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Effect of oral mineral and energy supplementation on blood mineral concentrations, energetic and inflammatory profile, and milk yield in dairy cows affected with dystocia

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ABSTRACT

The objectives of this study were to determine the effect of mineral/energy supplementation of dairy cows with dystocia on blood mineral concentrations, energetic and inflammatory profiles, and milk yield. Multiparous Holstein cows with dystocia were randomly assigned into two groups, (1) treated with a mineral/energy supplement (DME, $n = 18$) and (2) not treated (DNT, $n = 22$). A group of cows with normal parturition were randomly selected and were left untreated (NNT, $n = 25$). Cows in DME received an oral drench of 110 g of calcium and 400 g of propionate as calcium propionate plus 110 g potassium chloride and 150 g of magnesium sulfate administered within 6 h of calving and again 3 days post-partum.

Compared to cows with a normal parturition, dystocic cows had decreased plasma calcium concentrations, increased plasma haptoglobin, decreased milk yield at 1 day post-partum, and tended to have increased rectal temperatures from 1 to 12 days post-partum. Compared with cows in DNT, those in DME had decreased plasma calcium concentrations and increased plasma magnesium concentrations 2 and 3 days post-partum, and a tendency for an increase in rectal temperature from 1 to 12 days post-partum. Dystocia is detrimental to calcium homeostasis post-partum, but mineral/energy supplementation as undertaken in this study is not recommended for use in cows with dystocia.

Introduction

Hypocalcemia is associated with a decrease in smooth muscle contraction, suppression of dry matter intake (DMI), increase in body fat mobilization in the form of non-esterified fatty acids (NEFA) (Martinez et al., 2014), and with a reduction of neutrophil function (Martinez et al., 2012, 2014), which leads to an increased incidence of periparturient disease (Curtis et al., 1985; Martinez et al., 2012).

The decrease in DMI associated with hypocalcemia can potentially lead to other mineral imbalances because there are no specific hormonal regulators for magnesium (Mg) and potassium (K) homeostasis in ruminants (DeGaris and Lean, 2008). Plasma Mg concentrations commonly decrease sharply after calving (Hernandez et al., 1999; Melendez et al., 2002) and this fall has been shown to be greater in cows supplemented orally with calcium (Ca) (Dhiman and Sasidharan, 1999), so the latter should be combined with Mg supplementation, especially as Mg plays a crucial role in maintaining Ca homeostasis (Sampson et al., 1983; Littledike and Goff, 1987; Goff, 2000; Rude and Gruber, 2004). K supplementation is also recommended in cows with hypocalcemia as K depletion may occur in response to the reduced DMI (Peek et al., 2003; Oetzel, 2007).

There is good evidence that both hypocalcemia and dystocia predispose to post-partum diseases such as retained fetal membranes (RFM) and metritis (Curtis et al., 1985). What is not well established is the mineral and energy status of cows affected with dystocia. We hypothesized that cows with dystocia would be in a worse mineral and metabolic state than cows without dystocia, and that mineral/energy supplementation of cows having dystocia would increase blood mineral concentration (especially Ca), prevent a decrease in DMI, improve energy balance and increase milk yield post-partum. Our objectives were to determine the effect of mineral/energy supplementation of dairy cows with dystocia on blood mineral concentrations, energetic and inflammatory profiles, and milk yield.

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Materials and methods

Cows and herd management

The study was conducted at the University of Florida Dairy Unit. All animal procedures were approved by the University of Florida Institutional Animal Care and Use Committee (IACUC D452; approved August 2004).

The herd consisted of 550 lactating Holstein cows that were housed in free-stall barns and milked three times a day. Yearly rolling herd average milk yield was 10,500 kg. Both pre- and post-partum cows were fed a total mixed ration (TMR) twice daily, formulated to meet their requirements according to National Research Council (2001). Dry cows were moved from a far-off to a close-up pen between 252 and 258 days of gestation (22–28 days before expected calving). The close-up diet contained acidogenic salts. The close-up and post-partum diets are shown in Table 1.

