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Prepartum Feeding of Cationic or Anionic Diets to Holstein Cows Given 30 or 60 Day Dry Periods: Comparison of Dry Matter Intake, Physiological Measures and Milk Production*

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ABSTRACT : Eighty-four Holstein cows were used to evaluate effects of feeding two diets that differed in dietary cation-anion difference (cationic; +28 or anionic; -138 mEq/kg DM) on prepartum and postpartum dry matter intake (DMI), body weight (BW), body condition score (BCS), serum Ca concentrations and on subsequent milk production and composition. Treatments were in a 2×3×2 factorial arrangement that included prepartum diet, dry period length (30 d dry, 30 d dry+estradiol cypionate (ECP), and 60 d dry), and prepartum and postpartum bST (POSILAC®, 10.2 mg/d). No interaction of prepartum diet with dry period length or bST supplementation was detected for any measure evaluated either prepartum or postpartum. No significant effects of prepartum diet on prepartum DMI, BW or BCS were observed. Mean DMI during the first 28 d postpartum were similar for cows fed the cationic or anionic diets prepartum (25.5 vs. 26.1 kg/d). During postpartum wk 1 to 14, no differences in mean BW or BCS were detected due to prepartum diet fed but decreases for both groups were observed during the first 6 wk postpartum. No differences due to prepartum diet were observed for mean milk or 3.5% FCM yields or for milk composition during the first 10 wk of lactation. Similarly, mean milk yield of cows during the first 21 wk did not differ significantly due to prepartum diet fed (38.5 vs. 38.6 kg/d). Overall, cows fed the prepartum cationic or anionic diets had similar mean postpartum serum concentrations of Ca (9.34 vs. 9.35 mg/dl). Subsequent milk production, milk composition and concentrations of Ca did not differ. Importantly, the two prepartum diets were equally satisfactory in minimizing incidence of milk fever and in supporting initiation of lactation, irrespective of dry period length and supplemental ECP and bST. (**Key Words** : Cationic-anionic Diets, Dairy Cows, DCAD, Milk Yield, Periparturient Period)

INTRODUCTION

A dry period of 50-60 d is recommended routinely for dairy cows so that they achieve maximum milk production and profitability during the ensuing lactation. Good nutritional management during the entire 50-60 d dry period, but especially the last-half, is critical to ensure that cows calve and enter the subsequent lactation prepared to meet the metabolic challenges of the lactation. Importantly, they also should be at lower risk for incidences of infectious and metabolic diseases (Drackley and Dann, 2005; Overton, 2005; Kamiya et al., 2006).

There recently has been interest in shortening the dry period (28 to 40 d) with similar overall goals. Rationale for this interest has been reviewed by Bachman and Schairer (2003), Grummer and Rastani (2004), Annen et al. (2004), and Overton (2005). In general, interest evolved because of development of improved guidelines for nutritional management throughout the dry period and the findings that mammary tissue regression and regeneration did not require a full 50-60 d dry period in order for cows to be prepared for the next lactation. Furthermore, recent studies that evaluated dry periods less than 40 d determined that subsequent milk production and health were not greatly compromised and that reproduction was improved slightly (Gulay et al., 2005; Gumen et al., 2005; Watters et al., 2006b).

Although there have been a number of studies reported to evaluate use of shorter dry periods, to date no pre-planned studies have been reported that compared specific diets fed during the periparturient period to meet the goals described. Recently, Overton (2005) described modified diet formulations considered suitable for cows given a 40-d

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Table 1. Dry matter concentrations and chemical composition of cationic and anionic close-up dry rations (CUD) and lactation total mixed ration (TMR) fed to Holstein cows[1]

