Formulation Strategies for Cation-Anion Difference in Diets of Late Pregnant Dry Cows

by David K. Beede
Dairy Science Department
Institute of Food and Agricultural Sciences
University of Florida, Gainesville

This article is written in response to numerous inquiries from feed company, private and university dairy nutritionists over the past several years about effective formulation strategies for late pregnant dry cow rations when the dietary cation-anion difference concept (DCAD) or anionic salts are considered for use. A number of the common questions, challenges and difficulties are addressed. A portion of this article was excerpted from the new book, LARGE DAIRY HERD MANAGEMENT edited by H. H. Van Horn and C. J. Wilcox (Beede et al., 1992b).

Feed for Thought

• Too often dry pregnant cows are neglected because they are not contributing to current cash flow and profit for the dairy business.

• Proper management of dry pregnant cows should be thought of as an investment in the next lactation. For maximum return on this investment, the dry cow program must include a well defined and monitored nutrition program. This investment does not have to be an expensive, high input endeavor. Return on investment can be quite profitable if done properly. It is simply a situation of placing a high enough priority on the dry cow program and managing the program properly to reap the benefits of the investment.

• One of the major management objectives should be to control subclinical hypocalcemia, milk fever, and DROOPY COW SYNDROME. This syndrome exists when cows do not expel fetal membranes in a timely fashion, and do not eat and milk well in early lactation. Besides controlling these early postpartum problems, research shows that full lactation milk yields and reproductive efficiency can increase if dry pregnant cows are fed and managed correctly.

• Even in well-managed herds where cows are in proper body condition, and clinical milk fever and ketosis are not major problems, an additional 500 to 1,000 pounds of milk in the following lactation can be produced by avoiding subclinical hypocalcemia. In pooled data (n = 274) it was found that if Holstein cows were fed conventional transition rations (50 to 90 g Ca per cow/ day, with a positive DCAD and no anionic salt supplementation), 51% were subclinically hypocalcemic at calving, 10% had clinical milk fever and only 39% were normal. When anionic salts were added to the rations (n = 284), 20% were subclinically hypocalcemic, 4% had clinical milk fever and 76% were normal (Oetzel et al., 1988; Beede et al., 1992b). This data set included about 40% first parity cows. It is estimated that at least two-thirds of the mature (second and greater parity) Holstein cows

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in the U.S. may experience some degree of subclinical or clinical hypocalcemia at parturition when fed conventional transition rations without anionic salt supplementation. Subclinical hypocalcemia likely affects lactational and reproductive performance in the next lactation. Nutritional management strategies should be implemented during the last 3 to 4 wk of pregnancy which will enhance lactational and reproductive performance postpartum.

• Cows fed transition rations with high contents of potassium (K) and sodium (Na) are at greater risk of subclinical hypocalcemia and milk fever. In my opinion, high calcium (Ca) intake prepartum is not the primary cause of subclinical hypocalcemia and milk fever. It never has been! Recently it was reported that the true absorption of Ca from alfalfa forage was only about 24% (Martz et al., 1990). Absorption of Ca from most commonly used feeds averages about 38% (NRC, 1989).

• In my opinion, the major dietary culprit and cause of milk fever, subclinical hypocalcemia and DROOPY COW SYNDROME is high potassium (K) in the prepartum diet. High dietary K, not dietary Ca, has been the main culprit during the recorded history of modern dairying because diets typically have been cationic, due to a relatively high concentration of K in forages. For years, dairymen and nutritionists have considered it unwise to feed significant amounts of alfalfa hay, or other high Ca-containing feeds in the transition ration, because "high Ca causes milk fever". The high K content of these forages is, in reality, the major cause of milk fever, subclinical hypocalcemia, and DROOPY COW SYNDROME!

• In many areas of the U. S. typical forages (alfalfa particularly and heavily fertilized grass forages) have high K contents (2.5 to 4.0% of DM). In these cases it may be necessary to design transition or pre-fresh rations in which at least two-thirds of the forage comes from minimally- or unfertilized, and thus lower K-containing forages. Dairymen growing their forage may need to have a specially designated dry cow forage production field. This forage-producing land should be fertilized with 0-0-0, and not 0-0-60. The manure spreader and slurry wagon should not be used on these fields.

• If dairymen cannot grow relatively low K-containing forages, they should purchase these forages for their late pregnant dry cows.

