FLORIDA DAIRY CHECK-OFF

DIETARY CATION-ANION DIFFERENCE (ELECTROLYTE BALANCE) IN LATE PREGNANCY[1]

D. K. Beede[2], C. Wang[2], G. A. Donovan[3], L. F. Archbald[3], and W. K. Sanchez[2]

Dairy Science Department[2], and
Department of Large Animal Clinical Sciences[3],
University of Florida, Gainesville

INTRODUCTION

Dietary cation-anion difference (DCAD), also termed dietary electrolyte balance, is a relatively new concept in dairy cattle nutrition and diet formulation. Certain physiological and productive functions of dairy cattle may be influenced by DCAD. In its most complete form DCAD is expressed in milliequivalents (meq) as: meq [(Na + K + Ca + Mg) - (Cl + SO_4 + H_2PO_4 + HPO_4)]/100g dry matter (DM). Sparse information about the bioavailability (absorbability) and physiological roles of Ca, Mg, SO_4, H_2PO_4 and HPO_4 have limited their inclusion in the functional expression. The most commonly used expressions are: meq [(Na + K) - Cl]/100g or meq (Na + K) - (Cl + S)/100g. Each of these ions is known as a fixed ion, because it cannot be metabolized to a more rudimentary chemical level.

A major effect of DCAD is on the systemic acid-base status of the cow. When DCAD is a negative value (more meq of anions relative to cations) the cow may become metabolically acidotic, whereas with a positive value metabolic alkalosis may result. The mechanism for these effects is related to the physiological need to maintain electrical neutrality in the body. To maintain neutral ionic charges fixed anions elevate systemic H^+ (decreasing blood pH), whereas fixed cations elevate HCO_3^-. Feeding a diet with a negative DCAD (anionic diet) in late pregnancy causes a mild acidosis, which causes mobilization of Ca from bone and perhaps enhances absorption of Ca from the gut (Fredeen et al., 1988). Other related consequences on metabolic and production performance responses have been reported and suggested; these will be presented subsequently in this paper.

Potential sources of supplemental anionic salts used to build a negative DCAD include: aluminum sulfate [$Al_2(SO_4)_3$], calcium chloride [$CaCl_2 \cdot 2H_2O$], calcium sulfate [$CaSO_4 \cdot 2H_2O$], magnesium chloride [$MgCl_2 \cdot 6H_2O$], magnesium sulfate [$MgSO_4 \cdot 7H_2O$], ammonium chloride [NH_4Cl], and ammonium sulfate [$(NH_4)_2SO_4$]. Generally, feed grade sources of $CaSO_4 \cdot 2H_2O$ (gypsum), $MgSO_4 \cdot 7H_2O$ (epsom salts), NH_4Cl, and $(NH_4)_2SO_4$ are more readily available in feed mills and less expensive; however, this may vary with location.

PREPARTUM DIETARY CALCIUM RESTRICTION AND MILK FEVER

The interval around parturition is crucial in the productive cycle of the dairy cow. Occurrences of metabolic diseases and related health problems

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(eg., milk fever, hypocalcemia, retained placenta, uterine prolapse, ketosis, displaced abomasum, and udder edema, etc) can be problematic and costly. Many problems associated with this complex may be tied directly or indirectly to milk fever and hypocalcemia (Curtis et al., 1983).

The most practiced means of controlling the incidence of milk fever is to restrict intake of Ca during late gestation. The NRC (1989) suggests Ca intake of 33 to 42 g/d for mature dry cows (1200 to 1500 lb body weight) during the last 2 mo of gestation.

Review of some of the literature suggests that restriction of Ca intake in the late prepartum period was not efficacious always for preventing milk fever (Josson et al., 1978; Kendall et al., 1970). Generally, only when Ca intake was restricted to less than 20 g/d could prevention be certain (Boda and Cole, 1954; Boda, 1956; Wiggers, 1975).

Often times it is very difficult to formulate diets from available feedstuffs which contain low Ca (about 0.39%, according to NRC, 1989) to achieve the prescribed rate of Ca intake; many forages typically are quite high in Ca content. Additionally, when not enough attention is given to amount of feed offered and number of cows being fed in a group, total ration and Ca intakes may be greater than prescribed; this may predispose cows to problems.

NEGATIVE DCAD IN LATE PREGNANCY

In some management systems it might be of great practical advantage to reduce DCAD during late gestation to assist in the prevention of milk fever and other related problems.

Norwegian studies (Ender et al. 1962; 1971) first showed that grass silage preserved with mineral acids (H_2SO_4 and HCl) prevented milk fever, whereas sugar beets with high Na and K contents caused milk fever. Later Dishington (1975) showed that diets with negative DCAD [from supplementation of a mixture of $CaCl_2{\cdot}H_2O$, $MgSO_4{\cdot}7H_2O$, and $Al_2(SO_4)_3$] also prevented milk fever. This was confirmed by (Dishington and Bjornstad, 1982).

