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Short communication: Effect of abomasal inorganic phosphorus infusion on phosphorus absorption in large intestine, milk production, and phosphorus excretion of dairy cattle

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ABSTRACT

The objective of the study was to evaluate the effect of inorganic phosphorus (Pi) infusion on P absorption in large intestine, milk production, and phosphorus excretion. Four ruminally and ileally cannulated crossbred cows were used in a 4 × 4 Latin square with 21-d periods. Cows were fed a total mixed ration containing 0.21% P, providing 50% of the cows' P requirement. Cobalt-EDTA was used as marker to measure large intestine digesta flow. On d 13 to 21 of each period, each cow was infused daily with 0, 20.1, 40.2, or 60.3 g of Pi into the abomasum and total collection was conducted on d 18 to 21. Ileal samples were collected every 9 h on d 18 to 21. Feed, digesta, and fecal samples were analyzed for total P and Pi using the molybdovanadate yellow method and blue method, respectively. All data were analyzed using PROC GLIMMIX in SAS 9.3 (SAS Institute Inc., Cary, NC) using contrasts to evaluate linear, quadratic, and cubic effects of Pi infusion dose. Dry matter intake, apparent dry matter digestibility, milk yield, and milk total P were unaffected by Pi infusion. Ileal flow and fecal excretion of total P and Pi increased linearly with increasing infused Pi. In the large intestine, net absorption of TP and Pi was increased linearly with increasing infused Pi. The magnitude of absorption from the large intestine was greater than reflected in current models, raising questions that could be evaluated with longer infusion periods or dietary alteration.

Key words: dairy cow, phosphorus absorption, phosphorus excretion

Short Communication

Manure phosphorus (P) contamination of surface water can impair growth and survival of aquatic species. The strong relationship between dietary P and manure P content in most species provides a useful approach to reduce environmental impact of livestock farms, but also makes important detailed knowledge of the fate of the dietary P and its utilization in the digestive tract. In dairy cattle, absorption of P mainly occurs in small intestine and is modulated by endocrine factors and nutritional factors (mineral content in the diet, P content of the diet, and the forms of different P in diet). Absorption of P in the large intestine of dairy cattle is rarely reported. Net absorption of P from large intestine in sheep ranges from 2 to 30% of the P flow entering the large intestine (Breves and Schroder, 1991). Sklan and Hurwitz (1985) reported rapid absorption of many ions in the small intestine, but in the large intestine absorption of P, Ca, Mg and K were low. Smith et al. (1955) reported higher P concentration in the rectum compared with cecum in sheep, suggesting net secretion of P in the large intestine. Hoeller et al. (1988) reported net Pi secretion into the colon with a Pi-free infusate in the colon of sheep and net Pi uptake with infusate containing 2.5 to 6.5 mmol/L of Pi. The objective of the current study was to determine the effect of infused Pi on phosphorus absorption in large intestine, milk production, and phosphorus excretion of dairy cattle

All protocols and procedures were approved by Virginia Tech Institutional Animal Care and Use Committee. Four ruminally and ileally cannulated crossbred [Swedish Red or Brown Swiss × (Holstein × Jersey)] early-lactation cows averaging 76 DIM (SD = 38) were fed a diet containing 0.21% P, providing ∼50% of the cows' calculated P requirement (NRC, 2001). Treatments (abomasal infusion of 0, 20.1, 40.2, or 60.3 g/d inorganic phosphate solution) were imposed in a 4 × 4 Latin square design with 21-d periods. Cows

