# Effect of Dietary Fiber Level on the Evaluation of Standardized Phosphorus Digestibility in Growing Pigs (Postprint)

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## Abstract

This study investigated the effects of dietary cellulose supplementation level on endogenous phosphorus loss (EPL) in growing pigs and the standardized ileal digestibility (SID) and standardized total tract digestibility (STTD) of phosphorus in corn-soybean meal diets through two experiments. Twenty-eight growing pigs (average body weight: (25.1$±$2.0) kg) fitted with simple T-cannulas in the distal ileum were allocated to 4 groups with 7 replicates per group and 1 pig per replicate according to a completely randomized design. In Experiment 1, pigs were fed phosphorus-free diets with four cellulose supplementation levels of 0 (control), 3%, 6%, and 9%. In Experiment 2, pigs were fed corn-soybean meal diets with four cellulose supplementation levels of 0 (control), 3%, 6%, and 9%. Both experiments consisted of a 5-d adaptation period, a 2-d fecal collection period (Days 6 and 7), and a 2-d digesta collection period (Days 8 and 9). Chromium(III) oxide was used as an indicator to determine EPL and phosphorus digestibility in growing pigs. The results showed that total tract EPL in growing pigs linearly decreased with increasing dietary fiber supplementation level ($P<0.05$); the apparent ileal digestibility (AID), SID, and STTD of phosphorus also linearly decreased with increasing dietary cellulose supplementation level ($P<0.05$ or $P<0.01$). Based on these results, under the conditions of this experiment, the appropriate cellulose supplementation level in phosphorus-free diets for pigs was 3% to 6%, while no cellulose supplementation was recommended for corn-soybean meal diets; dietary cellulose supplementation level significantly affected the determination of EPL in growing pigs and phosphorus digestibility in corn-soybean meal diets ($P<0.05$).

## Full Text

# Effects of Dietary Fiber Supplemented Level on the Determination of Standardized Digestibility of Phosphorus for Growing Pigs

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### Abstract

Two experiments were conducted to investigate the effects of dietary fiber supplemented level from purified cellulose on the estimation of endogenous phosphorus (P) loss (EPL), and standardized ileal digestibility (SID) and standardized total tract digestibility (STTD) of P in corn-soybean meal diets for growing pigs. Twenty-eight growing pigs with initial body weight of (25.1$±$2.0) kg were surgically fitted with simple T-cannulas at the distal ileum. According to a completely randomized design, the pigs were assigned to 4 groups with 7 replicates per group and 1 pig per replicate. In Experiment 1, pigs were fed phosphorus-free diets (PFD) containing 4 levels of purified cellulose supplementation [0 (control), 3%, 6% and 9%]. In Experiment 2, pigs were fed corn-soybean meal diets containing 4 levels of purified cellulose supplementation [0 (control), 3%, 6% and 9%]. Both experiments consisted of a 5-day pre-test period, 2 days of fecal collection (days 6 and 7), and 2 days of ileal digesta collection (days 8 and 9). Chromic oxide was used as an indigestible marker to determine basal EPL and P digestibility. The results showed that the estimates of basal EPL for total tract of pigs decreased linearly with increasing dietary fiber supplemented level ($P<0.05$). The apparent ileal digestibility (AID), SID and STTD of P in diets also decreased linearly with increasing fiber supplemented level ($P<0.05$ or $P<0.01$).

Based on these results, under the conditions of this experiment, the suitable addition level of cellulose is 3% to 6% in P-free diets for growing pigs, while no cellulose addition is recommended in corn-soybean meal diets. Dietary fiber supplemented level significantly influences the determination of EPL for growing pigs and P digestibility in corn-soybean meal diets ($P<0.05$).

**Key words:** endogenous loss; fiber; growing pigs; phosphorus; standardized digestibility

# 1. Materials and Methods

## 1.1 Experimental Materials

Cellulose was purchased from Fiber Sales Development Co. (USA), with a measured neutral detergent fiber (NDF) content of 55.96%.

