Short communication: Blood mineral and gas concentrations of calves born to cows fed prepartum diets differing in dietary cation-anion difference and calcium concentration

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ABSTRACT

Eighty-two multiparous Holstein cows were fed diets differing in dietary cation-anion difference (DCAD) and Ca concentrations in a randomized block design experiment beginning 4 wk before anticipated calving to determine the effects on colostrum yield and quality and acid-base balance and mineral status of newborn calves. Treatments were arranged as a 2 × 2 factorial to provide 2 DCAD [−22 mEq/100 g of dry matter (NEG) or −3 mEq/100 g of dry matter (NEU)] and 2 supplemental Ca concentrations (1.3 or 1.8% of dry matter). After calving, cows were milked within 2 to 8 h and colostrum yield was recorded. Calves were fed 200 g of IgG of a commercial colostrum replacer within 4 h of birth. No differences were observed in birth weight or dystocia score among treatments, which averaged 42.7 kg and 1.12, respectively. Colostrum yield was not different among treatments and averaged 8.75 kg. Colostrum quality, as measured using a Brix refractometer, was not affected by DCAD but was higher for 1.3% compared with 1.8% Ca: 21.58% and 19.87%, respectively. Colostrum IgG concentrations were higher for NEG compared with NEU and for 1.3% compared with 1.8% Ca. No differences were observed in concentrations of serum IgG, Ca, P, K, Cl, anion gap, or whole-blood pH, partial pressure of O₂, or SO₂ of calves among treatments. Serum Mg and lactate concentrations were higher and CO₂ tended to be lower for calves born to cows fed 1.3% compared with 1.8% Ca. Interactions of DCAD and Ca were observed for serum Na and Cl, which were higher for NEU-1.3% Ca and NEG-1.8% Ca compared with NEU-1.8% Ca and NEG-1.3% Ca. Whole-blood partial pressure of CO₂, and HCO₃ exhibited an interaction of DCAD and Ca and tended to be lower for NEU-1.3% Ca and NEG-1.8% Ca compared with NEU-1.8% Ca and NEG-1.3% Ca. Results

of this trial indicate that feeding prepartum diets with 1.8% compared with 1.3% supplemental Ca reduced colostrum quality and serum concentrations of Mg and lactate in calves immediately after birth. Feeding NEG supported higher colostrum IgG concentrations. Blood mineral concentrations and blood gas balance tended to differ, but the effects were not consistent across DCAD and Ca.

Key words: dietary cation-anion difference, calcium, colostrum, blood mineral

Short Communication

Feeding a negative DCAD prepartum diet has been adopted by many dairy producers in the United States as a means of reducing the incidence of hypocalcemia or milk fever (NAHMS, 2014). Clinical hypocalcemia in the United States has been reported to affect approximately 5 to 7% of multiparous cows, whereas approximately 50% of multiparous cows are reported to have subclinical blood Ca concentrations (Reinhardt et al., 2011). Feeding a negative DCAD diet creates a compensated metabolic acidosis, which positively alters Ca homeostatic mechanisms. Previous research has reported decreased blood pH and blood gas concentrations of cows fed acidogenic diets (Oetzel, 1988), but the effects on the newborn calf have not been extensively studied. Metabolic and respiratory acidosis, typically the result of dystocia, are strongly correlated with increased incidence of calf mortality (Szenci, 1985; Lombard et al., 2007). Tucker et al. (1992) did not observe any effect of feeding dams a negative versus positive DCAD diet prepartum on serum mineral concentrations of calves. However, others have reported negative effects on IgG absorption in calves whose dam were fed negative DCAD diets (Joyce and Sanchez, 1994; Guy et al., 1996; Quigley and Drewry, 1998). More recently, Collazos et al. (2017) reported a transient metabolic acidosis in calves born to dams fed acidogenic diets prepartum. The objectives of this trial were to determine the effects of prepartum DCAD and dietary Ca

Received March 26, 2018.

Accepted June 13, 2018.

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concentration on colostrum quality, newborn calf blood minerals, and gas concentration.

