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Effect of postparturient oral calcium administration on serum total calcium concentration in Holstein cows fed diets of different dietary cation-anion difference in late gestation

S. Afshar Farnia[a], A. Rasooli[a,b], M. Nouri[a,*], A. Shahryari[c], M. Khosravi Bakhtiary[d], P.D. Constable[e]

[a] Department of Clinical Sciences, School of Veterinary Medicine, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[b] Department of Animal Health Management, School of Veterinary Medicine, Shiraz University, Shiraz, Iran
[c] Department of Basic Sciences, School of Veterinary Medicine, Shahid Chamran University of Ahvaz, Ahvaz, Iran
[d] FKA Agriculture and Animal Husbandry Company, Isfahan, Iran
[e] College of Veterinary Medicine, University of Illinois, Urbana, USA

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ABSTRACT

Minimizing the severity of post parturient hypocalcemia and the incidence of subclinical hypocalcaemia in multiparous dairy cows are important goals of the transition period. The primary objective of this study was to determine whether feeding an acidogenic ration in late gestation combined with oral $CaCl_2$ administration after parturition improved calcium homeostasis when compared to feeding an acidogenic ration prepartum or oral $CaCl_2$ administration postpartum alone. Forty-two Holstein dairy cows were randomly assigned to one of three groups of 14 cows. Group L were fed a low DCAD ration. Groups L + Ca and M + Ca were fed a low or moderate DCAD ration, respectively, and administered 50 g Ca as a $CaCl_2$ solution at calving and 12 h later by ororuminal intubation in 500 mL of water. Mean serum [calcium] was lower immediately after parturition in group M + Ca (7.1 mg/dL) than group L + Ca (8.2 mg/dL). Oral $CaCl_2$ administration increased mean serum [calcium] at 6 h after treatment in groups M + Ca (8.0 mg/dL) and L + Ca (8.7 mg/dL), but most of this increase had disappeared at 12 h after treatment. Group L + Ca had a higher serum [calcium] at time = 6 h and 12 h than the other two groups, and a higher serum [calcium] than group M + Ca at 1 and 2 days after treatment. We conclude that feeding an acidogenic ration in late gestation combined with oral $CaCl_2$ administration provided a higher serum [calcium] at 6 and 12 h after parturition than feeding an acidogenic ration prepartum or oral $CaCl_2$ administration postpartum alone.

1. Introduction

Minimizing the severity of postparturient hypocalcaemia and the incidence of subclinical hypocalcaemia in multiparous dairy cows remains an important goal of the transition period. Feeding an acidogenic diet is a practical and effective method of decreasing the incidence of clinical and subclinical hypocalcaemia in large confinement herds where it is possible to feed a total mixed ration to cows in late gestation (Oetzel et al., 1988; Moore et al., 2000; Charbonneau et al., 2006). Acidogenic diets are currently targeted to provide a dietary cation-anion difference (DCAD) of − 10 to − 15 mEq/100 g of dry matter and at least 0.5–0.6% calcium content on a dry matter basis, and are fed for at least 14 days before the anticipated calving date. Metabolic adaptations to hypocalcemia are controlled by parathyroid (PTH) and 1,25-dihydroxyvitamin D_3 (calcitriol) hormones that are considered the main Ca regulatory hormones in mammals (Ramberg et al., 1984). Multiparous cows have fewer intestinal vitamin D receptors resulting in decreased intestinal epithelial cell responsiveness to vitamin D (Horst et al., 1990). Administration of selected Vitamin D_3 formulations has the potential to provide a practical method for controlling postparturient hypocalcemia. For example, daily oral administration of 3 mg of 25-hydroxyvitamin D_3 to periparturient multiparous Holstein cows fed an acidogenic diet improved calcium homeostasis (Wilkens et al., 2012), and subcutaneous administration of 0.3 mg of 1,25-dihydroxyvitamin D_3 at calving improved calcium homeostasis and improved measures of innate immune function in early-lactation Holstein cows (Vieira-Neto et al., 2017).

