

Effects of soybean meal particle size on growth performance of nursery pigs¹

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ABSTRACT: We used 360 nursery pigs (35 ± 3 d of age) in two 21-d growth assays to determine the effects of soybean meal particle size on growth performance. In both trials, there were six pigs per pen and 10 pens per treatment. Pigs were weaned on d 21 and fed the same phase I diet for 7 d after weaning, followed by a phase II diet from d 7 to 14. On d 14, all pigs were weighed and randomly allotted to one of three dietary treatments. Experimental diets contained 61.9% corn, 34.4% soybean meal, and 3.7% vitamins and minerals. In Exp. 1, 90 barrows and 90 gilts (9.2 ± 2.3 kg BW) were fed diets containing extruded-expelled soybean meal ground to 965, 742, or 639 μm , which resulted in whole-diet particle sizes of 728, 719, and 697 μm , respectively. Reducing extruded-expelled soybean meal particle size from 965 or 742 to 639 μm in the diet did not affect ($P > 0.10$) ADG (541, 538, and 542 g/d), ADFI (886, 875, and 855 g/d; as-fed basis), or gain:feed ratio (0.61, 0.61, 0.64), respectively. In Exp. 2, 90 barrows and 90 gilts (9.9 ± 2.6 kg BW) were fed diets containing solvent-extracted soybean meal ground to 1,226, 797,

or 444 μm , which resulted in whole-diet particle sizes of 732, 681, and 629 microns, respectively. Like Exp. 1, reducing particle size of solvent-extracted soybean meal did not affect ($P > 0.10$) ADG (482, 487, and 484 g/d), ADFI (738, 742, and 736 g/d; as-fed), or gain:feed (0.65, 0.65, and 0.65). Reducing particle size of extruded-expelled soybean meal or solvent-extracted soybean meal increased the angle of repose (maximum degree at which a pile of material retains its slope), indicating that as particle size decreased, flowability characteristics decreased. However, the angle of repose of the complete diets was greater than that for the soybean meals, which indicates that decreasing the particle size of soybean meal had minimal effects on flow characteristics of the complete diet. Previous research has shown that decreasing grain particle size improves digestibility and feed efficiency, and decreased soybean meal particle size has resulted in improved amino acid digestibility. However, the results of our experiments suggest decreasing particle size of either extruded-expelled soybean meal or solvent-extracted soybean meal does not affect nursery pig growth performance.

Key Words: Particle Size, Pigs, Soybean Oilmeal

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J. Anim. Sci. 2003. 81:2118–2122

Introduction

Significant improvements in grain processing technology have been made over the past 30 yr, resulting in improvements in nutrient utilization for pigs. Decreasing particle size of grain in swine diets increases

surface area, allowing for greater interaction with digestive enzymes and improved digestibility (Healy et al., 1994). Feed costs are the greatest economic cost of swine production, and improving the efficiency of feed utilization has a tremendous impact on the cost of production (Goodband et al., 1995).

An average grain particle size of 600 to 700 μm is recommended in diets to optimize growth performance and efficiency responses (Goodband et al., 1995; Wondra et al., 1995a; Mavromichalis et al., 2000). Whereas it has been confirmed that smaller particles optimize pig performance, there is limited information on the effects of soybean meal particle size on pig performance.

Fastinger and Mahan (2003) reported that decreasing soybean meal particle size to 600 μm improved essential AA digestibility in growing-finishing pigs. How-

¹Contribution No. 03-203-J from the Kansas Agric. Exp. Stn., Manhattan. Appreciation is expressed to North Central Kansas Processors, Washington, KS, and Cargill, Inc., Kansas City, KS, for providing the extruded-expelled soybean meal and solvent-extracted soybean meal, respectively.

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Received January 17, 2003.

Accepted May 21, 2003.

ever, physical properties of ingredients can affect flowability in holding bins and feeders. Particle size is directly correlated with diet flowability; as particle size decreases, flowability becomes poorer. The flowability of the diet is measured by the angle of repose, which is defined as the maximal degree at which a pile of material retains its slope (Appel, 1994).

Therefore, the objectives of our experiments were to evaluate the effects of various particle sizes of extruded-expelled soybean meal and solvent-extracted soybean meal on growth performance of nursery pigs and to measure its influence on complete diet flowability.