## 1.2 Experimental Design and Animals

Twenty-eight "Duroc × Landrace × Yorkshire"crossbred barrows with an average body weight of (25.1$±$2.0) kg were selected and fitted with simple T-cannulas at the distal ileum through surgical procedures. Following a completely randomized design, the pigs were allocated to 4 groups with 7 replicates per group and 1 pig per replicate. Experiment 1 employed a completely randomized design in which 4 groups were fed P-free diets with cellulose supplementation levels of 0 (control), 3%, 6%, and 9% to investigate the effects of dietary cellulose level on EPL determination. Diet composition and nutrient levels are presented in Table 1 .

Experiment 2 also used a completely randomized design in which 4 groups were fed corn-soybean meal diets with cellulose supplementation levels of 0 (control), 3%, 6%, and 9%. The corn-soybean meal mixture had a corn to soybean meal ratio of 3.1:1.0. This experiment aimed to investigate the effects of dietary cellulose level on the determination of P standardized digestibility. Diet composition and nutrient levels are presented in Table 2 . The same animals and grouping were used as in Experiment 1.

Experimental pigs were housed individually in metabolism cages. After surgery, the pigs were allowed a 2-week recovery period in the metabolism cages with routine care. The trial commenced when feed intake and excretion returned to normal and remained stable. Room temperature was maintained between 18–22°C. Daily feed allowance was calculated as 4% of body weight and provided in two equal meals at 08:00 and 17:00. Water was supplied at three times the feed intake level. The experiment was conducted at the Changping Experimental Base of the State Key Laboratory of Animal Nutrition.

## 1.3 Sample Collection and Processing

Each experimental period consisted of a 5-day pre-test period, 2 days of fecal collection, and 2 days of digesta collection. Chromic oxide was used as an indigestible marker and was included in the experimental diets daily at 08:00. On day 5, the cages were cleaned. Fecal samples were collected on days 6 and 7, randomly sampled, and immediately stored in plastic bags at -20°C. Ileal digesta were collected on days 8 and 9 from 08:00 to 18:00 for 10 consecutive hours. A soft plastic bag (approximately 250 mL) was attached to the cannula with a rubber band. When filled, the bag was immediately removed and stored at -20°C. After collection, digesta and fecal samples from each pig were pooled

separately, dried at 65°C for 48 hours, ground, mixed thoroughly, and stored in sealed bags at low temperature pending analysis.

### 1.4 Measurement Indicators and Methods

Dry matter content of diets, digesta, and feces was determined by drying at 105°C for 5 hours. Chromium and P contents in diets and digesta were measured by colorimetric methods [6]. Dietary calcium (Ca) content was determined according to GB/T 6436-2002, and dietary cellulose level was determined according to GB/T 6434-1994.

### 1.5 Calculation Methods

Apparent digestibility of P was calculated using the following formula:

Apparent digestibility of P (%) = 100 - (chromium content in diet / chromium content in digesta) × (phosphorus content in digesta / phosphorus content in diet) × 100.

P excretion in digesta and digestible P were calculated as follows:

P excretion in digesta (mg/kg) = phosphorus content in digesta × chromium content in diet / chromium content in digesta; Digestible P (mg/kg) = total P intake - P excretion in digesta.

P excretion in feces was calculated using:

P excretion in feces (mg/kg) = phosphorus content in feces × chromium content in diet / chromium content in feces.

Standardized digestibility of P in soybean meal was determined using linear regression methods:

Ileal endogenous P flow = phosphorus content in digesta × chromium concentration in diet / chromium concentration in digesta; Standardized ileal digestibility of P (SID, %) = apparent ileal digestibility of P (AID, %) + (ileal endogenous P flow / phosphorus content in diet) × 100.