	Cationic CUD	Anionic CUD	Lactation TMR
Corn silage	45.46	41.40	22.38
Alfalfa hay	5.00	-	11.69
Corn grains	18.28	22.52	-
Cottonseed hulls	11.17	10.66	5.07
Whole cottonseed	-	-	10.71
Citrus pulp	-	-	9.94
Soybean meal	8.38	8.89	8.39
Hominy	-	-	16.07
Distillers grains	-	-	10.42
Cottonseed with lint	5.20	7.18	-
Prolak	2.55	2.43	-
Mineral mix	-	-	5.33
Springer minerals	2.92	6.44	-
Salt	0.50	0.48	-
Sodium	0.54	-	-
Chemical composition (%)[2]			
DM	62.07	63.04	62.35
CP	14.88	14.87	17.18
Sol CP[3]	29.25	28.11	32.66
ADF	26.17	23.93	22.58
NDF	40.53	37.29	34.66
EE[4]	3.81	4.15	3.56
TDN	67.22	67.55	67.83
NE_L (Mcal/kg)	1.52	1.54	1.56
K^+	1.14	1.02	-
Na^+	0.40	0.27	-
Cl^-	0.82	1.08	-
S^{-2}	0.33	0.34	-
Ca^{+2}	1.07	1.66	-
P^+	0.38	0.35	-
Calculated DCAD[5]	+28	-138	-

[1] From NEDHIA Forage Laboratory, Ithaca, NY, analyses of components.
[2] DM basis. [3] Percentage of the CP.
[4] Ether extract. [5] mEq/kg DM.

dry period when managed in one or two nutritional groups throughout the dry period and whether or not anionic salts are added to the diet. Rastani et al. (2005) reported that cows managed using one higher energy nutritional program during an actual 29 d dry period produced as much solids corrected milk, and the DMI was similar to cows given a 57 d dry period. Importantly, there also were similar changes in specific blood and liver metabolic variables as in cows managed using the typical two nutritional management phases during the 57 d dry period.

Objectives of the current study were 1) to compare and evaluate the efficacy of feeding cows prepartum a cationic diet with a reduced concentration of K or an anionic diet during a 30 d dry period and 2) to compare the results of giving a 30 d dry period to that of cows fed and managed in a more traditional two-phase nutritional feeding program and given a 60 d dry period. Measures used to evaluate whether these diets would be equally effective when fed in conjunction with use of a shortened dry period included DMI, BW, BCS, serum Ca, and subsequent milk production and composition.

MATERIALS AND METHODS

Experimental design

The experimental protocol was approved by the Institutional Animal Care and Use Committee of the University of Florida. Eighty four multiparous Holstein cows were assigned randomly to a 2×3×2 factorial arrangement of treatments approximately 8 to 9 wk before their expected calving dates (ECD). Cows were fed either a cationic (n = 42) or anionic (n = 42) diet during the 3 wk before ECD. Cows in 30 d dry period treatment group (n = 28) and 30 d dry period+estradiol cypionate (ECP; n = 29) group were provided an expected 30 d dry period and received the cottonseed oil excipient (7.5 ml) or 15 mg ECP in oil, respectively (2 mg/ml, Pharmacia and Upjohn, Kalamazoo, MI). Cows in the 60 d dry control group (n = 27) received no oil or ECP. One-half of the cows in 30 d dry period (n = 14), 30 d dry period+ECP (n = 15) and 60 d dry control group (n = 13) were supplemented biweekly with bST (0.4 ml bST; POSILAC®). This quantity of POSILAC® provided approximately 10.2 mg bST/d; injections began approximately 28 d (±3 d) before ECD and continued up to 60 d postpartum. After 60 d, all cows on experiment received the full dose of POSILAC® biweekly (500 mg/14 d). Full discussion of these treatments is in Gulay et al. (2003; 2004).