Materials and Methods

General

The Kansas State University Institutional Animal Care and Use Committee approved all experimental protocols used in this study. Pigs (Line 327 sire \times Cambrough 22 dams; PIC, Franklin, KY) were housed in environmentally controlled nurseries. Each pen (1.2 \times 1.5 m) had slatted metal flooring and contained a stainless steel self-feeder and one nipple waterer to allow ad libitum consumption of feed and water. Room temperature was initially 32°C at weaning (d 21) and was lowered 1.5°C each week to meet the comfort of the pig. Each treatment had 10 replications (pens) and six pigs per pen.

Pigs were provided a phase I diet from d 0 to 7 and a phase II diet from d 7 to 14 postweaning (Table 1). Experimental diets were fed in meal form for 21 d in both experiments. All diets were soybean meal-based and formulated to 1.2% lysine, 0.78% Ca, and 0.40% available P (Table 1). Fastinger and Mahan (2003) found improvements in AA digestibility with decreasing soybean meal particle size. Therefore, we formulated our diets below the anticipated lysine requirement for these pigs based on previous experiments conducted in our research facilities. Our justification was to allow for any potential changes in digestibility to be observed through improved pig growth performance. Ingredient nutrient compositions provided by the NRC (1998) were used in diet formulation. In both experiments, pigs were weighed and randomly allotted at the beginning of the 21-d experiment. Average daily gain, ADFI (as-fed), and feed efficiency (gain:feed) were determined by weighing pigs and measuring feed disappearance every 7 d.

Samples of soybean meal, corn (Exp. 2), and complete diets were analyzed for particle size in duplicate (ASAE, 1983) with a Ro-Tap (W. S. Tyler, Mentor, OH) equipped with 13 sieves. The angle of repose of the extruded-expelled soybean meal, solvent-extracted soybean meal, and complete diets, was determined on materials from both experiments (Appel, 1994). Briefly, angle of repose is measured by filling an 8.9-cm-diameter PVC cylinder with 500 g of the material to be tested. Then, the cylinder is removed and the material will fall away, leaving a cone-shaped pile on the 8.9-cm-diameter plate. The

angle of repose, or maximal angle at which a pile of material retains its slope, can be determined by taking the inverse tangent of the pile height divided by one half the diameter of the plate (Appel, 1994).

Experiment 1

Ninety barrows and 90 gilts (initially 9.2 ± 2.3 kg and 35 ± 3 d of age) were blocked by initial weight and gender, and then allotted randomly to one of three dietary treatments. Pigs were fed the experimental diet from d 14 to 35 postweaning (9.2 to 18.5 kg). A single lot of extruded-expelled soybean meal (Woodworth et al., 2001) was ground with a Sudenga hammer mill (Sudenga Industries, Inc., George, IA) equipped with 12.7-, 9.5-, and 6.4-mm screens. Particle size and particle size standard deviation were determined using ASAE (1983) procedures. Particle sizes were 965, 742, or 639 μm , with SD of 2.3, 2.1, 2.2, respectively, with corresponding whole-diet particle sizes of 728, 719, and 697 μm with SD of 2.4, 2.3, 2.2, respectively (Table 2). The corn used in these diets was from the same ground batch; however, we did not collect an individual sample for corn particle size analysis.

Experiment 2

Ninety barrows and 90 gilts (initially 9.9 ± 2.6 kg and 35 ± 3 d of age) were blocked by initial weight and gender, then allotted randomly to one of three dietary treatments. Pigs were fed experimental diet from d 14 to 35 postweaning (9.9 to 19.9 kg). A single lot of solvent-extracted soybean meal was obtained before particle size reduction at the plant and ground with a three-high roller mill (Roskamp Mfg., Inc., Waterloo, IA). Particle sizes were 1,226, 797, or 444 μm , with SD of 1.6, 1.6, and 1.8, respectively, which resulted in whole-diet particle sizes of 732, 681, and 629 μm with SD of 2.2, 2.1, and 2.2, respectively (Table 3). Corn particle size was 639 μm .

Statistical Analysis

Data from each experiment was analyzed as a randomized complete block design with pen as the experimental unit. Pigs were blocked based on weight in all experiments, and ANOVA was performed using the MIXED procedure of SAS (SAS Inst., Inc., Cary, NC). Contrasts were used to determine the effect of soybean meal particle size in diets. Linear and quadratic polynomial contrasts were used to determine the effects of decreasing soybean meal particle size.

