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The effects of forage particle length and exogenous phytase inclusion on phosphorus digestion and absorption in lactating cows

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ABSTRACT

Accurate estimates of phosphorus (P) availability from feed are needed to allow P requirements to be met with reduced P intake, thus reducing P excretion by livestock. Exogenous phytase supplementation in poultry and swine diets improves bioavailability of P, and limited research suggests that this strategy may have some application in dairy cattle rations. The effects of exogenous phytase and forage particle length on site and extent of P digestion were evaluated with 5 ruminally and ileally cannulated lactating cows (188 ± 35 d in milk). Cows were assigned in a 2 × 2 factorial arrangement of treatments in 2 incomplete Latin squares with four 21-d periods. Diets contained P slightly in excess of National Research Council requirements with all P from feed sources. During the last 4 d of each period, total mixed ration, refusals, omasal, ileal, and fecal samples were collected and analyzed for total P, inorganic P (Pi), and phytate (Pp). Total P intake was not influenced by dietary treatments but Pp intake decreased and Pi intake increased with supplemental phytase, suggesting rapid action of the enzyme in the total mixed ration after mixing. Omasal flow of Pi decreased with phytase supplementation, but we observed no effect of diet in ileal flow or small intestinal digestibility of any P fraction. Fecal excretion of total P was slightly higher and Pp excretion was lower for cows receiving diets supplemented with phytase. Milk yield and composition were unaffected by diets. When phytase was added to the mixed ration, dietary Pp was rapidly degraded before intake and total-tract Pp digestion was increased. The lack of effect of phytase supplementation on dietary P utilization was probably because these late-lactation cows had a low P requirement and were fed P-adequate diets.

Key words: phytase, phytate digestion, lactating dairy cow

INTRODUCTION

Dietary manipulation to reduce phosphorus (P) excretion by dairy cattle is an important approach to optimize whole-farm nutrient balance and minimize environmental P pollution from dairy farms (Morse et al., 1992; Wu et al., 2001). Phytate is approximately 70% of the total P in grains (Nelson et al., 1968) and although ruminal microorganisms have the capacity to liberate phosphate from the inositol ring of the phytate molecule (Clark et al., 1986; Morse et al., 1992), the degradation of phytate P (**Pp**) in the rumen may not be complete (Godoy and Meschy, 2001). Exogenous phytase supplementation has been reported to reduce fecal P excretion in lactating cows (Kincaid et al., 2005; Knowlton et al., 2007). Ruminal Pp degradation is influenced by digesta passage rate, physical properties of the ration, and grain type (Kincaid et al., 2005) and, in sheep, feed processing alters Pp digestion (Bravo et al., 2000; Park et al., 2000). Variation in availability of Pp is not accounted for in current ration formulation programs for dairy cows.

Digesta passage rate increases with decreasing forage particle length in ruminants (Rode et al., 1985). Faster passage rate due to finely chopped diets may limit ruminal phytate degradation in dairy cows because of the short-duration exposure of phytate molecule to microbial phytase. Ruminal phytate degradability decreased from 84% to 69 and 57% when ruminal passage rate increased from 0.02/h to 0.05 and 0.08/h, respectively (Park et al., 1999). This limitation could be resolved if sufficient postruminal phytate degradation is possible. Phytase activity depends on pH, and optimum phytase activity is at low pH (pH 4–5.5; Yanke et al., 1999). The proximal small intestine can serve as the primary site of postruminal phytate degradation because of its acidic pH. We hypothesized that ruminal phytate degradation would be incomplete in cows fed short-particle-length forage and that supplementation of rumen-protected phytase would compensate for this by releasing inorganic P from the phytate molecule in the proximal small intestine. Therefore, the objective of this study was to investigate site and extent of Pp degradation in lactating cows fed diets varying in forage

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particle length with and without exogenous ruminally protected phytase.

MATERIALS AND METHODS

Animals and Diets

Five crossbred [Swedish Red or Brown Swiss × (Holstein × Jersey)] ruminally and ileally cannulated first-lactation cows (BW of 472 ± 36 kg and 188 ± 35 DIM) were utilized in 2 incomplete 4 × 4 Latin squares. Eight cannulated cows were surgically prepared 2 yr before this experiment; in the interim, 2 lost their ileal cannula. To take full advantage of the statistical power offered by 6 cows, two 4 × 4 Latin squares balanced for carryover effects were established; the 8 treatment sequences (4 per square) were distinct. One row in each square was randomly selected for removal to yield 2 incomplete Latin squares. Six cows were then randomly assigned to square and row (treatment sequence). One of the 6 cows died unexpectedly before the study began of an unrelated health problem. In the resulting 5-cow experiment, each cow received each treatment one time, and carryover effects were balanced within square.

