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Effect of dietary phytase supplementation with different calcium/phosphorus ratio and net energy reduction on growth performance and nutrient digestibility in finishing pigs

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Abstract

The present experiment was conducted to assess the effect of *Buttiauxella*-derived phytase in finishing pigs fed corn/soybean meal diets with an increase in the calcium (Ca)/total phosphorus (P) (Ca/tP) ratio and a reduction in net energy on the growth performance and nutrient digestibility on the finishing pigs. A total of 90 crossbred ([Yorkshire × Landrace] × Duroc) finishing pigs with an average initial body weight (BW) of 56.94 ± 2.43 kg were used for an 11-week feeding trial. The pigs were randomly allotted to one of three dietary treatments (six replication/treatment and five pigs/pen) in a randomized complete block design according to their BW and gender. Dietary treatments consisted of supplementation of phytase (0.05, 0.07, and 0.1% in the control, Trt1 and Trt 2 diets, respectively) maintaining the Ca/tP ratio (1.67 : 1, 1.84 : 1, and 2.19 : 1 in control, Trt1 and Trt 2 diets, respectively) and reducing the net energy by 1% in Trt1 and Trt2 diets compared with the control diet. The results showed that dietary supplementation with phytase in the energy-reduced diet had a similar ($p > 0.05$) effect on the BW, average daily gain, average daily feed intake, and gain/feed ratio of the finishing pigs. Also, there were no effects ($p > 0.05$) of treatment matrixes on the nutrient digestibility of dry matter, nitrogen calcium, phosphorus, and gross energy. In conclusion, the increase of phytase and Ca/tP ratio and the reduction of net energy in the corn/soybean meal diet resulted in comparable growth performance and nutrient digestibility of finishing pigs relative to pigs fed the control diet.

Key words: Ca/tP ratio, growth performance, net energy, nutrient digestibility, phytase

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Introduction

The most of phosphorus (P) in the feed ingredients of plant origin is bound to phytate (Bedford, 2000), leading to low digestibility of P by animals. Moreover, previous research has revealed that anti-nutritional value of phytate in monogastric nutrition includes reduced trace mineral, amino acid digestibility, and depressed the activity of digestive enzymes (Woyengo and Nyachoti, 2013). Consequently, phytase has been used to replace partial inorganic P in the feed to remove the orthophosphate groups from phytate. Dietary inclusion of phytase has been confirmed to improve the digestibility and retention of P in pigs (Kies et al., 2006; Adhikari et al., 2016; Kim et al., 2017). Santos et al. (2014) reported that improved growth performance was observed in the microbial phytase group of grower pigs and it was better than the other groups with the same P level in diets containing inorganic P.

As the beneficial effects of phytase on pigs are continuously explored, the levels of calcium (Ca) and phosphorus (P) may also play an important role in the diet, especially for the diet supplemented with phytase, which can lead to negative effects on the utilization of phytate and the effectiveness of phytase (Brady et al., 2002). It has been found that a high dietary Ca/tP ratio is conducive to forming insoluble calcium phytate and /or reducing the activity of phytase (Selle and Ravindran, 2008). The impacts of supplementing phytase supplemental in the diet with Ca/tP ratios (1.5 : 1 to 2.0 : 1) decreased the absorption of P and limited the efficacy of phytase in weaning and growing-finishing pigs (Liu et al., 2000; Nahm, 2004). However, the present study differed from previous studies, we used the Ca/tP ratio (1.67 : 1 to 2.19 : 1) and net energy (down 1%) of corn/soybean meal diets to explore the effectiveness of supplemental phytase. Therefore, the objective of the present experiment was to assess the effects of reduced net energy diets contained different Ca/tP ratios and supplemented with microbial phytase on the growth performance and nutrient digestibility in finishing pigs.

Materials and Methods

The experimental protocol of the present study was approved by the Animal Care and Use Committee of Dankook University.

