Digestibility of Phosphorus by Growing Pigs of Fermented and Conventional Soybean Meal Without and With Microbial Phytase

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Digestibility of Phosphorus by Growing Pigs of Fermented and Conventional Soybean Meal Without and With Microbial Phytase[1]

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ABSTRACT: An experiment was conducted to test the hypothesis that the apparent total tract digestibility (ATTD) and the standardized total tract digestibility (STTD) of P in fermented soybean meal (FSBM) are greater than in conventional soybean meal (SBM-CV) when fed to growing pigs. Four diets were formulated to contain FSBM or SBM-CV and either 0 or 800 units/kg of microbial phytase. The only sources of P in these diets were FSBM and SBM-CV. A P-free diet to estimate basal endogenous losses of P was also formulated. Thirty barrows (initial BW: 14.0 ± 2.3 kg) were placed in metabolism cages and allotted to 5 diets in a randomized complete block design with 6 pigs per diet. Feces were collected for 5 d after a 5-d adaptation period. All samples of ingredients, diets, and feces were analyzed for P, and values for ATTD and STTD of P were calculated. Results indicated that the basal endogenous P losses were 187 mg/kg of DMI. As phytase was added to the diet, the ATTD and STTD of P increased ($P < 0.01$) from 60.9 to 67.5% and from 65.5 to 71.9%, respectively, in pigs fed FSMB. Likewise, addition of phytase to SBM-CV increased ($P < 0.01$) the ATTD and STTD of P from 41.6 to 66.2% and from 46.1 to 71.4%, respectively. The ATTD and STTD of P were greater ($P < 0.01$) in FSBM than in SBM-CV when no phytase was used, but that was not observed when phytase was added to the diet (soybean meal × phytase interaction, $P < 0.01$). In conclusion, the ATTD and STTD of P in FSBM was greater than SBM-CV when no microbial phytase was added, but when phytase was added to the diets, no differences between FSBM and SBM-CV were observed in the ATTD and STTD of P.

Keywords: fermented soybean meal, phosphorus, phosphorus digestibility, phytase, pig, soybean meal

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INTRODUCTION

Most P in soybean meal (**SBM**) is bound in the phytate complex (Eeckhout and De Paepe, 1994), which may contribute to environmental problems (Knowlton et al., 2004) and increased diet costs. However, the phytase enzyme may hydrolyze P that is bound to phytate; consequently, addition of microbial phytase may increase the apparent total tract digestibility (**ATTD**) and the standardized total tract digestibility (**STTD**) of P in SBM (Almeida and Stein, 2010).

It is likely that fermentation of SBM results in hydrolysis of phytate and release of phytate-bound P because the concentration of phytate-bound P in corn distillers dried grains with solubles is less than in corn (Almeida and Stein, 2010). The bioavailability of P in fermented SBM (**FSBM**) is, therefore, expected to be greater than in conventional SBM (**SBM-CV**; Ilyas et al., 1995), but previous research failed to demonstrate an increase in the bioavailability of P in FSBM compared with SBM-CV (Hong et al., 2004). The global production of FSBM is likely less than 100,000 tons, but production has increased in recent years because FSBM is often used as a replacement for fish meal in the swine and poultry industries. Historically, most of the production has taken place in Asia, but a facility to produce FSBM in the United States was established a few years ago.

The total amount of P in the diets, as well as the excretion of P from pigs, may be reduced if diets are formulated based on values for the STTD of P rather than the values for total P (Bünsen et al., 2008, 2009). Values for the STTD of P are calculated by correcting values for

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the ATTD of P for the basal endogenous losses of P (**EPL**; Petersen and Stein, 2006). The reason for the reduced excretion of P in diets formulated based on values for STTD, rather than the ATTD of P is most likely that values for the STTD of P are additive in mixed diets, but this is not always the case for ATTD values of P (Fan et al., 2001). Values for ATTD and STTD of P have been reported for SBM-CV without and with microbial phytase (Almeida and Stein, 2010), but not for FSBM. Therefore, the objectives of this experiment were to determine the ATTD and STTD of P in FSBM without and with microbial phytase and to test the hypothesis that ATTD and STTD of P in FSBM are greater than in SBM-CV.