Results

Experiment 1

Angle of repose increased from 44.2° to 51.9° as extruded-expelled soybean meal particle size decreased. Whole-diet angle of repose was greater than for the

Table 1. Ingredient and chemical composition of diets (Exp. 1 and 2)^a

Ingredient, %	Phase I	Phase II	Experimental
Corn	33.37	50.05	61.89
Soybean meal source ^b	12.80	27.20	34.41
Spray-dried whey	25.00	10.00	—
Spray-dried animal plasma	6.70	—	—
Choice white grease	6.00	—	—
Select menhaden fish meal	6.00	5.00	—
Lactose	5.00	—	—
Soy oil	—	4.00	—
Spray-dried blood meal	1.65	—	—
Antimicrobial ^c	1.00	1.00	0.50
Monocalcium phosphate, 21% P	0.75	0.97	1.50
Limestone	0.45	0.65	0.95
Zinc oxide ^d	0.38	0.25	—
Vitamin premix ^e	0.25	0.25	0.25
Salt	0.20	0.25	0.35
Trace mineral premix ^f	0.15	0.15	0.15
L-Lysine HCl	0.15	0.15	—
DL-Methionine	0.15	0.08	—
Calculated analysis			
Lysine, %	1.70	1.40	1.20
Ile:lys ratio, %	50	64	74
Met:lys ratio, %	30	32	28
Met Cys:lys ratio, %	56	57	59
Thr:lys ratio, %	61	61	68
Trp:lys ratio, %	18	18	22
Val:lys ratio, %	72	73	85
ME, kcal/kg	3,517	3,439	3,279
CP, %	22.40	21.30	21.30
Ca, %	0.90	0.87	0.77
P, %	0.80	0.76	0.73
Available P, %	0.66	0.48	0.39
Lysine:calorie ratio, g/Mcal	4.83	4.07	3.66

^aIn both experiments, a common Phase I diet was fed from d 0 to 7 postweaning, a common Phase II diet from d 7 to 14 postweaning, and experimental diets from d 14 to 35 postweaning. Values calculated on an as-fed basis.

^bDiets in Exp. 1 contained extruded-expelled soybean meal (46.0% CP) and Exp. 2 contained solvent-extracted soybean meal (46.5% CP).

^cPhase I & II diets provided 55 mg of carbadox/kg of the complete diet (as-fed) and experimental diets provided 27.5 mg of carbadox/kg of the complete diet (as-fed).

^dProvided 3,000 and 2,000 mg Zn/kg of complete diet.

^eProvided (per kilogram of diet): 11,025 IU of vitamin A; 1,654 IU of vitamin D₃; 44 IU of vitamin E; 4.4 mg of vitamin K (as menadione sodium bisulfate); 55.1 mg of niacin; 33.1 mg of pantothenic acid (as d-calcium pantothenate); 9.9 mg of riboflavin; 0.044 mg of B₁₂.

^fProvided (per kilogram of complete diet): 39.7 mg of Mn (oxide); 165.4 mg of Fe (sulfate); 165 mg of Zn (oxide); 16.5 mg of Cu (sulfate); 0.30 mg of I (as Ca iodate); and 0.30 mg of Se (as Na selenite).

Table 2. Effects of extruded-expelled soybean meal particle size on pig growth performance (Exp. 1)^a

Item	Soybean meal particle size, μm			SE	P-value	
	639	742	965		Linear	Quadratic
Angle of repose ^b						
Soybean meal	51.9	48.0	44.2	—	—	—
Diet	55.6	55.1	52.4	—	—	—
Diet particle size, μm	697	719	728	—	—	—
ADG, g	541	538	542	29.4	0.98	0.89
ADFI, g ^c	886	875	855	34.3	0.38	0.88
Gain:feed ratio	0.61	0.61	0.64	0.03	0.40	0.54

^a180 pigs (six pigs per pen and 10 pens per treatment) with an average initial BW of 9.2 kg. The trial was 21 d in length.

^bThe maximum angle in degrees at which a pile of material retains its slope.

^cExpressed on an as-fed basis.

Table 3. Effects of solvent-extracted soybean meal particle size on pig growth performance (Exp. 2)^a

Item	Soybean meal particle size, μm			SE	P-value	
	444	797	1,226		Linear	Quadratic
Angle of repose ^b						
Soybean meal	38.5	30.7	30.9	—	—	—
Diet	53.4	57.2	53.8	—	—	—
Diet particle size, μm	629	681	732	—	—	—
ADG, g	482	487	484	11.9	0.90	0.67
ADFI, g ^c	738	742	736	15.4	0.89	0.70
Gain:feed ratio	0.65	0.65	0.65	0.01	0.53	0.89

^a180 pigs (six pigs per pen and 10 pens per treatment) with an average initial BW of 9.9 kg. The trial was 21 d in length.

^bThe maximum angle in degrees at which a pile of material retains its slope.