Oral or subcutaneous administration of calcium salts provides a

* Corresponding author.
E-mail address: m.nouri@scu.ac.ir (M. Nouri).

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practical method for controlling postparturient hypocalcemia in small confinement herds or pasture fed herds where feeding an acidogenic total mixed ration in late gestation or periparturient administration of Vitamin D_3 formulations are not possible (Constable, 2014). Oral administration of calcium containing boluses, gels, or solutions immediately before or after calving, then at 12 to 24 h intervals for a total of 2 to 4 treatments (total calcium dose of approximately 80 to 200 g), is a practical and effective method for increasing serum calcium concentration ([calcium]) in the early post-partum period (Goff and Horst, 1993; Queen et al., 1993; Hernandez et al., 1999; Dhiman and Sasidharan, 1999; Sampson et al., 2009; Blanc et al., 2014; Martinez et al., 2016a). This treatment protocol decreases the incidence of health events in lame cows (Oetzel and Miller, 2012), and decreases the incidence of parturient paresis and left displaced abomasum in dairy cattle (Ringarp et al., 1967; Oetzel, 1996; Thilsing-Hansen et al., 2002). Interestingly, it appears that beneficial effects on serum [calcium] are more likely to be obtained if calcium is administered orally before parturition (Ringarp et al., 1967; Oetzel, 1996; Pehrson et al., 1998; Hernandez et al., 1999; Dhiman and Sasidharan, 1999; Thilsing-Hansen et al., 2002; Agger and Renny, 2004; Sampson et al., 2009; Martinez et al., 2016b) or within 24 h of calving (Hernandez et al., 1999).

The most commonly administered oral calcium formulation is calcium chloride ($CaCl_2$) that rapidly dissociates in the ruminant gastrointestinal tract, thereby providing a high luminal calcium concentration that may facilitate rapid passive absorption (Goff and Horst, 1993, 1994; Oetzel, 2013). Consequently, oral $CaCl_2$ administration increases plasma [calcium] in a dose-dependent manner for 2 to 8 h after administration (Martinez et al., 2016a). There do not appear to be any studies that have compared the efficacy of oral $CaCl_2$ administration immediately after calving in mitigating the postparturient decrease in serum [calcium] in multiparous cattle fed diets of different DCAD during late gestation. We hypothesized that the combined application of two practical and effective methods for controlling postparturient hypocalcemia, feeding an acidogenic diet during late gestation and oral $CaCl_2$ administration immediately after calving, would improve postparturient calcium homeostasis when compared to cows fed an acidogenic diet during late gestation or cows fed a moderate DCAD ration during late gestation and administered oral $CaCl_2$ immediately after calving. Accordingly, the primary objective of this study was to compare the serum [calcium] and urinary calcium excretion in the 24 h after parturition in multiparous cows administered oral $CaCl_2$ after parturition and fed an acidogenic diet during late gestation, to that of cows not receiving oral $CaCl_2$ or not fed an acidogenic diet. A secondary objective was to explore whether there was an effect of treatment on indices of energy homeostasis, milk production, and reproductive performance.

2. Materials and methods

2.1. Cows and herd management

Forty-two multiparous cows in their third or more lactation at a dairy farm in the Isfahan province of Iran were enrolled in the study over a three week period. The farm milked 3915 cows with a 305 mature cow equivalent milk production of 12,407 kg with 3.5% fat and 3.0% protein. The study was conducted in summer (mean ambient temperature of 29 °C) and approved by the Animal Care and Use Committee of the Department of Clinical Sciences at Shahid Chamran University of Ahvaz (No. 94.3.24.4002).