Feeding program

Cows in 60 d group were dried off 60 d before ECD and then were moved to the dry herd and fed the herd lower energy far-off dry diet, whereas cows in the two 30 d groups (30 d and 30 d+ECP) remained in the milking herd until dried off at 30 d before ECD. All cows were housed and managed in a free-stall barn beginning 30 d before ECD and trained to use electronic feed gates (American Calan, Inc., Northwood, NH). All cows were fed once daily (10:00-12:00 h) and daily feed adjustments were made to allow for 5 to 10% daily refusals. During the first week of the trial, while being trained to use the Calan gates, all cows were fed a low potassium close-up dry cationic diet (+28 mEq/kg DM; Table 1). Starting at 3 wk before ECD, cows either were continued on the same cationic close-up diet or were fed a close-up anionic diet (-138 mEq/kg DM; Table 1). After parturition, all cows were fed twice daily a total mixed ration (TMR) based on corn silage, whole cottonseeds (WCS), and grain concentrate. This ration met the requirements of high-producing lactating cows (Table 1; NRC, 1989).

Table 2. Least squares means and SE of BW, BCS and DMI during the prepartum and postpartum periods for Holstein cows fed cationic or anionic diets prepartum

	Prepartum (-28 to -1 d)		Postpartum (0 to 28 d)[1]	
	Cationic diet	Anionic diet	Cationic diet	Anionic diet
BW (kg)[2]	692.4±11.17	678.5±10.71	629.5±10.05	621.4±9.64
BCS[3]	3.43±0.05	3.37±0.05	3.12±0.05	3.08±0.05
DMI (kg/d)[4]	16.7±0.58	16.4±0.56	25.5±0.74	26.1±0.77

[1] All cows were fed the same TMR during the postpartum period.
[2] BW = Body weight. [3] BCS = Body condition score. [4] DMI = Dry matter intake.
Measures within prepartum and within postpartum periods did not differ (p>0.10).

Table 3. Least-suares means and SE for milk yield, 3.5% FCM and the SCC of Holstein cows fed cationic or anionic diets during the prepartum period [1]

Measurements	Cationic diet	Anionic diet
Milk yield (kg/d)[2]	37.5±1.22	38.7±1.08
3.5% FCM (kg/d)[2]	40.2±1.13	40.9±1.06
SCM (kg/d)[2]	38.6±0.54	39.4±0.52
Milk yield (kg/d)[3]	38.5±0.59	38.6±0.57
305-d milk yield (adjusted; kg)[4]	9,990±288	9,593±266
305-d ME milk yield (kg)[5]	9,905±311	9,550±290
SCC[2, 6]	421±42.0	429±40.0
% Protein[2]	2.89±0.04	2.84±0.03
% Fat[2]	4.01±0.09	3.88±0.07

[1] All cows were fed the same TMR during postpartum period.
[2] During 1 to 10 wk postpartum. [3] During 1 to 21 wk postpartum.
[4] Adjusted for previous actual 305 d milk yield.
[5] 305 d mature equivalent milk yield. [6] SCC = Somatic cell count ×1,000.
Measures did not differ (p>0.10).

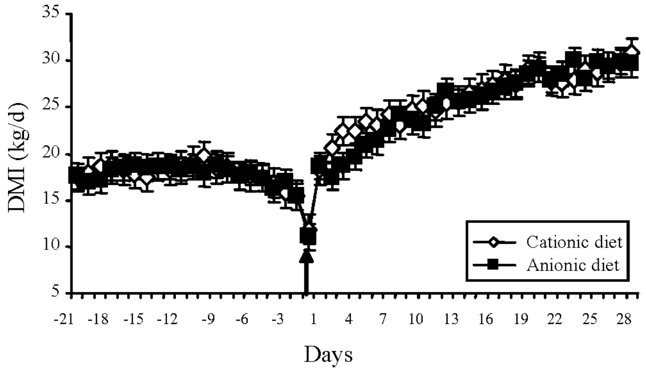

Figure 1. Least-squares means and SE for DMI of Holstein cows during the prepartum and early postpartum periods (-21 d through 28 d). Prepartum diets were fed beginning -3 wk through calving (indicated by arrow). All cows were fed the same TMR after calving.

