Apparent ileal digestibility of amino acids and the digestible and metabolizable energy content of dry extruded-expelled soybean meal and its effects on growth performance of pigs[1,2]

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ABSTRACT: We conducted three experiments to determine the apparent ileal digestibility of amino acids (Exp. 1), metabolizable and digestible energy (Exp. 2), and feeding value (Exp. 3) of dry extruded-expelled soybean meal with (DEH) or without (DENH) hulls compared with solvent-extracted soybean meal with hulls removed (SBMNH). Soybeans used to produce DEH were unadulterated prior to extrusion, but those used for DENH were dehulled prior to extrusion. In Exp. 1, six nonlittermate barrows (initially 39 kg) were fitted with ileal T-cannulas and used in a replicated 3 × 3 Latin square design digestion trial. Experimental diets (0.80% total lysine) were cornstarch-based and contained soybean meal from one of the three different sources as the sole source of lysine. Apparent ileal digestibilies of nutrients were similar ($P > 0.10$) for DEH and DENH. Apparent ileal digestibilies of CP, Lys, Ile, Leu, Arg, Phe, and Val were greater ($P < 0.05$) for DEH and DENH than for SBMNH. In Exp. 2, six barrows (initially 41 kg) were fed three corn-based diets containing 25% of one of the three soybean meal sources. A fourth diet was fed at the end of the trial containing all ingredients except soybean meal, so that energy values of the soybean meal could be determined by difference. Digestible energy and ME contents were similar ($P > 0.10$) for DEH and DENH and both had greater ($P < 0.05$) DE and ME contents than SBMNH. In Exp. 3, pigs (n = 216, initially 10.6 ± 1.3 kg and 35 ± 3 d of age) were blocked by weight and allotted to six dietary treatments. Corn-soybean meal-based diets (0.95% digestible lysine and 3.44 kcal/g ME) containing DEH or DENH were compared with similar diets containing SBMNH or solvent-extracted soybean meal with hulls (SBMH). In addition, a diet containing a second expelled soybean meal with hulls (ESBM) was compared with a diet containing SBMH and soy oil. Growth performance of pigs fed diets containing DEH or DENH was not different ($P > 0.10$) than that of pigs fed corresponding diets containing SMBH or SBMNH. Pigs fed ESBM had lower ($P < 0.05$) ADG and G/F compared with its corresponding SBMH and soy oil diet. In conclusion, DEH and DENH are more digestible than conventional soybean meal and can be successfully used in swine diets.

Key Words: Digestibility, Extruded Foods, Growth, Pigs, Soybean Oil

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Introduction

Raw soybean products contain trypsin inhibitors and other antinutritional factors (Liener, 1994) that will reduce digestibility of amino acids and consequently the growth performance of swine and poultry (Rudolph et al., 1983; Vandergrift et al., 1983; Herkelman et al., 1992). Heat treatment of raw soybeans has been shown to decrease the trypsin inhibitor concentration and elicit improved growth performance for nonruminants (Chang et al., 1987; Herkelman et al., 1991).

Nelson et al. (1987) reported that dry extrusion aids in the mechanical extraction of oil from soybeans. Recently, this technology has been adopted, and an alternative means of producing soybean meal for the livestock industry has been developed (Insta-Pro Express extruder/press system). This dry extrusion-expelling technique results in a meal with a greater fat content than conventionally processed, solvent-extracted soy-

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bean meal (5 vs 1%, respectively), but has similar trypsin inhibitor values. The nutritional adequacy of dry extruded-expelled soybean meal for swine has not been determined. Therefore, we conducted experiments to determine the digestible nutrient content of these meals and to evaluate their use in diets of young pigs.