Eighty-two Holstein calves born to multiparous cows (1.9 ± 1.0 lactations) fed diets differing in DCAD [-3 (neutral DCAD; **NEU**) or -21 (negative DCAD; **NEG**) mEq/100 g of DM] and Ca (1.3% or 1.8% of DM) were used in the trial (Diehl, 2017). Prepartum urine pH was reduced ($P < 0.0001$) for cows fed NEG compared with NEU and averaged 7.45, 6.66, 6.05, and 6.01 for 1.3% Ca + NEU, 1.8% Ca + NEU, 1.3% Ca + NEG, and 1.8% Ca + NEG (SE = 0.21), respectively. Serum Ca concentrations of the dams were not different among treatments immediately after calving and averaged 7.60, 7.94, 7.81, and 7.94 mg/dL for 1.3% Ca + NEU, 1.8% Ca + NEU, 1.3% Ca + NEG, and 1.8% Ca + NEG (SE = 0.20), respectively. Cows calved in a dry lot or were brought into a dry calving pen when parturition was near. Time of birth, sex, and dystocia score were recorded at calving. Calves were separated within 4 to 6 h after birth and fed a colostrum replacer to provide 200 g of IgG (Bovine IgG, Land O'Lakes Animal Milk Products Co., Shoreview, MN) via bottle or tube if necessary. Calves were individually housed in a calf barn or in individual calf hutches on sand.

Colostrum was harvested and sampled within 2 to 8 h of calving. Brix analysis was conducted immediately after colostrum harvest (MISCO DD-1 Refractometer, MISCO, Solon, OH) and an aliquot was frozen for IgG analysis using radial immunodiffusion (Bovine IgG Test Kit, Triple J Farms, Bellingham, WA). Blood samples were collected immediately after birth before colostrum feeding and again at 24 h after birth. Samples were placed on ice and immediately transported to the laboratory (University of Georgia Veterinarian Diagnostic Laboratory, Tifton) for analysis of lactate; pH; blood gases including partial pressure (p) of O₂, pCO₂, pSO₂, and pHCO₃; and minerals including Ca, Mg, Na, K, and Cl using an Advia 1800 Chemistry System (Siemens Medical Solutions USA Inc., Malvern, PA). Body weight was recorded before the calf entering individual calf pens on the day of birth.

The PROC MIXED procedures of SAS (SAS Institute Inc., Cary, NC) were used to analyze the data. The model included block (age and expected calving

date), DCAD treatment, Ca treatment, interaction of DCAD and Ca, day, and the interactions of day and treatments. Significance was declared when $P \leq 0.05$ and trends were declared when $P > 0.05$ and ≤ 0.10 . When an interaction was detected, the PDIF option was used for mean separation.

Gestation length was not affected by prepartum DCAD (278.7 and 277.2 d, SE = 0.9 d for NEG and NEU, respectively), but tended to be lower ($P = 0.0626$) for cows fed 1.8% Ca compared 1.3% Ca (279.2 and 276.1 d, SE = 0.9 d, respectively). Birth weight and dystocia score were not different among treatments ($P > 0.10$) and averaged 42.7 kg and 1.12, respectively. No differences ($P > 0.10$) were observed in colostrum yield among treatments and averaged 8.75 kg (Table 1). Colostrum quality, as assessed by Brix refractometry, was not different among DCAD treatments, but was higher ($P = 0.0442$) for 1.3% Ca compared with 1.8% Ca: 21.58% and 19.87%, respectively. Concentrations of IgG measured via radial immunodiffusion were higher for NEG compared with NEU ($P = 0.0034$) and averaged 9,982.1 and 5,395.0 mg/dL, respectively. Colostrum from cows fed 1.3% had higher ($P = 0.0120$) IgG concentrations compared with 1.8% Ca: 9,558.5 and 5,818.4 mg/dL, respectively.

Blood metabolites of calves are shown in Table 2. Concentrations of serum Ca ($P < 0.0001$), P ($P = 0.0023$), Mg ($P = 0.0327$), K ($P = 0.0195$), anion gap ($P = 0.0005$), whole-blood pCO₂ ($P < 0.0001$), and lactate ($P < 0.0001$) were higher but serum CO₂ ($P < 0.0001$) and whole-blood SO₂ ($P = 0.0004$) were lower on d 0 compared with d 1. No differences ($P > 0.10$) were observed among treatments in serum concentrations of Ca, P, K, anion gap, or whole-blood pH, pO₂, pCO₂, or pSO₂. Calves born to cows fed 1.3% Ca had higher concentrations of serum Mg ($P = 0.0391$) and lactate ($P = 0.0591$) compared with calves born to cows fed 1.8% Ca. A DCAD $\times$ Ca interaction was observed for serum Na ($P = 0.0232$), serum Cl ($P = 0.0619$), and whole-blood HCO₃ ($P = 0.0515$), which were higher for calves whose dams were fed NEG and 1.3% Ca compared with NEG and 1.8% Ca. A DCAD $\times$ day interaction was observed for serum CO₂ ($P = 0.0062$) and whole-blood HCO₃ ($P = 0.0237$). Serum

