Nutritional and Environmental Management of Phosphorus and Potassium

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Abstract

Management of phosphorus and potassium is important to reduce nutrient imports to the farm and to prevent accumulation of these nutrients in soils. Although P was traditionally overfed, research has shown that overfeeding P is not beneficial to either milk production or reproduction of dairy cows and will result in greater excretion of P. Supplementation of mineral sources of P have declined in recent years; however, dietary P concentrations have not decreased to recommended levels on many operations due to the inclusion of co-product feeds that are high in P. Potassium concentrations in dairy diets have gained less attention as K has not been correlated directly with environmental concerns. Nonetheless, the role of K in dairy diets and the role of this mineral on the farm should be evaluated. The positive K balance on many operations often leads to excess soil application rates of K. High concentrations of K in soils can result in leaching of K and can lead to high concentrations of K in grass forages grown on those soils. At the whole farm level and across stages of lactation, the need to have low K diets during the pre-partum period needs to be balanced with the value of high dietary cation-anion diets in early lactation which can be achieved with the use of K. Reducing the overfeeding of P and K is important to maintain the balance of these minerals on dairy operations.

Introduction

Management of environmentally sensitive nutrients on dairy operations begins with the nutrition program. The intake of nutrients will affect the amount of nutrient that is excreted, thus affecting the concentration of a particular nutrient in manure and the amount of that specific nutrient that must be handled by the livestock operation in the manure management system. Feeding to meet animal requirements, without overfeeding, will reduce the amount of nutrients in manure and can reduce costs associated with manure management.

Phosphorus

Phosphorus has gained a lot of attention in recent years as a nutrient of environmental concern. In particular, P has been implicated as a nutrient of concern in several high-profile watersheds, including the Chesapeake Bay and the Bosque Watershed in Texas. In both of these watersheds, much of the P entering the water was alleged to have come from livestock operations that had over-applied P to agricultural lands. The issue of P application rates has been complicated in the past by the fact that manure was often applied at a nitrogen based rate, leading to over-application of P. In situations where manure is applied at an N based rate, the concentration of P in the manure determined the P application rate. The situation was often exacerbated by the overfeeding of P in dairy diets, resulting in greater P concentrations in manure.

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Several studies have been conducted in recent years to evaluate the effect of reducing dietary P concentrations in the diets of dairy animals in an effort to reduce P excretion. A summary of various studies that focused on feeding diets with various P concentrations and resulting P excretions are provided in Table 1.

In the past, decreasing the P supplementation was a concern because of an association with decreased reproductive performance when dietary P concentrations were decreased. Numerous studies evaluated the effect of various dietary P concentrations on reproductive performance. In 1999, Valk and Sebek did not find any difference in reproductive performance for cows fed diets containing either 0.33, 0.28, or 0.24 % dietary P. Similarly, Lopez et al. (2004) did not find any difference in reproductive performance for cows fed either 0.37 or 0.57% dietary P, and Wu et al. (2000) reported similar reproductive performance for cows fed diets containing either 0.40 or 0.49% P.

In addition to the studies to evaluate acceptable levels of P in the diet, several studies were also conducted to look at the levels of P currently being fed in dairy diets in on-farm situations. A study conducted in 2001 found that on average, the P concentration of dairy diets was 34% above the recommended level (Dou et al., 2003), and a survey of nutritionists conducted in 1997 revealed that the average formulated dietary P concentration for high producing cows was 0.52% (Sansinena et al., 1999).

Although use of P mineral supplements has appeared to decline in recent years, the concentration of P in diets has not necessarily been reduced to recommended levels. The reason for this is the high concentration of P in many of the co-product feeds that are becoming more and more common in dairy rations.

A study conducted in Texas in 2005 and 2006 revealed that the P concentration of total mixed rations (n = 54) averaged 0.44% of the dietary DM (Nennich et al., 2007). Even though the dietary P concentration in these diets were much above recommended levels, a review of the formulated rations (n = 19) found that the diets did not include any inorganic P supplements.

High base dietary P concentrations create an interesting dilemma, especially in areas that are environmentally P sensitive. In many cases, reducing the P concentrations of the diet would result in a more expensive diet since less co-product feeds would be able to be included in the ration. Feeding diets with greater dietary P concentrations will require either a larger land base for manure application, or the implementation of a technology to remove P from the manure handling system. In the complex dairy systems today, the costs associated with manure handling and application should not be ignored, and must be weighed against the supposed "savings" associated with feeding co-product feeds that are high in P.