Materials and Methods

General

Protocols used in these experiments were approved by the Kansas State University Institutional Animal Care and Use Committee. All pigs used were offspring of PIC L326 or L327 boars and C22 sows. The dry extruded-expelled soybean meal products used in these trials were produced and provided by Insta-Pro International, a division of Triple “F” Inc., Des Moines, IA. Two dry extruded-expelled soybean meal products were processed by the Insta-Pro Express extruder/press system, using the Model 2500 Insta-Pro Dry-Extruder and Model 1500 Continuous Horizontal Press. Dry extruded-expelled soybean meal with hulls (**DEH**) was produced from soybeans that were unaltered prior to extrusion, and dry extruded-expelled soybean meal with hulls removed (**DENH**) was produced from soybeans that were dehulled prior to extrusion. Extruder temperatures and production rates for DEH and DENH were 156 and 158°C and 850 and 873 kg/h, respectively. The solvent-extracted soybean meals with added hulls (**SBMH**) or with hulls removed (**SBMNH**) used in these trials were obtained commercially and were representative of typical low- and high-protein soybean meal, respectively. The alternative expelled soy product (**ESBM**; SoyPLUS, Ralston, IA) evaluated in Exp. 3 is commercially available and used commonly as a bypass protein source in ruminant diets. All soybean products were analyzed to determine DM, CP, GE, ash, crude fat, crude fiber, and AA contents by AOAC (1995) methods and urease activity, FFA, and peroxide value by AOCS (1990) methods before beginning the experiments (Table 1).

Experiment 1

Six nonlittermate barrows were used to compare the apparent ileal digestibility of nutrients from SBMNH, DEH, and DENH. Each pig was fitted surgically with a simple T-cannula approximately 15 cm anterior to the ileocecal valve with procedures similar to those described by Knabe et al. (1989). Pigs were used previously to determine the digestibility of amino acids in different corn varieties (O’Quinn et al., 2000) but were allowed a 15-d adjustment period before the start of this experiment. Pigs (initially 37.2 to 39.9 kg) were housed in stainless-steel metabolism cages (1.5 × 0.6 m) designed to allow separate collection of urine and feces, and were allotted randomly to one of three dietary treatments in a replicated 3 × 3 Latin square design.

Diets were formulated using analyzed nutrient compositions of the three soybean meal sources (Table 1). The diets (Table 2) were cornstarch-based and formulated so that each soybean meal source provided the same amount of total lysine (0.80%). All diets contained 0.25% chromic oxide as an indigestible marker.

Each 5-d feeding period consisted of a 3-d acclimation period followed by 2 d (8 h/d) for collection of ileal digesta. Feed was divided into two equal meals and fed at 0600 and 1800 each day. All pigs were fed 1.361, 1.452, and 1.542 kg/d during Periods 1, 2, and 3, respectively. Water was provided twice daily at a rate of 2:1 water:feed (wt:wt). Average weight of the pigs at the end of Period 3 ranged from 46.3 to 49.4 kg.

Ileal digesta were collected between 0600 and 1400 on two consecutive days by attaching a latex balloon to the cannula. Digesta in the balloon were removed every 15 min and stored on ice during the 8-h collection period. At the end of each day’s collection period, each animal’s total collection was homogenized and a 200-g subsample was collected and frozen. The two subsamples from each pig in its respective period were homogenized, freeze-dried, and finely ground before chemical analyses for Cr (Kimura and Miller, 1957), CP, DM, ash, and AA (AOAC, 1995). All nutrient digestibilities were calculated using chromic oxide as an indigestible marker.

Experiment 2

In Exp. 2, six nonlittermate barrows (initially 39.0 to 42.3 kg), which differ from those in Exp. 1 were used to determine DE and ME values for the three soybean meal sources. Housing for pigs was similar to that described for Exp. 1. Pigs were allotted to one of three experimental treatments in a replicated 3 × 3 Latin square design. Diets (Table 3) were formulated to contain 25% of one of the three different soybean meal sources evaluated in Exp.1. Because the corn in each diet also supplied energy, a fourth diet containing all ingredients except soybean meal was fed at the end of the experiment. The fourth collection period was used to determine the energy value of the corn, so energy values for the soybean meals could be determined by difference (Adeola and Bajjalieh, 1997). Corn was ground to a mean particle size of 540 μm.