Body condition scores and body weights

Body condition scores (1 to 5, thin to fat, on a 1/4 point scale; Ferguson et al., 1994) and BW of cows were recorded at 60 and 30 d before ECD. Thereafter, measures were once weekly on the same day each week through 28 d postpartum and then biweekly until ~ 100 d postpartum.

Blood collection, handling and storage

Blood samples from 80 cows (cationic diet = 39, anionic diet = 41) were collected from the coccygeal vein three times weekly before the a.m. feeding or milking (07:30-10:00 h) using Vacutainer® needles (2.54 cm) and 10×100 mm tubes without anticoagulant (Becton-Dickinson, Fairlawn, NJ). Blood was allowed to clot at room temperature for ~1 h after collection and serum harvested after centrifugation (-4°C). Serum was stored in capped polypropylene tubes at -20°C until analyzed. Serum samples for determination of Ca were prepared according to the procedure described by Miles et al. (2001) and analyzed using a Flame Atomic Absorption Spectrophotometer (Perkin-Elmer Model 5000).

Milk samples

Milk samples were collected at three consecutive milking shifts (08:30, 15:00, and 01:30 h) on the same day each week during the first 10 wk of lactation. All samples were analyzed for contents of fat, protein and SCC at Southeast Milk Laboratory, Inc. (Belleview, FL). Milk yield was recorded at each daily milking from 3 to 150 d postpartum.

Statistical analyses

Proc Mixed procedures of SAS (Littell et al., 2000) were used to analyze the data and to estimate individual daily and/or weekly least squares means for specific variables and treatments. Mathematical models included the main effects prepartum diet treatment, dry period treatments (30 d, 30 d+ECP and 60 d), bST treatment, and season (I = cows with dry periods during hotter months (September, October, March, April, and May), II = cows with dry periods during cooler months (November, December, January, and February)), and all interactions. However, no significant interactions of bST or dry period treatment with the prepartum diet treatment were detected during the overall prepartum or postpartum periods for any of the variables evaluated in the overall experiment, as listed in Table 2 and 3.

RESULTS

Changes in dry matter intake

Prepartum : Mean DMI of cows fed the cationic and anionic diets prepartum did not differ during the prepartum

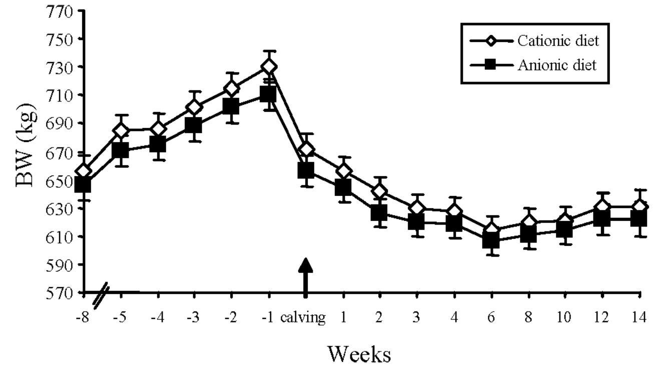

Figure 2. Least-squares means and SE for BW of Holstein cows during the prepartum and early postpartum periods (-3 wk through 14 wk). Prepartum diets were fed beginning -3 wk through calving (indicated by arrow). All cows were fed the same TMR after calving.

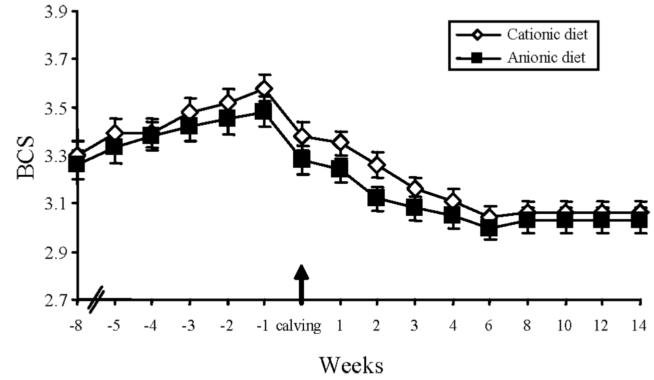

Figure 3. Least-squares means and SE for BCS of Holstein cows during the prepartum and early postpartum periods (-3 wk through 14 wk). Prepartum diets were fed beginning -3 wk through calving (indicated by arrow). All cows were fed the same TMR after calving.

