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Nitrogen and Phosphorus Excretion from Pigs Fed Different Soybean Fractions

B.W. Senne, S.D. Carter, L.A. Pettey and J.A. Shriver

Story in Brief

Six sets of four littermate barrows (75 lb BW) were used to determine nitrogen and phosphorus excretion of pigs fed different soybean fractions. Treatments were cornstarch-based diets with either soybean meal, soybean meal + 4% soy hulls, soy protein concentrate, or soy protein isolate used as source of nitrogen. All diets were formulated to contain .75% digestible lysine. Pigs were housed individually in metabolism chambers and fed the diets for 5 d to allow for total collection of urine and feces. Rate and efficiency of gain were not affected by dietary treatment. Dry matter excretion was highest for pigs fed soybean meal + hulls. Nitrogen absorption, as percentage of intake, was higher for pigs fed soybean meal compared with pigs fed soybean meal + hulls. Pigs fed soy protein isolate absorbed more nitrogen than pigs fed soybean meal or soy protein concentrate. Retention of nitrogen, as percentage of intake, was lower for pigs fed soybean meal + hulls compared with all other treatments. Furthermore, pigs fed either soy protein concentrate or isolate retained more nitrogen than pigs fed soybean meal. Excretion of phosphorus (g/d) was greatest for pigs fed soybean meal + hulls. There were no differences in retention of phosphorus among pigs fed soybean meal, concentrate, or isolate. These results suggest that the retention of nitrogen increases and excretion of nitrogen decreases as level of refinement increases for soybeans. Furthermore, the addition of soybean hulls to soybean meal increases dry matter, nitrogen, and phosphorus excretion while decreasing nitrogen retention.

Key Words: Pigs, Soybeans, Nitrogen, Phosphorus, Excretion, Retention

Introduction

Removal of soluble and insoluble sugars from conventional soybean meal (SBM) results in specialty products such as soy protein concentrate (SPC) and soy protein isolate (SPI). These more refined fractions of the soybean do not contain oligosaccharides and other complex sugars that can be degraded by intestinal microbes and contribute to dry matter (DM) and N excretion as well as odor. Raffinose and stachyose are two oligosaccharides which have been shown to reduce dry matter and fiber digestibility and increase manure volume in chickens (Coon et al., 1990). Removal of antinutritional factors from soybean meal should also improve N utilization (Jongbloed and Lenis, 1992). Previous research at OSU (Senne et al., 1999) has shown that pigs fed SBM have over three times the N and twice the P excretion compared with pigs fed a purified diet formulated to result in minimal nutrient excretion (Figure 1). Although not commonly fed to growing pigs, nutrient excretion values for different fractions of soy protein feed ingredients should provide insight into the degree of contribution the soluble and insoluble sugars of SBM makes to DM, N, and P excretion. Thus, the purpose of the experiment reported herein was to examine soybean meal and soy specialty products and determine their relationship to nitrogen and phosphorus excretion of growing pigs.

Materials and Methods

Procedure. Six sets of four littermate barrows (75 lb) were allotted randomly on the basis of weight within litter to four dietary treatments in a 14-d test. All diets were formulated using cornstarch and one of four soybean fractions. Diet 1 contained SBM as the primary source of dietary N (Table 1). In Diet 2, soybean hulls replaced a portion of the SBM and cornstarch in Diet 1 and were added at the amount needed to equalize nitrogen content. Diets 3 and 4 contained SPC and SPI, respectively, as a source of dietary N. All diets were formulated to contain .75% digestible lysine. Crystalline methionine and threonine were added as needed to provide an ideal ratio to lysine. Soy oil was added to make all diets isocaloric. Calcium carbonate and dicalcium phosphate were used to balance the Ca:available P to 1.9:1 for all diets. Trace minerals and vitamins were added to meet or exceed NRC (1998) standards. Potassium sulfate and sodium carbonate were used to equalize the electrolyte content of the diets.

Pigs were housed individually in metabolism chambers (2.5 × 3.3 ft) with galvanized mesh floors and allowed ad libitum access to both feed and water. Experimental diets were fed for a 7-d adaptation period followed by a 5-d total collection period. Pigs were weighed at the beginning of the experiment and on d 0 and 5 of the collection period to monitor average daily gain (ADG) and collection of urine, feces, and refused feed was performed daily.