• It always has been considered a "best management practice" to introduce components of the lactation ration into the transition ration to potentiate digestive and metabolic adaptation and improve feed intake early postpartum. However, using a large portion of high-K containing feedstuffs and (or) adding a Na-containing buffer to a transition ration are "worst management practices" because they increase the likelihood of subclinical hypocalcemia and other related periparturient problems.

• After dietary K has been lowered as much as practically possible, one effective potential nutritional strategy for late pregnant dry cows may be implementation of the dietary cation-anion difference (DCAD) concept or anionic salt supplementation.

Basics of DCAD.

Calculation of DCAD. The DCAD is the milliequivalent difference between specific major physiologically active macromineral cations and anions. The most commonly used expression for DCAD is: meq [(Na + K) - (Cl + S)]/ 100g diet DM. Each of these macromineral ions is a strong ion, having significant influence on the acid-base status of the cow. Each ion exerts its effect according to its valence or electrical charge. Table 1 gives pertinent periodic table information about ions in the functional expression.

Table 1. Periodic table information about ions used in calculation of dietary cation-anion difference (DCAD).

Ion	Atomic weight (g/ mole)	Valence (charge)	Milliequivalent weight (g)
Na	23.0	+1	.023
K	39.0	+1	.039
Cl	35.5	-1	.0355
S	32.0	-2	.016

To calculate DCAD (meq/ 100g DM) the expression is: [(%Na in diet DM divided by 0.023) + (%K divided by 0.039)] - [(%Cl divided by 0.0355) + (%S divided by 0.016)]. An example calculation is given in Table 2 for a dry cow diet with recommended (NRC, 1989) concentrations of Na, K, Cl and S. It is paramount to note that calculated DCAD values differ considerably depending upon the per unit of weight basis used (e.g., per 100 g, per kilogram, or per pound of diet DM; Table 2).

Table 2. Example calculation of dietary cation-anion difference (DCAD) for dry pregnant cows, based on current recommendations for Na, K, Cl, and S (NRC, 1989).[1]

	Dietary concentration, DM basis		Milliequivalent weight	DCAD, milliequivalents per:		
Item	(%)	(mg/ 100g)	(g)	100 g[2]	1 kg	1 lb
Na	.10	100	.023	4.35	43.48	19.72
K	.65	650	.039	16.67	166.67	75.60
Cl	.20	200	.0355	5.63	56.34	25.25
S	.16	160	.016	10.00	100.00	45.36
DCAD[3]	--	--	--	5.39	53.81	24.71

[1]All values are on 100% DM basis.
[2]Milliequivalents/ 100g DM = % ion in diet DM divided by milliequivalent weight.
[3]DCAD = meq [(Na + K) - (Cl + S)]/ unit weight of DM.

Physiological Responses. When DCAD is negative (more milliequivalents of anions relative to cations), a mild metabolic acidosis may be produced, whereas with a positive DCAD value, metabolic alkalosis may result. Mechanism for these effects is related to the physiological need to maintain electrical neutrality of the body. To maintain neutral ionic charges, consequent to input of fixed anions, systemic hydrogen ion concentration $[H^+]$ is increased. In contrast, if fixed cations are introduced, an elevation in HCO_3^- results. Feeding a diet with negative DCAD (anionic diet) in late pregnancy results in an inflow of negatively charged ions (Cl^-, $SO_4^=$) systemically. Consequently, positively charged ion $[H^+]$ is increased to neutralize the influx of anions. Mild metabolic acidosis (with lower blood pH) ensues. Compensatory mechanisms in the kidneys and bone are triggered to correct alterations in blood pH. Bone tissue serves as an important source of $CO_3^=$ which buffers and corrects mild acidosis. In the process, bone Ca (and P) is mobilized. Additionally, absorption of Ca from the gut of lactating goats fed an anionic diet was enhanced compared with an alkalotic diet; however, this effect was not detected in nonlactating pregnant animals (Fredeen et al., 1988). This sequence of metabolic events proceeds continuously and recurs as long as cows continue to consume anionic (acidogenic) diets. Thus, higher blood Ca concentrations are maintained and the metabolic machinery to increase blood Ca at calving is readily functional. Beneficial effects of negative DCAD on vitamin D metabolism also have been reported (Gaynor et al., 1989; Goff, 1992). Therefore, formulating for a negative DCAD can be immensely helpful when there is sudden increased demand for Ca as milk synthesis and lactation are initiated.

