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Effects of prepartum dietary cation-anion difference and source of vitamin D in dairy cows: Lactation performance and energy metabolism

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ABSTRACT

The objectives of this experiment were to evaluate the effects of feeding diets with 2 dietary cation-anion difference (DCAD) levels and supplemented with either cholecalciferol (CH) or calcidiol (CA) during late gestation on lactation performance and energetic metabolism in dairy cows. The hypothesis was that combining a prepartum acidogenic diet with calcidiol supplementation would benefit peripartum Ca metabolism and, thus, improve energy metabolism and lactation performance compared with cows fed an alkalogenic diet or cholecalciferol. Holstein cows at 252 d of gestation were blocked by parity (28 nulliparous and 51 parous cows) and milk yield within parous cows, and randomly assigned to 1 of 4 treatments arranged as a 2 × 2 factorial, with 2 levels of DCAD (positive, +130, and negative, −130 mEq/kg) and 2 sources of vitamin D, CH or CA, fed at 3 mg per 11 kg of diet dry matter (DM). The resulting treatment combinations were positive DCAD with CH (PCH), positive DCAD with CA (PCA), negative DCAD with CH (NCH), or negative DCAD with CA (NCA), which were fed for the last 21 d of gestation. After calving, cows were fed the same lactation diet. Body weight and body condition were evaluated prepartum and for the first 49 d postpartum. Blood was sampled thrice weekly prepartum, and on d 0, 1, 2, 3, and every 3 d thereafter until 30 d postpartum for quantification of hormones and metabolites. Lactation performance was evaluated for the first 49 d postpartum. Feeding a diet with negative DCAD reduced DM intake in parous cows by 2.1 kg/d, but no effect was observed in nulliparous cows. The negative DCAD reduced concentrations of glucose (positive = 4.05 vs. negative = 3.95 mM), insulin (positive = 0.57 vs. negative = 0.45 ng/mL), and insulin-like

growth factor-1 (positive = 110 vs. negative = 95 ng/mL) prepartum. Treatments did not affect DM intake postpartum, but CA-supplemented cows tended to produce more colostrum (PCH = 5.86, PCA = 7.68 NCH = 6.21, NCA = 7.96 ± 1.06 kg) and produced more fat-corrected milk (PCH = 37.0, PCA = 40.1 NCH = 37.5, NCA = 41.9 ± 1.8 kg) and milk components compared with CH-supplemented cows. Feeding the negative DCAD numerically increased yield of fat-corrected milk by 1.0 kg/d in both nulliparous and 1.4 kg/d in parous cows. Minor differences were observed in postpartum concentrations of hormones and metabolites linked to energy metabolism among treatments. Results from this experiment indicate that replacing CH with CA supplemented at 3 mg/d during the prepartum period improved postpartum lactation performance in dairy cows.

Key words: dairy cow, dietary cation-anion difference (DCAD), vitamin D, lactation

INTRODUCTION

Feeding acidogenic salts and products to manipulate the DCAD prepartum minimizes the decline in blood total calcium immediately after calving and reduces the incidence of milk fever in dairy cows (Ender et al., 1971; Block, 1984), although subclinical hypocalcemia remains prevalent in dairy herds (Reinhardt et al., 2011; Chapinal et al., 2012; Martinez et al., 2016). Subclinical hypocalcemia reduces DMI (Martinez et al., 2014), impairs energy metabolism (Chamberlin et al., 2013; Martinez et al., 2014), and suppresses immune function (Kehrli and Goff, 1989; Martinez et al., 2014). Cows induced to have subclinical hypocalcemia had signs of insulin resistance with reduced insulin concentrations and increased lipid mobilization despite increased blood glucose concentrations (Martinez et al., 2014). Furthermore, neutrophils from cows induced to have subclinical hypocalcemia had less cytosolic ionized Ca (iCa) and impaired phagocytic and killing activities

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(Martinez et al., 2014). Such changes in metabolism and immune function might explain the increased risk of diseases observed in cows that suffer from clinical and subclinical hypocalcemia (Seifi et al., 2011; Martinez et al., 2012). Therefore, the inability to maintain proper Ca homeostasis affects energy metabolism and immune function, which likely predisposes cows to diseases beyond milk fever, as observed by Curtis et al. (1983). Altering the DCAD of the prepartum diet to negative values improves peripartum Ca metabolism and increases milk yield in the first months of the subsequent lactation (Lean et al., 2014).