period; mean DMI were 16.7 and 16.4 kg/d (Table 2). Cows in both diet groups maintained DMI greater than 16 kg/d through -8 d. However, there was a dramatic decrease in mean DMI the day before calving (Figure 1) in both diet groups, but decreases from -8 d to -1 d were similar for cows fed the cationic (39%) and anionic (37%) diets.

Postpartum : Mean DMI during the postpartum period (1 to 28 d) were similar (25.5 and 26.1 kg/d) for cows fed cationic and anionic diets prepartum (Table 2). Overall, cows fed the cationic diet tended to have slightly greater DMI ($p<0.15$) during the first week following parturition, but mean DMI of cows in both diet groups was greater than 23 kg/d at 8 d postpartum (Figure 1).

Changes in body weights and body condition scores

Prepartum : The BW of cows in both groups increased during the prepartum period, but no differences were detected in mean BW for diet treatments (Table 2). Cows fed the cationic diet had numerically greater BW (656 kg) than cows fed anionic diet (646 kg) at -8 wk (Figure 2). The

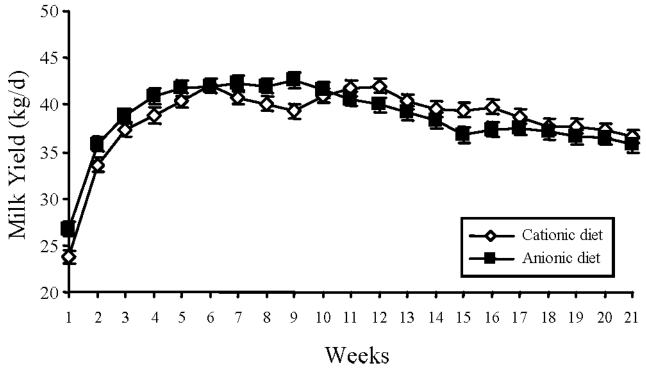

Figure 4. Least squares means and SE for daily milk yields of Holstein cows during the first 21 wk of lactation.

mean increases from -8 wk to -1 wk were 11.3 and 9.9% for cationic and anionic diet groups (Figure 2). Similarly, no differences were observed in mean BCS of diet groups during the prepartum period (Figure 3). At -8 wk the mean BCS of cows fed cationic and anionic diets were 3.30 and 3.26. The increase in mean BCS was similar (0.28 vs. 0.22 points) in both diet groups of cows from -8 wk to parturition (Figure 3).

Postpartum : During the postpartum period no differences due to prepartum diet were detected for mean BW or BCS (1 to 14 wk). Mean BW and BCS for cows in the two prepartum diet groups of cows followed similar patterns. Decreases in BW and BCS were seen through the first 6 wk after calving but thereafter they essentially maintained their mean BW and BCS (Figures 2 and 3).

Milk, 3.5% fat corrected milk (FCM) and solids corrected milk (SCM) yields

During the first 10 wk of lactation no differences were observed in mean milk, 3.5% FCM, or SCM yields or in percentages of protein and fat, and the SCC for cows fed the different prepartum diets. Similarly, mean milk yield (MY) during the first 21 wk did not differ significantly due to prepartum diet fed (Table 3; Figure 4). Milk yields of cows fed the anionic diet tended to have slightly ($p<0.15$) greater mean daily production during the first 10 wk of lactation (38.7 vs. 37.5 kg/d). Overall, no difference in mean MY of cows in cationic and anionic diet groups was detected during the first 21 wk in lactation (38.6 vs. 38.5 kg/d) or between the 305-d mature equivalent (ME) milk yields (9,905±311 kg vs. 9,550±290 kg; Table 3).