Experimental design

Ninety crossbred finishing pigs ([Yorkshire × Landrace] × Duroc), with an average initial body weight (BW) of 56.94 ± 2.43 kg (SD), were randomly allotted into 3 dietary treatments of 6 replication/treatment (3 barrows and 2 gilts/pen) in a completely randomized design according to their BW and gender. The three dietary treatments were: 1) CON, corn/soybean meal diet with 0.05% phytase (0.7% Ca and 0.42% total P, 1.67 : 1 Ca/tP); 2) Trt1, corn/soybean meal diet with 0.7% phytase (0.7% Ca and 0.38% total P, 1.84 : 1 Ca/tP); 3) Trt2, corn/soybean meal diet with 0.1% phytase (0.7% Ca and 0.32% total P, 2.19 : 1 Ca/tP). The *Buttiauxella* phytase used in this experiment was provided by Danisco Animal Nutrition (Aarhus, Denmark). All the diets in Table 1 used in this experiment were formulated to meet or exceed the National Research Council (NRC, 2012). All finishing pigs were housed in an environmentally controlled room with the temperature maintained at 20℃, and each pen was equipped with a stainless-steel feeder and a nipple drinker. All pigs could *ad libitum* access to feed and water throughout the 11-weeks trial.

Table 1. Composition of finishing pig diets (as fed-basis).

Ingredient (%)	Control	Trt1	Trt2
Corn	63.49	65.11	65.28
Rice bran	1.00	1.00	1.00
Soybean meal	16.59	15.43	15.52
Corn-distillers dried grains with solubles	5.98	6.00	6.00
Palm kernel meal	2.00	2.00	2.00
Tallow	4.60	4.10	4.00
Molasses	3.00	3.00	3.00
Limestone	1.31	1.41	1.55
Mono dicalcium phosphate	0.65	0.44	0.11
Salt	0.35	0.35	0.35
DL-Methionine, 99%	0.05	0.06	0.06
Lysine, 50%	0.45	0.50	0.50
Theronine, 98.5%	0.07	0.09	0.09
Tryptophan, 20%	0.11	0.14	0.14
Betaine	0.10	0.10	0.10
Vitamin and mineral premix[z]	0.20	0.20	0.20
Phytase	0.05	0.07	0.10
Nutrient composition (%)			
Net energy ($MJ \cdot kg^{-1}$)	10.33	10.22	10.22
Dry matter	86.64	86.55	86.53
Crude protein	14.39	14.04	14.09
Crude fat	7.24	6.79	6.70
Crude fiber	2.90	2.88	2.89
Crude ash	5.17	5.05	4.94
Calcium	0.70	0.70	0.70
Total phosphorus	0.42	0.38	0.32
Available phosphorus	0.26	0.26	0.26
Ca : P ratio	1.67 : 1	1.84 : 1	2.19 : 1

[z] Vitamin and mineral premix provided the following per kilogram of diet: vitamin A, 5,512 IU; vitamin D_3, 1,378 IU; vitamin E, 28 IU; vitamin B_{12}, 28 μg; riboflavin, 8 mg; niacin, 41 mg; pantothenic acid, 22 mg; Cu (oxide), 8.8 mg; Fe (sulfate), 88 mg; I (CaI), 1 mg; Mn (oxide), 20 mg; Zn (oxide), 75 mg; Se (Na_2SeO_3), 0.3 mg.

Sampling and measurements

Body weight (BW) of individual pigs and feed consumption of each pen were determined at the beginning and the end of week 11 to calculate average daily gain (ADG), average daily feed intake (ADFI), and gain/feed ratio (G/F).

Chromium oxide (0.2%) was added to the diet as an indigestible marker 7 days prior to the fecal collection during week 11 for calculating the apparent digestibility of dry matter (DM), nitrogen (N), Ca, P, and gross energy (GE). Fecal samples were collected randomly from at least two pigs from each pen (1 barrow and 1 gilt). All the feed and fecal samples were heated at 70℃ for a constant 60 h and then grounded to pass through a 1-mm screen according to the method of Zhang et al. (2022). Diet and fecal samples were analyzed for DM (method 930.15; AOAC, 2000), N (method 968.06; AOAC, 2000), Ca (method 984.01; AOAC, 2000), P (method 965.17; AOAC, 2000). The determination of GE used a Parr 6400 oxygen-bomb calorimeter (Parr Instrument Co., Moline, IL, USA). The N was determined with Kjectec 2300 Nitrogen Analyzer (Foss Tecator AB, Hoeganaes, Sweden). Chromium levels were determined via UV-absorption spectrophotometry (UV-1201, Shimadzu, Kyoto,

