The Effects of Dietary Soybean Hulls, Particle Size, and Diet Form on Nursery Pig Performance[1,2]

D. L. Goehring, M. D. Tokach, J. M. DeRouchey, J. L. Nelssen, R. D. Goodband, S. S. Dritz[3], and B. W. James[4]

Summary

A total of 1,100 nursery pigs (PIC C-29 × 359, initially 15.0 lb BW) were used in a 42-d growth trial to determine the effects of increasing soybean hulls (10 or 20%) and soybean hull particle size (unground or ground) in nursery pig diets fed in both meal and pelleted forms. The average particle size of the unground and ground soybean hulls were 617 and 398 μ, respectively. Pens of pigs (5 barrows and 5 gilts) were balanced by initial BW and randomly allotted to 1 of 8 treatments with 11 replications per treatment. A 2-phase diet series was used with treatment diets fed from d 0 to 14 for Phase 1 and d 14 to 42 for Phase 2. Treatments were arranged in a 2 × 2 × 2 factorial with main effects of 10 or 20% unground or finely ground soybean hulls with diets in pelleted or meal form. For individual phases and overall (d 0 to 42), no soybean hull × particle size × diet form or particle size × soybean hull interactions ($P > 0.37$ and $P > 0.17$, respectively) were observed; however, diet form × particle size interactions were observed for F/G and ADFI ($P < 0.05$ and $P < 0.10$, respectively). Grinding soybean hulls resulted in improved F/G and reduced ADFI when added to meal diets, but did not change F/G and had less effect on ADFI when added to pelleted diets. Diet form × particle size interactions ($P < 0.05$) also were observed for caloric efficiency on an ME and NE basis. Grinding soybean hulls slightly improved caloric efficiency in meal diets but worsened NE and ME caloric efficiency in pelleted diets. There was also a tendency for a diet form × soybean hulls interaction ($P < 0.06$) for ADFI and F/G. Increasing soybean hulls from 10 to 20% increased ADFI and worsened F/G in meal diets but resulted in slightly reduced ADFI and no changes to F/G when added to pelleted diets; furthermore, there were tendencies for diet form × soybean hulls interactions ($P < 0.06$) on caloric efficiency on an ME and NE basis in which increasing soybean hulls from 10 to 20% improved caloric efficiency to a greater extent in pelleted diets than in meal diets.

For main effects, pigs fed diets with 10% soybean hulls had reduced ($P <0.007$) ADFI and improved ($P < 0.03$) F/G but poorer caloric efficiency ($P < 0.001$) on an ME and NE basis than pigs fed diets with 20% soybean hulls. Grinding soybean hulls decreased ($P < 0.005$) ADG and ADFI and tended ($P < 0.08$) to reduce final weight but did not influence F/G. Pelleting soybean hull diets also increased ($P < 0.0001$) ADG, ADFI, and final weight but did not influence F/G. In summary, the improvement in caloric efficiency as high levels of soybean hulls were added to the diet indicate that the energy value of soybean hulls are greater than those used in diet formulation. Pelleting

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[3] Department of Diagnostic Medicine/Pathobiology, College of Veterinary Medicine, Kansas State University.

[4] Kalmbach Feeds, Inc., Upper Sandusky, OH.

provided the expected improvement in ADG and eliminated the negative effect on F/G with increasing soybean hulls. Regrinding soybean hulls below the particle size at receiving (617 μ) reduced performance.

Key words: nursery pig, particle size, soybean hulls

Introduction

Soybean hulls are a readily available co-product from the cracking and dehulling process of soybean oil extraction, but because of soybean hulls' low energy value (corn NE = 1,202 kcal/lb; soybean hulls NE = 455 kcal/lb; INRA 2004[5]) and the lack of published data, soybean hulls may be an underutilized ingredient in many swine diets. Previous studies at Kansas State University have shown that up to 5% soybean hulls can be added to nursery pig diets without affecting growth performance (see Goehring et al., "The Effects of Soybean Hulls on Nursery Pig Growth Performance" p. 127). These results suggest that the ME value of soybean hulls might be underestimated when fed at low inclusions in swine diets.