Analysis. Feed and fecal samples were analyzed for DM according to AOAC (1990) procedures. Fecal samples to be used for N and P analyses were freeze dried to preserve N content. Feed and fecal N was analyzed with a LECO carbon-nitrogen analyzer. Feed and fecal P was determined by Inductively Coupled Plasma spectrometry. Urinary N was determined via Kjeldahl methodology.

Data were analyzed as a randomized complete block design using analysis of variance procedures as described by Steel et al. (1997). Means were compared by preplanned non-orthogonal contrasts.

Results and Discussion

There were no differences ($P>.10$) detected in ADG for the 5-d collection period; however, pigs fed SPI consumed less feed per unit of gain than pigs fed SBM ($P<.03$) and SPC ($P<.08$). Daily DM excretion (Table 2) was greatest ($P<.01$) for pigs fed SBM+hulls. Pigs fed SBM and SPC had similar (56 vs 59 g/d) DM excretion values. Pigs fed SPI excreted less ($P<.07$) DM compared to pigs fed SPC.

Nitrogen. Intake of N was similar for pigs fed SBM or SBM+hulls;

however, pigs fed SPI consumed less (P<.03) N compared with pigs fed SBM or SBM+hulls. Fecal N (g/d) was greatest (P<.01) for pigs fed SBM+hulls and lowest (P<.01) for pigs fed SPI. Pigs fed SBM excreted an average of nearly 25% more fecal N than pigs fed SPC, which, in turn, excreted an average of 40% more than pigs fed SPI. Urinary N (g/d) was similar (P>.10) across all dietary treatments but decreased numerically as refinement increased. Absorption and retention of N on a grams per day basis were not different (P>.10) among treatments. Absorption of N, as percentage of intake, was lowest (P<.01) for pigs fed SBM+hulls and greatest (P<.01) for pigs fed SPI. Pigs fed SBM tended to have lower (P<.10) absorbed N compared with pigs fed SPC. Retention of N, as percentage of intake, was similar (P>.10) for pigs fed SBM, SPC, or SPI; however, pigs fed SBM+hulls retained less N than pigs fed any other treatment (P<.03). Retention of N, as percentage of absorbed N, was similar (P>.10) across all treatments.

Phosphorus Pigs fed SBM + hulls had greater (P<.04) P intake, fecal P, and total P excretion when compared with pigs fed SBM (Table 2). Urinary P was below detection levels for all treatments except SBM+hulls, therefore total P excretion values are identical to fecal P values for all treatments except SBM+hulls. No differences were observed (P>.10) in P excretion for pigs fed SPC or SPI. Retention of P, as percentage of intake, was lowest (P<.04) for pigs fed SPI.

The addition of soy hulls had a dramatic effect on DM excretion, absorbed and retained N, as a percentage of intake, and P excretion. These results are probably due to the high fiber and unavailable P content of soy hulls. When soy hulls are added back to SBM, an 18% increase in N and a 9% increase in total P excretion occurred (Figure 2). Total N excretion for pigs fed SPC was 12% less than pigs fed SBM, and pigs fed SPI had another 11% decrease in total N excretion compared with SPC pigs. Thus, pigs fed SPI had a 23% reduction in N excretion compared with pigs fed SBM. Nitrogen digestibility, while not significant, increased numerically as the soluble and insoluble sugars were removed from the soybean. This agrees with Leske et al., (1993) who reported a numerical decrease in CP digestibility in chickens fed stachyose and raffinose additions to SPC. As % N of the ingredients increased (7.7, 10.3, 13.2% for SBM, SPC, and SPI, respectively), total N excretion decreased. For every 1% increase in % N as the soy proteins became more refined, there was approximately a .5% decrease in total N excretion. Phosphorus excretion also was reduced by refinement of the soybean.

Implications

Removal of the soluble sugars and fiber content in soybean meal has the potential to increase apparent nitrogen digestibility and decrease phosphorus excretion. Although these more refined fractions of the soybean are not commonly fed to growing pigs, the development of low oligosaccharide soybean varieties should prove useful in minimizing nutrient excretion. Also, the practice of adding soy hulls back into soybean meal can increase nitrogen and phosphorus excretion, which can raise the environmental concerns of modern swine operations.

Literature Cited

AOAC. 1990. Official Methods of Analysis (15th Ed.). Association of Official Analytical Chemists, Arlington, VA.

Coon, C.N. et al. 1990. Poultry Sci. 69:787.

