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Influence of dietary phosphorus concentration on the digestibility of phosphorus in monocalcium phosphate by growing pigs

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ABSTRACT: An experiment was conducted to test the hypothesis that the dietary inclusion rate of P does not influence the digestibility of P. The experiment was conducted at 4 experiment stations where the same protocol was followed. A total of 60 growing pigs (initial BW: 22.22 ± 2.13 kg) were allotted to 6 dietary treatments with 10 replications per treatment. All pigs were placed in metabolism cages that allowed for the total, but separate, collection of urine and fecal materials. Six diets were formulated. The basal diet was based on corn (54.2%), soybean meal (20%), and cornstarch. No inorganic P was used, and the total concentration of P in the basal diet was calculated to be 0.29%. Five additional diets were formulated by adding monocalcium phosphate (MCP) in increments of 0.34% to the basal diet and thereby creating diets that were calculated to contain 0.36, 0.43, 0.50, 0.57, and 0.64% total P, respectively. Ground limestone was also added to these diets to maintain a calculated Ca:P ratio of 1.2:1. The balances of Ca and P and the apparent total tract digestibility (ATTD) of Ca and P were calculated for each diet. The contribution of P from the basal diet was then subtracted from the MCP-containing diets to calculate the balance and ATTD for P in MCP. Results of the experiment showed that the absorption and retention of both Ca and P increased (linear, $P < 0.001$) with increasing concentrations of Ca and P in the diet. The ATTD for Ca ranged from 62.3 to 66.8% and was not influenced by the dietary concentration of Ca. However, the ATTD for P increased from 38.4 to 65.2% as increasing levels of MCP were added to the diet (linear, $P < 0.001$). Increasing P intake from MCP increased (linear, $P < 0.001$) the excretion of P in the feces, but the quantity of P that was absorbed and retained also increased (linear, $P < 0.001$) as more P from MCP was added to the diet. When measured as a percentage of P intake, P retention was not influenced by the dietary P concentration. The ATTD for P in MCP ranged from 79.5 to 88.5% and was not affected by the concentration of P in the diet. Results of this experiment demonstrated that the digestibility and absorption of P from MCP are not influenced by the dietary concentration of P.

Key words: calcium, digestibility, intake, monocalcium phosphate, pig, phosphorus

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INTRODUCTION

Historically, P availability in feed ingredients has been assessed by measuring relative bioavailability (Cromwell, 1992). Using this approach, it is necessary to feed animals below their estimated P requirement, because data for relative bioavailability are based on the retention of P in the animal (Cromwell, 1992; Crenshaw, 2001). This creates challenges in formulating experimental diets, because the P requirement of pigs is relatively low compared with the P concentration in many feed ingredients and the requirement of P as a percentage of the diets decreases as pigs become older (NRC, 1998). In addition, data on relative bioavailability do not estimate the quantity of P excreted from the animals. To estimate P excretion in the manure, it is necessary to measure P digestibility in feed ingredients. When data on P digestibility are measured, the quantity of P that is absorbed from the gastrointestinal tract of the animal is estimated. If P is absorbed in excess of the requirement of the pig, the excess is expected to be excreted in the urine (Fernandez, 1995; Crenshaw, 2001). If this is correct, the dietary P concentration would not be expected to affect the digestibility of P.

However, it has been suggested that the absorption of P from the gastrointestinal tract of the pig is downregulated if the pig is fed above its requirement for P (Ketaren et al., 1993; Eeckhout and de Paepe, 1997), but this hypothesis has not been experimentally verified. Therefore, the objective of the current experiment was to test the hypothesis that total tract digestibility of P in monocalcium phosphate (**MCP**) is independent of the concentration of P in the diet. A second objective was to investigate how dietary P concentrations influence the balance and digestibility of Ca in diets fed to pigs.

MATERIALS AND METHODS

The experiment was conducted at 4 experiment stations in the United States as part of the research conducted by the NCCC-42 and the S-1012 regional committees on swine nutrition and reproduction. The 4 stations were Texas Tech University (Lubbock), North Carolina A&T University (Greensboro), the University of Nebraska (Lincoln), and South Dakota State University (Brookings). In total, 10 replications were used in this experiment with 2 replications used at each station except South Dakota State University where 4 replications were used. The 4 stations followed the same experimental protocol, but used pigs with different genetic backgrounds according to the pigs that were available at each station. The experimental protocol was reviewed and approved by the Institutional Animal Care and Use Committee at each participating station.