Soybean hulls from U.S. processing plants vary in particle size, but a recent study by Moreira et al. (2009[6]) showed that reducing the particle size of soybean hulls from 751 μ to 439 μ, increased the ME value for finishing pigs and improved growth performance. Validation of the response to grinding soybean hulls on growth performance is needed; in addition, because soybean hulls have a low bulk density, research on the effects of pelleting complete diets containing high amounts of soybean hulls is needed.

Therefore, the objectives of this study were to evaluate the effects of (1) soybean hulls (10 and 20%), (2) soybean hull particle size (617 vs. 398 μ), and (3) diet form (meal and pellet) on the growth performance of nursery pigs in a commercial setting.

Procedures

The protocol for this experiment was approved by the K-State Institutional Animal Care and Use Committee. The study was conducted at the Cooperative Research Farm's Swine Research Nursery (Sycamore, OH), which is owned and managed by Kalmbach Feeds, Inc.

A total of 1,100 pigs (PIC C-29 x 359, initially 15.0 lb BW) were used in a 42-d growth trial. Pens of pigs (5 barrows and 5 gilts per pen) were balanced by initial BW and randomly allotted to treatments with 11 replications (pens) per treatment. Each pen had slatted metal floors and was equipped with a 4-hole stainless steel feeder and one nipple-cup waterer for ad libitum access to feed and water.

Pigs were weaned and started on a common pelleted starter diet for 10 d prior to the initiation of the experiment. A 2-phase diet series was used with treatment diets fed

[5] INRA (Institut National de la Recherche Agronomique). 2004. Tables of composition and nutritional value of feed materials, Sauvant, D., J-M. Perez, and G. Tran, Eds. Wageningen Academic Publishers, The Netherlands and INRA, Paris, France.

[6] Moreira, I., M. Kutschenko, D. Paiano, C. Scapinelo, A. E. Murakami, and A. R. Bonet de Quadros. 2009. Effects of different grinding levels (particle size) of soybean hull on starting pigs performance and digestibility. Braz. Arch. Biol. Technol. 52(5):1243–1252.

from d 0 to 14 for Phase 1 and d 14 to 42 for Phase 2 arranged in a 2 × 2 × 2 factorial. The dietary treatments were corn-soybean–based diets containing 10 or 20% unground or finely ground soybean hulls in pelleted and meal form (Table 1). Phase 1 diets contained 4% fish meal and 10% spray-dried whey. Phase 2 diets contained no specialty protein sources. Pig weight and feed disappearance were measured on d 0, 7, 14, 21, 28, 35, and 42 to determine ADG, ADFI, and F/G.

A single lot of soybean hulls were used for the study with 50% used as received, whereas the other 50% was ground through a hammer mill equipped with a 1/16-in. screen at K-State Grain Science Feed Mill. The resulting particle sizes were 617 and 398 µ, respectively. All soybean hulls were then shipped to Kalmbach Feeds, Inc. for feed manufacturing. Samples of soybean hulls and complete diet were collected for chemical analysis. Proximate analysis was conducted by Ward Laboratories, Inc. (Kearny, NE) on the soybean hulls (Table 2). All diets were formulated to the same standardize ileal digestible (SID) lysine level. Feed samples were collected from each feeder during each phase and combined for a single composite sample of each treatment per phase. The pellet durability index (PDI) and percentage fines were determined for pelleted diets (Table 3), and bulk densities were determined for all diets (Table 4).

Data was analyzed using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Room was included in the model as a random effect and contrasts were used to test for the following interactions: (1) form × soybean hulls × soybean hull particle size, (2) form × soybean hull particle size, (3) form × soybean hulls, and (4) soybean hulls × soybean hull particle size. Main effects of diet form, soybean hulls, and soybean hull particle size were also tested. Differences between treatments were determined by using least squares means ($P < 0.05$), and trends were declared at $P < 0.10$.

Results and Discussion

Unground soybean hulls had a lower bulk density than ground soybean hulls, and diets containing 20% soybean hulls had lower bulk densities and increased particle sizes than diets with 10% soybean hulls. Soybean hulls did not affect pellet durability, regardless of the amount of soybean hulls or particle size, but diets with 20% soybean hulls had decreased percentage fines.

