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Dietary Cation-Anion Balancing of Rations in the Prepartum or Late Dry Period[1]

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The art of feeding dairy cattle is rapidly becoming the basic and applied science of dairy cattle nutrition. Because dry cow feeding and management set the stage for both production and reproductive performance after parturition, dairymen are more concerned with dry cow feeding and management practices that enhance performance. The prepartum period (last 3 to 4 weeks of the dry period) has been designated by many dairymen as the period to make any needed changes in the dry cow ration to increase performance and reduce metabolic problems. Already, a number of dairymen are feeding more vitamin E (800 to 1000 IU/cow/day) and selenium during the prepartum period to reduce the incidence of retained placenta and cystic ovaries. A properly balanced ration with increased amounts of grain and plenty of hay (long or chopped) helps in reducing metabolic problems. The objective is to have the cow calve in good body condition (3.25 to 3.75), healthy and with a good appetite.

In recent years, Florida dairymen have been able to reduce the incidence of milk fever and subclinical hypocalcemia during the early postpartum period by feeding adequate amounts of calcium, phosphorus, and magnesium. Earlier studies at Arizona by Scott (1965) suggested that a lack of available phosphorus in the diet of lactating dairy cows is the predisposing factor in milk fever. More recently, it has been shown that dairy cows on high alkaline diets during the dry period are more prone to milk fever. An acidogenic diet tends to prevent hypocalcemia and milk fever. Dietary cations (positively charged) such as sodium (Na), and potassium (K) are alkalogenic; dietary anions (negatively charged) such as chlorine (Cl), sulfur (S), and phosphorus (P) are acidogenic.

The NRC (1989) suggests 0.39% calcium (33 to 43 gms) and 0.24% phosphorus (20 to 26 gms/day) in the ration dry matter for mature dry cows during the last two months of the dry period. While these levels of calcium and phosphorus are considered low, they appear to be adequate to meet the needs of the dry cow.

Reducing the level of calcium in dairy rations during the late dry period is not always successful in reducing the incidence of milk fever. Also, in some areas where feedstuffs in use are high in calcium, it is more difficult to restrict the level of calcium in the diet.

Feeding trials by Oetzel (1991) reveal that dry cows receiving both restricted calcium diets and high calcium diets had less incidence of milk fever. Greatest incidence of milk fever occurred when the diet dry matter (DM) contained about 1.16% calcium. Less incidence was observed as the level of calcium was increased or decreased from 1.16%. The level of sulfur in the diet also influenced the incidence of milk fever. Increasing the sulfur content of the diet reduced the incidence of milk fever, with the lowest incidence at 0.45 to 0.50% sulfur.

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With low dietary sulfur (0.10 to 0.15%) the incidence was 50 to 60%. When the diet DM contained 0.50% sulfur the incidence was very near 0%. Sulfur and chlorine are the two anions used to make the rations more acidic or negatively balanced.

Dietary Cation-Anion Balancing

Dietary cation-anion balancing is a new concept that has received much attention recently as a nutritional tool for reducing milk fever in early lactation as well as improving health and production. The dietary electrolytes are balanced according to the charges they contain. Because cations are positively charged and anions are negatively charged, the ration is balanced to be either negative or positive. A negatively balanced ration favors prepartum dry cows and reduced incidence of milk fever, whereas a positively balanced ration favors lactating cows and increased levels of milk production. That is, lactating cows do better with a positively balanced ration and prepartum cows with a negatively balanced ration. Mineral elements considered in cation-anion balancing are sodium, potassium, chlorine and sulfur.

Diets can be manipulated with relative ease by adding either anionic salts or cationic salts to the ration. In order to effectively balance the diet, the present ration or feedstuffs should be analyzed for sodium, potassium, chlorine, and sulfur. If possible, select forages for dry cows that are lower in potassium. This may be a problem since all forages tend to be high in potassium. The information in Table 1 shows the molecular weight of each element and its valence (positive or negative charge).

To create a well-balanced ration using the cation-anion approach, about 150 to 250 total grams of a combination of compounds such as ammonium chloride, ammonium sulfate, calcium chloride, calcium sulfate and magnesium sulfate are needed daily per cow. The amount needed will vary with the concentration of potassium and sodium in the ration. Information regarding the compounds is in Table 2. Because anionic diets stimulate greater mobilization of calcium from bone, they should not be fed the entire dry period. The anionic salts used in the prevention of milk fever are quite unpalatable to dairy cows. As a result, they should be used with caution and mixed thoroughly in the dry cow ration.

The anionic salts may be mixed with a carrier (Table 3) such as corn meal for ease of handiing and mixing in the ration. With the use of a carrier such as corn meal, the mixture would be designed so that each cow would receive about 1 lb daily during the 3 to 4 week prepartum period. The anionic salts may be proportioned in the mixture to give the desired concentration of sulfur and chlorine for the ration.