MATERIALS AND METHODS

The Institutional Animal Care and Use Committee at the University of Illinois reviewed and approved the protocol for this experiment.

Diets, Animals, and Experimental Design

Pigs used in the experiment were the offspring of G-performer boars mated to F-25 gilts (Genetiporc, Alexandria, MN). The ingredients that were used in the experiment (Table 1) included FSBM (PepSoyGen, Nutra Ferma, North Sioux City, SD) and SBM-CV (Solae), which is produced by aerobic fermentation of SBM in the presence of *Aspergillus oryzae* and *Lactobacillus subtilis*, and SBM-CV (Solae, Gibson City, IL). Thirty growing barrows (initial BW: 14.0 ± 2.3 kg) were placed in metabolism cages and allotted to 5 diets in a randomized complete block design with 6 replicate pigs per diet. Each metabolism cage was equipped with a feeder and a nipple drinker.

Five diets were formulated (Table 2). Two diets contained 47.0% (as-fed basis) FSBM and either 0 or 800 phytase unit (**FTU**) of microbial phytase (Optiphos 2000, Enzyvia, Sheridan, IN) per kilogram. Two additional diets contained 50.0% (as-fed basis) SBM-CV and either 0 or 800 FTU of phytase/kg. The only sources of P in the diets were FSBM and SBM-CV. The quantity of SBM in the diets was determined to equalize the concentration of P among diets, and phytase was included at an amount close to the greatest quantities that are used in commercial diets. The last diet, a P-free diet, was used to measure basal EPL (Petersen and Stein, 2006). Vitamins and minerals, except P, were included in all diets to meet or exceed the requirements for growing pigs (NRC, 1998).

Table 1. Nutrient composition of fermented soybean meal (FSBM) and conventional soybean meal (SBM-CV), as-fed basis

Item	FSBM	SBM-CV
GE, kcal/kg	4,511	4,313
DM, %	90.76	87.97
CP, %	55.54	47.22
Ca, %	0.29	0.56
P, %	0.78	0.66
Ash, %	6.69	6.30
Acid-hydrolyzed ether extract, %	1.44	1.43
NDF, %	8.82	6.14
ADF, %	4.53	4.26
TIU,[1] mg/kg	1.10	4.00
Phytase,[2] FTU/kg	<70	<70
Phytate, %	1.38	1.51
Phytate-bound P,[3] %	0.39	0.43
Phytate-bound P, % of total P	50.00	64.5
Nonphytate P,[4] %	0.39	0.23
Nonphytate-bound P, % of total P	50.00	35.5
Carbohydrates, %		
Glucose	0.23	0.00
Sucrose	0.00	9.36
Maltose	0.00	0.27
Fructose	0.37	0.00
Stachyose	0.00	6.56
Raffinose	0.00	0.98
Indispensable AA, %		
Arg	3.78	3.42
His	1.37	1.21
Ile	2.60	2.17
Leu	4.29	3.57
Lys	3.13	2.97
Met	0.75	0.63
Phe	2.81	2.33
Thr	2.07	1.73
Trp	0.71	0.73
Val	2.77	2.30
Dispensable AA, %		
Ala	2.39	1.95
Asp	6.12	5.16
Cys	0.87	0.69
Glu	9.81	8.39
Gly	2.35	1.94
Pro	2.98	2.46
Ser	2.49	1.92
Tyr	1.98	1.67
Total AA	53.27	45.24

[1]TIU = trypsin inhibitor units.

[2]FTU = phytase units.

[3]Phytate-bound P was calculated as 28.2% of phytate (Tran and Sauvant, 2004).

[4]Nonphytate P was calculated as the difference between total P and phytate-bound P.