Animals and Diets

Six growing barrows (average initial BW: 22.22 ± 2.13 kg) were used in each replication of the experiment; therefore, a total of 60 pigs were used in the 10 replications. Pigs were placed in metabolism cages and randomly allotted to 6 treatments. The metabolism cages allowed for total, but separate, collections of urine and fecal material. Six experimental diets were formulated (Tables 1 and 2). The basal diet contained corn, soybean meal, and cornstarch and was formulated to contain 0.29% total P. Inorganic P was not included in the basal diet. Five additional diets were formulated by adding MCP to the basal diet in increments of 0.34%, which increased the total dietary concentration of P in increments of 0.07%. Therefore, the 5 MCP-containing diets were formulated to contain 0.36, 0.43, 0.50, 0.57, and 0.64% total P, respectively. The concentration of relative bioavailable P in the 6 diets was calculated at 0.06, 0.12., 0.18, 0.24, 0.29, and 0.35%, respectively (NRC, 1998). Ground limestone was added to all diets in quantities sufficient to maintain a 1.2:1 Ca:total P ratio. A single source of salt, vitamins, and microminerals was used at each station. A commercial source of monohydrate MCP (Nutra Flo Inc., Sioux City, IA) was used at all stations. This source of MCP analyzed 15.6% Ca and 21.0% P.

Feeding and Sample Collections

The BW of the animals was recorded at the beginning of the experiment. The average BW of pigs within each replicate was used to calculate the daily feed allowance as 3 times the estimated maintenance requirement for energy (i.e., 106 kcal of ME/kg$^{0.75}$; NRC, 1998). The daily allotment of feed was provided in 2 equal meals. Orts were collected and weighed before each feeding. Samples of each experimental diet were collected as diets were mixed and stored at −20°C.

Each experimental period lasted 14 d. The initial 7 d were considered an adaptation period to the diets. Ferric oxide in the amount of 0.5% was mixed into the morning meals on d 8 and 13. Urine collections were initiated immediately after feeding the morning meal on d 8 and ceased before feeding the morning meal on d 13. Urine was collected over a preservative of 50 mL of 6 *N* sulfuric acid. Fecal collections were initiated as the marker appeared in the feces for the first time after d 8 and ceased when the marker appeared in the feces for the first time after d 13 as described by Adeola (2001). During the collection period, urine and fecal materials were collected morning and afternoon. Urine was weighed, thoroughly mixed, and a 20% subsample was collected and stored at −20°C immediately after collection. Fecal materials were also stored at−20°C as they were collected. At the conclusion of the experiment, urine samples were thawed, mixed within animal and diet, and a subsample was collected for chemical analy-

Table 1. Ingredient composition of experimental diets (as-fed basis)

	Calculated total P, %					
Ingredient, %	0.29	0.36	0.43	0.50	0.57	0.64
Ground corn	54.20	54.20	54.20	54.20	54.20	54.20
Cornstarch	22.75	21.97	21.19	20.41	19.63	18.85
Soybean meal, 48% CP	20.00	20.00	20.00	20.00	20.00	20.00
Soybean oil	1.24	1.61	1.98	2.35	2.72	3.09
Ground limestone	0.69	0.76	0.83	0.90	0.97	1.04
Monocalcium phosphate	—	0.34	0.68	1.02	1.36	1.70
L-Lys·HCl	0.27	0.27	0.27	0.27	0.27	0.27
DL-Met	0.07	0.07	0.07	0.07	0.07	0.07
L-Thr	0.09	0.09	0.09	0.09	0.09	0.09
L-Trp	0.01	0.01	0.01	0.01	0.01	0.01
Salt	0.40	0.40	0.40	0.40	0.40	0.40
Vitamin premix[1]	0.03	0.03	0.03	0.03	0.03	0.03
Micromineral premix[2]	0.25	0.25	0.25	0.25	0.25	0.25

[1]Provided the following quantities of vitamins per kilogram of complete diet: vitamin A, 6,954 IU as vitamin A acetate; vitamin D_3, 989 IU as D-activated animal sterol; vitamin E, 33 IU as α tocopherol acetate; vitamin K_3, 2.60 mg as menadione dimethylpyrimidinol bisulfite; thiamin, 1.98 mg as thiamine mononitrate; riboflavin, 5.94 mg; pyridoxine, 1.98 mg as pyridoxine hydrochloride; vitamin B_{12}, 0.026 mg; D-pantothenic acid, 19.80 mg as calcium pantothenate; niacin, 33.00 mg; folic acid, 0.66 mg; and biotin, 0.10 mg.