From d 0 to 14, no interactions ($P > 0.23$) were observed. Increasing dietary soybean hulls from 10 to 20% improved ($P < 0.003$) ADG, F/G, and caloric efficiency on an ME and NE basis (Table 5). Grinding soybean hulls worsened ($P < 0.003$) ADG, F/G, and caloric efficiency, whereas pelleted soybean hull diets increased ($P < 0.001$) ADG and ADFI but did not affect F/G or caloric efficiency.

From d 14 to 42, tendencies were observed for diet form × soybean hull particle size and diet form × soybean hulls interactions ($P < 0.10$) in which grinding soybean hulls reduced ADFI in meal diets but had less of an effect on ADFI in pelleted diets. Similarly, increasing soybean hulls from 10 to 20% increased ADFI and worsened F/G in meal diets but had no effect on F/G and slight increases in ADFI in pelleted diets. Additionally, there were tendencies for diet form × soybean hulls interactions ($P < 0.10$) on ME and NE caloric efficiencies in which 20% soybean hulls improved caloric efficiency to a greater extent in pelleted diets than in meal diets. For main effects, increasing soybean hulls from 10 to 20% increased ($P < 0.002$) ADFI and worsened ($P < 0.001$) F/G but had no effect on ADG. Increasing soybean hulls also improved ($P < 0.04$) caloric efficiency on an ME and NE basis, indicating the energy value of soybean hulls was underestimated in diet formulation. Grinding soybean hulls tended ($P < 0.06$) to decrease ADG and decreased ($P < 0.001$) ADFI without influencing F/G or caloric efficiency. Pelleting the diets also increased ($P < 0.001$) ADG and ADFI but had no effect on F/G or caloric efficiency.

Overall (d 0 to 42), there were no soybean hull level × particle size × diet form or particle size × soybean hull level interactions ($P > 0.37$ and $P > 0.17$, respectively); however, diet form × particle size interactions occurred for F/G and ADFI ($P < 0.05$ and $P < 0.10$, respectively) in which grinding the soybean hulls improved F/G and reduced ADFI when added to meal diets but did not change F/G and had less effect on ADFI when added to pelleted diets. Additionally, diet form × particle size interactions ($P < 0.05$) were observed for caloric efficiency on an ME and NE basis. Grinding soybean hulls slightly improved caloric efficiency in meal diets, but worsened NE and ME caloric efficiency in pelleted diets. A tendency for a diet form × soybean hulls level interactions ($P < 0.06$) was observed for ADFI and F/G in which increasing soybean hulls from 10 to 20% increased ADFI and worsened F/G in meal diets but resulted in slightly reduced ADFI and no changes to F/G in pelleted diets. Increasing the amount of soybean hulls reduced the dietary energy content of the diet. To meet the energy requirement, ADFI increased, but with no change in pigs' ADG, the result was poorer F/G. Furthermore, tendencies for diet form × soybean hulls level interactions ($P < 0.06$) were observed for caloric efficiency on an ME and NE basis. Increasing soybean hulls from 10 to 20% improved caloric efficiency to a greater extent in pelleted diets than in meal diets. The increase in soybean hulls reduced the calculated energy concentration in the diet to a greater extent than F/G increased. Pelleting the diets containing high levels of soybean hulls may have improved digestibility and resulted in a greater improvement in caloric efficiencies.

For main effects, increasing soybean hulls from 10 to 20% increased ($P < 0.007$) ADFI but worsened ($P < 0.03$) F/G (Table 6). Dietary energy decreased with 20% soybean hulls in the diet, and ADFI increased to compensate for the lower energy diet. Because ADG was unchanged despite soybean hull inclusions, pigs gained the same amount on lower energy diets, resulting in improved ($P < 0.001$) caloric efficiency on an ME and NE basis. This suggests that the energy value for soybean hulls is overestimated. Grinding soybean hulls reduced ($P < 0.005$) ADG and ADFI, whereas pelleted diets improved ($P < 0.001$) ADG and ADFI, but pelleting the diets and grinding the soybean hulls did not affect F/G or caloric efficiency. Grinding the soybean hulls tended ($P < 0.08$) to reduce final pig weight. Feeding pelleted diets increased ($P < 0.001$) final weight.