### 1.6 Statistical Analysis

Data were analyzed using the General Linear Model (GLM) procedure of SAS 9.3 statistical software. Results are expressed as means ± standard error, with $P<0.05$ considered statistically significant.

## 2. Results and Analysis

All pigs remained healthy throughout the experimental period and showed no obvious signs of P deficiency, consuming all allocated feed.

### 2.1 Effects of Dietary Cellulose Level on Dry Matter Digestibility and P Excretion in P-Free Diets

As shown in Table 3 , dietary cellulose level had no significant effect on feed intake, dry matter intake, ileal digesta P excretion, or total tract dry matter digestibility (P>0.05). However, ileal dry matter digestibility and total tract P excretion decreased linearly with increasing cellulose supplementation (P<0.05), indicating that higher dietary cellulose levels significantly reduced ileal dry matter digestibility and total tract P excretion. Total tract dry matter digestibility values were 88.99%, 89.74%, 88.86%, and 88.55% for cellulose levels of 0, 3%, 6%, and 9%, respectively, with the 3% level showing the highest value. Ileal dry matter digestibility values were 89.77%, 82.95%, 78.51%, and 80.53% for the same cellulose levels, with the control group showing the highest value, demonstrating that increasing dietary cellulose level reduced ileal dry matter digestibility. The 9% cellulose group had the lowest total tract P excretion at 1,210 mg/kg, while the control group had the highest at 1,799 mg/kg. As total tract P excretion decreased linearly with increasing cellulose level, EPL also decreased linearly.

### 2.2 Effects of Dietary Cellulose Level on Dry Matter Digestibility and P Digestibility in Corn-Soybean Meal Diets

As shown in Table 4 , dietary cellulose level did not significantly affect total tract P excretion or apparent total tract digestibility (ATTD) of P, with no significant linear differences (P>0.05). Dry matter intake remained relatively stable and was not significantly affected by cellulose level (P>0.05). Ileal dry matter digestibility decreased linearly with increasing cellulose level (P<0.01), indicating that higher cellulose levels significantly reduced ileal dry matter digestibility. Ileal digesta P excretion increased linearly with cellulose supplementation (P<0.01), demonstrating that cellulose addition significantly increased ileal P excretion. Total tract dry matter digestibility and P AID, SID, and STTD all decreased linearly with increasing cellulose level (P<0.05 or P<0.01). However, total tract P excretion and P ATTD showed quadratic responses to cellulose level, with the 9% cellulose group showing the highest total tract P excretion and the control group showing the highest P ATTD. Within cellulose levels of 0–3% and 6–9%, total tract P excretion increased with cellulose level, while within 3–6%, it decreased. The 9% cellulose group had the lowest P ATTD and STTD, while the control group had the highest. Within cellulose levels of 0–3% and 6–9%, P ATTD and STTD decreased with increasing cellulose level, while within 3–6%, P ATTD increased.

Both P SID and STTD decreased linearly with increasing cellulose level (P<0.01). The control group had the highest P SID and STTD at 61.04% and 85.78%, respectively. As cellulose level increased, P SID decreased from 61.04% to 57.88%, and P STTD decreased from 85.78% to 59.61%.