Potential Anionic Salts. Common sources of supplemental anionic salts used to build a negative DCAD include ammonium sulfate, calcium sulfate, magnesium sulfate, ammonium chloride, calcium chloride, and magnesium chloride. Chemical formulas and other important information about the salts are in Table 3. Special attention must be paid to the degree of hydration of specific anionic salts when using them in formulation. Generally, feed grade sources of ammonium sulfate, calcium sulfate (gypsum), magnesium sulfate (epsom salts), and ammonium chloride generally are more readily available in feed mills and are less expensive (Table 3). However, this may vary with location. Aluminum sulfate and magnesium chloride are quite expensive, but have been used occasionally. Price of magnesium chloride varies, depending on source and grade (Table 3, footnote 3). Calcium chloride is relatively inexpensive and has been used successfully, but it is very hygroscopic and caustic, and not a common ingredient in many feed mills.

Calcium Status and Other Periparturient Metabolic Problems.

The most commonly recognized and definable metabolic disease associated with low blood Ca is clinical parturient paresis or milk fever. However, possible relationships or associations of other metabolic disorders (e.g., ruminal stasis, displaced abomasum, retained fetal membranes, prolapsed uterus, early metritis and ketosis) with clinical and subclinical hypocalcemia have been suspected and evaluated by practitioners and researchers (Curtis et al., 1983; Risco, 1992).

Table 3. Chemical composition and relative costs of commonly available anionic macromineral salts.

Mineral salt	Chemical formula	Cost (\$/ ton)[1]	Cost (¢/ equivalent)	Percent of salt, as-fed					
				N	Ca	Mg	S	Cl	DM[2]
Ammonium sulfate	$(NH_4)_2SO_4$	350	2.6	21.2			24.3		100.0
Calcium sulfate	$CaSO_4 \cdot 2H_2O$	200	1.9		23.3		18.6		79.1
Magnesium sulfate	$MgSO_4 \cdot 7H_2O$	500	6.8			9.9	13.0		48.8
Ammonium chloride	NH_4Cl	750	4.4	26.2				66.3	100.0
Calcium chloride	$CaCl_2 \cdot 2H_2O$	450	3.6		27.3			48.2	75.5
Magnesium chloride[3]	$MgCl_2 \cdot 6H_2O$	1850	20.7			12.0		34.9	46.8

[1]Prices FOB Minneapolis, MN, as-fed (Byers, 1992).
[2]The degree of hydration (or DM content) of the various salts should be accounted for in the formulation process.
[3]Other quoted prices for magnesium chloride: \$2,000/ ton (food grade), FOB Danville, VA; \$400/ ton (technical grade), FOB NJ; \$1,200 to 2,400/ ton (food or research grade - depending on degree of refinement and purity), FOB NJ; \$275/ ton (technical grade), FOB Salt Lake City, UT.

Research on Negative DCAD in Late Pregnancy.

Experimental results showed that feeding anionic diets in late gestation reduced milk fever (Table 4) and increased concentrations of Ca in blood compared with cationic diets (Ender et al., 1962, 1971; Dishington, 1975; Block, 1984; Oetzel et al., 1988; Gaynor et al., 1989; Wang, 1990; Goff, 1992; Seymour et al., 1992). In addition, there is evidence that cows fed anionic diets prepartum had less subclinical hypocalcemia, lower incidence of retained fetal membranes, improved reproductive performance, and produced more milk the next lactation (Table 5). Also Massey et al. (1993) showed that cows were 7.35 times more likely to have a displaced abomasum if hypocalcemic (serum total Ca concentration less than or equal to 8 mg/ dl) within 18 hours of calving than cows with serum total Ca greater than 8 mg/ dl. There were no differences between treatment groups (cationic vs. anionic diets) in body condition or umbilical-udder edema scores taken 1 to 2 wk prepartum in this study. However, another study suggested a trend for reduced edema in first parity animals fed an anionic diet (Tucker et al., 1992).

Positive effects of negative DCAD treatment on subsequent lactational and reproductive performance were economically important. For example in a recent field study (Beede et al., 1992a), additional milk income realized during the full lactation amounted to about $52 per cow (719 lb extra milk x $0.145 per lb milk) x 0.5 [if 50% of the value of extra milk was expended as feed cost]. Cost of additional anionic salts for one cow during 3 wk before freshening was about $5. Improvement in milk yield alone potentially can return about $10 for each $1 invested. Of course this does not include any estimate of potential economic gain because of reduced incidence of milk fever and other health problems, and improved reproductive performance. The associations are strong for potential economic gains in these areas as well.