Feeding and Sample Collection

Feed was supplied in the amount of 2.5 times the daily maintenance energy requirement (i.e., 106 kcal of ME/kg of $BW^{0.75}$; NRC, 1998). The daily amount of feed was divided into 2 equal meals that were fed at 800 and 1700 h. Water was available at all times. Individual pig

Table 2. Composition of experimental diets, as-fed basis[1]

	FSBM		SBM-CV		
Item[2]	0 FTU[2]/kg	800 FTU/kg	0 FTU/kg	800 FTU/kg	P free
Ingredient, %					
Fermented soybean meal	47.00	47.00	—	—	—
Soybean meal, 48% CP	—	—	50.00	50.00	—
Gelatin[3]	—	—	—	—	20.00
Soybean oil	—	—	—	—	4.00
Solka Floc[4]	—	—	—	—	4.00
Ground limestone	1.00	1.00	1.00	1.00	0.80
Sucrose	15.00	15.00	15.00	15.00	20.00
Cornstarch	36.30	36.26	33.30	33.26	49.22
AA mixture[5]	—	—	—	—	0.78
Sodium chloride	0.40	0.40	0.40	0.40	0.40
Phytase premix[6]	—	0.04	—	0.04	—
Vitamin-mineral premix[7]	0.30	0.30	0.30	0.30	0.30
Potassium carbonate	—	—	—	—	0.40
Magnesium oxide	—	—	—	—	0.10
Total	100.00	100.00	100.00	100.00	100.00
Analyzed composition					
GE, kcal/kg	4,016	4,012	3,885	3,907	3,965
DM, %	92.36	92.09	91.15	91.00	92.22
CP, %	27.36	27.70	24.28	22.19	24.31
Ca, %	0.54	0.62	0.78	0.65	0.32
P, %	0.38	0.39	0.38	0.33	0.01
Ash, %	4.62	4.37	4.52	4.24	1.17
NDF, %	4.35	4.21	3.17	2.93	3.44
ADF, %	2.12	2.09	2.21	2.20	3.24
Phytase, FTU/kg	<70	910	<70	690	—

[1]FSBM = fermented soybean meal; SBM-CV = conventional soybean meal; and P free = P-free diet.

[2]FTU = phytase units.

[3]Pork gelatin obtained from Gelita Gelatine USA Inc. (Sioux City, IA).

[4]Fiber Sales and Development Corp. (Urbana, OH).

[5]Contained the following AA (%, as-is basis): DL-Met, 0.27; L-Thr, 0.08; L-Trp, 0.14; L-His, 0.08; L-Ile, 0.16; and L-Val, 0.05.

[6]Optiphos 2000 (2,000 FTU/g; Enzyvia, Sheridan, IN).

[7]Provided the following quantities of vitamins and microminerals per kilogram of complete diet: vitamin A as retinyl acetate, 11,128 IU; vitamin D_3 as cholecalciferol, 2,204 IU; vitamin E as DL-α tocopheryl acetate, 66 IU; vitamin K as menadione nicotinamide bisulfite, 1.42 mg; thiamine as thiamine mononitrate, 0.24 mg; riboflavin, 6.58 mg; pyridoxine as pyridoxine hydrochloride, 0.24 mg; vitamin B_{12}, 0.03 mg; D-pantothenic acid as D-calcium pantothenate, 23.5 mg; niacin as nicotinamide and nicotinic acid, 44 mg; folic acid, 1.58 mg; biotin, 0.44 mg; Cu, 10 mg as copper sulfate; Fe, 125 mg as iron sulfate; I, 1.26 mg as potassium iodate; Mn, 60 mg as manganese sulfate; Se, 0.3 mg as sodium selenite; and Zn, 100 mg as zinc oxide.

BW were recorded at the beginning and at the end of the experiment, and the amount of feed supplied each day was also recorded. Pigs were fed their experimental diets for 12 d. The initials 5 d were considered an adaptation period to the diet. Chromic oxide and ferric oxide were added to the diet as indigestible markers in the morning meals on d 6 and d 11, respectively. The fecal collections started when chromic oxide appeared in the feces and ceased when ferric oxide appeared, as described previously (Adeola, 2001). Feces were collected twice daily and stored at −20°C immediately after collection.