Block (1984) tested this approach using 20 cows each receiving a basal diet with DCAD's of +45 meq (cationic diet) or -17 meq/100g (anionic diet) in a 2 yr switchback design. None of the cows consuming the anionic diet for 5 wk prepartum had milk fever, whereas an incidence of 47.4% (9 of 19) was observed for cows consuming the cationic diet. Subsequently, cows fed the anionic diet prepartum had higher (7% increase) 305-d milk yields than cows fed the cationic diet. Also, within the cationic diet group, cows which did not have clinical milk fever had 16% higher milk yields than those that had milk fever. Blood plasma Ca and hydroxyproline concentrations, an indicator of bone tissue mobilization, were greater for cows fed the anionic than cationic diet, suggesting that the dietary manipulation enhanced mobilization of Ca from bone, thus making it available at the time of high metabolic demand around parturition.

More recently, Oetzel et al. (1988) reported results of a trial in which 12 cows each were fed dietary treatments containing -7.5 or +18.9 meq/100g with either 53 or 105g Ca/d for 3 wk prepartum. The anionic diet was made by supplementing 100g each of NH_4Cl and NH_4SO_4 /cow/d. The incidence of milk fever was 4% in cows fed the anionic diet, but 17% without the addition of the ammonium salts. Cows fed the anionic diet had higher total and ionized Ca (iCa) in blood at parturition. Using risk analysis, it was found that when Ca intake was high, supplementation with ammonium salts reduced risk of hypocalcemia ten-fold.

With 18 mature Jersey cows fed a diet containing over 90% alfalfa haylage, Gaynor et al. (1989) used additions of chloride salts of Mg, NH_4, and Ca to make a DCAD of +22 meq/100g diet and compared it with +66 and +126 meq/100g diets having added alkalogenic salts (eg., $NaHCO_3$) for 6 wk prepartum. Though still having a positive DCAD, the +22 meq diet tended to result in less clinical milk fever and higher blood total Ca within 36 h of parturition. Plasma concentrations of 1, 25 di-OH vitamin D were increased with +22 meq/100g compared with the other two treatments.

DAIRY CHECK-OFF EXPERIMENT

In each of the previous studies, under controlled experimental conditions, the number of cows per treatment was relatively small. Additionally, in some studies the cationic treatments were made with very high positive DCAD, seemingly to increase chances of detecting differences in response compared with the negative DCAD.

In 1990 we undertook a large field experiment in a commercial dairy to compare the effects of feeding an anionic (acidogenic) diet compared with a control diet formulated as close as possible to NRC (1989) recommendations, for dry cows during the last 2 mo of pregnancy. The anionic diet was -25 meq/100g DM by supplementation of 108g of NH_4Cl, 53g of $(NH_4)_2SO_4$ and 34g of $MgSO_4 \cdot 7H_2O$/cow/d (Treatment). The Treatment and Control (+5 meq/100g) diets were composed of the same basal ingredients, but the Treatment diet contained more Ca (1.81 vs 0.92%), higher Cl (1.06 vs 0.55%) and higher S (0.44 vs 0.30%) from the mineral supplement; Na and K concentrations were similar. From December 24, 1989 through April 30, 1990, 510 dry cows were group-fed their respective treatments in late pregnancy (3 to 5 wk prepartum). Blood samples were drawn within 18 h of calving and prior to treatment of all clinical milk fever cases.

Concentrations of Blood Serum Ca and P, and Incidences of Milk Fever and Hypocalcemia. Results of this experiment showed that blood serum concentrations of iCa (4.31 vs 3.80 mg/dl) and total serum Ca (7.94 vs 7.10 mg/dl) were higher for cows fed the Treatment (anionic diet) than Control diet (Table 1, $P < .01$). Concentrations of serum phosphorus also were higher for Treatment than Control cows (4.44 vs 3.64 mg/dl, $P < .01$). In addition, the incidence of clinical milk fever (cows diagnosed and treated for milk fever) by treatment group and parity were: Treatment diet, $\leq$ 2 parities = 0%, and $\geq$ 3 parities = 5%; Control diet, $\leq$ 2 parities = 0%, and $\geq$ 3 parities = 12% (treatment and parity effects, $P < .01$). The incidence of hypocalcemia (iCa $\leq$ 4 mg/dl) was: Treatment diet, $\leq$ 2 parities = 2%, and $\geq$ 3 parities = 28%; Control diet, $\leq$ 2 parities = 16%, and $\geq$ 3 parities = 66% (treatment and parity effects, $P < .01$). There were no differences between treatment groups in body condition or umbilical-udder edema scores taken 1 to 2 wk prepartum. The incidences of retained placenta, dystocia, displaced abomasum, metritis (at the first postpartum evaluation) or clinical ketosis were not affected by treatments, based on evaluation of farm health records.