A cation-anion balance is calculated by subtracting anion milliequivalents from cation milliequivalents (meq.). While several formulas have been used, the following equation (Equation 1) is suggested for dry cows.

$$\text{Cation}-\text{anion balance} = \text{meq.}\ [(Na + K) - (Cl + S)]/100\ \text{gms DM}$$

As an example, assume the prepartum dry cow ration contains on a dry matter basis 0.23% sodium, 0.9% potassium, .90% chlorine and .39% sulfur (Table 4). The percentage of an element in a compound may be expressed as pounds per hundred pounds or grams per hundred grams. Note that the results are expressed as meq. per hundred grams. To calculate the ration balance, divide the percent of the element in the ration by the milliequivalent for the element (sodium calculation is 0.23/0.023 = +10.0 meq. etc.). The cation-anion balance in the above example would be sodium = + 10.0, potassium (0.89/.039) = +22.8, chlorine (0.9/.0355) = -25.4, and sulfur (0.39/.016) = - 24.4, for an overall cation-anion difference of -17.0 meq/100 gms dry matter. Because most forages and oil meals are high in potassium, exercise care in formulating a negatively balanced ration. Rations that are high in potassium and sodium take considerably more chlorine and sulfur to make them negative. While the concentration of chlorine may be increased in the ration without problems, increasing the concentration of sulfur above 0.4% of the ration dry matter is not recommended. Excessive sulfur interferes with the metabolism of certain other minerals such as selenium and it reduces performance. High concentrations of potassium in rations may lead to a greater incidence of hypocalcemia and possibly milk fever in a dairy herd. The two rations in tables 4 and 5 are negatively balanced.

A mineral mixture should be purchased or formulated to provide the extra minerals and vitamins needed in the dry cow ration. The special anionic salt mix should be formulated to provide the desired negative cation-anion balance for feeding prepartum dairy cows.

Table 1. Minerals elements commonly used in calculating the cation-anion balance of rations.

Mineral	Molecular Wt. (grams)	Valence (Charge)	Equivalent Wt. (grams)	meq. Wt.[1] (mg)
Sodium	23	+1	23	.023
Potassium	39	+1	39	.039
Chlorine	35.5	-1	35.5	.0355
Sulfur	32	-2	16	.016

[1] meq = milliequivalent, mg = milligrams. Meq wt = Mol wt divided by valence divided by 1000.

Table 2. Relative cost and chemical composition of commonly available anionic salts.

Mineral Salt	Chemical formula	Mol. Wt.	Cost[1] ($/cwt)	% of element	
				Cl	S
Ammonium sulfate	$(NH_4)_2SO_4$	132.1	11.00	--	24.3
Calcium sulfate	$CaSO_4$•$2H_2O$	172.2	8.50	--	18.6
Magnesium sulfate	$MgSO_4$•$7H_2O$	246.5	21.00	--	13.0
Ammonium chloride	NH_4Cl	53.5	39.00	66.3	--

1 Prices obtained from Lakeland Cash, Lakeland, Florida. (1992).

Table 3. Combination and composition of three compounds mixed with corn meal for use in feeding the prepartum cows.

Anionic Salt	gms/cow	S	Cl	K	Na
		---gms---			
Ammonium sulfate $(NH_4)_2SO_4$	40[1]	9.7	--	--	--
Ammonium chloride (NH_4Cl)	100	--	66.3	--	--
Magnesium sulfate $MgSO_4$•$7H_2O$	60	7.8	--	--	--
Carrier (corn meal)	253.6	0.3	0.1	0.8	0.1
Total/cow/day	453.6	17.8	66.4	0.8	0.1

453.6 grams = one pound. [1]The proportion and amounts needed will vary.

A number of studies show less milk fever when cows are fed a ration with a negative cation-anion balance during the late dry period. The reduction in incidence of milk fever appears to be due primarily to the greater mobilization of calcium from bone stores. Research has shown that cows fed anionic diets have higher blood calcium levels at calving (Table 6).

Present research indicates that watching the cation-anion balance may have potential for improving milk yield in the subsequent lactation, and reducing the incidence of both retained placenta and of milk fever. Research is underway at the University of Florida (1992) to help to define the parameters needed to make recommendations.

The principle of evaluating dairy cattle rations in terms of the anion-cation balance is fairly straightforward. Most of the available research indicates that diets which are acidogenic (negative cation-anion balance) are beneficial to calcium absorption and in the reduction of the incidence of milk fever. The feeding of such rations should be during the last 3 to 4 weeks of the dry period.

In addition to reducing the incidence of milk fever, an increase in milk production in the subsequent lactation has been reported by two studies. Beede et al. (1992) and Block (1984) reported an increase of about 720 and 1070 lbs more milk in the subsequent lactations as a result of feeding the anionic balanced diet. In contrast, Seymour et al. (1992) found no benefit from feeding multiparous (more than one lactation) cows an anionic diet prepartum compared to an otherwise balanced dry cow diet. In the lst lactation cows, days open (123 vs 94 d) and milk yield (71.9 vs 64.7 lb/d) were both reduced for cows receiving negatively balanced rations (-6 vs + 16 meq/l00 grams of dry matter).

