Prevention of Milk Fever by Application of the Dietary Cation-Anion Balance Concept

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Milk fever in dairy cows results from an acute deficiency of blood calcium which typically occurs in the time immediately before or after calving. Clinical hypocalcemia increases in likelihood with increasing age of the cow. The average incidence of milk fever is about 8 to 9% in U.S. dairy herds (Sanchez, et al., 1992), but may be much higher on individual farms.

Many mature cows experience hypocalcemia at calving without showing clinical signs of milk fever. A field study using over 500 cows in Florida found that 66% of cows in third or greater lactation had subclinical hypocalcemia (serum ionized calcium < 4.0 mg/100 ml) (Beede, et al., 1991). Clinical milk fever has been associated with increased incidence of dystocia, retained placenta, prolapsed uterus, and displaced abomasum. Cows with subclinical hypocalcemia were 4.8 times more likely to have left abomasal displacement, regardless of whether they developed clinical signs of milk fever (Massey, et al., 1993). Because it is often untreated, it is possible that subclinical hypocalcemia has a greater impact on the profitability of dairies than clinical milk fever.

Two nutritional strategies have evolved for the prevention of milk fever:

1. Limit the non-lactating cow's intake of calcium.

The National Research Council (NRC, 1989) suggests that an intake of 33 to 42 grams of calcium per day during the dry period will help control the incidence of milk fever. However, three problems arise from these guidelines. First, alfalfa contains relatively large amounts of calcium. For producers who rely on alfalfa as their source of forage, this requires that a different forage be grown or purchased for use in dry cow diets. Second, in addition to the maintainance of a separate inventory of dry-cow forage, this system requires that the cow go through a rather drastic change in forage type with the onset of lactation. Finally, even with a change in forage, it is often very difficult to formulate a dry cow ration that results in calcium intakes of less than 50 grams per day.

2. Manipulation of the cation-anion difference (DCAD) of the dry cow diet.

A negative DCAD in the dry cow diet results in greater mobilization of bone calcium and increased serum calcium. This is a fairly new approach to controlling the incidence of milk fever. The DCAD is the sum of the positively-charged ions sodium (Na) and potassium (K) minus the sum of the negatively-charged ions chloride (Cl) and sulfur (S) in the diet. Although the mechanism is not completely understood, feeding "close-up" cows (3 weeks prepartum) a diet with a negative DCAD has decreased, or even eliminated in some studies, the occurrence of milk fever (Sanchez, et al., 1992; Block, et al., 1984).

When the onset of lactation requires a large output of calcium in milk, the cow is ready to respond by using bone calcium stores and possibly, by increasing absorption of calcium from her diet. In addition to decreasing milk fever incidence, a negative DCAD in the dry period has increased milk yield in the subsequent lactation (Block, et al., 1984) and improved reproductive performance (Beede, et al., 1991). Some dairy producers might feed a negative DCAD in the dry period in order to improve fertility or milk production, even if clinical milk fever has not been a problem in their herd.

USING THE DCAD METHOD

Before formulating diets for a negative DCAD, dairy producers should ascertain that the ration meets the dry cow's requirements for protein, energy, vitamins, and other minerals. The strategy in using the DCAD method is to formulate close-up cow diets which lower the DCAD to -10 to -15 mEq per 100 grams of diet dry matter. The DCAD is calculated using the percentage of minerals in the diet dry matter, adjusted for atomic weight and charge. To calculate the DCAD as mEq/100 g DM, the following equation is used:
DCAD = [(%Na/.023) + (%K/.039)] - [(%Cl/.0355) + (%S/.016)]

The equation can be saved on a programmable calculator, computer spreadsheet, or ration-balancing program for repeated use.

The typical dry cow diet has a mildly positive DCAD. For example, the DCAD for a dry cow diet formulated to meet NRC recommendations for Na, K, Cl, and S can be calculated as follows:

0.10% Na	mEq Na	=	(0.10%)/(.023)	=	4.35 mEq Na
0.65% K	mEq K	=	(0.65%)/(.039)	=	16.67 mEq K
0.20% Cl	mEq Cl	=	(0.20%)/(.0355)	=	5.63 mEq Cl
0.16% S	mEq S	=	(0.16%)/(.016)	=	10.00 mEq S

Add the cations and subtract the anions to result in the following:

(Na + K) - (Cl + S) = (4.35 + 16.67) - (5.63 + 10.00) = <u>+5.39 mEq/100 g DM</u>

If these values were being calculated on a per kg basis, they would be increased by a factor of 10 (53.9 mEq/**kg** DM).

How is the DCAD of the dry cow diet changed?

