Potassium in the Early Lactation Dairy Cow and its Impact on Milk and Milk Fat Production

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Take Home Messages

- Increased potassium content in early lactation diets with potassium carbonate can improve milk production and milk fat production
- Potassium level in the early lactation diet affects milk fatty acid composition
- The effect of potassium on milk fatty acids appears to be related to bio-hydrogenation in the rumen

Introduction

Potassium (K) is the principal intracellular cation of most body tissues. Potassium ions participate in many essential biological processes such as the maintenance of osmotic potential within cells, nerve impulse transmission, enzyme reactions in cellular metabolism, the maintenance of normal kidney function, and cardiac, skeletal and smooth muscle function. Because milk is an intracellular fluid, milk contains a large amount of K.

Published research suggests that the early lactation dairy cow is in negative K balance (Bannink et al., 1999; Nennich et al., 2006; Silanikove et al., 1997). Potassium retention and excretion, along with the effect of K on milk production, were evaluated using a combination of data from various total collection metabolism trials (Nennich et al., 2005 and 2006). Potassium retention in this data set was positive for over 85% of cows in the calibration dataset; however, in a set of early lactation cows, K retention was negative for all cows. Early lactation cows (less than 75 days in milk) had an average K retention of –66 g/d (Figure 1). Excretion of K appears to be directly related to K intake. Figure 2 shows the relationship of K intake and K excretion.

Potassium metabolism of cows in the early lactation dataset varied from cows in the calibration dataset. Early lactation cows tended to excrete greater amounts of K even though K intakes were similar to cows in the calibration dataset (Figure 2). Due to the greater K excretion and the greater secretion of K in milk, early lactation cows were in a negative K balance. Silanikove et al. (1997) found that cows in early lactation are often in a negative K balance and suggested that increased amounts of K in the diet may be beneficial to milk production.

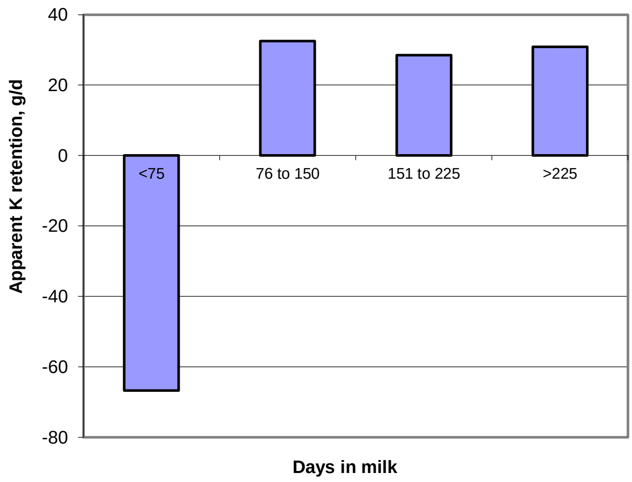

Figure 1. Apparent potassium retention of lactating cows at various days in milk.

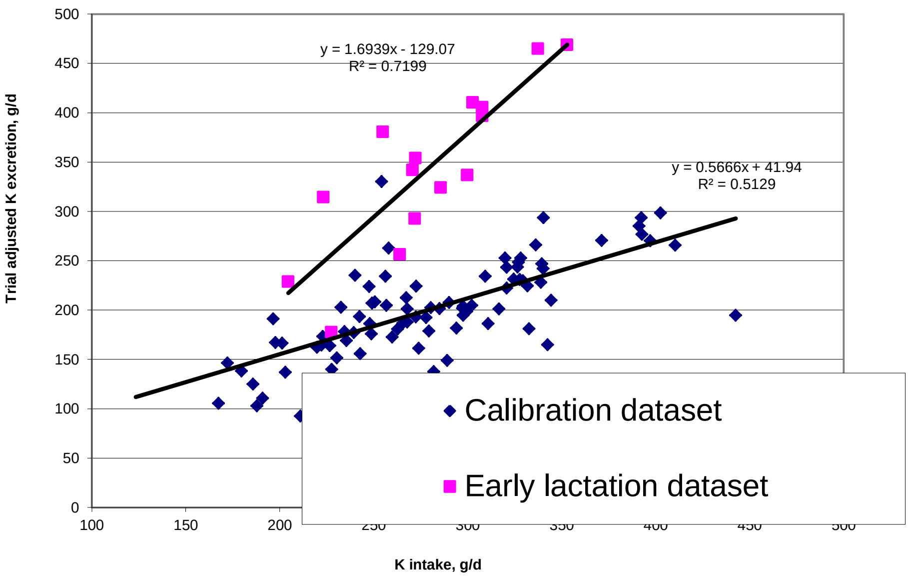

Figure 2. The relationship of potassium intake and potassium excretion for cows in the calibration and early lactation datasets.