Post-partum rectal temperature, disease diagnosis, and milk yield

All cows had rectal temperatures measured between 06.00 and 08.00 h from days 1 to 6 post-partum and on day 12 using a M700 Digital Thermometer (GLA Agricultural Electronics). Common post-partum diseases, such as retained fetal membranes (RFM), metritis, mastitis, and displaced abomasum (DA), were diagnosed by trained farm personnel as previously reported (Machado et al., 2014). Milk production was recorded for each of the three milkings that started at 06.00, 14.00 and 22.00 h, and the milk yield for each day was the sum of the three milkings.

Experimental design

Sample size was based on measurement of blood total Ca concentration. To detect a difference of 0.5 mg/dL in mean blood total Ca concentration (standard deviation 0.8 mg/dL; expected cow loss of 10%), with 80% power at a 95% level of confidence 20 cows were needed per group (SAS Version 9.3, SAS Institute).

Multiparous Holstein cows with dystocia (calving score 2–5 as described by Lombard et al., 2007) were included in the study. None of the cows had a Cesarean section. Immediately after calving, body condition score (BCS) was evaluated using a 1–5 scale (Ferguson et al., 1994). Cows with dystocia were randomly assigned into two groups (treated or not), and a third reference group of cows without dystocia were randomly selected and left untreated.

Treated dystocic cows (DME; $n = 18$) were treated with an oral mineral/energy supplement comprising 516 g of calcium propionate (NutroCAL 100; Kemin AgriFoods North America; i.e. approximately 110 g of Ca and 400 g of propionate), plus an additional 110 g of potassium chloride and 150 g of magnesium sulfate mixed in 10 gallons (45.4 L) of water. The amounts supplemented were based on a formula designed by J.P. Goff to supply approximately half of the daily electrolyte intake of an adult dairy cow (Oetzel, 2007).

All drenches were administered within 6 h of calving and again 3 days post-partum. The first treatment was mainly aimed at maintaining Ca concentrations in the first 3 days post-partum (Goff et al., 1996; Kimura et al., 2006) and the second treatment was mainly aimed at preventing excessive NEFA mobilization in the first 6 days post-partum (McArt et al., 2012), although the overall goal was to improve mineral and energy status in the first 12 days post-partum.

Untreated dystocic cows (DNT; $n = 22$) were not given a supplement, nor did they receive the additional water. This was also the case for the selected cows which had a normal calving (NNT; $n = 25$).

Randomization of cows with dystocia was achieved by using the Randbetween function in Excel (Microsoft). Using the function, 40 random numbers (0 or 1) were generated in a column in Excel; this column was used to assign cows into each dystocia group as they calved with 1 = DME and 0 = DNT. Eutocic cows were recruited into the study by drawing numbers from a hat after enrolling two cows with dystocia. On a few occasions, a eutocic cow was enrolled after enrolling one cow with dystocia instead of two.

Table 1
Ingredient and nutrient composition of pre- and post-partum diets (dry matter basis).

Item	Diet	
	Pre-partum	Post-partum
Ingredient, % DM		
Corn silage	28	36.1
Sorghum silage	29.8	–
Alfalfa hay	–	11
Oat hay	15.2	–
Wheat straw	2	–
Ground corn	13.2	15.6
Citrus pulp	–	6.5
Soybean meal	3.8	4.7
SoyPlus	3.8	4.7
Whole cottonseed	–	8.0
Cottonseed meal	–	4.7
Molasses	–	5.0
Pre-partum mineral supplement	1.9	–
Post-partum mineral supplement	–	3.7
Bovachlor[a]	2.3	–
Nutrient profile		
NE_L, Mcal/kg	1.45	1.61
CP, %	14.1	16.5
NDF, %	42.8	31.2
ADF, %	27.2	21.0
Starch, %	20.8	24.9
NFC, %[b]	31.3	41.2
Ether extract, %	3.8	4.4
Ash	8.05	6.7
Ca, %	0.82	0.95
P, %	0.34	0.42
Mg, %	0.31	0.32
K, %	1.18	1.59
Na, %	0.15	0.35
Cl, %	0.95	0.49
S, %	0.29	0.21
DCAD,[c] mEq/kg	−82	+290

DM, dry matter; NE_L, net energy for lactation; CP, crude protein; NDF, neutral detergent fiber; ADF, acid detergent fiber; NFC, non-fiber carbohydrate; DCAD, dietary cation-anion difference.