The four feeding periods consisted of 3 d of diet acclimation followed by 4 d of total collection of feces and urine. Ferric oxide (1% of diet) was used as the indigestible marker to identify the beginning and end of each fecal collection period. It was added to the first meal of the collection period, and fecal collection began with the appearance of marked feces. It also was added in the ninth meal, and fecal collection stopped with the appearance of marked feces. Feces were collected twice daily and pooled for each period. After mixing, a representative subsample was used for DM determination and another sample was freeze-dried and ground for chemical analysis. Urine was collected into

Table 1. Analyzed composition of soybean meals[a]

	Solvent-extracted		Dry extruded-expelled		Expelled
Item	With hulls	Without hulls	With hulls	Without hulls	With hulls
DM, %	88.66	88.25	94.59	95.96	88.80
CP, %	45.40	47.14	47.52	50.47	42.14
GE, kcal/g	4.17	4.25	4.67	4.71	4.68
Ash, %	6.52	6.76	6.03	6.24	5.51
Crude fat, %	1.20	1.14	4.89	5.86	5.43
Crude fiber, %	6.60	3.60	4.80	3.30	6.40
Urease activity, Δ pH	0.03	0.03	0.03	0.03	0.03
Free fatty acid, %	5.10	9.10	1.70	0.90	2.80
Peroxide value, mEq/kg	23	21	33	40	2.4
Amino acids, %					
Arginine	3.27	3.37	3.85	3.57	2.83
Histidine	1.24	1.27	1.27	1.35	1.17
Isoleucine	2.02	2.14	2.08	2.31	1.95
Leucine	3.60	3.66	3.68	3.89	3.28
Lysine	2.68	2.97	2.96	3.11	2.47
Methionine	0.62	0.66	0.65	0.69	0.61
Phenylalanine	2.30	2.41	2.41	2.58	2.20
Threonine	1.62	1.83	1.85	1.93	1.70
Tryptophan	0.58	0.68	0.73	0.72	0.60
Valine	2.11	2.30	2.24	2.46	2.02
Alanine	1.87	2.12	2.10	2.21	1.82
Aspartic acid	4.88	5.29	5.28	5.59	4.77
Cystine	0.71	0.73	0.82	0.83	0.65
Glutamic acid	7.97	8.30	8.19	8.72	7.59
Glycine	1.85	1.99	1.99	2.07	1.80
Proline	2.20	2.35	2.32	2.44	2.09
Serine	1.91	2.10	2.16	2.19	2.05
Tyrosine	1.72	1.69	1.69	1.78	1.58

[a]Values (as-fed basis) represent the mean of one sample analyzed in duplicate.

plastic bottles containing 25 mL of 6 *N* HCl. Ten percent of each day's output (volume basis) was stored frozen, pooled within a collection period, and centrifuged (2,000 × g) to remove trace amounts of particulate matter. Feces and urine were analyzed for GE using adiabatic bomb calorimetery.

Table 2. Percentage composition of diets, Exp. 1[a]

	Soybean meal source		
		Dry extruded-expelled	
Ingredient	Solvent-extracted without hulls	With hulls	Without hulls
Cornstarch	68.57	69.01	70.13
Soybean meal	27.47	27.03	25.91
Monocalcium phosphate	2.29	2.29	2.29
Limestone	0.67	0.67	0.67
Salt	0.35	0.35	0.35
Vitamin premix[b]	0.25	0.25	0.25
Trace mineral premix[c]	0.15	0.15	0.15
Chromic oxide	0.25	0.25	0.25
Calculated analysis, %[d]			
CP	12.65	12.43	12.60
Lysine	0.80	0.80	0.80
Ca	0.75	0.75	0.75
P	0.66	0.65	0.65

[a]Values expressed on an as-fed basis.
[b]Provided per kilogram of complete feed: 11,024 IU vitamin A; 1,653 IU vitamin D_3; 44.1 IU vitamin E; 4.4 mg menadione; 9.92 mg riboflavin; 33.1 mg pantothenic acid; 55.1 mg niacin; and 0.04 mg vitamin B_{12}.
[c]Provided per kilogram of complete feed: 39.7 mg Mn, 165.4 mg Fe, 165.4 mg Zn, 16.5 mg Cu, 0.30 mg I, and 0.30 mg Se.
[d]Based on analyzed values reported in Table 1.