Various studies have looked at the role of P nutrition on the whole-farm balance and on soil P concentrations. The majority of the P imported to farms is typically imported through feed. A study of 41 western commercial dairy operations found that on average, 85.4% of P imports to the farm were in the form of feed (Spears et al., 2003). In a study looking at 6 commercial dairy operations in Idaho, 94.6% of the P imports were from feed (Hristov et al., 2006). The overall balance of P on dairy operations can also be affected by the cropping strategies used on the operations. A study by Ghebremichael et al. (2007) found that P balance could be reduced by 4.8 kg/ha (4.2 lb/acre) and 9.6 kg/ha (8.45 lb/acre) a with increased productivity of grass forage and increased forage feeding in the diet, respectively.

Potassium

Potassium is not a nutrient that is directly related to environmental concerns. However, K does play an important role in dairy nutrition. The K in manure has value as a fertilizer, and K needs to be managed to prevent over application to soils. Potassium can also accumulate in grass forages when soil concentrations of K are high and may result in feeding challenges for dairy operations.

Fisher et al. (1994) reported that DM intake was improved and milk production unchanged when dietary K increased from 1.6 to 3.1% of dietary DM. A further increase of the K level to 4.6 % of diet dry matter decreased feed intake and milk yield. As the concentration of K in the diet increased, animals drank more water and excreted more urine, K, and sodium (Na). There is also a potential for K to interfere with absorption of magnesium (Mg) when high levels of K are fed. The ideal dietary concentration of K for high producing cows appears to be between 1.6 and 3.1%. Cows were physiologically challenged when fed concentrations of K from 3.1 to 4.6 % of dietary DM.

There are 3 reasons that current guidelines for K and Na are greater than NRC (2001) recommendations. First, early lactation cows eat less than mid-lactation cows, and there is a need to increase nutrient concentrations to reflect reduced feed intakes. Second, most of the macromineral 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 suggest that cows can be deficient in K and Na in early lactation.

The metabolism of K in early lactation cows is different from that of cows in later lactation, as cows in early lactation may be 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.

Potassium retention and excretion of lactating dairy cows, 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; Nennich et al., 2006). Potassium retention for cows in the data set was positive for over 85% of cows (calibration dataset); however, in a set of early lactation cows, K retention was negative for all cows. Early lactation cows tended to excrete greater amounts of K, even though K intakes were similar to cows in the calibration dataset (Figure 1). Due to the greater K excretion and the greater secretion of K in milk, early lactation cows were in a negative K balance, with early lactation cows (less than 75 DIM) having an average K retention of –0.145 lb/day.

Dietary K and whole farm nutrient management

Any program that increases the amount of K fed to cows must consider the overall effect of K on the dairy. Feeding extra K to pre-calving dry cows can contribute to milk fever problems. Therefore, a nutrient management plan that considers K in both the manure and purchased fertilizer is needed to avoid growing forages with excessively high K. There are several whole-farm case histories that have evaluated K balance. These examples help illustrate the importance of nutrient management plans to control excess K in soils and harvested forages. An alternative approach is to specifically segregate forages of low and high K for use with pre-partum and post-partum cows, respectively.

A study of dairy operations in Idaho found that, on average, 92% of the K was imported to the farms in feed (Hristov et al., 2006). Evaluation of the balance of K on the Idaho dairy operations found that, with the exception of one dairy operation, the farms had significant surpluses of K on the operations each year. Overall, the estimated milk K efficiency on the farms was 11% (Hristov et at., 2006).

Similarly, an evaluation of K mass balances (Wang et al., 1999) evaluated at the Cornell University Dairy Farm found that 89.7% of K was imported in feed and that only approximately 43% of the K was exported through milk, wasted feed, and animals. Over the years, feed imports of K, as a percentage of total imports, increased greatly because fertilizer sources of K were drastically reduced. Reductions of fertilizer K and increases in the amount of K captured in milk resulted in the net balance of K on the farm being reduced by 30%. Interestingly, the soil K concentration was not increased in soils over a period of 25 years, most likely due to the K leaching through the soil profile (Wang et al., 1999).

Conclusions

Dietary concentration of P and K need to be evaluated to prevent overfeeding and to improve the balances of these minerals on dairy operations. The P concentrations in co-product feeds may result in increased dietary P concentrations, resulting in either a greater land base being needed for P application or the implementation of technologies that can concentrate P and allow it to be economically exported from the dairy operation. Concentrations of K in dairy diets need to be evaluated to insure that animal requirements are being met without overfeeding. Soil application rates of K also need to be evaluated to prevent over application of K that may lead to K leaching or increased K concentration in grass forages.

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Table 1. Summary of various studies conducted to evaluate dietary P concentration on fecal P excretion.