[2]Provided the following quantities of minerals per kilogram of complete diet: Cu, 26 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 0.31 mg as potassium iodate; Mn, 26 mg as manganese sulfate; Se, 0.31 mg as sodium selenite; and Zn, 130 mg as zinc oxide.

sis. Fecal materials were dried in a forced-air oven and weighed before analysis.

Chemical Analysis

All chemical analyses were performed at South Dakota State University. Samples of diets, urine, and feces were digested in perchloric acid (procedure 2.3.01; AOAC, 2000), and the concentration of P was determined by a UV-visible spectroscopy spectrophotometer (model UV 2101 PC; Shimadzu Scientific Instruments, Columbia, MD) at 650 nm (procedure 3.4.11; AOAC, 2000). Accuracy of the procedure was verified using National Institute of Standards and Technology (US Department of Commerce, Washington, DC) reference standard 1570a (standard reference material). Concentrations of Ca in the samples were determined using atomic absorption (procedure 4.8.03; AOAC, 2000).

Calculations

Total feed intake for each animal was summarized at the conclusion of the experiment. The intake of Ca and P was then calculated for each animal by multiplying feed intake by the analyzed concentration of Ca and P in the diets used at each station. The excretions of Ca and P in the urine and feces were calculated for each pig by multiplying the analyzed concentrations by the total quantity of urine and feces voided by each pig. The apparent total tract digestibility (**ATTD**) of P was calculated for each diet according to Eq. [1] (Petersen and Stein, 2006):

$$\text{ATTD (\%)} = [(\text{Pi} - \text{Pf})/\text{Pi}] \times 100, \quad [1]$$

where Pi = the total intake (g) of P from d 8 to 13 and Pf = the total fecal output (g) of P.

The retention of P as a percentage of intake was calculated for each pig and diet using Eq. [2] (Petersen and Stein, 2006):

$$\text{Pr (\%)} = [(\text{Pi} - (\text{Pf} + \text{Pu}))/\text{Pi}] \times 100, \quad [2]$$

where Pr = the retention (%) of P and Pu = the urinary output (g) of P from d 8 to 13.

The retention of P was also calculated as grams per day using Eq. [3]:

$$\text{Pr (g/d)} = [(\text{Pi} - (\text{Pf} + \text{Pu}))]/5. \quad [3]$$

The ATTD and retention of Ca were also calculated using Eq. [1], [2], and [3], respectively.

The ATTD of P in MCP was calculated according to the difference procedure (Adeola, 2001). The contribution of P from the basal diet was subtracted from the intake and output of P in pigs fed each of the 5 MCP-containing diets. The ATTD and the retention of P originating from MCP in each of these diets were then calculated according to Eq. [1], [2], and [3], respectively.

Statistical Analysis

Data were analyzed using the PROC GLM procedure (SAS Inst. Inc., Cary, NC). The model included diet, station, and the diet × station interaction as main effects. However, no diet × station interactions were observed, and the interaction was removed from the model in the final analysis. Contrast statements were used to analyze linear and quadratic effects of adding MCP to the basal diet and an α value of 0.05 was used

Table 2. Energy and nutrient composition of experimental diets (as-fed basis)[1,2]

	Calculated total P, %					
Item	0.29	0.36	0.43	0.50	0.57	0.64
ME, kcal/kg	3,540	3,540	3,540	3,540	3,540	3,540
CP, %	14.00	14.00	14.00	14.00	14.00	14.00
Ca, %	0.42	0.47	0.55	0.69	0.72	0.84
Total P, %	0.26	0.32	0.39	0.47	0.53	0.64
Relative bioavailable P, %	0.06	0.12	0.18	0.24	0.29	0.35

[1]Values for Ca and total P were analyzed, whereas values for ME, CP, and available P were calculated (NRC, 1998).

[2]All diets were calculated (NRC, 1998) to contain 0.95% Lys, 0.29% Met, 0.54% Met plus Cys, 0.61% Thr, and 0.17% Trp.

to assess significance of the contrasts. The pig was the experimental unit for all analyses.