Table 3. Percentage composition of diets, Exp. 2[a]

Ingredient	Periods 1, 2, and 3	Period 4[b]
Corn	71.59	96.22
Soybean meal[c]	25.00	—
Monocalcium phosphate	1.39	1.81
Limestone	1.07	1.02
Salt	0.35	0.35
Chromic oxide	0.25	0.25
Vitamin premix[d]	0.20	0.20
Trace mineral premix[e]	0.15	0.15

[a]Values expressed on an as-fed basis.
[b]The corn diet was used to determine the energy value of corn, so energy values of the soybean meal products could be determined by difference.
[c]The three experimental treatments contained solvent-extracted soybean meal without hulls or dry extruded-expelled soybean meal with hulls or without hulls.
[d]Provided per kilogram of complete feed: 8,818 IU vitamin A; 1,323 IU vitamin D_3; 35.3 IU vitamin E; 3.5 mg menadione; 7.9 mg riboflavin; 26.5 mg pantothenic acid; 44.1 mg niacin; and 0.04 mg vitamin B_{12}.
[e]Provided per kilogram of complete feed: 39.7 mg Mn, 165.4 mg Fe, 165.4 mg Zn, 16.5 mg Cu, 0.30 mg I, and 0.30 mg Se.

Feed was divided into two equal meals and fed at 0600 and 1800 each day. Daily feed intakes for each pig were 1.225, 1.452, 1.633, and 1.814 kg/d for Periods 1, 2, 3, and 4, respectively. Water was provided twice daily at a rate of 2:1 water:feed (wt:wt). Average weight of the pigs at the end of Period 4 ranged from 58.5 to 62.6 kg.

Experiment 3

A total of 216 weanling pigs (initially 6.1 ± 1.2 kg and 21 ± 3 d of age) was used in a 35-d growth trial to determine the influence of different soybean meal-processing techniques on growth performance. Pigs were weaned initially into pens (six pigs per pen) and fed for 14 d two diets similar to those used in commercial production. The first diet (1.6% total lysine, 0.45% methionine, 0.9% Ca, and 0.8% P) was fed at a rate of 0.45 kg per pig, and the other diet (1.45% lysine, 0.43% methionine, 0.9% Ca, and 0.8% P) was fed for the remainder of the 14-d period. On d 12, pigs were weighed and allotted randomly by sex, ancestry, and weight into six replications of six pens. Each pen contained six pigs. On d 14 after weaning, pigs averaged 10.6 kg and 35 d of age.

Starting on d 14 after weaning, six experimental diets (Table 4) were fed for 21 d. All diets were fed in meal form and were formulated so that three preplanned comparisons could be evaluated. Four diets were formulated to contain equal apparent ileal digestible lysine and ME concentrations. Nutrient and digestibility values used for SBMNH, DEH, and DENH were from Exp. 1 and 2, whereas those for SBMH were from the NRC (1998). Two diets containing DEH and DENH were compared with two diets containing SBMH and SBMNH with added soy oil (4.57 and 3.21%, respectively). The DEH and DENH originated from the same batches used in Exp. 1 and 2. A fifth diet containing ESBM was formulated to contain total lysine (1.10%) and crude fat (4.32%) contents similar to those for DENH. Pigs fed this diet were compared with those fed a diet containing SBMH and 1.61% soy oil formulated to contain the same total lysine and crude fat concentrations. These two diets were formulated on a calculated total nutrient basis because digestibility values were not available for ESBM. The ESBM was included in this experiment to determine whether another expelled soybean product would influence growth performance differently than solvent-extracted soybean meal.

Pigs were housed in an environmentally controlled nursery at the Kansas State University Swine Teaching and Research Center. The temperature of the nursery was initially 34°C and was reduced approximately 1.5°C each week thereafter. Each pen was 1.2 × 1.5 m and contained one nipple waterer and one four-hole self-feeder to provide pigs ad libitum access to water and feed. Pigs were weighed and feed disappearance was determined weekly to determine ADG, ADFI, and the gain/feed (**G/F**) ratio.

Statistical Analysis

Data for Exp. 1 and 2 were analyzed using the GLM procedure of SAS (SAS Inst. Inc., Cary, NC) with pig as the experimental unit. Data from both trials were analyzed as a replicated 3 × 3 Latin square design in which the model included the effects of treatment, square (replication), period, and two-way interactions of pig and square. Data for Exp. 3 were analyzed as a randomized complete block design with pen as the experimental unit. Three planned comparisons were evaluated. Contrast statements were used to compare the growth performance of pigs fed diets containing DEH, DENH, or ESBM with their corresponding solvent-extracted soybean meal and added soy oil diets formulated to contain the same lysine and energy concentrations.