Cows were group housed in three pens of equal area and equivalent stocking density in a dry-lot facility during the last 3 week of gestation. Cows in two pens were fed an acidogenic close-up cow diet, and cows in the third pen were fed a moderately acidogenic close-up cow diet. Diets were fed ad libitum twice a day, starting 21 days before the anticipated calving date. Feed bunk TMR samples of close-up cow diets were collected for chemistry analysis (Table 1). Cows were moved to separate covered maternity pens when parturition was imminent, and were fed the same TMR as when group housed. At calving, the calf was immediately separated from the dam. Postpartum cows in all three groups were housed in the same free stall barn, milked three times a day, and fed a lactating cow TMR twice a day.

Table 1
Ingredients and chemical composition of the two close-up rations (low DCAD and moderate DCAD) and the lactation ration fed during the study to 42 Holstein cows.

Ingredients	Low DCAD close-up ration	Moderate DCAD close-up ration	Lactation ration
	(% DM)	(% DM)	(% DM)
Legume forage hay, mature	12.0	19.5	24.2
Corn silage	45.5	38.5	21.0
Beet sugar pulp, dried	0	0	7.8
Barley grain, rolled	16.9	16.9	4.7
Corn grain, ground, dry	7.1	8.2	14.6
Corn gluten meal, dried	0	0	3.2
Cotton seed, whole with lint	2.1	2.1	5.7
Soybean, meal, solv. 44% CP	6.3	6.2	8.1
Fish meal, anchovy	1.5	1.5	3.4
Soybean, seed, whole heated	0.8	0.8	3.8
Rice bran	0	1.17	0
Canola meal, mech. extract	3.1	3.1	0
Calcium carbonate	1.39	0	0.57
Calcium phosphate(Di)	0.18	0.19	0.26
Magnesium oxide	0.18	0.19	0.21
Salt	0	0	0.26
Sodium bicarbonate	0	0	0.94
Bentonite	0.4	0.4	0.33
Biotin	0.004	0.004	0.004
Selenium	0.004	0.004	0.004
Choline chloride	0.24	0.24	0.24
Monensin	0.01	0.01	0.01
Vitamin premix[a]	0.5	0.5	0.4
Mineral premix[b]	0.5	0.5	0.4
Magnesium sulfate (H_2O)	0.89	0	0
Calcium chloride ($2H_2O$, 77–80% $CaCl_2$)	0.37	0	0
Chemical analysis			
DM (% as fed)	38.7	42.3	48.5
NDF (% DM)	33.9	34.9	33.0
ADF (% DM)	21.2	22.4	22.0
Forage NDF (%)	26.6	27.2	21.8
NFC (%)	43.3	43.8	39.6
Sugar (%)	4.0	4.4	5.1
Starch (%)	18.9	19.4	20.3
Forage (%)	57.5	58.0	45.2
CP (%)	13.4	14.0	17.4
Soluble protein (% of CP)	28	27	33
RDP (%)	9.5	10.2	10.7
Ca (%)	1.10	0.51	0.90
P (%)	0.41	0.42	0.50
Mg (%)	0.43	0.32	0.33
K (%)	1.10	1.10	1.35
Na (%)	0.12	0.12	0.43
Cl (%)	0.81	0.54	0.42
S (%)	0.35	0.21	0.25
DCAD (mEq/100 g dietary DM)[c]	−11.3	+5.03	+26.3

[a] Premix contained 1,800,000 IU of vitamin A/kg, 200,000 IU of vitamin D/kg, and 15,000 IU of vitamin E/kg.
[b] Premix contained 0.32 g of Co/kg, 13.1 g of Cu/kg, 0.5 g of I/kg, 0.042 g of Fe/kg, 32 g of Mn/kg, 8 g of Se/kg, 56.2 g of Zn/kg.
[c] We analyzed macro minerals (potassium, sodium, calcium, sulfur, chlorine, magnesium and calcium) through wet chemistry method. The ingredient and nutrient composition of the diets fed to close-up and fresh cows are represented in Table 1. NRC (2001) requirements were used for diet formulation.