The treatments, inclusion of phytase (1,500 FTU/kg of diet DM) and forage particle length (short vs. long), were administered in a 2 × 2 factorial arrangement. Diets were otherwise identical in composition (Table 1) and formulated to meet or exceed NRC (2001) requirements for dairy cows. Dietary P concentration was 0.43% of DM. Particle length treatments were long forage or short forage, achieved by differential processing of grass hay and corn silage. Grass hay was cut to 6.35 and 0.64 cm using a tub grinder (New Holland 390, Racine, WI) for long forage and short forage treatments, respectively, with hay sufficient for the duration of the study cut in advance. Theoretical length of cut for corn silage at harvest was 0.95 cm, and corn silage for SF was passed through a leaf mulcher (Flowtron Leaf Eater, Malden, MA) on the fine setting daily before mixing the experimental diets. Phytase was added to the vitamin-mineral mix premade in batches sufficient for 1 period. Corn silage, grass hay, grain mix, and vitamin-mineral mix (with or without phytase) were mixed daily at 1200 h to prepare the experimental TMR.

When cows were not in the metabolism stalls for total collection (described below), they were group-housed in a freestall barn and fed once daily via the Calan door system (American Calan, Northwood, NH). Cows were fed 10% excess of the previous day's intake at 1230 h, and feed refusals were measured daily. Milk yield was measured twice daily at each milking, at 0600 and 1800 h. All protocols and procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee (IACUC #10-105 DASC).

Experimental Design and Sampling

Each of four 21-d periods consisted of 14 d of dietary adaptation in freestalls, 3 d of adaptation to metabolism stalls, and 4 d of total collection. Lithium cobalt (Co)-EDTA solution (Uden et al., 1980) and ytterbium (Yb)-labeled corn silage (Harvatine et al., 2002) were used as liquid and solid phase markers, respectively, to measure digesta flow. Immediately before each feeding, markers were dosed ruminally to supply 0.11 g/d each of Co and Yb. Cows were milked twice daily at 0600 and 1800 h, and milk weights were recorded at each milking. Milk samples were collected at each milking and stored at −20°C for future analysis. Beginning on d 17 of each period, cows were fed 25% of their daily feed allowance 4 times daily at 0600, 1200, 1800, and 2400 h to reduce diurnal variation in intake and digestion. On d 16, 24 h before the onset of total collection, cows were fitted with harnesses that linked to a cup covering the vulva (Fellner et al., 1988) for total daily urine collection into a 12-L jug that was maintained on ice (Knowlton et al., 2010). Beginning at 1800 h on d 17, feces were collected from behind each cow 4 times daily and stored in a 130-L tub. At 1800 h on d 18, 19, 20, and 21, feces, urine, and refusals were weighed, and homogeneous subsamples were collected and stored at −20°C until further analysis.

Table 1. Ingredient and nutrient composition of diets

Item	% of DM
Ingredient	
Corn silage	41.7
Grass hay	13.5
Cottonseed meal	15.6
Corn, ground	12.3
Soybean meal, 48%	7.9
Molasses, dehydrated	3.5
Beet pulp, dehydrated	2.9
Vitamin-mineral mix[1]	1.9
Sodium bicarbonate	0.6
Nutrient	
DM	58.5
CP	17.7
NDF	32.6
ADF	18.8
Ca	0.66
P	0.43

[1]Vitamin-mineral mix contains vitamin A 26,400 kIU/kg, vitamin D 8,800 kIU/kg, vitamin E 44,000 IU/kg, 7.6% Ca, 5.9% Cl, 4.7% Na, 0.85% S, 0.45% Mg, 0.03% K, 3,500 mg/kg Zn, 2,000 mg/kg Fe, 2,000 mg/kg Mn, 300 mg/kg Cu, 90 mg/kg Se, 70 mg/kg I, and 50 mg/kg Co.