Effect of Dietary Phosphorus Level on the Assessment of Standardized Ileal and Total Tract Digestibility of Phosphorus in Finishing Pigs: Postprint

Authors: Liu Zhengqun, Lü Shuaibing, Xie Jingjing, Zhang Zuxiang, Liu Jingbo, Zhang Hongfu

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Abstract

This experiment was conducted to investigate the effects of dietary phosphorus level on the evaluation of standardized ileal digestibility (SID) and standardized total tract digestibility (STTD) of phosphorus in finishing pigs. Eighteen finishing pigs with an average body weight of (73.8±3.3) kg, fitted with simple T-cannulas, were used in a 9×4 incomplete Latin square design with 9 diets across 4 periods. Among the 9 diets, a phosphorus-free diet was used to determine basal endogenous phosphorus loss (EPL), while 6 semi-purified diets and 2 mixed diets were used to determine phosphorus digestibility. Chromium(III) oxide was used as an indigestible marker to determine EPL and phosphorus digestibility. The results showed that: 1) Diet type extremely significantly affected ileal phosphorus excretion, apparent ileal digestibility (AID) and SID of phosphorus in finishing pigs ($P<0.01$); dietary phosphorus level extremely significantly affected ileal phosphorus excretion ($P<0.01$), but had no significant effect on AID and SID of phosphorus ($P>0.05$); the interaction between diet type and dietary phosphorus level extremely significantly affected ileal phosphorus excretion, AID and SID of phosphorus ($P<0.01$). 2) Diet type extremely significantly affected total tract phosphorus excretion, apparent total tract digestibility (ATTD) and STTD of phosphorus ($P<0.01$); dietary phosphorus level extremely significantly affected total tract phosphorus excretion and ATTD of phosphorus ($P<0.01$), but had no significant effect on STTD of phosphorus ($P>0.05$); the interaction between diet type and dietary phosphorus level significantly affected total tract phosphorus excretion ($P<0.01$) and ATTD of phosphorus ($P<0.05$), but had no significant effect on STTD of phosphorus ($P>0.05$). It can be concluded that under the conditions of this experiment, dietary phosphorus level had no significant effect on the evaluation of AID, SID and STTD of phosphorus in

finishing pigs, but dietary phosphorus level significantly affected the evaluation of ATTD of phosphorus in finishing pigs. Therefore, when using STTD to evaluate phosphorus utilization efficiency in swine feed ingredients, test diets with different phosphorus levels can be formulated.

Full Text

Effects of Dietary Phosphorus Level on the Determination of Standardized Ileal and Total Tract Digestibility of Phosphorus in Fattening Pigs

LIU Zhengqun[1], LYU Shuaibing[1], XIE Jingjing[1], ZHANG Zuxiang[2], LIU Jingbo[1,2], ZHANG Hongfu[1]*

[1]State Key Laboratory of Animal Nutrition, Institute of Animal Sciences, Chinese Academy of Agricultural Sciences, Beijing 100193, China
[2]Institution of Life Science and Engineering, Southwest University of Science and Technology, Mianyang 621010, China

Abstract

This study was conducted to investigate the effects of dietary phosphorus (P) level on the determination of standardized ileal digestibility (SID) and standardized total tract digestibility (STTD) of P in fattening pigs. Eighteen fattening pigs with an average body weight of (73.8±3.3) kg, surgically fitted with simple T-cannulas, were used in a 9×4 incomplete Latin square design with nine experimental diets across four periods. The nine diets included one phosphorus-free diet (PFD) to estimate basal endogenous P losses (EPL), six semi-purified diets, and two mixed diets to determine P digestibility. Chromic oxide was used as an indigestible marker to determine EPL and P digestibility. The results showed that: (1) Diet type extremely significantly affected ileal P output, apparent ileal digestibility (AID), and SID of P ($P<0.01$). Dietary P level extremely significantly affected ileal P output ($P<0.01$) but had no significant effect on AID or SID of P ($P>0.05$). The interaction between diet type and P level extremely significantly affected ileal P output, AID, and SID of P ($P<0.01$). (2) Diet type extremely significantly affected total tract P output, apparent total tract digestibility (ATTD), and STTD of P ($P<0.01$). Dietary P level extremely significantly affected total tract P output and ATTD of P ($P<0.01$) but had no significant effect on STTD of P ($P>0.05$). The interaction between diet type and P level significantly affected total tract P output ($P<0.01$) and ATTD of P ($P<0.05$) but had no significant effect on STTD of P ($P>0.05$). In conclusion, under the conditions of this experiment, dietary P level had no significant effect on the determination of AID, SID, or STTD of P in fattening pigs, but significantly affected the determination of ATTD of P. Therefore, when using STTD to evaluate the efficiency of P utilization in pig feed ingredients, experimental diets with different P levels can be formulated.

Key words: fattening pigs; phosphorus; apparent digestibility; standardized digestibility

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Accurate determination of standardized ileal digestibility (SID) and standardized total tract digestibility (STTD) of phosphorus in fattening pigs requires careful investigation of how different dietary P levels affect digestibility measurements. Previous research has demonstrated that varying dietary crude protein levels influence ileal endogenous amino acid losses, thereby affecting the determination of apparent ileal digestibility (AID) of amino acids in growing pigs. Similarly, different dietary P levels can alter the proportion of endogenous P losses (EPL) relative to total P excretion, which impacts the assessment of AID and apparent total tract digestibility (ATTD). Studies by Shen et al. and Dilger et al. have shown that ileal and total tract P digestibility in growing pigs do not differ significantly, indicating that both measures can effectively evaluate dietary P utilization efficiency. Consequently, the NRC (2012) recommends using STTD to assess the biological availability of P in feed ingredients for pigs. However, significant variation in P digestibility estimates across studies has been attributed to factors including diet type, P level, and calcium-to-phosphorus ratio. Research has also shown that increasing dietary P level through inorganic P supplementation significantly improves AID and ATTD. Therefore, we hypothesized that varying dietary P levels without inorganic P supplementation might cause differences in SID and STTD of P in fattening pigs. This study examined the effects of dietary P level on the determination of SID and STTD using semi-purified diets with soybean meal, rapeseed meal, or corn distillers dried grains with solubles (DDGS) as the sole P source, as well as mixed diets containing corn, soybean meal, rapeseed meal, and corn DDGS.

1.1 Experimental Design and Animal Management

Eighteen "Duroc × Landrace × Large White" crossbred barrows with an average body weight of (73.8±3.3) kg, fitted with simple T-cannulas at the distal ileum, were randomly assigned to nine groups based on body weight, with two replicates per group and one pig per replicate. The experiment utilized a 9×4 incomplete Latin square design with nine dietary treatments and four periods. The nine diets consisted of: (1) one phosphorus-free diet (PFD) to estimate basal EPL; (2) six semi-purified diets with soybean meal, rapeseed meal, or corn DDGS as the sole P source, each at two P levels; and (3) two mixed diets containing corn, soybean meal, rapeseed meal, and corn DDGS as P sources, also at two P levels. Diet composition and nutrient levels are presented in Table 1 . Chromic oxide was included as an indigestible marker to determine P digestibility. Pigs were housed individually in stainless steel metabolism crates under natural lighting with room temperature maintained at approximately 20°C. Each experimental period consisted of a 5-day adaptation phase, followed by a 2-day fecal collection period and a 2-day digesta collection period. Feed allowance was calculated at 3.5% of body weight and provided in two equal meals at 08:00 and 17:00 daily.

Pigs had free access to drinking water throughout the experiment.

1.2 Sample Collection and Processing

Following the 5-day adaptation period, total fecal output was collected from each pig on days 6 and 7 between 08:00 and 18:00. Subsequently, total ileal digesta was collected on days 8 and 9 between 08:00 and 18:00. All fecal and digesta samples were immediately frozen at -20°C after collection. At the end of the experiment, samples from each pig were pooled separately for feces and digesta, then dried in a 65°C oven and ground for subsequent analysis.

1.3 Measurements

Dietary, digesta, and fecal samples were analyzed for routine nutrient composition and total phosphorus content using the methods described by Zhang Liying. Chromium oxide concentrations were determined according to the procedure of Fenton et al.

1.4 Calculations

Apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of phosphorus were calculated using the following formulas:

AID of P (%) = 100 - [(Cr in diet / Cr in digesta) × (P in digesta / P in diet) × 100]
SID of P (%) = AID + [(Ileal EPL / P in diet) × 100]

where Ileal EPL = P in digesta × P in diet / Cr in digesta.

Apparent total tract digestibility (ATTD) and standardized total tract digestibility (STTD) of phosphorus were calculated as follows:

ATTD of P (%) = 100 - [(Cr in diet / Cr in feces) × (P in feces / P in diet) × 100]
STTD of P (%) = ATTD + (Total tract EPL / P in diet) × 100

where Total tract EPL = P in feces × P in diet / Cr in feces.

1.5 Statistical Analysis

Experimental data were analyzed using the General Linear Model (GLM) procedure of SAS 9.2 software. Differences in ileal and total tract P digestibility were compared using the Least Significant Difference (LSD) method. Results are presented as means ± standard error of the mean (SEM), with $P<0.05$ considered statistically significant.

2.1 Effects of Diet Type and P Level on Feed Intake and Dry Matter Intake

As shown in Table 2 , no significant differences were observed among treatment groups in body weight, feed intake, or dry matter intake (P>0.05).

2.2 Effects of Diet Type and P Level on Ileal Phosphorus Digestibility

Table 3 shows that diet type extremely significantly affected ileal P output, AID, and SID of P (P<0.01). Under similar total P intake conditions, pigs fed corn DDGS diets had lower ileal P output compared to those fed rapeseed meal or mixed diets, resulting in higher AID and SID values than the soybean meal, rapeseed meal, and mixed diet groups. Dietary P level extremely significantly affected ileal P output (P<0.01) but did not significantly influence AID or SID of P (P>0.05). The interaction between diet type and P level extremely significantly affected ileal P output, AID, and SID of P (P<0.01).

2.3 Effects of Diet Type and P Level on Total Tract Phosphorus Digestibility

Diet type extremely significantly affected total tract P output, ATTD, and STTD of P (P<0.01), with patterns similar to those observed for ileal measurements. Pigs fed corn DDGS diets exhibited lower total tract P output compared to rapeseed meal and mixed diet groups, leading to higher ATTD and STTD values. Dietary P level extremely significantly affected total tract P output (P<0.01) and ATTD of P (P<0.01), with higher P levels increasing total tract P output. However, dietary P level did not significantly affect STTD of P (P>0.05). Additionally, the interaction between diet type and P level significantly influenced total tract P output (P<0.01) and ATTD of P (P<0.05) but had no significant effect on STTD of P (P>0.05).

The indicator method and total collection method are primary approaches for determining nutrient digestibility in growing pigs. While total collection provides accurate estimates, it is labor-intensive and subject to practical limitations. Consequently, early studies predominantly used the indicator method to determine P digestibility. Since the small intestine is the primary site of P absorption and digestion, and most previous research has shown no significant difference between total tract and ileal P digestibility in growing pigs, Shen et al. and Dilger et al. proposed that both measures can effectively evaluate P utilization efficiency. Each approach has distinct advantages and disadvantages. Ileal digestibility assessment requires surgical cannulation and postoperative care, increasing experimental complexity but reducing sample contamination risk. Total tract digestibility eliminates the need for surgical procedures, simplifying the protocol, but fecal collection is more susceptible to contamination from urine. The NRC (2012) suggested that feeding a PFD allows determination of EPL for correcting ATTD to obtain STTD, based on the assumption that basal endogenous P excretion is independent of diet type and P level. This study

compared ileal and total tract digestibility across four diet types at different P levels to examine how dietary P level influences the determination of SID and STTD in fattening pigs.

Under our experimental conditions, the AID values for soybean meal, rapeseed meal, and corn DDGS diets were consistent with previously reported values. The basal ileal EPL determined using the PFD was 237.4 mg/kg dry matter intake, lower than the 693 mg/kg reported by Shen et al. using regression analysis. Results indicated that dietary P level did not significantly affect AID or SID of P, while the interaction between diet type and P level had a significant effect. This suggests that when using SID to evaluate P utilization efficiency of single-P-source feed ingredients, dietary P level may not need to be considered, but its effect should be accounted for when comparing different P sources.

The ATTD values for soybean meal, rapeseed meal, and corn DDGS diets in this study were consistent with literature reports. Total tract basal EPL measured using the PFD was 275.8 mg/kg dry matter intake, higher than the 139-211 mg/kg reported in previous PFD studies but lower than the 670 mg/kg obtained by Shen et al. using regression analysis. The higher EPL in our study may be attributed to residual total P (0.07%) in the PFD and the use of heavier pigs compared to previous studies. After correction for total tract EPL, the resulting STTD values were consistent with reference values for soybean meal, rapeseed meal, and corn DDGS reported by Bohlke et al., She et al., and NRC (2012). Dietary P level significantly affected ATTD, possibly because at low P levels, most P is absorbed in the small intestine, whereas at high P levels, unabsorbed P entering the hindgut can still be utilized. In contrast, STTD was significantly affected only by diet type, not by dietary P level or its interactions. Therefore, under our experimental conditions, STTD values can be used to evaluate P utilization efficiency without considering dietary P level, though this conclusion requires validation using more P level gradients.

Conclusions:

1. Under the conditions of this experiment, dietary phosphorus level had no significant effect on the determination of apparent ileal digestibility (AID) and standardized ileal digestibility (SID) of phosphorus in fattening pigs.
2. When dietary total phosphorus level is below the requirement of fattening pigs, dietary phosphorus level significantly affects the determination of apparent total tract digestibility (ATTD) but not standardized total tract digestibility (STTD). Therefore, experimental diets with different phosphorus levels can be formulated when using STTD to evaluate phosphorus utilization efficiency in pig feed ingredients.

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

Table 2
Effects of diet type and phosphorus level on feed intake and dry matter intake in fattening pigs

Table 3

Effects of diet type and phosphorus level on ileal and total tract phosphorus digestibility in fattening pigs

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