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Calf Note #65 – Dietary cation-anion balance in dairy calves

Introduction

Growth of dairy calves and heifers is usually correlated with concentration of protein (ruminally degradable and undegradable), energy and vitamin and mineral content of the ration. However, the balance of the ionic strength of the diet has been shown to affect production of dairy cows – particularly during the dry period and early in lactation. A question asked by researchers at the University of Kentucky was "does dietary cation-anion balance affect performance of young calves?"

Cation-anion balance

Ions are classified as groups of one or more atoms with an electrical charge due to the gain or loss of electrons. Ions can have a positive charge (*cations*) or a negative charge (*anions*). In the body, cations and anions are abundant and are responsible for a wide variety of biological functions.

Minerals are particularly important ions in the body. Cations include calcium, potassium, sodium, magnesium and others. Important anions include sulfur, oxygen, chloride, among others. The cation-anion balance of a diet is usually calculated in *equivalents* or *milliequivalents*. An equivalent is defined as the weight of a substance (grams) divided by the equivalent weight (grams). In turn, the equivalent weight of a substance that contains 1 mole of ions. It is calculated as the molecular weight (grams) / valence (charge) of the substance. For example, one equivalent of sodium ion (Na^+) is calculated as molecular weight (23) / valence (1) = 23.

Calculation of dietary cation-anion balance in dairy cattle diets is typically calculated as the number of milliequivalents of (Na + K) – (Cl + S), which represents the amount of important cations (sodium and potassium) and anions (chloride and sulfur) in the diet. Other researchers may use other ions in the diet.

Manipulation of the dietary cation-anion balance (**DCAB**) has been shown to affect overall mineral metabolism in many animals, including dairy cattle. Reducing the DCAB (increasing the amount of anions in the diet and/or reducing the amount of cations) has been shown to reduce the incidence of parturient paresis (milk fever) in dairy cows – consequently, many dairy farmers regularly feed a negative DCAB diet to their dry cows.

There is relatively little information regarding the use of DCAB diets in calves. In two studies done at the University of Kentucky (1, 2), researchers fed calves varying DCAB diets to evaluate their effects on animal health and growth.

Experiment 1. In this study (1), 32 weaned calves (56 to 70 d of age) were fed calf starters containing –18, 5, 23, or 38 mEq, calculated as (Na + K) – (Cl + S) / 100 grams of dietary DM. The DCAB was manipulated by varying the amount of calcium chloride ($CaCl_2$) and sodium bicarbonate ($NaHCO_3$). Calves were fed for eight weeks and measures of growth, intake, and blood and urine parameters were measured.

TABLE 1. Effect of dietary cation-anion balance (DCAB) on performance in calves.

	Dietary DCAB (mEq/100 g DM)				
Item	**-18**	**5**	**23**	**38**	**SE**
Feed intake, kg/d[1]	3.79	3.94	4.41	3.93	0.18
BW gain, kg/d[1]	0.88	0.97	0.99	0.91	0.04
Plasma					
Ca, mg/100 mL[3]	10.10	10.56	10.58	10.72	0.15
Mg, mg/100 mL[3]	2.21	1.96	1.99	1.89	0.05
P, mg/100 mL	9.0	8.9	8.9	8.7	0.2
Na, mEq/L	121.1	120.2	121.5	121.0	0.8
K, mEq/L	5.1	5.3	4.9	5.2	0.1
Cl, mEq/L[2,3]	107.8	102.5	102.3	102.1	0.6
Blood pH[2,3]	7.341	7.381	7.377	7.382	0.004
Blood pCO_2[2,3]	43.2	47.7	47.0	48.7	0.8
Urine pH[2,3]	6.1	7.5	8.1	8.1	0.1

[1]Quadratic effect of DCAB ($P < 0.10$).
[2]Linear effect of DCAB ($P < 0.01$).
[3]Quadratic effect of DCAB ($P < 0.01$).

Changing DCAB from –18 to 38 had a quadratic effect on calf starter intake and body weight (BW) gain in this study. The optimal DCAB appeared to be at 23 mEq/100 g DM. At this point, calves tended to eat the greatest amount of starter and tended to grow faster than other calves. In addition, there were very large changes in blood metabolites, particularly in the concentration of blood minerals such as Ca, Mg, and Cl. In addition, blood pH and pCO_2 (partial pressure of CO_2) were significantly affected by DCAB. Changing DCAB from –18 to 38also increased urine pH in the calves.

Experiment 2. In this study, two levels of DCAB (-18, 13) were fed at two levels of Ca (0.42, 0.52%) in the calf starter diet. Again, DCAB levels were altered by changing the amount of $CaCl_2$ and $NaHCO_3$ in the diet. Calves (n = 32) were fed for 8 weeks. Measurements included feed intake, BW gain, blood measurements and bone breaking strength (bull calves were sacrificed at the end of the study and the 7th and 9th ribs were sampled and breaking strength determined as an index of bone density and strength. The deposition and mobilization of Ca in bones can have a significant effect on bone strength, which is very important for growing calves.

TABLE 2. Effect of dietary cation-anion balance (DCAB) and Ca on calf performance.

	Dietary DCAB (mEq/100 g DM)				
Item	**-18/0.42**	**-18/0.52**	**13/0.42**	**13/0.52**	**SE**
Feed intake, kg/d	3.60	3.34	3.61	3.67	0.18
BW gain, kg/d[1]	0.70	0.73	0.85	0.85	0.05
Plasma					
Ca, mg/100 mL	10.31	10.21	10.12	11.03	0.31
P, mg/100 mL	10.14	10.22	9.35	9.46	0.43
Cl, mEq/L[1,2]	108.4	108.0	101.6	100.2	1.0
Blood pH[1]	7.301	7.346	7.375	7.373	0.017
Blood pCO_2[1]	45.0	46.2	47.4	48.4	0.6
Urine pH[1]	6.06	6.03	7.38	7.50	0.15
7th rib strength, kg[1,2]	38.0	65.5	68.6	90.3	11.2
9th rib strength, kg[1]	27.5	42.5	48.7	58.1	8.6

[1]DCAB effect ($P < 0.05$).
[2]Ca effect ($P < 0.05$).

Calves fed diets containing 13 DCAB tended (*P* < 0.10) to eat more starter during the study (weeks 3 and 4). Calves fed 13 DCAB grew faster than other calves over the entire study (Table 2). There were also very significant effects on blood metabolites, pH and pCO_2. Clearly, the manipulation of DCAB can have a very important effect on mineral metabolism. Calves fed –18 DCAB had lower bone breaking strength compared to calves fed 13 DCAB. The level of Ca also affected bone strength. In this study, calves were fed below the NRC requirement for Ca (0.61%), and increasing bone strength with increasing Ca was probably a result of intakes closer to NRC requirements.

Conclusions

Dietary cation-anion balance can affect mineral metabolism in calves. The formulation of calf starter and growers should consider not only the mineral content of the diet, but the DCAB content as well. Additional research appears necessary to determine the optimal DCAB in starter formulations.

References

1. Jackson, J. A., D. M. Hopkins, Z. Xin, and R. W. Hemken. Influence of cation-anion balance on feed intake, body weight gain, and humoral response of dairy calves. J. Dairy Sci. 75:1281-1286.

2. Jackson, J. A. and R. W. Hemken. 1994. Calcium and cation-anion balance effects on feed intake, body weight gain, and humoral response of dairy calves. J. Dairy Sci. 77:1430-1436.