RESULTS

The analyzed values for dietary P were slightly lower than calculated for all diets (Table 3), but the spacing between levels of P in the diets was as expected, and dietary concentrations of P increased (linear, $P < 0.001$) as MCP was added to the diets. The ADFI and the excreted volumes of feces and urine were not influenced by dietary treatments. Therefore, the intake of P increased (linear, $P < 0.001$) as MCP was added to the diets. Likewise, fecal P excretion, P absorption, and P retention in grams per day increased (linear, $P < 0.001$) as more MCP was added to the diets. However, P retention as a percentage of P intake also showed a quadratic response to P intake (linear, $P < 0.001$; quadratic, $P < 0.05$) and reached a plateau for the 3 greatest concentrations of MCP supplementation. This response was caused by a quadratic increase in urinary excretion of P as more MCP was added to the diet (linear, $P < 0.001$; quadratic, $P < 0.01$). However, the ATTD for P increased (linear, $P < 0.001$) from 38.4 to 65.2% as increasing quantities of MCP were added to the diets.

The intake of Ca, the excretion of Ca in feces, Ca absorption, and Ca retention increased as increasing quantities of MCP were added to the diets (linear, $P < 0.001$; Table 4). Although the ATTD of Ca ranged from 62.3 to 66.9%, it was not influenced by the level of MCP in the diet. However, the excretion of Ca in the urine was reduced (linear, $P < 0.001$) as the inclusion of dietary MCP increased. This was true when Ca excretion was calculated as a percentage of Ca intake as well as in grams per day.

The intake of P that originated from MCP and the excretion of P from MCP in the feces increased (linear, $P < 0.001$) as the dietary inclusion of MCP increased (Table 5). The quantities of P from MCP that were absorbed and retained also increased (linear, $P < 0.001$) as the inclusion of MCP increased. However, when calculated as a percentage of P intake, the retention of P from MCP was not influenced by the inclusion of MCP in the diet, because the urinary excretion of P from MCP increased as more MCP was added to the

Table 3. Daily P balance and apparent total tract digestibility of P in experimental diets[1,2]

	Analyzed total P, %							*P*-value	
Item	0.26	0.32	0.39	0.47	0.53	0.64	SEM	Linear	Quadratic
Initial BW, kg	21.98	21.94	21.85	21.76	23.37	22.43	0.68	0.26	0.71
Feed intake, g	1,108	1,093	1,101	1,106	1,142	1,108	81	0.83	0.98
Fecal output, g	100	97	101	102	111	104	14	0.58	0.98
Urine output, g	4,718	4,902	5,531	5,515	4,078	5,013	1,332	0.93	0.71
P in diet, %	0.26	0.32	0.39	0.47	0.53	0.64	0.006	<0.001	0.002
P intake, g	2.83	3.47	4.28	5.23	6.10	7.06	0.41	<0.001	0.63
P in feces, %	1.8	1.9	2.0	2.2	2.3	2.5	0.11	<0.001	0.64
P in feces, g	1.73	1.80	1.93	2.12	2.45	2.48	0.20	0.001	0.74
P in urine, %	0.0014	0.0015	0.0018	0.0026	0.0064	0.0109	0.00148	0.68	0.14
P in urine, g	0.06	0.07	0.07	0.12	0.22	0.45	0.05	<0.001	0.002
P absorbed, g	1.10	1.67	2.36	3.11	3.65	4.58	0.28	<0.001	0.64
P digestibility,[3] %	38.4	48.8	54.6	58.9	60.1	65.2	3.10	<0.001	0.12
P retained, g	1.04	1.60	2.28	2.99	3.43	4.12	0.25	<0.001	0.89
P retained, %	36.5	46.9	53.1	56.9	56.9	59.0	3.23	<0.001	0.03

[1]Data are means of 10 observations per treatment.

[2]Data for fecal output and P percentage in feces are on a DM basis. All other data for intake and output are on an as-is basis.

[3]Apparent total tract digestibility.