^cExpressed on an as-fed basis.

extruded-expelled soybean meal, with a range of 52.4° to 55.6° for the whole diet. Reducing particle size of extruded-expelled soybean meal from 965 to 639 μm resulted in no differences ($P > 0.05$) in ADG, ADFI, or gain:feed of nursery pigs during week 1, 2, or 3, or the overall 21-d study (Table 2).

Experiment 2

Reducing particle size of solvent-extracted soybean meal from 1,226 to 444 μm increased the angle of repose from 30.8° to 38.5°. The angle of repose of the complete diets also increased as the soybean meal particle size decreased, which ranged from 53.4° to 57.2°. As in Exp. 1, reducing particle size of solvent-extracted soybean meal from 1,226 to 444 μm resulted in no differences ($P > 0.05$) in ADG, ADFI, or gain:feed of nursery pigs during wk 1, 2, or 3, or for the overall 21-d study (Table 3).

Discussion

Particle size reduction increases the surface area of grain, allowing for greater interaction with digestive enzymes (Goodband et al., 1995). Positive effects have been observed with reducing particle size of cereal grains for nursery pigs (Ohh et al., 1983; Healy et al., 1994), finishing pigs (Ivan et al., 1974; Owsley et al., 1981; Giesemann et al., 1990), and lactating sows (Wondra et al., 1995b,c). Fine grinding of grain used in swine diets optimizes pig performance and improves feed efficiency regardless of age (Goodband et al., 1995). Most research would suggest that reducing the mean particle size of corn to 600 μm results in marked improvements in feed efficiency (Wondra et al., 1995a) compared with a larger particle size. Hedde et al. (1985) reported an 8% increase in rate of gain for finishing pigs when particle size was reduced from coarse to fine. Experiments by Mahan et al. (1966) and Lawrence (1983) showed greater gain:feed in pigs when the particle size was reduced from coarse to fine.

Fastinger and Mahan (2003) recently evaluated the effects of solvent-extracted soybean meal particle size

(900 to 150 μm) on AA and energy digestibility. Apparent digestibility of the average of the 10 essential AA increased as particle size decreased, but energy digestibility and the average of the nonessential AA digestibilities was not affected. The largest improvement in AA digestibility was observed when particle size of the solvent-extracted soybean meal decreased from 900 to 600 μm .

In our experiments, we observed no differences in growth or feed efficiency with decreasing particle size of soybean meal in the diet. Although we used a relatively wide range of soybean meal particle sizes, we may not have observed differences in pig performance because soybean meal only represented 34.4% of the diet. Furthermore, the changes in soybean meal particle size had a relatively minor impact on entire diet particle size due to its inclusion rate compared to corn.

We formulated our diets to contain 1.2% total dietary lysine, which, based on previous studies in our facilities and the genetic makeup of the pigs, should have been slightly below the pigs estimated lysine requirement of 1.23% total lysine for ADG and 1.43% for feed efficiency (James et al., 2002). If our diets were formulated above the pig's requirement, the changes in AA digestibility may not result in improved growth performance. Also, we did not use L-lysine HCl in the diets in order to maximize the amount of soybean meal included in the diet. Therefore, our experiment was designed to allow differences due to soybean meal particle size to be observed by changes in ADG and feed efficiency.

We assessed flowability by measuring angle of repose. In both experiments, the angle of repose of the diets was greater than for the soybean meals, suggesting that the soybean meal would flow better than the complete diet. Soybean meal can have an angle of repose range from 32° to 37° (Appel, 1994). However, these reference values do not specify a material particle size and may not be appropriate for the range of particle size used today in swine diets. In our studies, we did not have any problems with feed flowability; however, it is important to point out that the design of feeders and bulk bins will also contribute to whether a material

flows. For example, any material, regardless of its angle of repose, may or may not bridge in a bulk bin or feeder depending upon its design. The greater angle of repose for extruded-expelled soybean meal (Exp. 1) vs. solvent-extracted soybean meal (Exp. 2) is likely due to their different fat contents (5.0 vs. 1.2% fat, respectively).

Implications

Although it is extremely important to finely grind the grain portion of swine diets to a particle size of 600 to 700 μm to improve digestibility, based on the results of these two studies, soybean meal particle size does not seem to affect nursery pig growth performance.