## 3. Discussion

### 3.1 Effects of Dietary Cellulose Level on EPL

Numerous studies have investigated fiber digestion and absorption in growing-finishing pigs and the effects of fiber on other dietary nutrients. Sève et al. [7] reported that pigs fed nitrogen-free diets showed significantly increased endogenous amino acid excretion as dietary fiber level increased from 3.0% to 6.0%, plateauing at 6% fiber. Furuya et al. [8] found that using purified cellulose, endogenous ileal amino acid flow tended to increase as neutral detergent fiber rose from 3.0% to 15.0%, though not significantly. Our study examined the effects of dietary cellulose level on EPL, which is critical for determining P standardized digestibility. Due to rapid mineral metabolism and reabsorption in the digestive tract, accurate measurement of endogenous P is challenging, and most values are estimates. For instance, NRC (1998) [9] proposed fecal EPL of 0.02 g/(kg · d), with urinary EPL considered negligible. Georgievskii et al. [10] reported that only a small fraction of P is excreted through the kidneys in growing pigs, accounting for only a few percent of total intake, with fecal endogenous P typically not exceeding 10% of total P intake. Jongbloed et al. [11] also reported endogenous P excretion of 8–10 mg/kg in pigs. Endogenous P excretion represents the inevitable minimum P loss during vital activities and forms the basis for studying feed P digestibility. Accurate estimation of EPL is a major concern in P standardized digestibility research. Our results showed that the 9% cellulose group had the lowest total tract P excretion (1,210 mg/kg), while the control group had the highest (1,799 mg/kg). As total tract P excretion decreased linearly with cellulose level, EPL also decreased linearly. This may be because cellulose stimulates P reabsorption in the large intestine, as most of the daily P requirement is recycled through the gastrointestinal tract, consistent with Fan et al. [12]. Total endogenous P secreted into the gastrointestinal tract includes P from saliva, gastrointestinal secretions, bile, pancreatic juice, and sloughed intestinal cells.

### 3.2 Effects of Dietary Cellulose Level on P Standardized Digestibility

Apparent digestibility of P is affected by endogenous P excretion and cannot accurately reflect P utilization efficiency. Accurate determination of P standardized digestibility is essential for improving P utilization efficiency. Standardized digestibility accounts for endogenous P excretion, providing a biological value closer to actual animal utilization.

Our results showed that P apparent digestibility decreased significantly with increasing dietary cellulose level, consistent with general findings. Dietary fiber has strong cation exchange capacity and can adsorb many minerals, reducing mineral utilization. Moore et al. [13] demonstrated that cellulose inhibits mineral (e.g., copper, calcium, P) digestion and absorption.

Using basal EPL to correct P apparent total tract digestibility (ATTD) yields P STTD. Our results showed that the control group had the highest P SID and

STTD (61.04% and 85.78%, respectively), significantly higher than other groups. As cellulose level increased, P SID decreased from 61.04% to 57.88%, and P STTD decreased from 85.78% to 59.61%. These results demonstrate that P SID and STTD decreased significantly with increasing cellulose level, consistent with general fiber nutrition research. This may be because higher cellulose levels increase indigestible components, reduce dietary energy concentration, and increase bulk, burdening the digestive tract and causing insufficient energy intake, thereby reducing P SID and STTD. Additionally, increased cellulose levels accelerate gastrointestinal motility, reducing digesta retention time and contact with digestive enzymes, ultimately lowering nutrient digestibility. Cherbut et al. [14] reported that dietary cellulose tends to reduce digesta retention time and increase passage rate, decreasing nutrient digestibility. Jorgensen et al. [15] confirmed that pigs fed high-fiber diets had 5–6 times faster digesta passage at the distal ileum. Wilfart et al. [16] also found that high fiber levels reduced solid digesta retention time in the small intestine. Therefore, using STTD data in formulated diets better estimates digestible P content from various ingredients, enabling more accurate diet formulation.

## 4. Conclusions

1. Increasing dietary cellulose level significantly reduces total tract EPL in growing pigs fed P-free diets. Under our experimental conditions, the suitable cellulose addition level in P-free diets for growing pigs is 3%–6%.
2. P SID and STTD in corn-soybean meal diets decrease significantly with increasing dietary cellulose level.

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**Table 1** Composition and nutrient levels of diets in experiment 1 (air-dry basis), %

**Table 2** Composition and nutrient levels of diets in experiment 2 (air-dry basis), %

**Table 3** Effects of dietary fiber supplemented level on digestibility of dry matter and P output in P-free diet

**Table 4** Effects of dietary fiber supplemented level on digestibility of dry matter and P in corn-soybean meal diet

*Note: Figure translations are in progress. See original paper for figures.*