Results

The concentration of many nutrients was determined (as-fed basis) to be greater for the DEH and DENH than for the SBMNH (Table 1). However, the dry extruded-expelled soybean meals had 6 to 7 percentage units greater DM than the conventionally processed soybean meals. Thus, when soybean meal sources are compared on an equal-DM basis, the nutrient profiles were similar.

Experiment 1

No differences ($P > 0.10$; Table 5) in apparent ileal digestibilities of nutrients were observed between DEH or DENH. However, the apparent ileal digestibilities of CP, arginine, isoleucine, leucine, lysine, phe-

Table 4. Percentage composition of diets, Exp. 3[a]

	Soybean meal source					
Ingredient	Dry extruded-expelled without hulls[b]	Solvent-extracted without hulls	Dry extruded-expelled with hulls[b]	Solvent-extracted with hulls	Expelled with hulls[c]	Solvent-extracted with hulls
Corn	66.01	60.18	64.37	55.66	57.24	58.79
Soybean meal	29.60	32.23	31.25	35.49	38.50	35.34
Soy oil	—	3.21	—	4.57	—	1.61
Monocalcium phosphate	1.54	1.55	1.54	1.49	1.39	1.46
Limestone	1.10	1.08	1.09	1.04	1.12	1.05
Medication[d]	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix[e]	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix[f]	0.15	0.15	0.15	0.15	0.15	0.15
Calculated analysis						
CP, %	20.42	20.19	20.19	20.73	20.98	20.92
Crude fat, %	4.31	5.92	4.04	7.17	4.32	4.32
ME, kcal/g	3.44	3.44	3.41	3.41	—	—
Lysine, total, %	1.09	1.11	1.09	1.10	1.10	1.10
Lysine, ileal digestible %	0.95	0.95	0.95	0.95	—	—
Methionine, %	0.32	0.32	0.31	0.31	0.33	0.32
Ca, %	0.80	0.80	0.80	0.80	0.80	0.80
P, %	0.70	0.70	0.70	0.70	0.70	0.70

[a]Values expressed on an as-fed basis.
[b]Dry extruded-expelled soybean meal products were processed using the Insta-Pro Express™ extruder/press system.
[c]Expelled soybean meal is a commercially available soybean meal product.
[d]Provided 55 mg of carbadox per kg of complete feed.
[e]Provided per kg of complete feed: 11,024 IU vitamin A; 1,653 IU vitamin D_3; 44.1 IU vitamin E; 4.4 mg menadione; 9.92 mg riboflavin; 33.1 mg pantothenic acid; 55.1 mg niacin; and 0.04 mg vitamin B_{12}.
[f]Provided per kg of complete feed: 39.7 mg Mn, 165.4 mg Fe, 165.4 mg Zn, 16.5 mg Cu, 0.30 mg I, and 0.30 mg Se.

Table 5. Apparent ileal digestibility (%) of nutrients in soybean meals, Exp. 1[a]

	Soybean meal source			
		Dry extruded-expelled		
Item	Solvent-extracted without hulls	With hulls	Without hulls	SEM
DM	84.8	85.7	85.8	0.6
CP	83.2[b]	86.2[c]	85.4[c]	0.8
Ash	37.3	36.5	33.3	1.7
Amino acids				
Arginine	91.4[b]	93.7[c]	93.8[c]	0.2
Histidine	88.1	89.4	89.9	0.6
Isoleucine	87.0[b]	89.7[c]	89.9[c]	0.4
Leucine	85.5[b]	88.5[c]	88.6[c]	0.5
Lysine	88.6[b]	90.9[c]	91.1[c]	0.5
Methionine	89.1	88.9	88.5	0.5
Phenylalanine	86.8[b]	90.0[c]	90.4[c]	0.4
Threonine	78.2	79.1	79.8	1.0
Tryptophan	87.0	88.4	87.3	0.6
Valine	85.2[b]	87.4[c]	87.4[c]	0.5
Alanine	82.3[b]	85.1[c]	85.4[c]	0.8
Aspartic acid	85.7[b]	88.9[c]	89.2[c]	0.5
Cystine	80.7	82.0	82.7	1.0
Glutamic acid	89.9[b]	92.5[c]	92.6[c]	0.3
Glycine	75.2	73.4	76.5	1.5
Proline	83.2	81.6	83.3	1.7
Serine	82.7[b]	84.7[c]	84.9[c]	0.6
Tyrosine	84.7	86.9	86.7	0.7

[a]Values are the means of six pigs (initially 39 kg) used in a replicated 3 × 3 Latin square design.
[b,c]Means within a row without common superscripts differ ($P < 0.05$).