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were individually fed in Calan doors (American Calan, Northwood, NH) once daily at 1200 h on d 1 to 7 and 4 times daily at 0600, 1200, 1800 and 2400 h on d 8 and 9 of each period. Cows had constant access to feed except during milking. Feed was offered at 5 to 10% in excess of the previous day's intake (wet basis). From d 10 to 21 of each period, cows were housed in individual tiestalls with wood shavings as bedding (amount used recorded daily), milked twice daily at 0600 and 1800 h, and fed 4 times daily, as on d 8 and 9, with continuous access to diet and water. On d 13 to 21 of each period, each cow was infused daily with 0, 20.1, 40.2, or 60.3 g of inorganic phosphate solution into the abomasum. The solution was made of monobasic potassium phosphate with potassium phosphate dibasic anhydrous in double distilled water and the P concentration of the solution was monitored daily. Cobalt-EDTA (**Co-EDTA**) was used (dosed 110 mg of Co/d) as a marker to measure digesta flow. Marker was dosed into the rumen through the rumen cannula 4 times per day at each feeding on d 9 to 21 of each period. Feed and feed refusals were sampled daily and stored at −20°C. Samples were stored at −20°C. On d 19 to 21, ileal samples and urine samples were collected every 9 h. Total fecal collection was conducted on d 18 to 21 of each period. At 1800 h on each day, feces were weighed, thoroughly mixed using an electric mixer, and a subsample was taken and stored at −20°C. Milk yield was recorded and milk samples collected at 8 consecutive milkings on d 18 to 21. Blood samples were obtained on d 20 and 21 of each period via venipuncture in coccygeal veins and saved in Vacuette tubes (Greiner bio-one, Monroe, NC). Serum was separated immediately by centrifugation at 1,850 × *g* for 10 min at 4°C and then was stored at −20°C.

Feed, feed refusals, wood shavings, and total collected fecal samples were thawed at room temperature then dried at 55°C forced-air oven (Thermo Scientific Precision 645, Danville, IN) and ground through a 1-mm screen in a Wiley mill (Arthur H. Thomas, Philadelphia, PA). The ileal samples were thawed then pooled on an equal wet basis over the 8 sampling times to yield a composite from each cow on each period. The pooled ileal samples were dried as described above. Ground feed and feed refusals were analyzed in duplicate for DM. Ground feed, feed refusals, wood shavings, total collected fecal samples, and pooled ileal samples were ground further through a 0.2-mm screen (Z-grinder) and analyzed for total P (yellow molybdovanadate method) and Pi (molybdate blue method; AOAC, 1984). Samples were digested by concentrated nitric acid and perchloric acid for total P analysis and extracted by 0.5% hydrochloric acid for Pi analysis. Milk samples were analyzed for fat, protein, SNF, lactose, MUN, and SCC (DHIA, Blacksburg, VA) and P. The composite ileal samples were also analyzed for Co using inductively coupled plasma-MS. Daily urine output was predicted using the equations presented in Holter and Urban (1992) and urinary P excretion was calculated by multiplying daily urine output by TP concentration in urine. The large intestine TP absorption in each treatment was calculated as the difference between ileal TP flow and fecal TP. Excretion of TP was calculated as fecal TP minus TP from wood shavings and urine TP. All data were analyzed using PROC GLIMMIX procedures of SAS (SAS Institute Inc., 2011). In the model, treatment and period were fixed effects and cow was a random effect. Preplanned contrasts were used to evaluate linear, quadratic, and cubic treatment effects of treatment. Differences were declared significant at $P < 0.05$ and trends at $P < 0.1$.

Despite the very low P content of the basal diet (0.21%, ~50% of requirement), the infused Pi dose did not affect digestibility of the DM or fecal DM excretion (Table 1). The *P*-value for cubic contrast on DMI is significant ($P < 0.05$), with cows supplied total 110% of their P requirement having DMI higher than in cows supplied 50, 80, or 140% of requirements. Valk et al. (2002) fed diets containing 67, 80, and 100% of requirements and observed no effects of dietary P on DMI or digestibility of DM in dairy cows. In contrast, Call et al. (1987) observed reduced DMI of the cows fed low P (0.24%) diet from 2 to 10 wk after parturition, as cows

Table 1. Effect of abomasal infusion of inorganic phosphorus (Pi) on DMI and digestibility

	P supply,[1] % of requirement					*P*-value		
Item	50	80	110	140	SE	Linear	Quadratic	Cubic
DMI, kg/d	19.8	19.6	23.2	20.7	1.03	0.16	0.22	0.04
P intake, g/d	42.7	41.5	45.4	43.9	2.85	0.50	0.96	0.36
Fecal DM, kg/d	6.22	7.19	6.96	7.92	0.71	0.11	0.99	0.40
DM digestibility, %	68.6	63.0	69.3	61.3	3.60	0.34	0.73	0.13

[1]Cows were abomasally infused with 0, 20.1, 40.2, and 60.3 g/d of inorganic P (Pi) solution to supply 50, 80, 110, and 140% of their calculated P requirement, respectively.