Jongbloed, A.W. and N.P. Lenis. 1992. Live. Prod. Sci. 31:75.

Leske, K.L. et al. 1993. Poultry Sci. 72:664.

NRC. 1998. Nutrient Requirements of Swine (10th Ed.). National Academy Press, Washington, DC.

Senne, B.W. et al. 1999. Okla. Agr. Exp. Sta. Res. Rep. P-973:280.

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Table 1. Composition of diets[a].

	Treatment			
Ingredient, %	SBM	SBM + hulls	SPC	SPI
Corn starch	65.19	60.38	76.44	79.23
Soybean meal, 48%	29.52	28.75		
Soybean hulls		4.11		
Soy protein concentrate			19.26	
Soy protein isolate				16.29
Soy oil	1.0	2.52		
DL-methionine	.11	.11	.12	.13
L-threonine	.07	.07		.05
NaCl	.27	.27	.27	.27
Dical. Phosphate	1.37	1.37	1.37	1.45
$CaCO_3$	.57	.53	.65	.76
K_2SO_4	.46	.46	.46	.46
$NaHCO_3$	.90	.90	.88	.80
Vit, Min PM	.30	.30	.30	.30

Antibiotic	.25	.25	.25	.25
Calculated analysis				
ME, Mcal, kg	3.4	3.4	3.4	3.4
Total CP, %	14.1	14.1	12.5	14.2
Total AA, %				
Lysine	.89	.89	.81	.86
TSAA	.53	.53	.49	.49
Threonine	.61	.62	.54	.57
Tryptophan	.19	.19	.17	.18
Digestible AA, %				
Lysine	.75	.75	.75	.75
TSAA	.45	.45	.45	.45
Threonine	.49	.49	.49	.49
Tryptophan	.16	.16	.16	.16
Calcium, %	.61	.61	.61	.61
Total P, %	.49	.48	.44	.41
Available P, %	.32	.32	.32	.32

[a]As-is basis.

Table 2. Effects of different soybean fractions on nitrogen and phosphorus balance (dry matter basis).[a]

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	Treatment				
Item	SBM	SBM + hulls	SPC	SPI	SE
DM excretion, g/d	55.5[b]	102.5[c]	58.7[b]	41.2[b]	6.6
Apparent N balance, g/d					
N intake	38.1[b]	38.7[b]	34.2[bc]	32.9[c]	1.5
Fecal N excretion	3.3[b]	5.2[c]	2.6[d]	1.5[e]	.19
Urinary N excretion	8.2[b]	8.2[b]	7.7[b]	7.4[b]	.38
Total N excretion	11.5[b]	13.6[c]	10.2[bd]	8.9[d]	.51
Absorbed N	34.0[b]	34.2[b]	32.7[b]	31.3[b]	1.5
Retained N	25.8[b]	25.8[b]	25.1[b]	23.9[b]	1.4
Apparent N balance, %					
Absorbed, % of intake	91.2[b]	86.9[c]	92.7[b]	95.3[d]	.55
Retained, % of intake	69.2[b]	65.5[c]	70.9[b]	72.5[b]	1.5
Retained, % of absorbed	75.9[b]	75.3[b]	76.5[b]	76.1[b]	1.4
Apparent P balance,					

g/d					
P intake	7.5[b]	8.9[c]	6.7[bd]	6.4[d]	.29
Fecal P	2.3[bc]	2.9[c]	2.0[b]	1.8[b]	.20
Urinary P	--	.17	--	--	--
Total P	2.3[b]	3.1[c]	2.0[b]	1.8[b]	.21
Absorbed P	5.1[b]	6.0[c]	4.8[b]	4.5[b]	.28
Retained P	5.1[bc]	5.8[c]	4.8[b]	4.5[b]	.28
Apparent P balance, %					
Absorbed, % of intake	69.2[b]	67.8[b]	71.4[b]	71.1[b]	2.5
Retained, % of intake	69.1[b]	66.0[b]	71.4[b]	70.6[b]	2.6

[a]Least squares means for six individually penned pigs per treatment.
[b,c,d,e]Means within row with different superscripts differ, P<.05.