Practical Diet Formulation Using DCAD

When should negative DCAD and anionic salts be used? Obviously, with health difficulties such as milk fever, and problems associated with subclinical hypocalcemia (e.g., retained fetal membranes and displaced abomasum) and general poor early lactation performance, they should be considered strongly. Any high producing herd, without many obvious clinical situations, may benefit from alleviation of some subclinical problems, and lactational and reproductive performance may be improved (Beede et al., 1992a).

A late pregnant dry cow diet formulated to NRC (1989) recommendations for Na, K, Cl and S is mildly cationic with +5.4 meq/ 100g DM (Table 2). However, rarely under practical field conditions do diets exactly meet these recommendations. Typically, higher K concentrations are present because of generous use of high K-containing forages in these diets. Total dietary K concentrations may range between 1 and 1.8% or higher with a resultant DCAD range from +10 to +35 meq/ 100g DM. These cationic diets are problematic and can predispose cows to clinical milk fever, subclinical hypocalcemia and associated abnormalities. Potassium, being the main cation in late pregnant dry cow rations, is the major cause of subclinical hypocalcemia and milk fever. For years dairy producers favored not feeding alfalfa forages to late pregnant dry cows because it was believed that high Ca content of the forage caused milk fever. Actually, the relatively high K content of alfalfa forages caused milk fever due to the high positive DCAD. It is not unusual to have

Table 4. Summary of important factors in experiments characterizing effects of dietary cation-anion difference (DCAD) on the incidence of clinical milk fever.

DCAD (meq/ 100 g DM)[1]	Anionic or Cationic Salt Addition	Feeding Rate (g/ d)	Feeding Rate (meq/d)	Ca (g/ d)	P (g/ d)	Total Cows (No.)	Milk Fever (%)
Dishington, 1975							
-11.9	HCl	43	1179	99	39	6	17
	H_2SO_4	86	1754				
-2.2	$CaCl_2 \bullet 2H_2O$	33	449	108	39	6	0
	$MgSO_4 \bullet 7H_2O$	80	649				
	$Al_2(SO_4)_3 \bullet 16H_2O$	130	1237				
+34.6	$NaCO_3$	40	482	79	39	14	86
	$NaHCO_3$	40	476				
Block, 1984							
-12.9	$CaCl_2 \bullet 2H_2O$	31	422	93	32	19	0
	$MgSO_4 \bullet 7H_2O$	94	763				
	$Al_2(SO_4)_3 \bullet 16H_2O$	115	1095				
+33.1	$NaCO_3$	NS[2]	NS	85	34	19	48
	$NaHCO_3$	NS	NS				
Oetzel et al., 1988							
-7.5	NH_4Cl	100	1869	75[4]	27	24	4
	$(NH_4)_2SO_4$	100	1514				
+18.9	none	---	---	83[5]	30	24	17
Gaynor et al., 1989[3]							
+22	$MgCl_2 \bullet 6H_2O$	94	925	97	23	5	0
	NH_4Cl	43	804				
	$CaCl_2 \bullet 2H_2O$	37	503				
+60	none	---	---	101	23	6	33
+126	$NaHCO_3$	225	2679	99	25	6	17
Beede et al., 1992a							
-25.0	NH_4Cl	108	2019	186	35	260[6]	4
	$(NH_4)_2SO_4$	53	802				
	$MgSO_4 \bullet 7H_2O$	34	276				
+5.0	none	---	---	95	30	250[6]	9

[1] DCAD calculated as: meq [(Na + K) - (Cl + S)]/ 100g DM.
[2] NS = not specified in report.
[3] DCAD calculated as: meq (Na + K - Cl)/ 100g DM.
[4] Calcium intake (52 or 97g/ d) factored with anionic salt additions; calcium intake did not affect incidence of clinical milk fever.
[5] Calcium intake (54 or 112g/ d) factored with anionic salt additions; calcium intake did not affect incidence of clinical milk fever.
[6] About 40% primiparous and 60% multiparous cows in each treatment group.

Table 5. Summary of disease incidence and reproductive and lactational performance from research experiments.