[a] Bovachlor (Westway Feed Products LLC, Clewiston, FL) contains the following (DM basis): 60% CP, 0.4% Ca, 0.7% Mg, 2.2% K, 2.2% Na, 0.4% S, 24.4% Cl, and 22.2% inverted sugars.

[b] NFC was calculated by difference: NFC = 100 − (% neutral detergent fiber [NDF] + % crude protein [CP] + % ether extract + ash).

[c] DCAD calculated as follows: DCAD = (mEq of Na + mEq of K) − (mEq of S + mEq of Cl).

Plasma concentrations of Ca, Mg, K, NEFA, BHBA, and haptoglobin

Blood samples were obtained before treatment at calving (day 0) and at 1, 2, 3, 6 and 12 days post-partum from the middle coccygeal vein or artery via evacuated blood collection tubes containing sodium citrate as anticoagulant (Vacutainer; Becton Dickinson). All samples were obtained before the morning feeding.

Within 6 h of collection, blood samples were centrifuged at 3000 *g* for 10 min. Plasma samples were separated and stored at −20 °C until analysis. Plasma concentrations of Ca, Mg and K were determined by atomic absorption spectrophotometry (Martinez et al., 2012). Commercial kits were used to determine plasma concentrations of NEFA and BHBA (Martinez et al., 2012). Plasma concentrations of haptoglobin were determined using a colorimetric biochemical assay measuring haptoglobin–hemoglobin complex by the estimation of differences in peroxidase activity (Chan et al., 2004).

Statistical analyses

Continuous outcomes were analyzed by ANOVA for repeated measures (except for comparisons at calving) using the MIXED procedure of SAS. Models included the fixed effects of dystocia group, parity (second vs. third or greater lactation), BCS at calving (<3.75 vs. ≥3.75; Waltner et al., 1993), time (1, 2, 3, 6, and 12 days post-partum) and two-way interactions between dystocia group and other covariates. Analyte concentrations at calving were included in the repeated measures models as a covariate. Cow nested within group was included in the models as a random effect. Treatment group and interaction between treatment group and time was forced into the models but other covariates were manually removed if $P > 0.10$. When a main effect of dystocia group was observed, post-hoc multiple comparisons among the groups were performed. When an interaction between dystocia group and time was observed, post-hoc multiple comparisons among the groups within each time point were performed.

All cows were used in the analyses of analytes; however, one cow from DME, one cow from DNT and two cows from NNT inadvertently received dextrose intravenously at 4 (NNT), 7 (DME and DNT) and 12 days post-partum (NNT) as an adjunct therapy for other diseases; analyte data after dextrose treatment were not included in the analyses. Raw data for NEFA, BHBA, and haptoglobin were $\log_{10}$ transformed to achieve normality; after analysis, data were back-transformed to report least-squares means. The area under the curve was calculated for both NEFA and BHBA concentrations (non-transformed) using cubic spline interpolation and the trapezoidal rule using the EXPAND procedure of SAS. The area under the curve was also compared using the MIXED procedure of SAS (Yasui et al., 2014). Pre-planned contrasts were performed to evaluate the effect of dystocia (DME + DNT vs. NNT) on all outcomes.

Results

All continuous data are presented as least squares means ± SE. Plasma mineral concentrations are shown in Fig. 1. At calving, only plasma K concentration was significantly affected by group ($P < 0.001$); cows in DME and DNT had decreased ($P < 0.02$) plasma K concentrations compared with NNT (4.41 ± 0.15 vs. 4.67 ± 0.14 vs. 5.21 ± 0.13 mmol/L, respectively).