Table 4. Daily Ca balance and apparent total tract digestibility of Ca in experimental diets[1,2]

	Analyzed total P, %							*P*-value	
Item	0.26	0.32	0.39	0.47	0.53	0.64	SEM	Linear	Quadratic
Ca in diet, %	0.42	0.47	0.55	0.69	0.72	0.84	0.01	<0.001	0.30
Ca intake, g	4.60	5.19	6.10	7.66	8.29	9.25	0.56	<0.001	0.88
Ca in feces, %	1.8	1.8	2.0	2.6	2.7	3.0	0.20	<0.001	0.67
Ca in feces, g	1.77	1.78	2.04	2.61	3.11	3.17	0.36	0.001	0.72
Ca in urine, %	0.048	0.043	0.032	0.019	0.013	0.020	0.007	<0.001	0.24
Ca in urine, g	1.47	1.35	1.07	0.68	0.49	0.53	0.17	<0.001	0.46
Ca absorbed, g	2.83	3.41	4.06	5.05	5.18	6.08	0.37	<0.001	0.89
Ca digestibility,[3] %	62.3	66.5	66.8	66.4	64.1	66.9	3.79	0.63	0.62
Ca retained, g	1.36	2.06	2.98	4.37	4.69	5.55	0.32	<0.001	0.59
Ca retained, %	31.5	40.6	48.8	57.4	58.1	61.2	3.98	<0.001	0.11

[1]Data are means of 10 observations per treatment.

[2]Data for fecal output and Ca percentage in feces are on a DM basis. All other data for intake and output are on an as-is basis.

[3]Apparent total tract digestibility.

diet (linear, $P < 0.001$; quadratic, $P < 0.01$). The ATTD for P in MCP ranged from 79.5 to 88.5%, but it was not influenced by the inclusion level of MCP in the diet.

DISCUSSION

P Digestibility and Balance in Diets

The ATTD of P in the basal diet (38.4%) was close to the expected value based on ATTD values of 29 and 38% for P in corn and soybean meal, respectively (Bohlke et al., 2005). The value was also close to the ATTD of 42.8% that was measured in a corn-soybean meal diet that contained 0.14% MCP (Johnston et al., 2004).

The increase in ATTD of P by the inclusion of more inorganic P in the diets was expected and agrees with previous observations (Johnston et al., 2004; Stahly and Lutz, 2004). The reason for this observation is that P in MCP is more digestible than P in corn and soybean meal (Jongbloed and Kemme, 1990). Therefore, when more MCP is added to the diet, a greater proportion of the P in the diet originates from MCP, which increases the average ATTD for P in the diet.

The retention of P increased linearly as more MCP was added to the diets. It was expected that retention would increase as long as P intake was below the requirement and then plateau as P intake exceeded the requirement of the pigs. The requirement of available P for 20- to 50-kg pigs is 0.23% (NRC, 1998), and 2 of the levels of available P used in this experiment were 0.29 and 0.34%. These concentrations, therefore, were expected to be well above the requirement of the pigs. However, the requirements published by NRC are based on maximum growth performance of the animals (NRC, 1998). Approximately 80% of all the P in the body is used for bone tissue synthesis (Breves and Schroder, 1991), and the requirement for maximum bone tissue synthesis is greater than the requirement for maximum growth performance (NRC, 1998; Crenshaw, 2001). In addition, at high levels of P intake, retention of P in bone tissue accounts for practically all additional P retained (Stahly et al., 2005). It is, therefore, possible that the dietary concentrations of P in this experiment, although well above the estimated requirement for maximum growth performance, did not exceed the requirement for maximum bone tissue synthesis, which explains why a plateau for P retention was not reached.

Ca Digestibility and Balance in Diets

In the control diet, approximately 75% of the Ca originated from limestone, whereas the remaining Ca was from corn and soybean meal. The ATTD of Ca in

Table 5. Daily balance and apparent total tract digestibility of P in monocalcium phosphate by growing pigs[1]

	Added P from monocalcium phosphate, %						*P*-value	
Item	0.07	0.14	0.21	0.28	0.35	SEM	Linear	Quadratic
P intake, g	0.67	1.47	2.40	3.18	4.14	0.20	<0.001	0.81
P in feces, g	0.09	0.20	0.39	0.68	0.71	0.11	<0.001	0.86
P in urine, g	0.008	0.011	0.053	0.160	0.410	0.046	<0.001	0.002
P absorbed, g	0.59	1.27	2.01	2.51	3.44	0.18	<0.001	0.71
P digestibility,[2] %	88.5	85.0	82.8	79.5	83.5	5.8	0.35	0.48
P retained, g	0.58	1.25	1.96	2.35	3.03	0.17	<0.001	0.64
P retained, %	86.2	84.0	80.7	75.0	74.0	5.6	0.65	0.99

[1]Data are means of 10 observations per treatment.