Table 6. Energy values of soybean meal sources, kcal/g (as-fed basis), Exp. 2[a]

	Soybean meal source			
		Dry extruded-expelled		
Item	Solvent-extracted without hulls	With hulls	Without hulls	SEM
Digestible energy	3.66[b]	4.12[c]	4.21[c]	0.036
Metabolizable energy	3.41[b]	3.88[c]	3.96[c]	0.037

[a]Values are the means of six pigs (initially 41 kg) used in a replicated 3 × 3 Latin square design.
[b,c]Means within a row without common superscripts differ ($P < 0.05$).

nylalanine, valine, alanine, aspartric acid, glutamic acid, and serine were greater ($P < 0.05$) for the DEH and DENH than for the SBMNH. The advantage of the DEH and DENH averaged 2.6 percentage units and ranged from 1.4 (lysine) to 3.4 (phenylalanine) percentage units. Digestibility values for SBMNH were similar to those estimated by NRC (1998).

Experiment 2

No differences ($P > 0.10$; Table 6) in DE or ME were observed between DEH and DENH. The SBMNH had lower ($P < 0.05$) DE and ME values compared with DEH and DENH. The DE and ME values for SBMNH (3.66 and 3.41 kcal/g, respectively) were similar to published values (3.69 and 3.38 kcal/g, respectively; NRC, 1998).

Experiment 3

From d 0 to 14 after weaning when pigs were fed a common diet, ADG, ADFI, and G/F were 318 g, 400 g, and 0.80, respectively. For any time period or the cumulative study, pigs fed diets containing DEH and DENH had similar ($P > 0.10$; Table 7) ADG, ADFI, and G/F compared with those fed the diets containing SBMH and SBMNH and soy oil. From d 0 to 7, 14 to 21, or 0 to 21 of the experimental period, pigs fed the diet containing ESBM had decreased ($P < 0.05$) ADG and poorer ($P < 0.004$) G/F than pigs fed the similarly formulated diet containing SBMH and soy oil.

Discussion

Apparent ileal digestibilities of amino acids for SBMNH were similar to or greater than those reported in other research and literature reviews (Knabe et al., 1989; Southern, 1991; NRC, 1998). In our experiment, apparent ileal digestibilities of amino acids were not different for DEH and DENH. Likewise, the apparent ileal digestibilities of amino acids for SBMH and SBMNH have previously been shown to be similar (Southern, 1991; NRC, 1998). However, DEH and DENH had greater digestibility values than SBMNH. The improved digestibility we observed may have resulted from the higher fat contents of DEH and DENH compared with SBMNH. Mateos et al. (1982) observed that increasing the fat content of a diet fed to chicks decreased the rate of passage and thus may have improved the digestibility of the dietary components. Kass et al. (1980) also showed that rate of passage was correlated to the total-tract digestibility of dietary components in swine. The improvement in digestibility also could be explained by differences in processing, because Marty and Chavez (1993) showed that extruded, full-fat soybeans had greater total-tract CP digestibility when fed to pigs initially weighing 17.1 kg BW than conventionally processed, solvent-extracted soybean meal or full-fat soybeans processed by jet sploding, micronization, or roasting.

In Exp. 2, DEH and DENH had higher DE and ME values compared with SBMNH, reflective of the higher GE values initially present. Other research also has shown that extrusion improves the availability of energy to swine. Rodhouse et al. (1992) reported that extruded soybean meal had greater DE and ME compared with soybean meal that was not extruded. Marty and Chavez (1993) showed that extruded full-fat soybeans had greater DE values than full-fat soybeans processed by jet sploding, micronization, or roasting. Kim et al. (2000) also found that extruded soybeans had greater GE digestibility than roasted soybeans. Furthermore, Featherston and Rogler (1966) reported that extrusion caused the oil seed cells to rupture, and the subsequent release of oil increased fat digestibility when the soybeans were fed to chickens.