Study and Treatments	Dietary P (% of DM)	DMI (lb/day)	Milk (lb/day)	Fecal P Excretion (lb/day)
Wu et al., 2000				
0.31% Dietary P	0.31	50.7	77.2	0.082
0.40% Dietary P	0.40	49.4	80.5	0.115
0.49% Dietary P	0.49	51.6	79.8	0.149
Wu et al., 2001				
0.31% Dietary P	0.31	55.1	93.5	0.095
0.39% Dietary P	0.39	55.1	85.3	0.145
0.47% Dietary P	0.47	54.2	86.9	0.194
Knowlton et al., 2001				
Soybean meal; mineral	0.34	51.8	80.0	0.102
Soybean meal; wheat bran	0.34	46.1	73.4	0.089
Blood meal; mineral	0.36	49.6	74.5	0.101
Blood meal; wheat bran	0.38	45.4	71.4	0.086
Knowlton and Herbein, 2002				
0.34% Dietary P	0.34	55.8	109.1	0.093
0.51% Dietary P	0.51	58.7	106.7	0.193
0.67% Dietary P	0.67	53.1	101.0	0.239
Wu et al., 2003				
Low P, low forage	0.33	50.9	80.3	0.100
Low P, high forage	0.33	52.9	74.5	0.115
High P, low forage	0.42	51.2	80.5	0.140
High P, high forage	0.42	52.7	75.4	0.145
Wu, 2005				
Low P, Alfalfa Hay	0.32	56.9	93.7	0.127
Low P, Soyhulls	0.32	53.4	91.9	0.100
High P, Alfalfa Hay	0.44	59.3	95.7	0.213
High P, Soyhulls	0.44	57.6	98.1	0.181

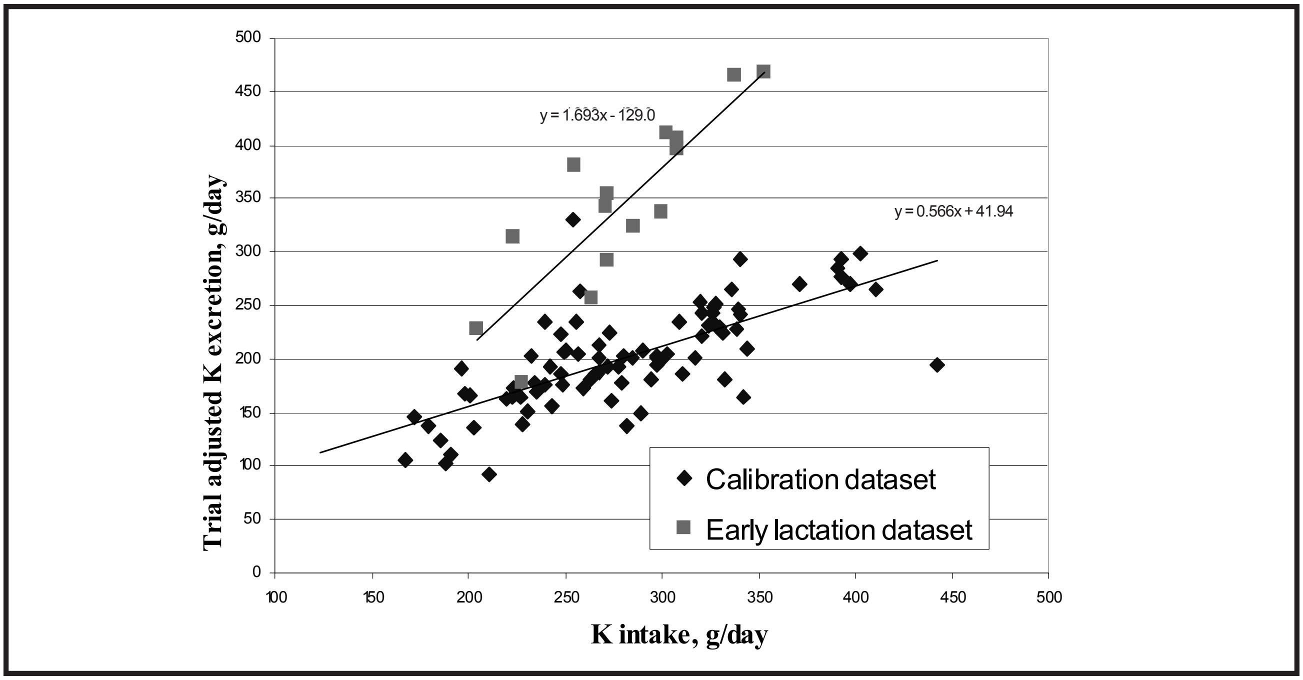

Figure 1. The relationship of potassium intake and potassium excretion for cows in the calibration and early lactation datasets (Nennich et al., 2006).