[2]Apparent total tract digestibility.

the basal diet was 62.3%, which is close to the value that can be calculated based on the ATTD of Ca in corn (49.6%), soybean meal (46.7%), and limestone (71 to 76%) that have been published (Bohlke et al., 2005; Stein et al., 2006; Widmer et al., 2007). The ATTD for Ca in the control diet also agrees with values reported for similar diets fed to finishing pigs (Liu et al., 1998).

The ATTD of Ca (62.3 to 66.8%) was not affected by dietary treatments. To maintain a constant Ca:P ratio across all diets, more limestone was added to the diets as more MCP was included. The fact that the ATTD for Ca did not change among diets indicates that the ATTD for Ca in MCP is similar to the ATTD for Ca in limestone. The lack of an effect of P concentration on the ATTD of Ca is in agreement with recent data showing that the ATTD for Ca in limestone is not affected by the presence or absence of P in the diet (Stein et al., 2006). In contrast, Eeckhout et al. (1995) reported a linear decrease in the ATTD of Ca as more P was added to the diet. However, the Ca:P ratio used by Eeckhout et al. (1995) was greater than in the present study, which may have influenced the results, because the Ca:P ratio influences the ATTD for Ca (Liu et al., 1998).

The urinary excretion of Ca decreased as the concentration of dietary P and Ca increased. This observation is in agreement with data showing that pigs fed a P-free diet excrete larger amounts of Ca in the urine than pigs fed a diet containing P (Stein et al., 2006; Widmer et al., 2007). The reason for this phenomenon is believed to be that both Ca and P are needed for bone tissue synthesis. At the lower levels of P intake, there is more Ca available than needed for bone formation due to limited availability of P. The extra Ca would be excreted in the urine, but as more P is included in the diet, more P would be available for bone tissue synthesis, which in turn can increase the need for Ca for this process, leaving less Ca to be excreted in the urine. In the present experiment, less than 10% of the absorbed Ca was excreted in the urine at the greatest P intake. This reduction in urinary Ca excretion is remarkable, because the intake of Ca increased more than the intake of P as more MCP was included in the diets. The reason for this observation is most likely that although the dietary Ca:P ratio was constant at 1.2:1 for all diets, the ratio of absorbed Ca to absorbed P was reduced as more MCP and limestone were added to the diets because of the increase in ATTD of P. Based on these observations, it is concluded that the digestibility and absorption of Ca from limestone and MCP is constant across the levels of P intake that were used in this experiment.

Digestibility of P in MCP

The ATTD of P in MCP ranged from 79.5 to 88.5% and was not influenced by the concentrations of P in the diets. The MCP that was used in the experiment was from the same source as the MCP used by Petersen and Stein (2006), who reported values for ATTD of P of 81.1 and 81.7%, respectively, for inclusion rates of 0.80 and 0.97% MCP in the diet. Thus, the average ATTD obtained in the present experiment and the lack of any influence of the inclusion rate of MCP on the ATTD of P is in agreement with Petersen and Stein (2006). The ATTD of P in MCP obtained in this experiment also concurs with Jongbloed et al. (1991), who measured the ATTD of P in 3 sources of MCP and reported values of 75, 83, and 84%. Likewise, an average ATTD of P in MCP of 82% was reported by Grimbergen et al. (1985). The ATTD of P in MCP has also been reported in the range of 90 to 92% (von Rodehutscord et al., 1994; Eeckhout and de Paepe, 1997), but it is recognized that differences in ATTD of P exist among sources of MCP (Jongbloed et al. 1991; Eeckhout and de Paepe, 1997).

The fact that the ATTD of P in MCP did not change with increasing inclusion rate of MCP indicates that the pig has a high capacity for P digestion and absorption. The absorption of P takes place mainly in the small intestine (Breves and Schroder, 1991; Bohlke et al., 2005). The absorption of P from the small intestine into the enterocytes takes place via an active process using a Na-dependent symport carrier or via passive diffusion (Breves and Schroder, 1991; Jongbloed and Mroz, 1997). The active transport dominates at low dietary P concentrations, but passive diffusion is more important if the dietary P concentration is close to the requirement of the pigs (Jongbloed and Mroz, 1997). The lack of an effect of dietary P concentration on the ATTD of P from MCP even when P was at or above the requirement indicates that passive absorption of P is as effective as active absorption.

In conclusion, the ATTD of P in MCP is not influenced by the dietary concentration of P if the concentration of P in the diet is at or below 0.64%. Therefore, the concentration of P in diets used to measure the digestibility of P in feed ingredients is not critical, because the same value for ATTD will be measured regardless of the inclusion level of P.

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