J. Dairy Sci. 96:1156–1163
http://dx.doi.org/10.3168/jds.2012-5851

Effect of dietary phytate on phosphorus digestibility in dairy cows[1]

P. P. Ray,[2] J. Jarrett, and K. F. Knowlton
Department of Dairy Science, Virginia Polytechnic Institute and State University, Blacksburg 24061

ABSTRACT

The objective was to evaluate the effect of dietary phytate P (Pp) supply on ruminal and postruminal Pp digestion and net disappearance of P from the lower digestive tract of lactating cows. Six ruminally and ileally cannulated crossbred lactating cows were used in 2 incomplete Latin squares with four 21-d periods (17 d of diet adaptation, 4 d of total collection). Dietary treatments were low Pp, medium Pp, and high Pp, and a high inorganic P (Pi) diet with the same total P content as the highest Pp diet but with P mostly from inorganic sources. The diets contained 0.10, 0.18, 0.29, and 0.11% Pp and 0.43, 0.48, 0.54, and 0.53% total P on a dry matter basis, with cottonseed meal used to increase Pp content. Ytterbium-labeled corn silage and Co-EDTA were used as particulate and liquid phase markers to measure omasal and ileal digesta flow. Omasal and ileal digesta were collected every 6 h on d 20 and 21 and rumen contents were collected on d 21. Samples were analyzed for total P (molybdovanadate yellow method), Pi (blue method), and Pp (high performance ion chromatography). Phytate P and total P intake increased linearly with increasing dietary Pp. Ruminal Pp disappearance also increased linearly with dietary Pp but the magnitude of change was small. Small intestinal net disappearance of Pi was not affected by dietary Pp. Phytate P was hydrolyzed in the large intestine but its hydrolysis was not influenced by dietary Pp. Net disappearance of Pi form the large intestine did not vary with dietary Pp. Dry matter digestibility decreased linearly with increasing dietary Pp, as did apparent digestion of P, and fecal P increased linearly. Dry matter digestibility was higher for high Pi than for high Pp, likely due to the effect of cottonseed meal in the latter diet. Replacing a portion of Pp with Pi resulted in decreased P excretion but this effect was confounded with increased fecal dry matter for the high-Pp (high-cottonseed meal) diet. In lactating cows Pp digestibility was not negatively influenced by dietary Pp and fecal P excretion was regulated by dietary total P rather than by form of dietary P.
Key words: phytate, digestibility, dairy cow

INTRODUCTION

Accurate prediction of P availability could allow new dietary P manipulation strategies to reduce P excretion without affecting production and performance of dairy cows. The digestibility of P is higher in inorganic P supplements than in grains and byproduct feed ingredients (Chicco et al., 1965; Witt and Owens, 1983), and digestibility of organic P in the latter types of feed may also vary. Phytate P (**Pp**) contributes the majority of P in grains and most of the byproduct feed ingredients (Eeckhout and Depaepe, 1994; Ravindran et al., 1994). Ruminants can utilize P from phytate because ruminal microorganisms are capable of synthesizing phytase enzyme, which can release a phosphate group from the phytate molecule (Nelson et al., 1976; Clark et al., 1986; Morse et al., 1992), but ruminal Pp hydrolysis is variable. It is influenced by the type of grain, processing of feed ingredients, and supplemental exogenous phytase enzyme (Park et al., 2000; Bravo et al., 2002; Kincaid et al., 2005). The variation in ruminal Pp hydrolysis may be due to the alteration in endogenous phytase activity (Yanke et al., 1998) or due to physical or chemical alterations of the phytate molecule.

Modern dairy rations contain large amounts of high-phytate grains and byproduct feed ingredients. Increased Pp intake together with high DMI may limit ruminal Pp hydrolysis by reducing the duration of Pp exposure to microbial phytase while increasing the amount of substrate (phytate). In addition, saturation of ruminal phytase activity may occur in high-grain (high-phytate) diets. High-grain diets also are associated with reduced secretion of saliva, possibly decreasing salivary P available for microbial use and for absorption in the small intestine (Scott and Buchan, 1985). Incomplete ruminal hydrolysis of Pp can be compensated only if large intestinal hydrolysis of remaining phytate occurs and if released inorganic P (**Pi**) is absorbed from the large intestine. Little data are available on changes in ruminal and postruminal Pp hydrolysis with dietary Pp concentration in rumi-

Received June 19, 2012.
Accepted October 7, 2012.
[1]This project was supported by National Research Initiative Competitive Grant no. 2009-55206-05267 from the USDA Cooperative State Research, Education, and Extension Service. Author Ray received fellowship support from the John Lee Pratt Foundation.
[2]Corresponding author: drray@vt.edu