As expected, in Exp. 3, pigs fed diets containing DEH and DENH had similar growth performance compared with pigs fed the corresponding diets containing SBMH and SBMNH and soy oil, and formulated on a basis of equal apparent digestible lysine and ME. This suggests that the dry extruder-expeller process is capable of reducing the antinutritional factors found in raw soybeans to concentrations similar to those of commercially available, solvent-extracted soybean meal. Similarly, Zhang et al. (1993) showed that soybeans that were dry extruded at 138 or 154°C and then expelled had the same feeding value for chicks as soybeans that were only extruded at the same temperatures, or commercially obtained, dehulled soybean meal.

In Exp. 3, pigs fed the diet containing ESBM had poorer ADG and G/F than those fed the diet containing SBMH and soy oil and formulated on a basis of equal total lysine and crude fat. The ESBM used in our ex-

Table 7. Influence of different soybean meal processing techniques on growth performance of nursery pigs, Exp. 3[a,b]

	Soybean meal source							Contrasts, $P <$[c]		
Item	Dry extruded-expelled without hulls	Solvent-extracted without hulls	Dry extruded-expelled with hulls	Solvent-extracted with hulls	Expelled with hulls	Solvent-extracted with hulls	SEM	1	2	3
Day 0 to 7										
ADG, g	399	426	420	428	375	454	13.42	0.17	0.65	0.001
ADFI, g	700	701	696	714	708	734	22.34	0.96	0.57	0.41
G/F	0.57	0.61	0.61	0.60	0.53	0.62	0.017	0.18	0.78	0.002
Day 7 to 14										
ADG, g	562	556	543	517	532	568	21.56	0.83	0.40	0.26
ADFI, g	940	930	926	907	958	966	30.37	0.83	0.66	0.84
G/F	0.60	0.60	0.59	0.57	0.56	0.59	0.018	0.98	0.48	0.22
Day 14 to 21										
ADG, g	693	687	707	685	631	693	21.00	0.83	0.46	0.05
ADFI, g	1,252	1,225	1,231	1,271	1,291	1,229	37.64	0.63	0.46	0.26
G/F	0.55	0.56	0.57	0.54	0.49	0.56	0.016	0.71	0.14	0.004
Day 0 to 21										
ADG, g	549	554	554	543	511	568	8.08	0.71	0.36	0.001
ADFI, g	958	948	945	961	981	969	18.05	0.69	0.55	0.65
G/F	0.57	0.58	0.59	0.57	0.52	0.59	0.010	0.47	0.20	0.001

[a]A total of 216 pigs (10.6 kg and 35 d of age) were allotted to provide six pigs per pen and six pens per treatment.
[b]Pigs were fed a common diet for the first 14 d after weaning with overall ADG = 318 g, ADFI = 400 g, and G/F = 0.80.
[c]Contrasts were 1) dry-extruded-expelled without hulls vs solvent-extracted without hulls; 2) dry extruded-expelled with hulls vs solvent-extracted with hulls; and 3) expelled with hulls vs solvent-extracted with hulls.

periment is commonly used as a bypass protein source for ruminants but is sometimes included in swine diets as a replacement for conventional soybean meal. Chang et al. (1987) showed that soybean meal processed as a rumen-escape protein source had lower digestibilities of many amino acids at the end of the small intestine and total tract compared with normal processed soybean meal. Thus, the poorer growth performance of pigs fed ESBM in our trial could have been the result of poorer amino acid digestibility compared with pigs fed the diet containing SBMH. Our data suggest that not all expelled soybean meal products are similar and that expelled soybean meal intended to be used as a high bypass protein source for ruminants will not support maximum growth performance of pigs.

Implications

Our results suggest that dry extruded-expelled soybean meal with hulls or with hulls removed has greater apparent ileal digestibilities of amino acids and greater digestible and metabolizable energy than commercially available, solvent-extracted soybean meal. Growth performance of pigs fed diets containing dry extruded-expelled soybean meal or solvent-extracted soybean meal was similar when diets were formulated on the basis of equal apparent ileal digestible lysine and metabolizable energy, suggesting that the dry extruder-expeller technology sufficiently inactivates the antinutritional factors associated with raw soybeans. Price and availability of the products should help dictate which soybean meal source to include in swine diets. Our data also suggest that not all expelled soybean meal products have the same feeding value for swine.

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