Chemical Analysis

All samples were analyzed in duplicate. Fecal samples were dried at 65°C in a forced-air oven and ground through a 1-mm screen in a Wiley mill (Model 4, Thomas Scientific, Swedesboro, NJ) before analysis. Diets, ingredients, and fecal samples were analyzed for DM (method 930.15; AOAC Int., 2007). Phosphorous and Ca were analyzed in all samples by the inductively coupled plasma spectroscopy procedure (method 985.01 A, B, and C; AOAC Int., 2007) after wet ash sample preparation [method 975.03 B(b); AOAC Int., 2007]. Diets and ingredients were also analyzed for ADF (method 973.18; AOAC Int., 2007), NDF (Holst, 1973), and ash (method 942.05; AOAC Int., 2007), and for CP by combustion (method 990.03; AOAC Int., 2007) on a rapid N-cube protein/N apparatus (Elementar Americas Inc., Mt. Laurel, NJ). Fermented soybean meal and SBM-CV were analyzed for AA with an AA analyzer (Model L8800 Hitachi Amino Acid Analyzer, Hitachi

High Technologies America Inc., Pleasanton, CA) using ninhydrin for postcolumn derivatization and norleucine as the internal standard. Before analysis, samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C [method 982.30 E(a); AOAC Int., 2007]. Methionine and Cys were determined as Met sulfone and cysteic acid after cold performic acid oxidation overnight before hydrolysis [method 982.30 E(b); AOAC Int., 2007]. Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C [method 982.30 E(c); AOAC Int., 2007], and total fat concentration was measured in both sources of SBM by acid hydrolysis using 3*N* HCl (Sanderson, 1986) followed by crude fat extraction using petroleum ether (method 2003.06, AOAC Int., 2007) on an automated analyzer (Soxtec 2050, Foss North America, Eden Prairie, MN). Diets and ingredients were also analyzed for GE using adiabatic bomb calorimetry (Model 6300, Parr Instruments, Moline, IL) and for phytase activity (Phytex Method, Version 1, Eurofins, Des Moines, IA). The 2 sources of SBM were analyzed for trypsin inhibitor concentrations (method Ba 12-75; AOCS; 2006) and phytate (Ellis et al., 1977), and carbohydrates were analyzed as described by Cervantes-Pahm and Stein (2010).

Calculations and Statistical Analysis

The concentration of phytate-bound P in the 2 sources of SBM was calculated as 28.2% of analyzed phytate (Tran and Sauvant, 2004) and the concentration of nonphytate-bound P was calculated by subtracting phytate-bound P from total P. The ATTD, STTD, and EPL in each diet were calculated as described previously (Almeida and Stein, 2010). Data were analyzed as a 2 × 2 factorial using the MIXED procedure (SAS Inst. Inc., Cary, NC). Homogeneity of the variances among treatments was confirmed using the UNIVARIATE procedure, and this procedure was also used to test for outliers, but no outliers were identified. The fixed effects were source of SBM, phytase, and the interaction between SBM and phytase. Replicate was considered a random effect. The least squares means statement was used to calculate treatment means, and the PDIFF option was used to separate means if differences were detected. The pig was the experimental unit for all analyses, and an α level of 0.05 was used to assess significance among means.

RESULTS

The total amount of P in FSBM was 0.78%, whereas 0.66% P was present in SBM-CV, and the concentrations of phytate were 1.38 and 1.51% in FSBM and SBM, respectively (Table 1). Therefore, 0.39 and 0.43% P were bound in phytate in FSBM and SBM-CV, respectively. This corresponds to 50.0 and 64.5% of the total P in FSBM and SBM-CV, respectively. As a consequence, the concentrations of nonphytate-bound P were 0.39 and 0.23% in FSBM and SBM, respectively, which corresponds to 50.0 and 35.5% of the total P in FSBM and SBM, respectively.