Experiment	DCAD[1] (meq/ 100g DM)	Disease Incidence (%) Hypocalcemia[2]	RFM[3]	PR[4] (%)	DO[5] (%)	Milk Yield (lbs)[6]
Block, 1984	- 12.9	---	---	---		15,738
	+33.1	---	---	---		14,667
Oetzel et al., 1988	- 7.5	29	0	---		---
	+18.9	67	25	---		---
Beede et al., 1992a	- 25.0	19	22	71	124	20,661
	+5.0	50	21	54	138	19,940

[1] DCAD calculated as: meq [(Na + K) - (Cl + S)]/ 100 g diet DM.
[2] Hypocalcemia = serum or plasma ionized Ca less than 4.0 mg/ 100 ml within 18 h of calving, with or without clinical milk fever.
[3] RFM = retained fetal membranes longer than 24 hours post calving.
[4] PR = pregnancy rate 200 days postpartum.
[5] DO = Average days open for pregnant cows.
[6] 305-d mature equivalent milk yield.

highly fertilized forages (alfalfa or grasses) with 2 to 3.5% K, or even higher. High K-containing feeds present a serious concern in formulation of proper DCAD for late pregnant dry cows.

A Formulation Strategy. One suggested formulation strategy (Byers, 1992) utilizing the DCAD concept with some additions and modifications is presented. Objective is for the final total ration formulation to have a DCAD of -10 to -15 meq/ 100g DM. Table 6 presents examples of three different formulation problems that can arise. These are discussed subsequently in the article.

1. All basal feed ingredients should be analyzed for Na, K, Cl and S contents before ration formulation begins. It particularly is important to analyze forages and byproduct feeds because their macromineral element contents may vary considerably from standard tabular values (D. K. Beede, personal observation, 1992). Recently, some Cl concentrations have been published (NE DHIA Forage Laboratory, Ithaca, NY, December, 1992).

2. Select feeds, particularly forages, for the basal diet with as low a K content as practically possible. Before anionic salt supplementation is considered, calculate the DCAD of the basal diet which has been formulated to meet recommendations for energy and other nutrients.

3. At this point, supplementation with the appropriate anionic salts should be considered (Table 3). First inclusion should be magnesium sulfate, calcium sulfate, ammonium sulfate or a combination. These salts should be supplemented until total

S in the diet DM reaches 0.4%, the suggested maximum tolerable concentration (NRC, 1989, 1980). Typically, in practice, most nutritionists account for S from all feed ingredients and use this in calculation of DCAD. The bioavailability of S from many feed sources is quite low; this S likely is not very influential on the cow's physiology. However, the S from anionic salts usually contributes the majority of the dietary S and apparently is quite available. It has major influence in the DCAD calculation and on the cow's acid-base status. Therefore, total S is used in the DCAD calculation in the field. In most diets, supplementation of S-containing anionic salts will contribute about 12 to 17 anionic meq/ 100g DM to the DCAD expression, depending on S content of the basal dietary ingredients.

If magnesium sulfate is supplemented, it is recommended that total Mg should not exceed 0.4% of diet DM. Research showed that intake of a concentrate mixture containing magnesium sulfate was greater than if the mixture contained calcium chloride, ammonium chloride or ammonium sulfate (Oetzel and Barmore, 1992). If the maximum Mg concentration is reached before the maximum target S concentration is obtained, calcium or ammonium sulfate should be supplemented to achieve 0.4% S. Degree of hydration of available anionic salts should be verified when calculating their anionic contribution. For example, various calcium sulfates may vary in molecules of water per molecule of the salt.

4. Next, supplementation of enough ammonium chloride, calcium chloride or magnesium chloride, or a combination should be used to achieve -10 to -15 meq/ 100g DM. Typically, ammonium chloride can be used to do this. Practically, supplemental Cl is used to counterbalance the remaining K that was not counterbalanced already by addition of S-containing salts. For every 0.1% K remaining, 0.09% Cl is needed to counterbalance it. With 0.90 to 1.2% K in diets, Cl content generally ranges between 0.8 and 1.1% of DM. Content of Cl is dictated to some extent by how much Na was present in the basal diet and how much S was supplemented.

   In Table 6, Diets A, B and C demonstrate what is needed to maintain -15 meq/ 100g DM when the K content of diets increases from 1.0 to 1.5 to 2.0%. Additions of ammonium chloride were used to maintain the desired DCAD. Ammonium chloride additions had to be increased 1.8- and 2.7-fold in Diets B and C compared with Diet A to maintain the desired DCAD.