Lactational and Reproductive Performance. Milk production data were from the regular DHI tests (10 test months) and data for reproductive performance were from the dairy's regular herd health records. Milk yield during the next lactation (305-d ME) was 3.61% greater (20,627 *vs* 19,908 lbs, $P < .01$) for cows fed the Treatment (anionic diet) during the late prepartum period compared with cows fed Control. All cows were co-mingled and fed the same diet during their lactation.

Reproductive performance after calving also was improved for cows fed the Treatment compared with Control diet (Table 1). Conception rates at 150, 200, and 250 d after calving were 11 to 17 percentage units higher for cows receiving the Treatment diet compared with the Control. Number of services per conception ($P < .16$) and average days from calving to confirmed pregnancy ($P < .10$) tended to be reduced for cows fed the Treatment compared with the Control diet.

DISCUSSION AND SUMMARY

Results of this Check-Off experiment indicated that incorporating anionic (acidogenic salts) into the ration of cows during the last 3 to 5 wk before calving made it much easier for the cow to cope with the high metabolic demand for calcium during early lactation. Reduced incidences of clinical milk fever and subclinical hypocalcemia occurred with the feeding of the acidogenic diet. This occurred even though the diet of cows fed the negative DCAD contained 1.81% Ca, dry basis (compared with 0.92% Ca in Control). This works out to an estimated Ca intake of 181 g/cow/day if dry matter intake is estimated at 22 lbs/day for a mature (1400 lb BW) Holstein cow. Although this high dietary concentration and rate of Ca intake is not typically recommended for late pregnant dry cows it was used in this experiment to test and challenge the effectiveness of the negative DCAD formulation. Observations and conversations from the field have indicated no difficulties of feeding 150 to 200 g Ca/cow/day if the anionic (acidogenic) agents also are supplemented properly. Formulation to provide 120 to 150g Ca/cow/day is recommended with the anionic salts.

Positive effects of the negative DCAD treatment on subsequent lactational and reproductive performance were noted in the Check-Off experiment. The additional milk income realized during the full lactation amounted to about $52 per cow (719 lbs extra milk x $0.145 per lb milk) x 0.5 [if 50% of the value of the extra milk was expended as feed cost]. The cost of the additional anionic salts for one cow during the month before freshening will be $3 to $5. The improvement in milk yield alone potentially can return about $10 for each $1 invested. Of course, this does not include any estimate of the potential economic advantage because the incidence of milk fever was less and reproductive performance was significantly improved.

It appears that we now have a reasonably practical way, through manipulation of the dietary cation-anion difference in the late prepartum ration, to reduce the incidence of hypocalcemic-related problems in the early postpartum cow, and improve reproductive and lactational performance.

TABLE 1. Experimental results from 1990 Check-Off Project in which Holstein cows were fed diets with negative (Treatment) or positive (Control) cation-anion difference (aka., electrolyte balance).[a]

Measurement	Treatment - 25 meq/100g	Control + 5 meq/100	Signif
Clinical milk fever incidence, %			
≤ 2 lactations	**0**	**0**	NS[b]
≥ 3 lactations	**5**	**12**	P < .01
All cows	**4**	**9**	P < .01
Subclinical hypocalcemia incidence, %[c]			
≤ 2 lactations	2	**16**	P < .01
≥ 3 lactations	28	**66**	P < .01
All cows	19	**50**	P < .01
	- - - - - - - - All Cows	- - - - - - - -	
Serum iCa, mg/dl	**4.31**	3.80	P < .01
Serum Ca, mg/dl	**7.94**	7.10	P < .01
Serum P mg/dl	**4.44**	3.64	P < .01
Milk yield, lbs [305-d ME]	**20,627**	19,908	P < .01
Conception rate, %			
@ 100 d postpartum	35	**28**	P < .26
@ 150 d postpartum	55	**42**	P < .03
@ 200 d postpartum	71	**54**	P < .01
@ 250 d postpartum	77	**66**	P < .06
Services/Conception	**3.0**	3.4	P < .16
Ave. days to first heat	68	**72**	P < .22
Ave. days open (for preg cows)	124	138	P < .10

[a] Cows calving from December 24, 1989 through April 30, 1990 were divided randomly into two groups (260 cows on Treatment and 250 cow on Control) and were fed the experimental diets for 3 to 5 wk prepartum. After calving cows were co-mingled and fed the same lactation ration. Lactational and reproductive performance data presented are through December, 1990.

[b] NS = Not a significant effect of dietary treatment.

[c] Blood serum ionized calcium (iCa) concentrations ≤ 4.0 mg/dl defined a cow as being hypocalcemic.

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