Neither FSBM nor SBM-CV had any detectable phytase activity. Likewise, no phytase was detected in the 2 diets that contained no microbial phytase, but the phytase concentration was close to expected values for the 2 diets with added phytase, although the FSBM-diet contained 110 FTU/kg more than expected, and the diet containing SBM-CV contained 110 FTU/kg less than expected (Table 2).

One pig fed the diet containing SBM-CV and phytase failed to consume the allotted amount of feed and was removed from the experiment, but all other pigs successfully completed the experiment. Neither the source of SBM nor the amount of phytase influenced ADFI or basal EPL (Table 3). There was, however, an interaction ($P < 0.05$) between source of SBM and phytase for daily P intake because pigs fed the diet containing SBM-CV with phytase had less P intake than pigs fed SBM-CV without phytase, which was caused by the analyzed differences in P concentrations between the 2 diets. However, no differences in P intake were observed between pigs fed diets containing FSBM without and with phytase. Phosphorus concentration in feces and daily P output were reduced ($P < 0.01$) when phytase was used in the diets, and P concentration in feces and daily P output were less ($P < 0.01$) in pigs fed FSBM than in pigs fed SBM-CV. The reductions in fecal P concentration and P output that were induced by phytase were, however, greater in pigs fed SBM-CV than in pigs fed FSBM, resulting in an interaction ($P < 0.01$) between source of SBM and phytase.

Daily absorption of P was greater ($P < 0.01$) in pigs fed FSBM than in pigs fed SBM-CV and was also greater ($P < 0.05$) when phytase was added to the diets. The ATTD and STTD of P were also greater ($P < 0.01$) when phytase was used compared with no phytase in the diets, regardless of the source of SBM. The increases in ATTD and STTD when phytase was used were, however, greater for SBM-CV than FSBM, resulting in an interaction ($P < 0.01$) between SBM source and phytase. However, feeding FSBM rather than SBM-CV resulted in an increase ($P < 0.01$) in the ATTD as well as in the STTD of P.

The intake of Ca was less ($P < 0.01$) if pigs were fed FSBM without phytase than if the other diets were provided, and the interaction between source of SBM and phytase was significant ($P < 0.01$) for Ca intake. The concentration of Ca in feces was greater ($P < 0.05$) in pigs fed SBM-CV than in pigs fed FSBM, and phytase reduced ($P < 0.01$) Ca concentration in the feces, but the reduction

Table 3. Effects of phytase on the apparent total tract digestibility (ATTD) of P and Ca and the standardized total tract digestibility (STTD) of P in fermented soybean meal (FSBM) and conventional soybean meal (SBM-CV)[1]

	FSBM		SBM-CV			*P*-value		
Item	<70 FTU[2]/kg	9100 FTU/kg	<70 FTU/kg	890 FTU/kg	Pooled SEM	Source of SBM[3]	Phytase	Source of SBM × phytase
Feed intake, g of DM/d	479.7	482.2	488.1	481.2	13.6	0.57	0.84	0.97
P intake, g/d	2.0	2.0	2.0	1.7	0.1	0.14	0.17	0.02
P in feces, %	2.8	2.1	4.2	2.4	0.1	<0.01	<0.01	<0.01
P output, g/d	0.8	0.7	1.2	0.6	0.1	<0.01	<0.01	<0.01
Absorbed P, g/d	1.2	1.4	0.8	1.2	0.1	<0.01	<0.01	0.19
ATTD of P, %	60.9	67.5	41.6	66.2	2.0	<0.01	<0.01	<0.01
Basal EPL,[4] mg/d	89.5	90.0	91.1	90.0	2.9	0.57	0.84	0.97
STTD of P,[5] %	65.5	71.9	46.1	71.4	2.0	<0.01	<0.01	<0.01
Ca intake, g/d	2.8	3.2	4.2	3.4	0.1	<0.01	0.33	<0.01
Ca in feces, %	5.0	4.6	6.4	4.3	0.3	0.02	<0.01	0.03
Ca output, g/d	1.4	1.4	1.8	1.1	0.1	0.46	0.02	0.01
Absorbed Ca, g /d	1.4	1.8	2.3	2.3	0.1	<0.01	0.08	0.06
ATTD of Ca, %	50.7	55.9	56.5	67.4	3.1	0.02	0.02	0.45

[1]Data are means of 6 observations per treatment, except for the treatment with SBM-CV and phytase, which had only 5 observations.