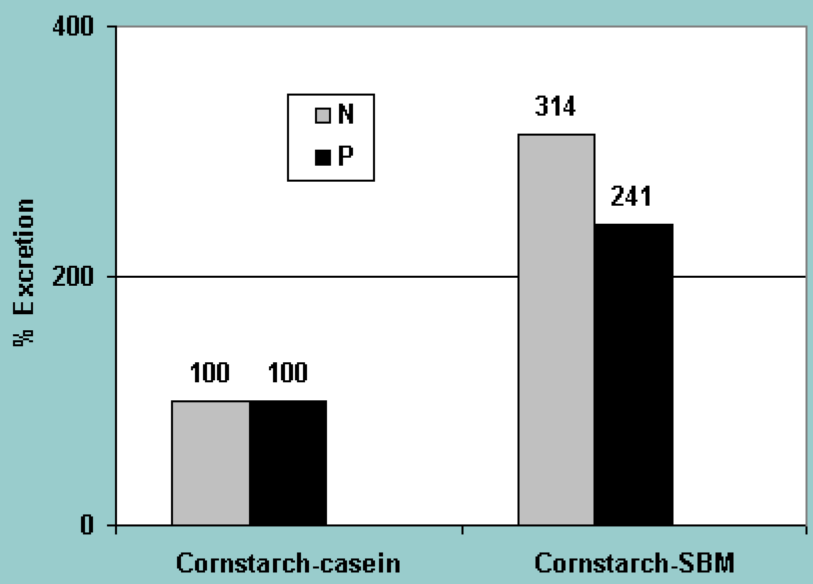

Figure 1. Nitrogen and phosphorus excretion as percentage of intake.[a]

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Calculated analysis				
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Total AA, %				
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TSAA	.53	.53	.49	.49
Threonine	.61	.62	.54	.57
Tryptophan	.19	.19	.17	.18
Digestible AA, %				
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TSAA	.45	.45	.45	.45
Threonine	.49	.49	.49	.49
Tryptophan	.16	.16	.16	.16
Calcium, %	.61	.61	.61	.61
Total P, %	.49	.48	.44	.41
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[a]As-is basis.

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Urinary N excretion	8.2[b]	8.2[b]	7.7[b]	7.4[b]	.38
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Retained N	25.8[b]	25.8[b]	25.1[b]	23.9[b]	1.4
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Absorbed, % of intake	91.2[b]	86.9[c]	92.7[b]	95.3[d]	.55
Retained, % of intake	69.2[b]	65.5[c]	70.9[b]	72.5[b]	1.5
Retained, % of absorbed	75.9[b]	75.3[b]	76.5[b]	76.1[b]	1.4
Apparent P balance,					

g/d					
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Absorbed, % of intake	69.2[b]	67.8[b]	71.4[b]	71.1[b]	2.5
Retained, % of intake	69.1[b]	66.0[b]	71.4[b]	70.6[b]	2.6

[a]Least squares means for six individually penned pigs per treatment.
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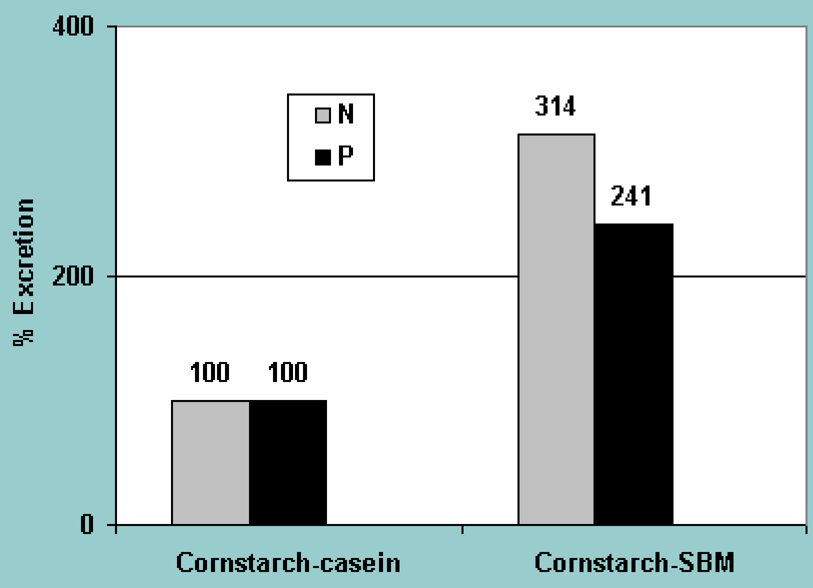

Figure 1. Nitrogen and phosphorus excretion as percentage of intake.[a]