Potassium's role in milk production can be tied to the concept of dietary cation anion difference (DCAD). Potassium is a cation that raises the DCAD, which represents interaction among the macrominerals. Interacting effects among the macrominerals Na, K**,** chloride (Cl), and sulfur (S) have been observed in the pre-calving cow, but little has been written on this subject for the post-calving cow. DCAD affects the cow by altering its acid-base status. For a general review and broader examination of these and other related topics please see the review by Block (1994). There are differences in the response to DCAD that depends on the source of Na and K used in these studies. This difference appears to show up mainly in cows in the early lactation period. Perhaps the most complete study on the effects of Na, K, and DCAD on early lactation dairy cows was by Elliot Block and associates from McGill University, Quebec (E. Block, personal communication, 1999). They fed a control diet with no added Na or K (DCAD of +18 meq/100g DM) and two higher (+25 and +52) DCAD diets to early lactation (0 – 10 weeks in milk) Holstein cows. Within the higher DCAD diets they manipulated the source of DCAD (by using either sodium bicarbonate or potassium carbonate alone or a combination of both) to determine the individual or combined effects of Na and K.

Block and associates determined that the combination of Na and K yielded the best response in DMI and milk production and that the +52 DCAD diet yielded the highest milk production response. The combinations of Na and K also resulted in the highest blood bicarbonate concentrations.

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In 2008 we completed a study to evaluate the relationship of level of K feeding in early lactation when DCAD was increased with K carbonate (White et al., 2008). Cows were on study from ~ 15 days in milk until ~ 85 days in milk. Diets were formulated to be similar in all nutrients except K (see Tables 1 and 2) with K levels of 1.3% and 2.1% of DM; and DCAD levels of 25 and 42 meq/100g DM.

Table 1. Summary of diet composition for early lactation DCAD study.

Component	% DM
Alfalfa hay	13.4
Corn Silage	12.1
Blue grass straw	8.6
DDGS	10.3
Whole cottonseed	6.2
Grain Mix	49.4

Table 2. Summary of nutrient composition of diets in early lactation DCAD study.

% of DM	Control	DCAD+
DM	60.1	59.4
CP	16.1	16,1
ADF	19.8	19.3
NDF	35.0	34.7
Ash	7.0	8.6
Ca	0.69	0.66
P	0.37	0.36
Mg	0.43	0.45
K	1.28	2.07
DCAD, meq/100g	25	42

The inclusion of a higher amount of K in the early lactation diet resulted in an increase in production of milk, 3.5% FCM, and milk fat (Table 3). This increase was not associated with an increase in DMI, and therefore appears to be unrelated to energy intake.

Table 3. Body weight, dry matter intake, milk production, and milk component production in early lactation DCAD study.

Item	Control	DCAD+	P<
BW, kg	669	674	0.49
DMI, kg	26.2	26.8	0.20
Milk, kg	39.3	40.8	0.01
ECM, kg	41.3	44.3	0.24
3.5% FCM, kg	42.2	46.1	0.09
Fat, kg/d	1.55	1.75	0.03
True protein, kg/d	1.16	1.14	0.12

Table 4 summarizes the evaluation we conducted on milk fat samples from this same study (Harrison et al., 2010). Milk samples from one-half the cows in each treatment group that represented a range from low to high milk production were selected for characterization of milk fatty acids. A limited set of the milk fatty acids is shown in Table 4. The added dietary potassium carbonate decreased unsaturated and trans-fatty acids, and increased C18:0 in milk.

Table 4. Milk fatty acid composition in early lactation DCAD study.