[2]FTU = phytase units. The phytase used was Optiphos 2000 (Enzyvia, Sheridan, IN).

[3]SBM = soybean meal.

[4]EPL = basal endogenous P loss. This value was measured in pigs fed the P-free diet and determined to be 187 mg/kg of DMI. The daily basal EPL was calculated by multiplying the daily DMI by 187 mg/kg of DMI.

[5]Values for STTD were calculated by correcting values for ATTD for basal EPL.

was greater for SBM-CV than for FSBM (interaction, $P < 0.05$). Daily Ca output was also reduced ($P < 0.05$) when phytase was added to SBM-CV, but this was not the case if phytase was added to FSBM, which resulted in an interaction between SBM source and phytase ($P < 0.05$). Daily absorption of Ca was greater ($P < 0.01$) in pigs fed SBM-CV than in pigs fed FSBM, and the ATTD of Ca was less ($P < 0.05$) for pigs fed FSBM than for pigs fed SBM-CV. However, phytase increased ($P < 0.05$) the ATTD of Ca in the 2 phytase-containing diets.

DISCUSSION

Soybean meal contains both phytate-bound P and nonphytate-bound P (Eeckhout and De Paepe, 1994). The chemical name of the phytate molecule is *myo*-inositol hexaphosphate (IP6) because it has 6 atoms of P bound to the inositol molecule, and the molecular weight of this molecule is 660.04 g/mol (Selle et al., 2009). The molecular weight of P is 30.974 g/mol (Ham, 2008), and the 6 P in phytate, therefore, equates to 28.2% of the total weight of phytate (Tran and Sauvant, 2004).

The concentrations of sucrose and oligosaccharides in SBM-CV were close to expected values (Grieshop et al., 2003). However, no sucrose or oligosaccharides were detected in FSBM, which indicates that these carbohydrates are fermented during the production of FSBM. This observation is in agreement with the report of Cervantes-Pahm and Stein (2010) that no sucrose or oligosaccharides were present in FSBM. The removal of these carbohydrates was the reason the concentrations of CP, NDF, P, and other nutrients were greater in FSBM than in SBM-CV. As a consequence, the concentration of AA was also greater in FSBM than in SBM-CV, which is in agreement with previous data (Cervantes-Pahm and Stein, 2010).

The P concentration in SBM-CV was close to the value of 0.69% reported by NRC (1998). The basal EPL that was calculated in this experiment (187 mg/kg of DMI) is in agreement with previously reported values (Stein et al., 2006; Widmer et al., 2007), which indicates that the basal endogenous loss of P is relatively constant among experiments.

The 2 diets that contained phytase were formulated to contain 800 FTU, and the analyzed values were 910 and 690 FTU for FSBM and SBM-CV, respectively. The reason for these small differences from the expected value is most likely inaccuracies in the analyses of phytase and possibly also inaccuracies in diet mixing. It is unlikely that the analyzed difference between the 2 diets contributed to different responses to microbial phytase because the response to microbial phytase obtained after the inclusion of 500 FTU usually declines. The fact that the response to microbial phytase was much greater for SBM-CV than for FSBM also indicates that the P digestibility in SBM-CV was not compromised because the analyzed value was slightly less than expected.

The analyzed values for P were close to the expected values in all diets, whereas some unintended variations in the analyzed values for Ca were observed. The main

reason for the variations in Ca concentrations was most likely that SBM-CV contained twice as much Ca as expected (NRC, 1998).