Previous mean lactation 305-d ME milk yields did not differ significantly for cows fed cationic or anionic diets prepartum (10,567±275 vs. 10,444±255 kg; Table 3). When current 305-d ME milk yields of cows were adjusted for actual 305-d MY in the previous lactation no difference was detected between mean yields for the cationic and anionic diet groups (9,990±288 vs. 9,593±266 kg; Table 3).

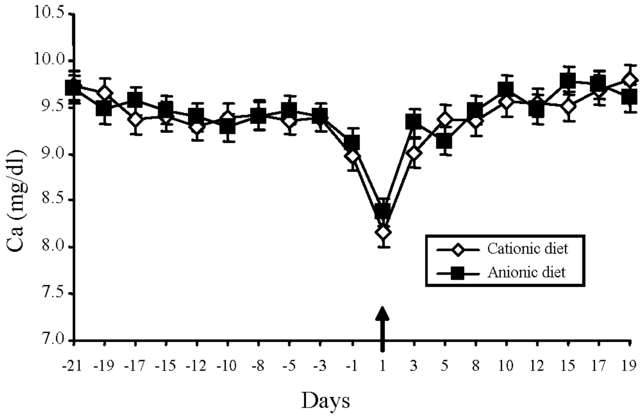

Figure 5. Least-squares mean concentrations and SE for Ca in serum of Holstein cows during the prepartum and early postpartum periods (-21 d through 19 d). Prepartum diets were fed beginning -3 wk through calving (indicated by arrow). All cows were fed the same TMR after calving.

Serum calcium concentrations

Mean concentrations of Ca in serum did not differ significantly (-21 d to +19 d) due to prepartum diet fed. However, changes in the periparturient pattern of serum concentrations of Ca were observed; concentrations declined around parturition and were least the day following calving (Figure 5). However, only 16 of 80 cows sampled had serum concentrations of Ca less than 7 mg/dl on the day following calving. Overall, neither of the diets fed prepartum was superior to the other in maintaining Ca concentrations during the peripartum period. Cows fed the prepartum cationic or anionic diets had similar mean serum concentrations of Ca (9.34 vs. 9.35 mg/dl), and 8 out of 16 cows in each diet group showed the reduced concentrations (<7 mg/dl) the day after calving. No incidences of clinical hypocalcaemia were observed in any cow irrespective of prepartum diet fed.

DISCUSSION

There has been increased interest in shortening the dry period to 28 to 40 d. However, to date there is limited information available from pre-planned experiments to evaluate and compare diets fed to cows that experience shortened dry periods. The overall benefits of the shortened dry period, in addition to those for the traditional dry period, are the opportunity to increase total lactation milk yield and profitability, and to simplify the nutritional management of dairy cows by feeding a single diet throughout the dry period (Annen et al., 2004; Bachman and Schairer, 2004; Overton, 2005; Rastani et al., 2005; Watters et al., 2006a, b). Greater milk production by today's genetically superior Holstein cows has resulted in maintenance of greater milk production levels at 50 to 60 d before ECD. This suggests that there is an increased potential for these cows to milk longer during the current lactation, which would make it more profitable to shorten the dry period (Bachman, 2002; Gulay et al., 2003; Annen et al., 2004; Overton, 2005). Of course, to realize the goals described and to improve the economic benefits implies that nutritional management during the periparturient period will meet all the needs of the cows. This management is necessary to minimize metabolic challenges and diseases and to achieve a high level of milk production so that the milk produced during the extra time cows are milked during the current lactation will more than offset any possible loss in milk yield that might occur during the subsequent lactation.