Cholecalciferol (vitamin D₃) is one of the inactive forms of the vitamin and it is the product of UV light reacting with 7-dehydrocholesterol (Horst et al., 1994). Activation of vitamin D₃ into 1,25-dihydroxyvitamin D₃ or calcitriol occurs after 2 hydroxylation steps mediated by cytochrome P450 enzymes. The first hydroxylation occurs in the hepatic mitochondria and microsomes and is effected by vitamin D-25-hydroxylases (CYP2R1, CYP2J2, CYP27A1) forming 25-hydroxyvitamin D₃ (calcidiol). The second hydroxylation takes place in the kidney and is carried out by the cytochrome P450 enzyme CYP27B1, also known as 1 α -hydroxylase. The 1 α -hydroxylase is tightly regulated by the coordinated actions of parathyroid hormone, calcitonin, and 1,25-dihydroxyvitamin D₃ (Yoshida et al., 2001; Liu et al., 2006).

Most prepartum diets for dairy cows are supplemented with cholecalciferol, with a recommended dose of approximately 0.5 mg for a 650-kg cow (NRC, 2001). However, despite cholecalciferol supplementation and other prepartum dietary manipulations, the prevalence of subclinical hypocalcemia remains high during the first days of lactation (Reinhardt et al., 2011; Chapinal et al., 2012; Martinez et al., 2016). Recent findings demonstrated improvements in peripartum Ca metabolism in cows supplemented daily with 3 mg of calcidiol per day, or 120,000 IU, combined with a diet containing a low DCAD (Wilkins et al., 2012). Cows fed a combination of 3 mg of calcidiol and a diet with negative DCAD had greater mean plasma concentrations of iCa during the last days of gestation and first days of lactation compared with cows fed a diet with positive DCAD or not supplemented with calcidiol (Wilkins et al., 2012). Nevertheless, feeding 5.4 mg/d of calcidiol for the last 13 d prepartum seemed to cause more detrimental than beneficial effects on cows (Weiss et al., 2015). Thus, available data indicate that feeding more than 3 mg/d of calcidiol in the last 2 wk of gestation might be excessive and not benefit transition cows.

We hypothesized that supplementation with calcidiol is superior to supplementation with cholecalciferol in maintaining blood Ca concentrations during the peri-

parturient period, which would benefit metabolism and lactation performance. We also hypothesized that the benefits of calcidiol are potentiated when fed with an acidogenic diet. The objectives of this experiment were to evaluate the effects of feeding diets with distinct DCAD and supplemented with 2 sources of vitamin D during late gestation on productive performance and energy metabolism in dairy cows.

MATERIALS AND METHODS

This article is one of a series of 3 companion papers (Martinez et al., 2018; Rodney et al., 2018). The University of Florida Institutional Animal Care and Use Committee approved all procedures involving cows in the experiment under the protocol number 201408331. Throughout the article, the vitamins fed will be referred to as cholecalciferol (**CH**) and calcidiol (**CA**), whereas measurements in blood plasma will be referred to as vitamin D₃, 25-dihydroxyvitamin D₃, and 1,25-dihydroxyvitamin D₃.

Cows and Housing

The experiment was conducted in the University of Florida Dairy Unit from February to July 2014. Eighty pregnant dry Holstein cows (28 nulliparous and 52 parous) were enrolled in the experiment. Selection criteria included apparently healthy cows with no history of disease within 30 d before enrollment. Throughout the article, cows of lactation 0 at enrollment will be designated as nulliparous cows, whereas those enrolled in lactation >0 will be designated as parous cows. Nulliparous cows were enrolled in the experiment because of the scarce data on the effects of manipulating DCAD prepartum on postpartum lactation performance (Moore et al., 2000).

Body weight and BCS were (mean $\pm$ SD), respectively, 600.9 $\pm$ 34.5 kg and 3.58 $\pm$ 0.25 for nulliparous, and 738.6 $\pm$ 88.6 kg and 3.55 $\pm$ 0.41 for parous cows on the day of enrollment, and lactation number for parous cows prepartum was (mean $\pm$ SD) 1.96 $\pm$ 0.98. Cows at 252 d of gestation were moved to the experimental freestall barn to acclimate to the facilities and to individual feeding gates (Calan Broadbent feeding system, American Calan Inc., Northwood, NH). The first 3 d of feed intake were not considered for statistical analysis because cows were learning how to use the feeding gates. Therefore, measurements started at 255 d of gestation.

All prepartum cows were housed together in a freestall barn with sand-bedded stalls, and each cow was randomly assigned to an individual feeding gate. Immediately after calving, cows were moved to a second pen within the same barn and assigned to an individual

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