Literature Cited

- Appel, W. B. 1994. Physical properties of feed ingredients. Pages 151–152 in *Feed Manufacturing Technology*. 4th ed. Am. Feed Industry Assoc., Inc., Arlington, VA.
- ASAE. 1983. Method of determining and expressing fineness of feed materials by sieving. Page 325 in ASAE Standard S319, *Agriculture Engineers Yearbook of Standards*. St. Joseph, MI.
- Fastinger, N. D., and D. C. Mahan. 2003. Effects of soybean meal particle size on amino acid and energy ileal digestibilities in grower-finisher swine. *J. Anim. Sci.* 81:697–704.
- Giesemann, M. A., A. J. Lewis, J. D. Hancock, and E. R. Peo, Jr. 1990. Effect of particle size of corn and grain sorghum on growth and digestibility by growing pigs. *J. Anim. Sci.* 68(Suppl. 1):104. (Abstr.)
- Goodband, R. D., M. D. Tokach, and J. L. Nelssen. 1995. The effects of diet particle size on animal performance. MF-2050. *Feed Manufacturing*, Manhattan, KS.
- Healy, B. J., J. D. Hancock, G. A. Kennedy, P. J. Bramel-Cox, K. C. Behnke, and R. H. Hines. 1994. Optimum particle size of corn and hard and soft sorghum for nursery pigs. *J. Anim. Sci.* 72:2227–2236.
- Hedde, R. D., T. O. Lindsey, R. C. Parrish, H. D. Daniels, E. A. Morgenthien, and H. B. Lewis. 1985. Effect of diet particle size and feeding H_2 -receptor antagonists on gastric ulcers in swine. *J. Anim. Sci.* 61:179–186.
- Ivan, M., L. R. Giles, A. R. Alimon, and D. J. Farrell. 1974. Nutritional evaluation of wheat. I. Effect of preparation on digestibility of dry matter, energy, and nitrogen in pigs. *Anim. Prod.* 19:359–365.
- James, B. W., M. D. Tokach, R. D. Goodband, J. L. Nelssen, S. S. Dritz, C. W. Hastad, K. R. Lawrence, and J. L. Usry. 2002. The optimal true ileal digestible lysine requirement for nursery pigs between 27 to 44 lb. *Kansas Agric. Exp. Stn. Rep. Prog.* 897:63–65.
- Lawrence, T. J. L. 1983. The effects of cereal particle size and pelleting on the nutritive value of oat-based diets for the growing pig. *Anim. Feed Sci. Tech.* 8:91–97.
- Mahan, D. C., R. A. Pickett, T. W. Perry, T. M. Curtin, W. R. Featherston, and W. M. Beeson. 1966. Influence of various nutritional factors and physical form of feed on esophagogastric ulcers in swine. *J. Anim. Sci.* 25:1019–1023.
- Mavromichalis, I., J. D. Hancock, B. W. Senne, T. L. Gugle, G. A. Kennedy, R. H. Hines, and C. L. Wyatt. 2000. Enzyme supplementation and particle size of wheat in diets for nursery and finishing pigs. *J. Anim. Sci.* 78:3086–3095.
- NRC. 1998. *Nutrient Requirements of Swine*. 10th ed. Natl. Acad. Press, Washington, DC.
- Ohh, S. J., G. L. Allee, K. C. Behnke, and C. W. Deyoe. 1983. Effect of particle size of corn and sorghum grain on performance and digestibility of nutrients for weaned pigs. *J. Anim. Sci.* 57(Suppl. 1):260. (Abstr.)
- Owsley, W. F., D. A. Knabe, and T. D. Tanksley, Jr. 1981. Effect of sorghum particle size on digestibility of nutrients at the terminal ileum and over the total digestive tract of growing-finishing pigs. *J. Anim. Sci.* 52:557–566.
- Wondra, K. J., J. D. Hancock, K. C. Behnke, R. H. Hines, and C. R. Stark. 1995a. Effects of particle size and pelleting on growth performance, nutrient digestibility, and stomach morphology in finishing pigs. *J. Anim. Sci.* 73:757–763.
- Wondra, K. J., J. D. Hancock, G. A. Kennedy, K. C. Behnke, and K. R. Wondra. 1995b. Effects of reducing particle size on energy and nitrogen metabolism in second parity sows. *J. Anim. Sci.* 73:427–432.
- Wondra, K. J., J. D. Hancock, G. A. Kennedy, R. H. Hines, and K. C. Behnke. 1995c. Reducing particle size of corn in lactation diets from 1,200 to 400 micrometers improves sow and litter performance. *J. Anim. Sci.* 73:421–426.
- Woodworth, J. C., M. D. Tokach, R. D. Goodband, J. L. Nelssen, P. R. O'Quinn, D. A. Knabe, and N. W. Said. 2001. 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. *J. Anim. Sci.* 79:1280–1287.