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Effects of dietary phosphorus concentration and body weight on postileal phosphorus digestion in pigs

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ABSTRACT

Two experiments were conducted to determine the effects of dietary P concentration and BW on postileal digestion of P in pigs. In Exp. 1, 48 growing pigs (BW: 27.8 ± 1.7 kg) were fitted with a T-cannula at the distal ileum and allotted to 6 dietary treatment groups. The basal diet was a corn-soybean meal (SBM) based diet without dicalcium phosphate (DCP) supplementation, and dietary total P concentration was calculated to be 3.3 g/kg. Five additional diets were formulated by the inclusion of DCP in increments of 5.4 g/kg to the basal diet and thereby creating experimental diets that were calculate to contain 4.3, 5.3, 6.3, 7.3, and 8.3 g/kg total P, respectively. In Exp. 2, 16 growing pigs (BW: 25.9 ± 1.3 kg), 16 growing-finishing pigs (BW: 61.3 ± 2.5 kg), and 16 finishing pigs (BW: 98.3 ± 3.9 kg) were surgically fitted with a T-cannula at the distal ileum. Each BW group of pigs was fed the moderate P diet (a corn-SBM diet without DCP addition) or the adequate P diet (a corn-SBM diet supplemented with 14.5 g/kg of DCP). In each study, the 9 d experimental periods consisted of 5 d of adaption period, 2 d of feces collection, and 2 d of ileal digesta collection. In Exp. 1, ileal and fecal P output, ileal digested P, total tract digested P, the apparent ileal digestibility (AID) and apparent total tract digestibility (ATTD) of P increased with increasing dietary total P level (linear, $P < 0.01$). There was no difference between the AID and ATTD of P for pigs within each diet. In Exp. 2, ileal P output and digested P, and ATTD of P were affected by the interaction between BW and diet ($P < 0.05$). Growing-finishing pigs and finishing pigs had greater amount of postileal digested P, the proportion of postileal digested P to total tract digested P, the apparent postileal digestibility of P, and hindgut disappearance of P than growing pigs ($P < 0.05$). The values for ATTD of P were greater than the estimates of AID of P for growing-finishing pigs and finishing pigs, regardless of diet ($P < 0.05$). In contrast, there was no difference between the AID and ATTD of P for growing pigs. In summary, postileal P digestion of pigs was affected by BW, but dietary total P level has marginal effects on postileal P digestion in growing pigs.

1. Introduction

The soaring price of phosphates (P) and environmental pressure of P excretion from manure are major concerns in swine production (Knowlton et al., 2004). A better understanding of the digestive physiology of P will allow an optimization of P utilization in pigs. It is generally recognized that the small intestine is the major site of P absorption, and the amount of postileal digested P is

Abbreviations: ADFI, average daily feed intake; ADG, average daily gain; AID, apparent ileal digestibility; APID, apparent postileal digestibility; ATTD, apparent total tract digestibility; BW, body weight; CP, crude protein; DCP, dicalcium phosphate; DM, dry matter; DMI, dry matter intake; P, phosphorus; SBM, soybean meal

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similar to the amount of endogenous secreted P in the large intestine of pigs, which lead to zero P retention in the large intestine (Partridge, 1978; Crenshaw, 2001). The physiological roles of the large intestine in maintaining P homeostasis were not taken into account when mathematical models were established to predict metabolic fate of dietary P in the digestive tract and the dynamics of body ash in pigs (Létourneau-Montminy et al., 2011, 2015). The lack of physiological impact of the large intestine on P utilization was demonstrated because no differences were observed between the apparent ileal digestibility (AID) and apparent total tract digestibility (ATTD) of P in growing pigs fed cornstarch-based semipurified diets or corn-based practical diets (Dilger and Adeola, 2006; Metzler et al., 2008; Rutherfurd et al., 2014). However, there were inconsistencies in previous studies about the role of the large intestine on P digestion. A considerable amount of postileal digested P (from 286 to 1424 mg/kg) was observed in growing-finishing and finishing pigs fed corn-soybean meal (SBM) based diets (Liu et al., 2000; Seynaeve et al., 2000; Liu et al., 2017). On the contrary, the large intestine of growing pigs may have a net secretion of P ranged from 289 to 522 mg/kg (Jongbloed et al., 1992; Larsen and Sandström, 1993; Houdijk et al., 1999). One plausible explanation is the role of large intestine in total tract P hemostasis depending on the development of the gastrointestinal tract (Urriola and Stein, 2012). For this reason, it is possible that the inconsistent results among previous studies were observed because of the different BW of experimental animal.