In previous published studies milk production and composition, incidences of diseases, changes in blood and liver metabolites, and reproductive performance were used to evaluate efficacy and safety of adopting a shortened dry period (Gulay et al., 2003; Annen et al., 2004; Gumen et al., 2005; Watters et al., 2006a, b). In a general way all of the responses evaluated are linked to the nutrition and health of the cows during the peripartal period. During the typical 50 to 60 d dry period high producing dairy cows now are managed routinely during two nutritionally distinct phases of about equal length. These are described as the far-off and close-up dry periods (Drackley, 1999; Drackley and Dann, 2005; Overton, 2005). This nutritional management pattern better prepares cows to meet the metabolic challenges of ensuing lactation and, importantly, the cows are at lesser risk for occurrence of infectious and metabolic diseases during the peripartal period (Grummer and Rastani, 2004; Overton, 2005).

The current research focused on evaluating diets that were fed during the shortened dry period that provided needed nutrients and energy without allowing unwanted increases or decreases in BW and BCS and also minimized possible occurrence of milk fever and associated diseases. The experimental design used in the current study allowed comparison of the results when the two diets were fed during the shortened dry period. It also allowed comparison of the results of the 30 d and the traditional 60 d dry periods. The latter comparison is that which typically has been used by others (Annen et al., 2004; Rastani et al., 2005). Recently, Overton (2005) described diets formulated with modified non-fiber constituents and reduced energy content that were intermediate between the far-off and close-up diets typically fed. These modified diets were considered suitable for cows given a 40 d dry period and could be fed to cows in either one or two nutritional groups during the dry period whether or not anionic salts are added to the diet. Based upon the formulation and rationale for their use, sufficient nutrients would be provided to avoid either an increase or decease in BW and BCS outside accepted norms, and the cows still would be prepared for calving and initiation of lactation. Thus, these diets would be acceptable for cows given a 30 to 40 d dry period.

The prepartum and postpartum changes in DMI as cows approach calving are well documented (Coppock et al., 1972; Bertics et al., 1992) and similar changes were observed for cows in the current study, irrespective of prepartum diet fed or length of the dry period. Overall, no significant differences in mean DMI were detected between prepartum diet treatment groups. Furthermore, the trends in DMI, BW and BCS for the 60 d dry group also agreed with others (Block, 1984; Oetzel et al., 1991; Moore et al., 2000). Thus, there was no apparent difference in diet palatability across diets fed prepartum. Based upon the DMI observed for the two diet groups, similar prepartum and postpartum BW and BCS changes would be expected and would have a similar effect on the ability of the cows to begin lactation satisfactorily. Indeed, the cows in both diet groups displayed the typical physical and physiological responses with no evident occurrence of clinical diseases.

Research into the actions and benefits of regulating the DCAD or K concentrations in pre-calving diets has been extensive during recent years, but not when cows experience a shortened dry period. In the current study, dietary K was calculated to be 1.02% of diet DM for the anionic and 1.14% of diet DM for the cationic diet. These low quantities of K in the cationic diet fed likely helped cows fed this diet maintain serum concentrations of Ca at an acceptable level and reduced the risk of milk fever in cows fed both diets (Goff et al., 1997; Horst et al., 1984; Suttle, 2000). Thus, an important result of the current study was that serum Ca was not affected differently due to prepartum diet fed and no incidence of milk fever was seen.

In conclusion, results of the current study indicated that the two diets fed were equally effective by all criteria used to evaluate them. In general, milk production responses did not differ and DMI, BW and BCS responses were similar. Overall, no significant differences in Ca concentrations were detected and no incidences of periparturient diseases were recorded. Furthermore, feeding these two diets prepartum did not result in different yields of milk, FCM, SCM or milk component percentages during the first 10 wk of lactation or in the milk yield during the first 21 wk of lactation. Similar 305-d MY also were obtained. It seems that either positive or negative DCAD diets can be fed prepartum to Holstein cows as long as K in the cationic diet is below 1.2% of diet DM (Goff et al., 1997) which will maintain serum Ca at satisfactory levels. Thus, the two diets were equally effective in supporting the physical and physiological status of the cows given the 30 d dry period such that they responded equally well when either diet was fed prepartum. Furthermore, responses also were similar to those seen in the 60 d dry cows.

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