The DCAD can be decreased by adding anionic (sometimes called "acidogenic") salts to the dry cow diet. There are several chloride and sulfur salts commonly used to manipulate DCAD (Table 1). Note that feed grade salts are not always pure and may contain water and other minerals (Table 2). Aluminum sulfate and magnesium chloride are quite expensive, but have been used in diets for dry cows. Calcium chloride has also been used in some formulations, but it is a caustic substance and is not available at all feed mills.

Anionic salts are not palatable and are best fed to dry cows as part of a total mixed ration (TMR). If cows are on pasture or are being fed dry forages, these salts must generally be combined with about 5 pounds of concentrate feed to achieve adequate intakes. This additional concentrate should be formulated for dry cows, as the minerals present in lactating cow feed may counteract the effects of the anionic salts. Pelleting mixtures of anionic salts does not improve intake. Magnesium sulfate is the most palatable anionic salt; the least palatable are ammonium and calcium chlorides (Oetzel and Barmore, 1992).

If more than 3,000 mEq of chloride and sulfur from anionic salts must be added to the diet, problems with acceptability or toxicity may occur. With high potassium forages (see Table 3), it may be difficult to achieve a negative DCAD. For instance, if each pound (454 g) of basal ration contains +136 mEq (+30 mEq/100 g DM), then the dry cow eating 23 pounds (10 kg) of that ration will consume +3,100 mEq daily. Adding 3,000 mEq of anions from anionic salts will lower the ration DCAD to +100 mEq per day. If this situation arises, feeds lower in potassium can be chosen for the basal ration to decrease the amount of salts necessary (see Table 3 for examples). Alternatively, agronomic practices can be altered to decrease the amount of potassium applied to crops destined for dry cow rations.

Standard packages of anionic salts have been formulated for use by nutritionists and dairy producers. While standard doses may perform well on many farms, the formulation does not allow

for the wide variation that can occur in diets due to use of various forages and differing agronomic practices. Examples of these packages include: 4 ounces magnesium sulfate + 4 ounces ammonium chloride **or** 4 ounces magnesium sulfate + 2 ounces ammonium chloride + 2 ounces ammonium sulfate (Shaver and Oetzel, 1990).

Detailed instructions for formulating diets with a negative DCAD are given in Appendix 1. Table 4 also gives an example of anionic salts added to diets which vary in potassium content.

Some considerations

- Force-feeding large amounts of anionic salts (e.g., more than 3,000 mEq per day) can be dangerous or even fatal to the cow. Because of the unpalatability of these supplements, however, the likelihood of toxicity occurring in practical feeding situations is low. In addition, a combination of two, three, or four salts will reduce the danger of toxicity.

- Anionic salts are **not an appropriate feed** for inclusion in lactating cow diets. After calving, the cow's normal metabolism already tends toward acidosis. Feeding an acidogenic diet will compromise feed intake and milk production. These diets appear to cause an increase in urinary calcium loss, which also may be undesirable in the lactating cow.

- Although many dairy producers must feed heifers and dry cows together, diets with a negative DCAD are not necessary for heifers. The negative effect of anionic salts on feed intake may be undesirable in animals which are still growing.

- The last three weeks before calving is the recommended time during which to feed anionic salts. The minimum effective period appears to be ten days. Anionic salts have been fed for as long as six weeks, but it is not recommended that they be used during the entire dry period.

- The current cost of feeding anionic salts is 20 to 30 cents per day. If a 3 to 7% increase in milk production occurs, the economic return from milk production alone will be about 10 to 1 (Oetzel, 1993).

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Table 1. Chemical formula and relative cost of commonly available anionic macromineral salts.

Anionic salt	Chemical Formula	Cost ($/Ton)[1]	MW[2]	EqW[3]	Cost (¢/eq.)
Ammonium Sulfate	$(NH_4)_2SO_4$	350	132.1	66.1	2.6
Calcium Sulfate	$CaSO_4 \bullet 2H_2O$	200	172.2	86.1	1.9
Magnesium Sulfate	$MgSO_4 \bullet 7H_2O$	500	246.5	123.2	6.8
Ammonia Chloride	NH_4Cl	750	53.5	53.5	4.4
Calcium Chloride	$CaCl_2 \bullet 2H_2O$	450	147.0	73.5	3.6
Magnesium Chloride[4]	$MgCl_2 \bullet 6H_2O$	1850	203.3	101.7	20.7

[1]Prices FOB Minneapolis, MN, as-fed basis (Byers, 1992).
[2] molecular weight (g)
[3] equivalent weight (MW/valence)
[4]Other quoted prices for magnesium chloride: $2,000/ton (food grade) FOB Danville, VA; $400/ton (technical grade), FOB NJ; $1200 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.

Table 2. Composition of commonly available anionic salts.