To our knowledge, the ATTD and STTD of P in FSBM have never been reported previously, but the greater digestibility of P in FSBM compared with SBM-CV is likely a result of the reduced concentration of phytate-bound P in FSBM compared with SBM-CV. It is likely that fermentation of FSBM resulted in hydrolysis of phytate bonds, which increased the concentration of free P in FSBM (Ilyas et al., 1995). We are not aware of other data showing the effects of fermentation of SBM on the concentration of phytate-bound P and on the digestibility of P. However, the effect of fermentation of SBM on P digestibility appears to be similar to the effect of fermentation of corn in ethanol plants because the digestibility of P in fermented corn coproducts also is greater than that in corn and nonfermented coproducts (Pedersen et al., 2007; Widmer et al., 2007; Stein et al., 2009). Fermentation, therefore, seems to be an effective way of improving the P digestibility of feed ingredients that contain phytate-bound P.

The ATTD and STTD of P in SBM-CV without phytase that were obtained in this experiment concur with previous values (Bohlke et al., 2005), and the ATTD and STTD of P that were obtained for SBM-CV with phytase were in agreement with values reported by Almeida and Stein (2010). These values were also similar to the values obtained for FSBM. The effect of adding microbial phytase on the ATTD and STTD of P was, therefore, much greater in SBM-CV than in FSBM. The reason for this observation is most likely that the amount of phytate-bound P is greater in SBM-CV than in FSBM; therefore, phytase hydrolyzed more phytate in SBM-CV than in FSBM and increased the digestibility of P. This observation is in agreement with data indicating that the effect of microbial phytase is much greater in corn than in corn distillers dried grains with solubles, which is also a fermented feed ingredient that has a relatively low concentration of phytate-bound P (Almeida and Stein, 2010). It, therefore, appears that the response to phytase that is obtained in a particular feed ingredient depends on the amount of substrate that is available. The practical consequence of these observations is that the response to adding microbial phytase may vary among diets, depending on the feed ingredients included in the diet. The greater the quantity of phytate-bound P in the diet, the greater will be the response to microbial phytase. Using a constant value for P release from microbial phytase in diet formulations across all types of diets regardless of the ingredients that are used may therefore not always give accurate estimates of digestible P in the diet.

The fact that the STTD of P in both sources of soybean meal was approximately 71% if microbial phytase was added to the diet indicates that this may be close to the maximum digestibility of P in SBM when fed to growing pigs. However, it is possible that older pigs may have a slightly greater digestibility of P in SBM than the young growing pigs we used in this experiment because the digestibility of phytate-bound P may increase as pigs get older (Baker, 2010).

The Ca in the diets originated from a combination of Ca in the SBM and Ca from limestone. The concentration of Ca was greater in SBM-CV than in FSBM, which is the reason Ca intake was greater for pigs fed diets containing SBM-CV than for pigs fed diets containing FSBM. The ATTD of Ca in the SBM-CV diet without phytase was similar to the value reported by Bohlke et al. (2005). The ATTD of Ca increased as phytase was used in the diet, regardless of the source of SBM. It is possible that Ca that was bound in the phytate complex was released by phytase, but the majority of Ca in both diets originated from limestone. It is therefore likely that the increase in the ATTD of Ca that was observed when microbial phytase was used is a result of increased absorption of Ca from limestone. The reason for this observation may be that phytase reduced the amount of phytate in the intestine, which reduced the capacity of phytate to chelate Ca, and this increased the amount of Ca available for absorption (Selle et al., 2009). The ATTD of Ca in a corn-SBM-limestone diet is increased by microbial phytase, which supports the hypothesis that phytase may reduce the ability of phytate to chelate Ca in the intestinal tract of pigs (Selle et al., 2009).

In conclusion, the ATTD and STTD of P are greater in FSBM than in SBM-CV if microbial phytase is not added to the diet. However, if microbial phytase is used, there is no difference in the ATTD or STTD of P between FSBM and SBM-CV, and both sources have STTD values around 71%. Fermented SBM contains more digestible P than does SBM-CV, which reduces the need for inclusion of inorganic P in diets containing FSBM.

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