Japan). The calculation of apparent total tract digestibility (ATTD) of nutrients was done using the formula given below: ATTD (%) = [1 − {(Nf × Cr_2O_3d) ／ (Nd × Cr_2O_3f)}] × 100, where Nf and Nd represented nutrient concentrations, and Cr_2O_3f and Cr_2O_3d represented chromium concentrations, each in feces and diet, respectively. These values were all presented as percentages of the total dry matter.

Statistical analysis

Data were analyzed as a completely randomized block design using the general linear model procedures (SAS Inst. Inc., Cary, NC, USA). For all response criteria, the pen serv as the experimental unit, and initial BW was used as a covariate for the ADG and ADFI. Two orthogonal contrasts were constructed to test the effect of Ca/tP and net energy on the diet. Variability in the data was expressed as the standard error of the mean (SEM). Probability of $p \leq 0.05$ and $0.05 < p \leq 0.10$ were defined as significant differences and tendencies, respectively.

Results

Growth performance

The effects of dietary supplementation of phytase to a net energy-reduced diet with a variable Ca/tP ratio on the growth performance of pigs are shown in Table 2. Phytase supplementation to the energy- reduced corn/soybean meal with variable Ca/tP diets (Trt 1 and Trt 2) had similar effects as that of the CON group on BW, ADG, ADFI, and G/F ratio of finishing pigs ($p > 0.05$).

Table 2. Effect of phytase supplementation on growth performance in finishing pigs.

Item	Treatment			SEM	p-value	
	CON	Trt1	Trt2		CON vs Trt1	Trt1 vs Trt 2
Body weight (kg)						
Initial	56.94	56.95	56.93	0.02	0.856	0.422
Week 11	113.61	114.35	114.87	1.04	0.448	0.728
Overall						
ADG ($g \cdot d^{-1}$)	787	797	805	14.35	0.450	0.725
ADFI ($g \cdot d^{-1}$)	2,565	2,570	2,574	28.08	0.850	0.922
G/F	0.307	0.310	0.312	0.003	0.222	0.627

Treatments were phytase 0.05% with Ca/tP 1.67 : 1 (control), phytase 0.07% with Ca/tP 1.84 : 1 (energy matrix) (Trt1), phytase 0.10% with Ca/tP 2.19 : 1 (energy matrix) (Trt2).
SEM, standard error of means; ADG, average daily gain; ADFI, average daily feed intake; G/F, ADG/ADFI.

Apparent total tract digestibility

Compared with the CON group, there were no significant effects ($p > 0.05$) of phytase supplementation to energy-reduced corn/soybean meal with variable Ca/tP diets on ATTD of dry matter, nitrogen, calcium, phosphorus, and energy in the Trt1 and Trt 2 groups ($p > 0.05$; Table 3).

Table 3. Effect of phytase supplementation on nutrient digestibility in finishing pigs.

Item (%)	Treatment			SEM	p-value	
	CON	Trt1	Trt2		CON vs Trt1	Trt1 vs Trt 2
During week 11						
DM	72.32	72.67	73.11	1.39	0.743	0.829
N	69.36	70.47	70.20	1.04	0.459	0.856
GE	71.36	72.30	72.20	1.07	0.515	0.952
Ca	50.54	51.56	52.06	1.14	0.379	0.761
P	41.55	42.43	42.62	1.39	0.575	0.923

Treatments were phytase 0.05% with Ca/tP 1.67 : 1 (control), phytase 0.07% with Ca/tP 1.84 : 1 (energy matrix) (Trt1), phytase 0.10% with Ca/tP 2.19 : 1 (Energy matrix) (Trt2).
SEM, standard error of means; DM, dry matter; N, nitrogen; GE, gross energy; Ca, calcium; P, phosphorus.