In conclusion, soybean hulls are a low-energy ingredient that increased crude fiber and NDF of the diet and worsened F/G when fed at 20% compared with 10%; however, pelleting these diets resulted in little change in F/G compared with the 20% inclusion fed in meal form. Pigs fed 20% soybean hulls also had improved caloric efficiency coupled with reduced F/G, which suggests that the published energy value for soybean hulls may underestimate the value in diets containing 20% or less soybean hulls. Pelleting diets not only gave the typical improvement in ADG, but also increased feed intake, which results in no improvement in feed efficiency compared with pigs fed a meal diet. Pelleting diets would normally be expected to improve F/G without altering ADFI, but the improved feed intake could be the result of providing a more dense feed, because soybean hulls in a meal diets reduced diet bulk density. The hypothesis that reducing the particle size of soybean hulls may improve its energy value was not proven true, because feed efficiency and caloric efficiency were not influenced by soybean hull particle size. Grinding soybean hulls finer than (617 μ) actually reduced feed intake and ADG.

Table 1. Phase 1 and Phase 2 diet composition (as-fed basis)[1,2,3]

	Phase 1		Phase 2	
Item Soybean hulls, %:	10%	20%	10%	20%
Ingredient, %				
Corn	46.15	37.06	55.07	45.91
Soybean meal, 46.5% CP	26.83	26.06	31.33	30.64
Soybean hulls	10.00	20.00	10.00	20.00
Select menhaden fish meal	4.00	4.00	--	--
Spray-dried whey	10.00	10.00	--	--
Monocalcium P, 21% P	0.50	0.50	1.05	1.05
Limestone	0.65	0.50	0.80	0.65
Salt	0.35	0.35	0.35	0.35
Zinc oxide	0.25	0.25	--	--
Vitamin E (20,000 IU)	0.055	0.055	0.055	0.055
Vitamin premix	0.05	0.05	0.05	0.05
Trace mineral premix	0.09	0.09	0.09	0.09
Se 600 premix	0.023	0.023	0.023	0.023
L-lysine HCl	0.213	0.200	0.315	0.300
DL-methionine	0.140	0.158	0.148	0.165
L-threonine	0.115	0.120	0.130	0.135
Ronozyme CT (10,000)[4]	0.019	0.019	0.019	0.019
CTC 50	0.40	0.40	0.40	0.40
Denagard 10	0.175	0.175	0.175	0.175
Total	100	100	100	100

continued

Table 1. Phase 1 and Phase 2 diet composition (as-fed basis)[1,2,3]

		Phase 1		Phase 2	
Item	Soybean hulls, %:	10%	20%	10%	20%
Calculated analysis					
Standardized ileal digestible (SID) amino acids, %					
Lysine		1.30	1.30	1.26	1.26
Isoleucine:lysine		62	62	61	61
Leucine:lysine		125	122	126	123
Methionine:lysine		36	36	34	35
Met & Cys:lysine		59	59	58	58
Threonine:lysine		64	64	63	63
Tryptophan:lysine		17.5	17.5	17.5	17.5
Valine:lysine		68	67	67	66
Total lysine, %		1.46	1.48	1.42	1.44
ME, kcal/lb		1,427	1,359	1,431	1,363
SID lysine:ME, g/Mcal		4.20	4.48	4.05	4.33
CP, %		21.7	21.8	21.0	21.1
Crude fiber, %		5.4	8.5	5.8	8.9
ADF[5]		6.8	10.6	7.3	11.0
NDF[6]		12.5	17.2	13.7	18.4
Ca, %		0.78	0.77	0.67	0.66
P, %		0.63	0.61	0.61	0.59
Available P, %		0.46	0.46	0.40	0.40

[1] Phase 1 diets fed from d 0 to 14; Phase 2 diets fed from d 14 to 42.
[2] Diets were fed in both meal and pelleted forms.
[3] Diets were fed with soybean hulls ground to 389 µ or unground at 617 µ
[4] Ronozyme CT (10,000) (DSM, Parsippany, NJ) provided 840 phytase units (FTU)/lb, with a release of 0.10% available P.
[5] Soybean hulls ADF values taken from INRA (Institut National de la Recherche Agronomique), 2004. All other values taken from NRC, 1998.
[6] Soybean hulls NDF values taken from INRA, 2004. All other values taken from NRC, 1998.