   Sodium and potassium chlorides cannot be used to change DCAD because they are neutral salts, each contributing a cation and an anion in the DCAD calculation. Therefore, net influence of each neutral salt on DCAD is zero.

5. If it is possible to achieve a DCAD of -10 to -15 meq/ 100g DM, dietary Ca should be raised to 1.5 to 1.8% of diet DM with no adverse effects (Beede et al., 1992a). Higher than traditionally recommended Ca supplementation in prepartum diets of pregnant dry cows is very likely beneficial (Verdaris and Evans, 1974; Oetzel et al., 1988; Oetzel, 1991). Calcium sulfate and(or) calcium chloride can be used to acquire

Table 6. Examples of resulting DCAD in formulations as affected by different potassium concentrations, a standard anionic salt package, and adjusting basal ration components with a high K-containing forage and a standard anionic salt package, DM basis.

		Increasing Anionic Salts With Increasing Dietary K To Maintain DCAD = -15 meq/ 100g			Effect of Increasing Dietary K With Standard Anionic Salt Package		Effect on DCAD of Adjusting Basal Ration Components with a Standard Anionic Salt Package		
Item	Basal Diet	Diet A	Diet B	Diet C	Diet D	Diet E	Diet F	Diet G	Diet H
Pounds/ cow/ day									
calcium sulfate	0	0.06	0.06	0.06	0.06	0.06	0.06	0.06	0.06
magnesium sulfate	0	0.22	0.22	0.22	0.22	0.22	0.22	0.22	0.22
ammonium chloride	0	0.18	0.33	0.48	0.18	0.18	0.18	0.18	0.18
Total Anionic Salts									
pounds/ cow/ day	0	0.46	0.61	0.76	0.46	0.46	0.46	0.46	0.46
meq/ cow/ day	0	2652	3924	5196	2652	2652	2652	2652	2652
DCAD									
meq/ 100 g DM	+11.4	-15.0	-15.0	-15.0	-9.9	+10.6	+19.1	+11.2	-9.4
Percent of Diet DM									
K	1.0	1.0	1.5	2.0	1.2	2.0	2.57	2.17	1.24
Na	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
Cl	0.25	0.79	1.25	1.70	0.79	0.79	0.89	0.85	0.80
S	0.22	0.40	0.40	0.40	0.40	0.40	0.45	0.43	0.40
Ca	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80	1.80
P	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Mg	0.30	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40
Percent of Crude Protein									
Soluble Protein	24	32	36	41	32	32	34	33	32
Degradable Intake Protein	58	62	64	67	62	62	66	64	62
Percent of Diet DM									
Corn silage	30.7	30.7	30.7	30.7	30.7	30.7	12.3	12.3	31.0
Grass silage	17.7	17.7	17.7	17.7	17.7	17.7	60.0	47.8	17.9
Concentrate	51.6	51.6	51.6	51.6	51.6	51.6	27.7	39.9	51.1

some of the supplemental Ca simultaneously during formulation of the proper DCAD.

There have been several reports from the field of failed attempts to successfully incorporate the DCAD concept (D. K. Beede, personal communications). In most of these cases the dietary Ca intake was not increased to recommended amounts. This problem has been demonstrated experimentally (Oetzel et al., 1988; Seymour et al., 1992). It has been difficult for some nutritionists and dairy producers to depart from the long held practice of maintaining relatively low dietary Ca concentrations and Ca intake in transition rations. However, there is no difficulty, and in fact there is a benefit, when increasing Ca content and intake, if the DCAD is -10 to -15 meq/ 100g DM. Phosphorus intake should be set at 40 to 50 g/ day. Calcium sulfate, calcium carbonate, dicalcium phosphate, phosphoric acid, monocalcium phosphate, and monosodium phosphate can be used to meet Ca and P recommendations. Supplementation to achieve 0.4% total dietary Mg (which is possible with added magnesium sulfate as recommended above in Step 3) is further recommended because subnormal blood Mg concentrations have been associated with milk fever (Sansom et al., 1983). The problem of Mg deficiency reducing Ca mobilization from bone has been implicated (Reddy et al., 1973; Contreras et al., 1982; Van de Braak et al., 1987).