The postileal digestion of P is related to microbial fermentation, which is also dependent on diet composition such as the amounts and sources of fibre and P (Larsen and Sandström, 1993; Metzler and Mosenthin, 2008; Urriola and Stein, 2012; Liu et al., 2017). It is hypothesized that increasing BW and dietary P concentration increased postileal digestion in pigs. Therefore, the objectives of the present study were to determine effects of dietary total P concentration on postileal P digestion in 27.8-kg growing pigs, and to compare the postileal P digestion between 25.9-kg growing, 61.3-kg growing-finishing, and 98.3-kg finishing pigs.

2. Material and methods

All of protocols used in the current study were approved by the Institutional Animal Care and Use Committee of the State Key Laboratory of Animal Nutrition at the Chinese Academy of Agricultural Science.

2.1. Animals and diets

In Exp. 1, 48 Duroc × Landrace × Yorkshire barrows (initial BW: 27.8 ± 1.7 kg) were fitted with a simple T-cannula at the distal ileum according to the surgical procedures described by Chen et al. (2013). Pigs were placed individually in stainless-steel metabolism crates (1.8 by 0.8 m) and randomly allotted to 6 treatment groups. The basal diet contained corn and SBM, and was formulated to contain 3.3 g/kg total P (Table 1). The concentrations of amino acids and DE in the basal diet meet the requirement for 25.0-kg growing pigs (NRC, 2012). The analyzed concentration of P in dicalcium phosphate (DCP) was 18.5% in Exp. 1 and Exp. 2. There was no supplementation of DCP to the basal diet. Five additional diets were formulated by inclusion of DCP in increments of 5.4 g/kg which increased dietary total P level in increments of 1.0 g/kg. Therefore, the calculated total P concentrations were 4.3, 5.3, 6.3, 7.3, and 8.3 g/kg in the 5 DCP-containing experimental diets, respectively. Limestone was included in all diets to maintain a constant 1.2:1 Ca:total P ratio. Chromic oxide was used as an indigestible marker at 5.0 g/kg on an as-fed basis to calculate nutrient digestibility (Liu et al., 2016).

In Exp. 2, 16 growing pigs (initial BW: 25.9 ± 1.3 kg), 16 growing-finishing pigs (initial BW: 61.3 ± 2.5 kg), and 16 finishing

Table 1
Ingredients and nutrient composition of the experimental diets used in Exp. 1, as-fed basis.

Item	Dietary total P concentration, g/kg					
	3.3	4.3	5.3	6.3	7.3	8.3
Ingredient, g/kg						
Corn	726.4	721.4	716.4	711.3	706.2	701.2
Soybean meal	225.0	225.0	225.0	225.0	225.0	225.0
Soy oil	30.0	30.0	30.0	30.0	30.0	30.0
Dicalcium phosphate	–	5.4	10.8	16.2	21.6	27.0
Limestone	8.1	7.7	7.3	7.0	6.7	6.3
Salt	3.0	3.0	3.0	3.0	3.0	3.0
Chromic oxide	5.0	5.0	5.0	5.0	5.0	5.0
Vitamin and mineral premix[a]	2.5	2.5	2.5	2.5	2.5	2.5
Total	1000.0	1000.0	1000.0	1000.0	1000.0	1000.0
Analyzed nutrient composition						
CP, g/kg	162.4	159.1	161.3	158.7	162.9	160.5
Total P, g/kg	3.43	4.21	5.38	6.15	7.07	8.16
Ca, g/kg	4.21	4.98	6.27	7.83	8.45	9.62
Ca-to-total P ratio	1.23	1.18	1.17	1.27	1.20	1.18

[a] Provided per kilogram of diet: 8800 IU of vitamin A; 880 IU of vitamin D; 64 IU of vitamin E; 4 mg of vitamin K (menadione sodium bisulfite); 70 μg of vitamin B_{12}; 14 mg of riboflavin; 60 mg of D-pantothenic acid; 30 mg of niacin; 6 mg of vitamin B_6; 200 μg of biotin; 1.2 mg of folic acid; 120 mg of Fe (as iron carbonate); 25 mg of Mn (as manganese oxide); 17 mg of Cu (as copper chloride); 0.3 mg of I (as ethylenediamine dihydroiodide); 0.2 mg of Se (as sodium selenite); and 120 mg of Zn (as zinc oxide).