Table 1. Colostrum yield and characteristics of cows fed diets differing in prepartum DCAD and Ca concentrations¹

Item	NEU		NEG		SE	P-value		
	1.3% Ca	1.8% Ca	1.3% Ca	1.8% Ca		DCAD	Ca	DCAD $\times$ Ca
Yield, kg/d	10.1	7.9	8.4	8.6	1.2	0.6092	0.4567	0.3085
Brix, %	21.42	19.16	21.74	20.58	0.81	0.2792	0.0442	0.4914
IgG, mg/L	6,135.9	4,654.0	12,981.1	6,982.8	1,171.0	0.0034	0.0120	0.1153

¹NEU = neutral DCAD; NEG = negative DCAD.

Table 2. Serum and whole-blood metabolites of calves born to cows fed diets differing in prepartum DCAD and Ca concentrations¹

Item	Day	NEU		NEG		SE	<i>P</i> -value			
		1.3% Ca	1.8% Ca	1.3% Ca	1.8% Ca		Day	DCAD	Ca	DCAD × Ca
Serum										
IgG, ² mg/dL	0	—	—	—	—	267.1		0.9547	0.9006	0.7063
	1	1,151.9	1,018.6	1,036.1	1,103.7					
Ca, mg/dL	0	11.37	11.56	11.61	11.64	0.24	<0.0001	0.9095	0.3447	0.9045
	1	10.73	10.89	10.49	10.93					
P, mg/dL	0	7.04	7.01	7.42	7.07	0.14	0.0023	0.4361	0.8940	0.8982
	1	6.73	6.68	6.53	6.89					
Mg, mg/dL	0	2.43	2.33	2.46	2.33	0.05	0.0327	0.5843	0.0391	0.6907
	1	2.38	2.33	2.33	2.23					
K, mEq/L	0	7.92	6.85	7.06	7.56	0.49	0.0195	0.8029	0.3047	0.1517
	1	7.61	6.23	6.78	6.72					
Na, ³ mEq/L	0	141.57	143.39	144.09	137.95	1.29	0.6009	0.3668	0.8845	0.0232
	1	139.63	143.54	140.87	140.55					
Cl, ³ mEq/L	0	101.3	102.44	102.01	98.05	1.02	0.1505	0.1259	0.9948	0.0619
	1	98.79	101.58	98.85	98.90					
CO ₂ , mmol/L	0	27.14	28.03	24.81	27.71	0.61	<0.0001	0.8515	0.0816	0.2773
	1	28.92	28.79	30.12	30.68					
Anion gap, mmol/L	0	21.02	19.59	22.63	19.57	0.71	0.0005	0.6911	0.1131	0.1825
	1	17.88	19.04	18.79	17.68					
Whole blood										
pH	0	7.19	7.24	7.20	7.20	0.02	<0.0001	0.7214	0.2102	0.2751
	1	7.29	7.30	7.31	7.32					
pO ₂ , ³ mmHg	0	41.25	44.52	44.00	38.09	4.19	0.5805	0.8799	0.4119	0.4806
	1	45.17	41.15	47.07	40.41					
pCO ₂ , ³ mmHg	0	73.93	63.11	65.54	71.75	3.24	<0.0001	0.9887	0.4415	0.0770
	1	59.15	53.26	55.65	56.31					
HCO ₃ , ⁴ mmol/L	0	28.10	26.74	25.51	27.69	0.70	0.2335	0.6726	0.6613	0.0515
	1	27.91	25.85	28.28	28.31					
SO ₂ , mmol/L	0	54.19	59.67	56.71	53.51	2.93	0.0004	0.8659	0.7214	0.3311
	1	65.18	63.48	67.50	62.72					
Lactate, mg/dL	0	7.70	6.47	8.19	6.67	0.47	<0.0001	0.5698	0.0591	0.8670
	1	6.16	5.79	5.30	4.90					

¹NEU = neutral DCAD; NEG = negative DCAD.²Serum IgG was not measured immediately after birth.³pO₂ = partial pressure of O₂; pCO₂ = partial pressure of CO₂.⁴Interaction of DCAD × Ca due to higher concentrations for NEG and 1.3% Ca compared with NEG and 1.8%.