Table 1. Ingredient and nutrient composition of diets

Item	Diet[1]			
	LPP	MPP	HPP	HPI
Ingredient, % of dietary DM				
Corn silage	46.1	45.6	45.2	45.8
Grass hay	9.42	9.33	9.25	9.36
Corn, ground	9.32	9.23	9.14	9.26
Cottonseed meal	—	12.5	24.7	—
Soybean meal, 48%	14.1	7.00	—	14.0
Beet pulp, dried	9.63	7.16	4.73	9.57
Cane molasses, dehydrated	2.99	2.96	2.93	2.97
Pro-Lak[2]	4.82	2.63	0.47	4.79
Urea	0.63	0.31	—	0.63
Limestone	0.92	1.25	1.54	0.91
Vitamin-mineral mix[3]	2.10	2.08	2.06	2.08
Monoammonium phosphate	—	—	—	0.65
Nutrient				
DM, %	56.2	54.0	54.5	54.1
CP, % of DM	18.2	17.6	18.6	17.0
NDF, % of DM	34.7	31.9	35.0	36.1
ADF, % of DM	18.3	16.7	18.7	19.0
Ca, % of DM	1.04	1.07	0.90	0.90
P, % of DM	0.43	0.48	0.54	0.53
Phytate P, % of DM	0.10	0.18	0.29	0.11

[1]LPP = low phytate P (Pp); MPP = medium Pp; HPP = high Pp; HPI = high inorganic P.

[2]H. J. Baker & Bro. Inc. (Sanford, NC).

[3]Contained 26,400 kIU of vitamin A, 8,800 kIU of vitamin D, and 44,000 IU of vitamin E per kilogram of DM; 37% Na; 60% Cl; 0.03% K; 0.3% Mg; 14% S; and 90 mg of Se/kg.

nants. Therefore, the objective of this study was to investigate the effect of dietary Pp on ruminal and postruminal P digestibility in dairy cows.

MATERIALS AND METHODS

Animals and Experimental Design

Six crossbred [Swedish Red or Brown Swiss × (Holstein × Jersey)] first-lactation cows averaging 463 kg of BW and 90 (±35) DIM were used in 2 incomplete 4 × 4 Latin squares. To create incomplete squares, the bottom row from the first square and third row from the second square were removed. These animals were a subset of the 8 animals used in a previous study (Ray et al., 2012b). The cows were fitted surgically with a half T-type ileal cannula made of Tygon (5 to 6 cm anterior to the ileocecal junction) and a ruminal cannula (Bar Diamond Inc., Parma, ID). Ileal cannulas were cleaned every other day and checked daily for correct position.

During diet adaptation, cows were housed in a freestall barn with constant access to water and fed once daily at 1200 h in a Calan door system (American Calan Inc., Northwood, NH). Dietary treatments were low, medium, and high Pp (**LPP**, **MPP**, and **HPP**, respectively), and a high-Pi (**HPI**) diet with the same total P content as the HPP diet but with P mostly from inorganic sources. The diets contained 0.10, 0.18, 0.29, and 0.11% Pp and 0.43, 0.48, 0.54, and 0.53% total P on DM basis (Table 1), with cottonseed meal (**CSM**) used to increase Pp content. Diets were formulated to meet or exceed NRC (2001) recommendations for all nutrients. Feed was offered ad libitum during diet adaptation.

After 15 d of diet adaptation, cows were moved to individual tiestalls in a metabolism barn for a 2-d barn acclimation period (d 16 and 17) followed by 4 d of total collection (d 18 to 21). While in the metabolism barn, cows were fed ad libitum 4 times daily at 0600, 1200, 1800, and 2400 h to minimize diurnal variation in digesta flow. Cows were milked twice daily at 0600 and 1800 h. On d 17 of each period, cows were fitted with urinary catheters for total collection of urine. Cows were observed for symptoms of infection, and rectal temperatures were recorded daily.

Ytterbium-labeled corn silage (Harvatine et al., 2002) and Co-EDTA (Udén et al., 1980) were used as particulate and liquid phase markers, respectively, to measure omasal and ileal digesta flow. Beginning on d 16 of each period, markers were dosed into the rumen before each feeding at a rate of 0.11 g of Yb or Co/cow per day. All protocols and procedures were approved by the Virginia Tech Institutional Animal Care and Use Committee (Blacksburg).

The daily omasal and ileal passage of nutrient was calculated using the following equation: