Effect of Basal Diet Composition on True Total Tract Digestibility of Phosphorus from Dicalcium Phosphate and Monocalcium Phosphate in Growing Pigs: Postprint

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Abstract

This study was conducted to investigate the effects of basal diet composition on the true total tract digestibility (TTTD) of phosphorus from dicalcium phosphate (DCP) and monocalcium phosphate (MCP) in growing pigs. Experiment 1 utilized 10 growing pigs with an average body weight of (30.4±1.8) kg, following a 10×8 incomplete Latin square design, to evaluate corn-soybean meal diets and wheat-soybean meal diets, each containing 5 DCP supplementation levels, across 8 periods of digestion trials. Experiment 2 utilized 10 growing pigs with an average body weight of (30.9±1.5) kg, following a 10×8 incomplete Latin square design, to evaluate corn-soybean meal diets and wheat-soybean meal diets, each containing 5 MCP supplementation levels, across 8 periods of digestion trials. Each digestion trial period consisted of a 5-day dietary adaptation phase and a 2-day fecal collection phase. The results showed: 1) Total fecal phosphorus excretion from corn-soybean meal diets was extremely significantly higher than that from wheat-soybean meal diets ($P<0.01$), while total tract digestible phosphorus content and apparent total tract digestibility (ATTD) of phosphorus from wheat-soybean meal diets were extremely significantly higher than those from corn-soybean meal diets ($P<0.01$). Dietary supplementation of DCP and MCP linearly increased total fecal phosphorus excretion, total tract digestible phosphorus content, and ATTD of phosphorus ($P<0.01$). 2) Using linear regression analysis, the TTTD of phosphorus from DCP in growing pigs fed corn-soybean meal and wheat-soybean meal diets was determined to be 82.33% and 82.88%, respectively, and the TTTD of phosphorus from MCP in growing pigs fed corn-soybean meal and wheat-soybean meal diets was determined to be 85.88% and 84.62%, respectively. It can be concluded that basal diet composition had no significant effect on the TTTD of phosphorus from DCP and MCP

in growing pigs.

Full Text

Effects of Basal Diet Composition on True Total Tract Digestibility of Phosphorus in Dicalcium Phosphate and Monocalcium Phosphate for Growing Pigs

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Abstract

Two experiments were conducted to investigate the effects of basal diet composition on the true total tract digestibility (TTTD) of phosphorus (P) in dicalcium phosphate (DCP) and monocalcium phosphate (MCP) for growing pigs. In Experiment 1, ten growing pigs with an average body weight (BW) of (30.4±1.8) kg were allocated to a 10×8 incomplete Latin square design and fed five DCP supplementation levels in corn-soybean meal (CSBM) diets and five DCP supplementation levels in wheat-soybean meal (WSBM) diets across eight digestion periods. In Experiment 2, ten growing pigs with an average BW of (30.9±1.5) kg were subjected to the same design but with five MCP supplementation levels in CSBM diets and five MCP supplementation levels in WSBM diets. Each digestion period consisted of a 5-day dietary adaptation phase followed by a 2-day fecal collection phase. The results showed that: 1) Total fecal P excretion was significantly higher in CSBM diets than in WSBM diets ($P<0.01$), whereas total tract digestible P content and apparent total tract digestibility (ATTD) of P were significantly higher in WSBM diets ($P<0.01$). Dietary supplementation with DCP or MCP linearly increased total fecal P excretion, total tract digestible P content, and ATTD of P ($P<0.01$). 2) Using linear regression analysis, the TTTD of P in DCP was estimated to be 82.33% and 82.88% for pigs fed CSBM and WSBM diets, respectively. The corresponding values for MCP were 85.88% and 84.62%, respectively. These findings indicate that basal diet composition does not significantly affect the TTTD of P in DCP or MCP for growing pigs.

Keywords: phosphorus; basal diet; growing pigs; true total tract digestibility; dicalcium phosphate; monocalcium phosphate

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Introduction

Phosphorus is an essential mineral element in animals that plays a critical role in physiological and metabolic functions. However, the P content in plant-based feedstuffs is relatively low, and 60%–80% of it exists as phytate, which is poorly utilized by monogastric animals due to the lack of endogenous phytase enzymes [1]. To meet nutritional requirements and enhance animal performance, inorganic P sources must be supplemented in diets. The most commonly used inorganic P sources are dicalcium phosphate (DCP) and monocalcium phosphate (MCP) [2-4]. Previous studies have demonstrated that linear regression analysis of the relationship between total P intake and digestible P can be used to derive the true digestibility of P in feed ingredients and estimate endogenous P losses in pigs [5-8]. Multiple factors influence P digestibility in diets, including dietary P level, calcium-to-P ratio, phytase activity, and the composition and content of dietary fiber and carbohydrates [8-14]. Nortey et al. [14] reported that substituting wheat with wheat middlings in wheat-based diets significantly reduced the apparent ileal and total tract digestibility of P. These findings indicate that dietary carbohydrate composition and content significantly affect P utilization efficiency. Therefore, to improve the efficiency of inorganic P utilization in growing pigs, it is necessary to determine whether the digestibility of P from inorganic sources is influenced by basal diet composition. Given the significant differences in phytase activity and carbohydrate composition between corn and wheat, and their status as primary energy sources in pig diets, this study evaluated the effects of basal diet composition on the TTTD of inorganic P from DCP and MCP by supplementing different levels of these phosphates in CSBM and WSBM diets.

Materials and Methods

1.1 Experimental Design and Animal Management The experiments were conducted at the Changping Experimental Station of the State Key Laboratory of Animal Nutrition. In Experiment 1, ten "Duroc × Landrace × Yorkshire" crossbred barrows with an average BW of (30.4±1.8) kg were used in a 10×8 incomplete Latin square design. Pigs were fed five DCP supplementation levels in CSBM diets and five DCP supplementation levels in WSBM diets across eight digestion periods. Diet composition and nutrient levels for Experiment 1 are presented in Table 1 . In Experiment 2, ten barrows with an average BW of (30.9±1.5) kg were subjected to the same experimental design but with five MCP supplementation levels in both CSBM and WSBM diets. Diet composition and nutrient levels for Experiment 2 are shown in Table 2 . Animals were housed individually in stainless-steel metabolism cages under natural lighting with room temperature maintained at approximately 20°C. Each digestion period comprised a 5-day dietary adaptation phase followed by a 2-day fecal collection phase. Feed allowance was calculated as 4% of BW and provided in two equal meals at 08:00 and 17:00 daily. Pigs had ad libitum access to water throughout the experimental period.

1.2 Sample Collection and Processing Following the 5-day adaptation period, total fecal output was collected from each pig between 08:00 and 18:00 on days 6 and 7 of each period. Fecal samples were immediately frozen at -20°C. After the collection period, all fecal samples from each pig were pooled, mixed thoroughly, dried at 65°C, and ground for subsequent analysis.

1.3 Analytical Methods Dietary proximate components and fecal dry matter and total P content were determined according to the methods described by Zhang [15]. Chromium(III) oxide content was analyzed using the procedure of Fenton and Fenton [16].

1.4 Calculation of Phosphorus Digestibility Apparent total tract digestibility (ATTD) of P was calculated using the following formula:

$$\text{ATTD of P (\%)} = 100 - \left[\left(\frac{\text{Cr content in diet}}{\text{Cr content in feces}} \right) \times \left(\frac{\text{P content in feces}}{\text{P content in diet}} \right) \times 100 \right]$$

Total fecal P excretion was calculated as:

$$\text{Total fecal P excretion (mg/kg)} = \left(\frac{\text{Cr content in diet}}{\text{Cr content in feces}} \right) \times \text{P content in feces} \times \text{Dry matter content of diet} \times 10$$

Total tract digestible P content was determined by:

$$\text{Total tract digestible P (mg/kg)} = \text{Total P intake} - \text{Total tract P excretion}$$

The TTTD of P was estimated using linear regression according to the equation:

$$\text{Digestible P (mg/kg)} = \text{TTTD} \times \text{Total P intake} - \text{Endogenous P loss}$$

As described in the equation above, linear regression of total tract digestible P against total P intake was performed, where the slope represented the TTTD of P in the diet.

1.5 Statistical Analysis Data were analyzed using the General Linear Model (GLM) procedure in SAS 9.3 software. Analysis of variance and significance testing were performed with multiple comparisons. Results are expressed as means ± standard error of the mean (SEM). Statistical significance was declared at $P<0.05$ and $P<0.01$.

Results

All pigs remained healthy throughout the experimental period and consumed their complete daily feed allowance.

2.1 Effects of Dietary DCP Supplementation on Phosphorus Digestibility (Experiment 1) As shown in Table 3 , total fecal P excretion, total tract digestible P content, and ATTD of P increased linearly with increasing DCP supplementation levels in both CSBM and WSBM diets ($P<0.01$). Additionally, total fecal P excretion and ATTD of P exhibited quadratic responses to DCP supplementation in CSBM diets ($P<0.05$). After DCP supplementation, total fecal P excretion was significantly higher in CSBM diets compared to WSBM diets ($P<0.01$), whereas total tract digestible P content and ATTD of P were significantly higher in WSBM diets ($P<0.01$). However, no significant diet type × P level interaction effects were observed for these parameters ($P>0.05$).

A significant linear relationship between total tract digestible P and total P intake is a prerequisite for determining true digestibility using linear regression, and this condition was satisfied in the present study. Based on regression equations calculated with P excretion expressed in mg/kg, the linear relationships for pigs fed DCP-supplemented CSBM and WSBM diets were Y = 0.8233X -2035.54 and Y = 0.8288X -1840.51, respectively (Table 5), where Y represents digestible P content and X represents total P intake. The estimated TTTD of P in DCP was 82.33% for CSBM diets and 82.88% for WSBM diets, with no significant difference between them ($P>0.05$). Corresponding endogenous P losses were 2036 and 1841 mg/kg dry matter intake, respectively, with determination coefficients (R^2) of 0.9481 and 0.9364, indicating good model fit.

2.2 Effects of Dietary MCP Supplementation on Phosphorus Digestibility (Experiment 2) As presented in Table 4 , increasing MCP supplementation levels in both CSBM and WSBM diets resulted in linear increases in total fecal P excretion, total tract digestible P content, and ATTD of P ($P<0.01$). Following MCP supplementation, total fecal P excretion was significantly lower in WSBM diets compared to CSBM diets ($P<0.01$), while total tract digestible P content and ATTD of P were significantly higher in WSBM diets ($P<0.01$). No significant diet type × P level interactions were detected for any of these parameters ($P>0.05$).

Linear regression analysis yielded the equations Y = 0.8588X -2062.44 and Y = 0.8462X -1874.62 for MCP-supplemented CSBM and WSBM diets, respectively (Table 5). The TTTD of P in MCP was estimated to be 85.88% for CSBM diets and 84.62% for WSBM diets, with no significant difference between diet types ($P>0.05$). Endogenous P losses were 2062 and 1875 mg/kg dry matter intake, respectively, with corresponding R^2 values of 0.9131 and 0.9228, demonstrating satisfactory regression model fit.

Discussion

3.1 Effects of Basal Diet Composition on Apparent Total Tract Digestibility of Phosphorus Under the conditions of this study, the ATTD of P in unsupplemented CSBM and WSBM diets ranged from 16.91%–18.27% and 28.99%–30.43%, respectively, which is consistent with previously reported values [16]. Supplementation with highly digestible P from DCP significantly increased total fecal P excretion and total tract digestible P content, consequently improving ATTD of P, which aligns with findings from Wu et al. [7], Liu et al. [17], and Seynaeve et al. [18]. Similar improvements in total fecal P excretion, total tract digestible P content, and ATTD of P were observed when MCP was supplemented, corroborating the results of Stein et al. [19]. Beers and Jongbloed [20] also reported that MCP supplementation significantly enhanced P digestibility in piglets. The significantly higher ATTD of P in WSBM diets compared to CSBM diets at similar total P concentrations may be attributed to the higher digestible P content in wheat versus corn [21]. Therefore, partial replacement of corn with wheat as an energy source could be considered in livestock production to reduce environmental P excretion.

3.2 Effects of Basal Diet Composition on True Total Tract Digestibility of Phosphorus Current methods for evaluating true P digestibility in feed ingredients include isotope dilution techniques, difference methods, and linear regression analysis [22]. Among these, the linear regression method proposed by Fan et al. [5] and Shen et al. [6] is considered a reliable and widely used approach for determining true P digestibility and endogenous P losses. The accuracy of this method depends on the assumption that endogenous P excretion and true digestibility of P in test ingredients are independent of dietary P level [5], a condition that was met in the present study.

Limited information is available regarding the true digestibility of P from inorganic sources in pig diets. Petersen and Stein [4] estimated the TTTD of P in common inorganic sources using a P-free diet method. In contrast, the current study determined the TTTD of supplemental inorganic P by adding varying levels of DCP and MCP to CSBM and WSBM diets and applying linear regression analysis. The estimated TTTD values for P in DCP were 82.33% and 82.88% in CSBM and WSBM diets, respectively, while corresponding values for MCP were 85.88% and 84.62%. No significant differences were observed between the two basal diets for either inorganic source. The regression equations indicated higher TTTD values for MCP-supplemented diets compared to DCP-supplemented diets, which is consistent with previous reports [2-4]. However, the TTTD values obtained in this study were lower than those reported by Petersen and Stein [4] using the P-free diet method, likely because total dietary P in the current study was derived from both supplemental inorganic sources and the basal CSBM or WSBM diets.

In conclusion, basal diet composition does not significantly affect the TTTD of P in DCP or MCP. Therefore, when formulating diets for growing pigs using

the TTTD values of P from DCP and MCP, there is no need to consider the effects of basal dietary carbohydrates or phytase activity on the digestibility of these inorganic P sources.

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Table 1 Composition and nutrient levels of diets used in experiment 1 (as-fed basis) %

Table 2 Composition and nutrient levels of diets used in experiment 2 (as-fed basis) %

Table 3 Effects of dietary dicalcium phosphate on the digestibility of phosphorus of growing pigs (experiment 1)

Table 4 Effects of dietary monocalcium phosphate on the digestibility of phosphorus for growing pigs (experiment 2)

Table 5 Effect of dietary type on the true digestibility of phosphorus in inorganic phosphorus for growing pigs

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