6. Supplementation of other nutrients (e.g., Se and fat soluble vitamins) should be set to recommendations or preferences.

Other Considerations and Precautions.

How Negative? The recommended target DCAD of -10 to -15 meq/ 100g DM perhaps is somewhat more negative than actually may be necessary to achieve good control of subclinical hypocalcemia. However, this range is suggested because it affords a margin of safety. Often total K intake is not very well controlled or known because of inaccurate knowledge about K contents of all feeds in the diet, and unaccounted for K intake from grazing pasture and(or) free-choice hay. One major difficulty with this formulation strategy can arise when total dietary K is relatively high (in excess of 1.2% DM). The optimal DCAD has not been determined in controlled experimentation.

Anionic Salts Are Not Savory. Anionic salts are unpalatable and not readily consumed by cows. A reasonable upper limit of the amount of anionic salts a cow will consume readily in the typical ration is about 3,000 meq/ day. It is unlikely that Diets B and C would be consumed in adequate amounts to achieve the desired effects (Table 6). With high dietary K it may not be possible to achieve a DCAD of -10 to -15 meq/ 100g DM with needed supplementation of anionic salts and still have a diet which will be consumed at an effective rate. In this case, the formulation strategy could be to obtain as low a DCAD as possible and still achieve adequate consumption of the total diet. If the DCAD resulting from this formulation is not less than -10 meq/ 100g DM it is suggested to decrease total Ca intake to 70 to 90 g/ day. Obviously, the most effective and profitable management strategy is to harvest or purchase low K-containing forages for late pregnant dry cows.

Standard Anionic Salt Packages. In the feed industry, standard formulation packages of anionic salts have evolved where it is desired to feed a number of herds a common package. As an example, feed 4 oz of magnesium sulfate plus 4 oz of ammonium chloride, or 4 oz of magnesium sulfate plus 2 oz of ammonium chloride plus 2 oz of ammonium sulfate. The convenience and utility of standard packages for feed formulators and manufacturers is obvious. This approach has been successful at times. However, other times it has not been successful. It is obvious that because of potential differences in concentrations of cations (in particular) and anions in basal feeds among different dairies that a standard package which might be suitable for one dairy may not be appropriate for another. If custom formulation cannot be done on a dairy-by-dairy basis, producers and (or) ration formulators must, at minimum, evaluate whether the standard package is appropriate; this requires that Na, K, Cl and S contents of the basal diet be analyzed and then the actual DCAD can be calculated with the standard package addition.

In Table 6 an example is given of what can happen to the DCAD of two different diets (Diet D and Diet E) when the same "standard anionic salts package" is used at a specified feeding rate (0.46 pounds per cow/ day). These could be different diets from neighboring dairy farms. The standard anionic salt package brought the DCAD in Diet D to -9.9 meq/ 100g DM. However, in Diet E where the K content was inherently higher (2.0 vs. 1.2%) the resulting DCAD was +10.6 meq/ 100g DM. It is very likely that using the standard anionic salt package in Diet E would not result in the desired responses. Another anionic salt package or a greater amount of the present package would be needed.

Adjusting Proportions of Base Components of the Ration. Another potential formulation problem and solution might be considered when it is difficult to achieve the recommended target DCAD (-10 to -15 meq/ 100g DM). In Table 6, Diet F represents an attempt to use 60% grass silage in the ration DM; but, the forage contains 4.0% K on a DM basis. The DCAD is + 19.1 meq/ 100g DM and fresh cows may have hypocalcemia and exhibit milk fever. Diet G (+11.2 meq/ 100g DM) and Diet H (-9.4 meq/ 100g DM) represent attempts to reduce the DCAD by altering the DM proportions of the base ration components ---- the grass silage, corn silage and concentrate. Of course, the corn silage and concentrate contain considerably less K. Diet H in which the corn silage portion was increased 2.5 times, the concentrate portion was increased 1.8 times and the grass silage portion was decreased roughly 70% compared with Diet F resulted in a DCAD near the recommendation. Diet H may be considered too rich in concentrate and corn silage by some for late pregnant dry cows. However, the likelihood of subclinical hypocalcemia and milk fever with Diet F is very great. The best management practice still would be to use a medium quality lower K-containing forage (1.5% or less) as the base forage of the ration.