Discussion

The findings from this study showed that dietary phytase supplementation to energy-reduced corn/soybean meal with variable Ca/tP ratio had no treatment effects on the growth and nutrient digestibility of finishing pigs. To our knowledge, until now there are no experiments investigating the effective association between net energy and phytase on finishing pigs. The research found that phytase activity may decline with high dietary Ca levels (Liu et al., 1998; Akter et al., 2016).

It is feasible to reduce dietary Ca levels in the supplemental phytase diet if phytase completely degrades phytate and could produce 2.82 g·kg^{-1} P and 3.04 g·kg^{-1} Ca (Zeng et al., 2015). Dietary Ca/tP ratio should be kept to a minimum in pigs' diet without impairing skeletal integrity or retarding growth (Selle and Ravindran, 2008). Zeng et al. (2016) found that supplementation of phytase at doses up to 20,000 unit·kg^{-1} in growing pigs' diet with the reduction of Ca/tP ratio maximized the phytase activity. In line with the present study findings, Adeola et al. (2006) reported that providing phytase to the maize-soy diets with Ca : P ratios of 1.2, 1.5, and 1.8 had no significant treatment effects between phytase and Ca : P ratio on weight gain and feed efficiency. Also, Zeng et al. (2011) showed supplementation of 250, 1,000, or 2,000 fytase unit, phytase·kg^{-1} in the low Ca/P or high Ca/P diets did not affect the growth and nutrient digestibility of weaning pigs. In contrast, Qian et al. (1996) demonstrated that Ca : P ratios increased from 1.2 to 2.0 in the diet supplemented with two levels of phytase (700 and 1,050 unit·kg^{-1} of diet), the ADG, ADFI, and G : F were significantly decreased with the increasing Ca : P ratios and the 1,050 unit·kg^{-1} of phytase had better effects on growth performance than 700 unit·kg^{-1} of phytase in weanling pigs. It indicates that dietary high Ca : P ratios disrupt phytate degradation and reduce phytase activity, while increased phytase levels reduced adverse effects on Ca : P ratios (Konieczka et al., 2020). Although the present study showed no differences in phytase added to the finishing pig diets, the phytase supplementation to the diet may inhibit the adverse effects of Ca/tP ratios, this is in the similar results of growth performance among the three treatments. This discrepancy between the present study and the work of Qian et al. (1996) may be explained by the differences in experimental treatments, diet composition, or the age of pigs.

Phytase plays an important role in promoting intestinal health and enhancing feed utilization for minerals and amino acids, which, in turn, decreases the excretion of minerals in feces and urine (Kiarie et al., 2013; Heyer et al., 2015). Moreover, exogenous microbial phytases can enhance the ATTD of phytate-P and permit lower dietary P levels, and reduce the excretion of undigested and excess P in pigs (Simons et al., 1990). Previous studies also demonstrated that supplementation of phytase in pigs' diet increased the ATTD of DM, N, GE, Ca, and P (Johnston et al., 2004; Kies et al., 2006; Woyengo et al., 2008). However, dietary phytase supplementation had no effects on the ATTD of DM, N, Ca, P, and GE among treatments

of finishing pigs in this study. This inconsistent results between the present study and the work of previous studies might be attributed to many factors, including types and concentrations of phytase, the age of animals (Woyengo et al., 2008; Liu et al., 2020; Sureshkumar and Kim, 2022). Additionally, Selle and Ravindran (2008) suggested that dietary Ca concentrations and Ca : P ratios are negatively affected phytase activity in monogastric diets, thus, a higher Ca : P ratio in the diet may diminish the efficacy of the supplemental phytase.

Conclusion

In conclusion, the corn/soybean meal diet supplemented with phytase does not affect growth performance and nutrient digestibility when increased Ca/tP ratio and declined net energy of diet. The results indicated that the altered Ca/tP ratio and net energy limited the effectiveness of phytase. However, the reason for net energy decreased the efficacy of phytase is not clear. Further studies are needed to determine the mechanisms involved in the association between net energy and phytase.

Conflict of Interests

No potential conflict of interest relevant to this article was reported.

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