the feeding of −160 mEq/kg from 21 to 42 d prepartum did not influence colostrum yield or calf birth BW. The effect that negative DCAD exerts on the cow's mineral metabolism and acid–base balance has been reported extensively (Horst et al., 1997; Charbonneau et al., 2006; Goff, 2008); however, reducing the DCAD by feeding more acidogenic diets prepartum might affect acid–base status of calves and influence postnatal performance.

The objectives of this experiment were to evaluate the effects of extending the dam's feeding duration, from 21 to 42 d, and reducing the level of negative DCAD prepartum, from −70 or −180 mEq/kg, on the acid–base balance, mineral and energy metabolism, and performance of the offspring postnatally. We hypothesized that growth, immunity, and morbidity would not be greatly affected, whereas acid–base balance and energy and mineral metabolism could be affected by the maternal DCAD treatment manipulations.

MATERIALS AND METHODS

Animals and Experimental Design

Animal procedures were approved by the University of Florida Institutional Animal Care and Use Committee. The experiment was conducted from January to June 2016 at the Dairy and Calf Research Units of the University of Florida (Alachua, FL). The experiment was a randomized block design with a 2 × 2 factorial arrangement of treatments. Weekly cohorts of parous cows were blocked by parity and 305-d milk yield. Within each block they were randomly assigned to 1 of 4 treatments with 2 levels of negative DCAD (−70 or −180 mEq/kg) fed for 2 durations [the last 21 d of gestation, designated as short (**S**), or the last 42 d of gestation, designated as long (**L**)].

Cows, Housing, and Prepartum Diets

Dams at 230 ± 3 d of gestation were moved to a barn with individual feeding gates for treatment administration. Cows were trained for 2 d before treatments started. A description of the diets is presented in Table 1. Cows in the S group were fed a diet with positive DCAD from 232 ± 3 to 255 d of gestation, and then they were switched to diets containing negative DCAD starting at 255 d of gestation until calving. Cows in the L group were fed the respective negative DCAD treatments from 232 ± 3 d of gestation to calving. Diets were isonitrogenous and isocaloric and were formulated to differ in the concentrations of strong ions to manipulate the DCAD to achieve −70 or −180 mEq/kg. Samples of forages and concentrates were collected weekly and analyzed for their chemical composition to ensure desired negative DCAD levels. Details of diet sampling and analyses are presented elsewhere (Lopera et al., 2016). Briefly, samples of individual ingredients were collected weekly, processed, and composited into 5 monthly samples that were subjected to chemical analyses.

Calf Management

Calves born to dams fed the −70 S (n = 9 heifers and 5 bulls), −70 L (n = 12 heifers and 3 bulls), −180 L (n = 11 heifers and 4 bulls), or −180 S (n = 12 heifers and 4 bulls) diets were used in the experiment. Twins and stillbirths were not included, and 1 dystocia case occurred. Gestation length of dams was calculated, and BW of all calves was recorded at birth. Day of birth was considered experiment d 0. Calves were separated from their dams, had their navels dipped with 2% iodine to prevent infection, and were fed 3.8 L of colostrum. Calves were fed pool colostrum from the farm, and samples were collected 3 times per week and placed at −20°C until analysis. All calves were transported to the University of Florida Calf Unit and housed in individual hutches, and calves received ad libitum calf starter grain (Ampli-Calf Starter 20, Purina Animal Nutrition LLC,