Anionic salt	Percent of salt, dry matter basis					
	N	Ca	Mg	S	Cl	DM[1]
$(NH_4)_2SO_4$	21.2			24.3		100.0
$CaSO_4 \bullet 2H_2O$		29.5		23.5		79.1
$MgSO_4 \bullet 7H_2O$			20.3	26.6		48.8
NH_4Cl	26.2				66.3	100.0
$CaCl_2 \bullet 2H_2O$		36.2			63.8	75.5
$MgCl_2 \bullet 6H_2O$			25.6		74.6	46.8

[1] dry matter percent

Table 3. Calculated dietary cation-anion difference (DCAD) of individual feedstuffs.[1,2] (Adapted from Block, E., 1991)

Feed	% of DM				
	Na	K	Cl	S	DCAD
Grass silage[3]	.11	3.10	.74[4]	.26	• 47.2
Alfalfa hay (late vegetative)	.15	2.56	.70	.31	• 33.1
Soybean meal	.03	1.98	.08	.37	• 26.7
Timothy hay (late vegetative)	.09	1.6	.37	.18	• 23.3
Oat hay[5]	.18	1.51	.52	.25	• 16.3
Corn silage	.01	.96	.30[4]	.15	• 7.2
Corn grain	.03	.37	.05	.12	• 1.9
Barley	.03	.47	.18	.17	- 2.3
Distillers' grain	.10	.18	.08	.46	-22.0

[1]Values from NRC (1988) for Na^+, K^+, Cl^- and $S^=$.
[2]DCAD calculated as mEq ($Na^+ + K^+$) - ($Cl^- + S^=$)/100g DM using the equation from page 2.
[3]Grass silage values from British Columbia Ministry of Agriculture and Fisheries, South Coastal Forage Competition, courtesy of D. L. Bates, P.Ag.
[4]Chloride value for grass and corn silage from samples from (3) as analyzed by W.K. Sanchez
[5]United States-Canadian Table of Feed Composition, National Academy Press, 1982.

Table 4. Example of DCAD calculation in three diets with differing potassium (K) concentrations and differing amounts of anionic salts added.

Item		Increasing Anionic Salts With Increasing Dietary K to Maintain DCAD = -15 meq/100 g Diet Dry Matter		
Percent of Diet DM	Basal Diet[1]	Diet A	Diet B	Diet C
K	1.0	1.0	1.5	2.0
Na	.15	.15	.15	.15
Cl	.25	.79	1.25	1.70
S	.22	.40	.40	.40
Ca	1.80	1.80	1.80	1.80
P	.5	.50	.50	.50
Mg	.3	.40	.40	.40
Pounds/cow/day Magnesium sulfate	0	.22	.22	.22
Calcium sulfate	0	.06	.06	.06
Ammonium chloride	0	.18	.33	.48
DCAD, meq/100 g (without added anionic salts)	+11.4	+11.4	+24.2	+37.0
Added meq [Cl + S] per 100 g DM (assuming cow eating 22 lb DM)	0	-26.4	-39.2	-52.0
DCAD, meq/100 g (with added anionic salts)	+11.4	-15.0	-15.0	-15.0

[1]Basal diet is 31% corn silage, 18% grass silage, and 51% concentrate (DM basis).

Appendix: Instructions for diet formulation

In order to formulate a diet with -10 to -15 mEq/100 g dry matter:

1. First, it is essential to analyze all feeds for macrominerals (calcium, phosphorus, magnesium, sodium, potassium, chloride, and sulfur). Forages and by-product feeds are extremely variable in their mineral concentrations, and "book" values cannot be relied upon.

2. Consider the formulation of the basal diet. Whenever possible, select feed ingredients with a low DCAD (especially forages). If the basal DCAD is greater than +20 mEq/100 g dry matter, large amounts of anionic salts will be necessary, and feed intake problems are likely.

3. Add the appropriate anionic salts. Magnesium sulfate is recommended as the first addition because it appears to be the most palatable, and because it can be used to meet the cow's requirement for magnesium. Formulate to 0.4% dietary magnesium (dry matter basis).

4. Add calcium sulfate or ammonium sulfate next to achieve a dietary S concentration of 0.4% dry matter.

5. Add chloride sources (ammonium, calcium, or magnesium chloride) to bring the DCAD down to -10 to -15 mEq/100 g dry matter.

6. Check dietary non-protein nitrogen and degradable protein. Reduce the use of ammonium salts if NPN is greater than 0.5% (more than 3.1% of crude protein from NPN) or degradable protein is greater than 70% of total CP.

7. If it is possible to lower DCAD to -10 to -15, add calcium to achieve calcium intakes of 150 to 180 g/day (1.5 to 1.8% diet dry matter). In field reports where problems were encountered with the feeding of negative DCAD, many were due to inadequate dietary calcium.

8. Formulate to provide a daily intake of 40 to 50 g phosphorus. Check the formulation to ensure that other nutrient requirements (energy, protein, vitamins, and minerals) are met.

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