Lactating cows seem to respond more to a positively balanced ration. The opposite appears to be the case for dry cows. Work by Sanchez et al. (1992) and Tucker et al. (1988) showed that milking cows fed a ration containing a positive 20.0 meq. per 100 grams produced more milk than cows having a negative 10.0 cation-anion balanced ration.

Nonlactating cows should be properly managed during the dry period to assure top production in the subsequent lactation. Properly balanced rations designed to avoid metabolic problems and fed during the prepartum period will assist the dairyman in reaching his objectives.

In summary, the use of negatively balanced cation-anion rations during the late dry or prepartum period requires excellent monitoring and management. The cows must be separated from the remaining herd and fed a total mixed ration as a group. Cows on pasture during the prepartum period are not suitable since the ration cannot be controlled. The different compounds such as ammonium chloride must be selected and proportioned in the ration to give the desired negative balance. The concentration of chlorine may vary in the ration dry matter but the sulfur concentration should remain below 0.4%. A negatively balanced ration varying from a -10 to -20 is usually adequate.

Table 4. Negatively balanced cation-anion ration in number 1.

		DM	CP	TDN	Na	K	Cl	S
Feedstuffs	**lbs**	**----lbs----**			**----gms----**			
Sorghum Silage	20.0	6.0	0.50	3.20	0.9	27.2	2.7	3.6
Bermudagrass hay	3.0	2.7	0.24	1.35	0.1	21.1	0.0	2.2
Corn meal	5.0	4.5	0.43	4.00	0.7	7.5	0.8	2.3
Whole Cottonseed	2.0	1.8	0.42	1.80	0.1	8.1	0.0	2.1
Cottonseed hulls	4.0	3.6	0.16	1.60	0.4	14.2	0.4	3.2
Soybean meal (48%)	0.8	0.7	0.42	.62	0.1	6.4	0.2	1.2
Distillers grain	1.0	0.9	0.27	0.80	2.3	1.8	0.7	1.7
Mineral Mix	0.5	0.5	0.00	0.00	18.1	--	17.0	4.5
Special Mix*	1.0	0.9	0.00	--	0.1	0.8	66.4	17.8
Totals	38.3	21.6	2.48	13.37	22.8	87.1	88.2	38.6
Requirements	-	-	2.20	13.00	-	-	-	-
Percent Element in Feed (DM)	-	-	-	-	.23	0.89	0.90	0.39

* Special mix given in Table 2. Cation-anion balance = -17.0

Table 5. Negatively balanced cation-anion ration in ration 2.

Feedstuffs	lbs	DM	CP	TDN	Na	K	Cl	S
		----lbs----			----gms----			
Corn Silage	20.0	6.0	0.5	4.00	0.3	29.9	0.0	4.1
Bermuda hay	3.0	2.7	0.24	1.35	0.1	21.1	0.0	2.2
Corn meal	3.0	2.7	0.26	2.40	0.4	4.5	0.5	1.4
Cottonseed	2.0	1.8	0.42	1.80	0.1	8.1	0.0	2.1
Wet Brew (30%)	15.0	4.5	1.14	3.00	4.7	1.8	3.5	6.5
CSH	3.0	2.67	0.12	1.20	0.3	10.6	0.3	1.1
Mineral Mix	0.5	0.47	0.00	0.00	15.0	0.0	17.0	4.5
Special Mix*	1.0	0.96	0.00	0.00	0.1	0.8	66.4	17.8
Totals	46.5	22.80	2.68	13.75	21.0	76.8	87.7	39.7
Requirements	-	-	2.20	13.00	-	-	-	-
Percent Element in Feed (DM)	-	-	-	-	0.20	0.74	0.85	0.38

* Special mix given in Table 2. Cation-anion balance = -19.8

Table 6. Experimental results from an experiment in which Holstein cows were fed diets with negative (treatment) or positive (control) cation-anion difference.[a]

Measurement	Treatment (-25 meq/100g)	Control (+5 meq/100g)
Clinical milk fever, %		
< 2 lactations	0	0
> 2 lactations	5	12
All cows	4	9
Subclinical, %		
< 2 lactations	2	16
> 2 lactations	28	66
All cows	19	50
Serum iCa. Mg/dl[b]	4.31	3.80
Serum Ca. Mg/dl	7.94	7.10
Serum P. Mg/dl	4.44	3.64
MY, lb (305-d ME)	20,627	19,908

[a] Beede et al. (1992); cows calving from Dec. 24, 1989 through Apr. 30, 1990 were divided randomly into two groups (260 cows on Treatment and 250 cows on Control) and were fed experimental diets for 3 wk prepartum. After calving cows were commingled and fed the same lactation diet.
[b] Blood serum ionized calcium (Ca) concentrations < 4.0 mg/dl defined a cow as being hypocalcemic.

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