Item, % of total FA	DCAD	Con	P<
c16:1	1.32	1.47	0.03
c18:0	14.2	12.6	0.02
t6,t8 c18:1	0.31	0.36	0.03
t9 c18:1	0.26	0.29	0.07
t10 c18:1	0.4	0.68	0.03
t11 c18:1	1.05	1.43	0.11
t12 c18:1	0.55	0.61	0.09
c9,t11 CLA	0.34	0.44	0.03

This suggests that one mechanism for the increase in milk fat production is ruminally based. This contention is supported by observations of Jenkins et al. (2010) in which it was demonstrated with *in vitro* fermenters that potassium is involved at the rumen level in the process of bio-hydrogenation (see Figure 3). The data of Jenkins et al. (2010) suggests that the pathway of bio-hydrogenation is shifted toward an “alternative” pathway in low K diets as unsaturated FA are hydrogenated to 18:0.

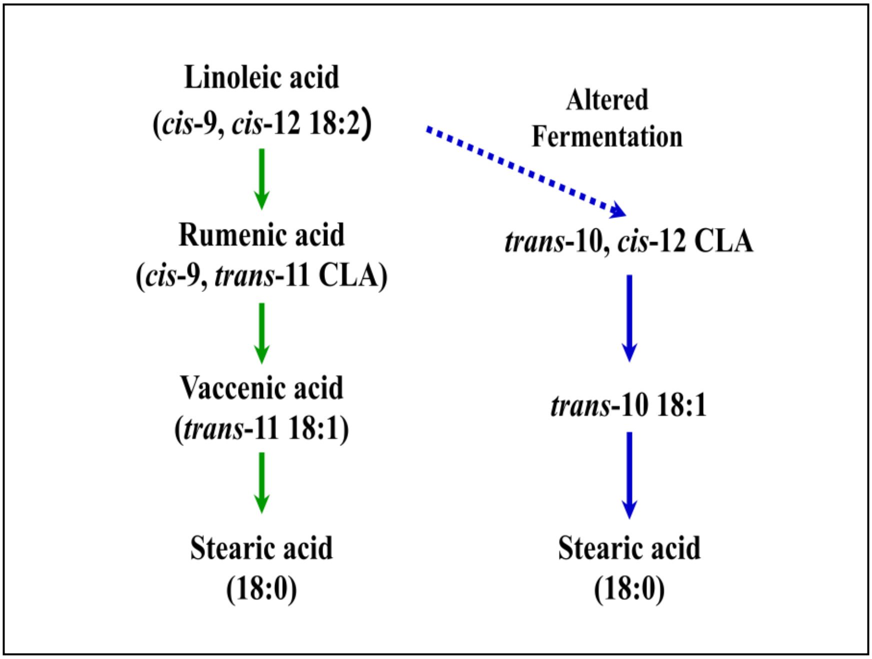

Figure 3. The shift in BH intermediates produced from linoleic acid resulting from altered fermentation in the rumen (Bauman and Lock, 2006).

▪ Special Considerations

Our current recommendations are to formulate for 1.6 % K, and to increase to 1.8 to 2% for heat stress. Sodium levels can be increased to assist in achieving a DCAD of >35meq/100g DM. Sodium should not exceed 0.8% of the ration DM. Do not use NaCl for the Na, or KCl for the K as the Cl will reduce DCAD value. There are three reasons that guidelines for Na and K are higher than NRC (2001). First, because early lactation cows eat less than mid-lactation cows, there is a need to increase nutrient concentrations to reflect reduced feed intakes. Second, most of the macro-mineral research was conducted with low and medium producing cows; high producing cows secrete more of these minerals in milk and generate more acid in the rumen and blood. Third, the higher concentrations of Na and K represent an additional role these nutrients play in rumen buffering and acid-base balance, and recent data suggests that cows can be deficient in K and Na in early lactation.

No recommendation is given for sodium (Na) because of its dependency on K and DCAD concentrations. Salt *per se* is not a required nutrient by dairy cows. However, because salt is one of the four taste sensors on the tongue we recommend a minimum of salt (~ 0.1 lb) in every lactation ration. Chloride should be kept to as close to the minimum NRC recommendations as possible to avoid complications due to chlorides contribution in subclinical metabolic acidosis.

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