Best Ration Systems. Because of the relative unacceptability (low palatability) of anionic salts it is recommended that diets be fed as totally mixed rations (TMR) and that cows have continuous access to the ration. Feed intake pattern of a corn silage-based TMR changed when anionic salts were fed with cows eating more smaller meals throughout a 24-hour period compared with cows not fed anionic salts (Wang et al., 1990). Totally mixed rations with some wet ingredients (e.g., silages and wet brewers or distillers grains) aid consumption. Feeding of anionic salts in top-dress supplements (4 to 8 lb per cow/ day) has been successful if very palatable ingredients are included (e.g., distillers dried grains and sugarcane molasses); pelleting and addition of feed flavors also have helped achieve adequate intake. Adequate feed bunk space (minimum of 2.5 linear feet/ cow) is an important management strategy, particularly when the ration is not very acceptable. Variations of the above mentioned strategies may have to be tried in specific situations to obtain acceptable intake.

Watch Total NPN. If ammonium sulfate and (or) ammonium chloride are used, care should be taken to adjust total NPN in the ration. If diets inherently contain considerable quantities of soluble N or degradable intake protein (DIP) (e.g., from ammoniated forages, NPN-containing liquid supplements, alfalfa haylage, etc.), either ammonium salts should be used judiciously (or eliminated) or adjustment in amounts of basal ingredients should be made. Typically, it is recommended that not more than 0.5% of the diet DM come from urea or other NPN source on a N-equivalent basis. Total NPN of the diet should not exceed 0.25% and DIP should not exceed 70% of total crude protein, DM basis (Byers, 1992). Other toxicity problems with anionic salts are not serious practical concerns because the salts are not very palatable (Oetzel and Barmore, 1992) and over-consumption is unlikely. Additionally, use of a combination of two, three or even four anionic salts will reduce the potential risk of toxicity from any one element.

Length of Feeding Interval. A question often asked is how long should negative DCAD diets be fed before calving to realize desired effects. This has not been researched. Feeding has been for as long 6 wk with no apparent problems. At least 10 days of feeding is thought necessary. Typically feeding for 3 to 4 wk is recommended to ensure success with the formulation strategy, especially given typical variation in calving dates relative to expected calving dates. This recommendation suggests that in order to maximize benefits from the DCAD approach, producers need to group dry cows into a far-off group (greater than 30 days before calving) and a close-up or pre-fresh group (less than 30 days prepartum). Obviously, without appropriate grouping it becomes increasingly expensive to use the DCAD approach. Potential effects on physiology, health and bone anatomy of cows fed anionic salts for extended periods of time are unknown. Grouping of dry cows is a best management practice whether anionic salts are used or not. On some dairies, late pregnant dry cows are fed some of the lactation diet (e.g., concentrate portion) for prepartum adaptation. If this contains a Na-containing buffer, it should not be fed because this buffer is cationic, makes the DCAD more positive, and could predispose cows to subclinical hypocalcemia and milk fever. Conversely, diets with negative DCAD, supplemented with substantial amounts of anionic salts, are not recommended for lactating cows under any circumstances as they will have deleterious effects on physiological and productive performance. Cows should be switched to a lactation ration with a positive DCAD immediately after calving. Cationic diets are most efficacious for lactating cows (Tucker et al., 1988; Sanchez et al., 1992)

Summary and Conclusions

The dietary cation-anion difference concept is a potentially beneficial nutritional management strategy for late pregnant dry cows which can aid in reduction of milk fever and hypocalcemic-related periparturient problems. Knowing the Na, K, S and Cl contents of all feed ingredients, particularly the forages, or of the total basal ration is required to formulate properly with anionic salt supplementation. The formulation strategy will be easiest to implement and most successful when the K content of the ration is relatively low (0.65 to 1.1% of DM), Na concentration is 0.10 to 0.18% of DM, and calcium intake is 150 to 180 g per cow/ day. Expert ration formulation and good transition feeding management are needed to realize benefits of this strategy. Implementation of the DCAD concept will not correct problems such as fat cow syndrome, fatty liver, primary ketosis or udder edema. The simple fact that anionic salts have been added to a transition ration, without consideration for many factors outlined in this article, does not necessarily ensure that the DCAD concept has been employed correctly and that beneficial responses will result. If dietary K is too high, and not properly counterbalanced with appropriate anions, metabolic problems likely will still occur. It is not that the DCAD concept and anionic salts have failed, but rather that the concept was not correctly implemented.

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