Table 2. Chemical analysis of soybean hulls (as-fed basis)

Item	Percentage	
DM	91.91	
CP	9.8 (12.2)[1]	
ADF	40.1	
NDF	55.3	
Crude fiber	32.7 (33.3)	
Ca	0.54 (0.52)	
P	0.11 (0.15)	
	Ground	Unground
Bulk density, lb/bu[2]	38.09	32.74
Particle size, μ	389	617

[1] Values in parentheses were used in diet formulation.
[2] Diet samples taken from the top of each feeder in each phase.

Table 3. Quality of pelleted diets

Grind type:	Unground		Ground	
Item Soybean hull level, %:	10%	20%	10%	20%
Phase 1				
PDI, %[1]	95	95	94	95
Modified PDI, %	93	92	89	92
Fines, %	7.6	0.5	6.6	3.6
Phase 2				
PDI, %	97	97	95	94
Modified PDI, %	94	95	92	92
Fines, %	6.1	1.5	1.8	0.8

[1] PDI: pellet durability index; samples were taken from each feeder during each phase. A composite sample was made for each treatment.

Table 4. Bulk density of experimental diets (as-fed basis)[1,2]

		Treatments							
	Diet form:	Meal				Pellet			
	Grind type:	Unground		Ground		Unground		Ground	
Item	Soybean hulls, %:	10%	20%	10%	20%	10%	20%	10%	20%
Bulk density, lb/bu									
Phase 1		47.9	44.7	48.5	46.6	59.6	55.7	57.5	56.9
Phase 2		54.3	49.1	54.5	50.2	60.0	58.5	60.0	60.1
Particle size, μ									
Phase 1		355	400	360	364	--	--	--	--
Phase 2		430	558	423	500	--	--	--	--

[1] Diet samples collected from the tops of each feeder during each phase.
[2] Phase 1 was d 0 to 14; Phase 2 was d 14 to 42.

Table 5. Interactions of soybean hulls level, particle size and complete diet form on nursery pig performance[1]

Diet form:	Meal				Pellet						
Grind type:	Unground		Ground		Unground		Ground			Diet form × soybean hulls	
Item / Soybean hulls, %:	10%	20%	10%	20%	10%	20%	10%	20%	SEM[2,3]	particle size	Diet form × soybean hulls
d 0 to 14											
ADG, lb	0.35	0.40	0.33	0.37	0.45	0.45	0.39	0.43	0.061	0.35	0.33
ADFI, lb	0.61	0.65	0.60	0.62	0.74	0.70	0.72	0.74	0.061	0.45	0.19
F/G	1.79	1.64	1.90	1.73	1.70	1.55	1.95	1.75	0.142	0.21	0.88
Caloric efficiency[4]											
ME	2,550	2,227	2,705	2,349	2,421	2,109	2,783	2,378	198.8	0.23	0.90
NE	1,822	1,555	1,934	1,1641	1,730	1,472	1,989	1,661	141.0	0.23	0.90
d 14 to 42											
ADG, lb	1.40	1.38	1.35	1.36	1.44	1.41	1.40	1.41	0.032	0.86	0.96
ADFI, lb	2.04	2.12	1.94	2.04	2.10	2.09	2.03	2.09	0.068	0.10	0.07
F/G	1.46	1.53	1.43	1.49	1.46	1.48	1.46	1.49	0.026	0.19	0.09
Caloric efficiency											
ME	2,085	2,088	2,052	2,034	2,091	2,020	2,095	2,027	36.0	0.19	0.10
NE	1,459	1,425	1,435	1,388	1,463	1,379	1,466	1,383	24.8	0.19	0.10
d 0 to 42											
ADG, lb	1.05	1.05	1.01	1.03	1.11	1.09	1.05	1.08	0.039	0.91	0.79
ADFI, lb	1.56	1.62	1.49	1.56	1.65	1.61	1.59	1.64	0.064	0.10	0.06
F/G	1.49	1.54	1.47	1.52	1.49	1.49	1.51	1.52	0.016	0.05	0.06
Caloric efficiency											
ME	2,130	2,102	2,109	2,066	2,128	2,028	2,161	2,066	22.8	0.05	0.06
NE	1,494	1,439	1,479	1,414	1,493	1,389	1,517	1,415	15.8	0.05	0.06
BW, lb											
d 0	15.0	15.1	14.9	14.9	14.9	15.0	15.1	15.0	0.15	0.22	0.52
d 14	19.9	20.7	19.5	20.1	21.2	21.4	20.4	21.0	0.96	0.80	0.36
d 42	59.0	59.3	57.4	58.2	61.4	60.8	59.3	60.4	1.76	0.96	0.73