CO₂ exhibited a greater increase from d 0 to 1 in calves from cows fed the NEU compared with NEG. Whole-blood HCO₃ decreased from d 0 to 1 (27.42 to 26.88 mmol/L) in calves born to cows fed NEG, whereas it increased (26.60 to 28.29 mmol/L) in calves from cows fed NEU.

Research on the effects of prepartum DCAD and Ca on calves has been limited. No differences were observed in colostrum yield due to DCAD, which is consistent with previous reports (Weich et al., 2013). However, colostrum quality was affected by both DCAD and Ca concentration of prepartum diets. Colostrum quality was initially measured by Brix refractometer immediately after harvest. Research using the Brix refractometer has correlated a Brix score of 22% to be equivalent to an IgG concentration of 5,500 mg/dL, indicating high-quality colostrum (Jones and Heinrichs, 2011). Our Brix measures indicated quality was lower for cows fed 1.8% Ca versus 1.3% Ca prepartum. Brix scores

averaged 19.87 and 21.58%, respectively. When IgG were measured by radial immunodiffusion, quality was positively affected by feeding either a negative DCAD (NEG) and or moderate Ca (1.3% Ca). Prepartum DMI was higher than predicted by NRC for all treatments, so Ca intake was higher than expected for the 1.8% Ca diet but did not alter serum Ca concentrations of the cows. It is not clear how this would affect IgG concentrations in the colostrum. Additional research is needed to confirm these results as the effect of DCAD on colostrum quality is important for colostrum management to achieve successful passive transfer in calves fed the colostrum.

No differences were observed among treatments in IgG concentration in the serum of calves. Joyce and Sanchez (1994) and Guy et al. (1996) reported that calves fed colostrum from cows fed acidogenic diets had lower serum IgG concentration. However, Morrill et al. (2010) reported similar concentrations of serum IgG

and apparent efficiency of absorption in calves born to dams fed diets with or without anionic salts prepartum. Collazos et al. (2017) did not observe any difference in serum IgG or IgG apparent efficiency of IgG absorption of calves born to cows fed diets with -7 or -18 mEq/100 g of DM DCAD. Results from our current trial suggest that there was no effect of DCAD on the apparent efficiency of IgG absorption in calves based on serum IgG concentrations after feeding 200 g of IgG from a colostrum replacer. The literature is lacking data regarding the effect of dietary Ca supplementation prepartum and its effect on IgG absorption, but the results from this trial suggest that it does not have an effect.

The metabolic status of calves was measured by the incidence of respiratory and metabolic acidosis. Normal calves with little to no respiratory distress will have a serum pCO_2 of 55 ± 3 mmHg (Szenci, 1985). Our results indicate the average pCO_2 concentrations of calves for treatments were greater than 55 ± 2 mmHg, meaning little to no respiratory distress was observed. Serum pH is used in combination with pCO_2 as an indicator of metabolic acidosis. Serum pH was within the normal range (Poulsen and McGuirk, 2009) and was not affected by prepartum DCAD. This is consistent with Tucker et al. (1992) who concluded that feeding negative DCAD diets prepartum had no effect on acid-base status or blood mineral status of calves. In contrast, Collazos et al. (2017) reported that calves born to cows fed a -7 mEq/100 g of DM DCAD diet displayed metabolic acidosis at birth, whereas calves born to cows fed a -18 mEq/100 g of DM DCAD diet exhibited a transient metabolic acidosis. The reason for the different response in serum CO_2 or HCO_3 to DCAD from 0 to 1 d of age is not readily apparent. However, the values remain within normal limits so the effect is not likely to have an effect on calf health or performance.

Results of this trial suggests feeding an acidogenic diet to cows prepartum does not alter blood mineral or gas concentrations in calves compared with calves born to dams fed a nonacidified diet. Feeding a fully acidified diet did result in higher quality colostrum as measured by IgG concentrations. However, increasing the dietary Ca concentrations prepartum to 1.8% compared with 1.3% may negatively affect colostrum quality and result in lower Brix and IgG concentrations which could negatively affect calf health when fed in the production setting. Neither prepartum DCAD nor Ca concentration affected apparent absorption efficiency of IgG.

ACKNOWLEDGMENTS

Partial funding for this research was provided by Phibro Animal Health Corporation. We acknowledge and appreciate the assistance of Tracey Cook and the farm crew at the Dairy Research Center for assistance in animal care and sample collection and Melissa Tawzer and Lea Cocker for assistance with sample analysis (University of Georgia, Tifton).

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