[1] A total of 1100 pigs (PIC C-29 × 359, initially 15.0 lb BW) were used in a 42-d study with 10 pigs per pen and 11 pens per treatment.
[2] No soybean hull × particle size × diet form interactions, $P > 0.37$.
[3] No particle size × soybean hull interaction, $P > 0.17$.
[4] Caloric efficiency is express as kcal/lb gain.

Table 6. Main effects of soybean hulls level, particle size, and complete diet from on nursery pig performance[1]

	Diet form		Soybean hulls particle size		Soybean hulls			Probability, *P*<		
Item	Meal	Pellet	Unground	Ground	10%	20%	SEM	Soybean hulls	Soybean hulls particle size	Diet form
d 0 to 14										
ADG, lb	0.36	0.43	0.41	0.38	0.38	0.41	0.060	0.003	0.003	0.0001
ADFI, lb	0.62	0.72	0.67	0.67	0.67	0.68	0.058	0.58	0.84	0.0001
F/G	1.76	1.74	1.67	1.83	1.83	1.67	0.128	0.002	0.002	0.63
Caloric efficiency[2]										
ME	2,458	2,422	2,326	2,554	2,615	2,265	178.1	0.0001	0.002	0.63
NE	1,738	1,713	1,645	1,806	1,869	1,582	126.2	0.0001	0.002	0.63
d 14 to 42										
ADG, lb	1.37	1.41	1.41	1.38	1.39	1.39	0.027	0.71	0.06	0.01
ADFI, lb	2.03	2.08	2.08	2.02	2.03	2.08	0.064	0.002	0.0008	0.008
F/G	1.48	1.47	1.48	1.47	1.45	1.50	0.020	0.001	0.31	0.70
Caloric efficiency										
ME	2,065	2,059	2,071	2,052	2,081	2,042	28.1	0.04	0.30	0.74
NE	1,427	1,423	1,431	1,418	1,456	1,394	19.4	0.0001	0.30	0.75
d 0 to 42										
ADG, lb	1.04	1.08	1.08	1.05	1.06	1.07	0.037	0.45	0.005	0.0001
ADFI, lb	1.56	1.63	1.61	1.57	1.57	1.61	0.02	0.007	0.004	0.0001
F/G	1.51	1.50	1.50	1.51	1.49	1.52	0.01	0.03	0.82	0.69
Caloric efficiency										
ME	2,102	2,096	2,097	2,101	2,132	2,266	11.4	0.0001	0.83	0.76
NE	1,457	1,453	1,454	1,456	1,496	1,414	7.9	0.0001	0.82	0.78
BW, lb										
d 0	15.0	15.0	15.0	15.0	15.0	15.0	0.10	0.83	0.87	0.71
d 14	20.0	21.0	20.8	20.3	20.3	20.8	0.94	0.002	0.002	0.0001
d 42	58.5	60.5	60.1	58.8	59.3	59.7	1.67	0.42	0.08	0.0001

[1] A total of 1,100 pigs (PIC C-29 × 359, initially 15.0 lb BW) were used in a 42-d study with 10 pigs per pen and 11 pens per treatment.
[2] Caloric efficiency is express as kcal/lb gain.