The Effects of Soybean Hulls in Corn-Soybean Meal and Corn-Soybean Meal-Dried Distillers Grains with Solubles Diets on Nursery Pig Performance[1,2]

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Summary

Two experiments were conducted to evaluate the effects of soybean hulls in diets with and without corn dried distillers grains with solubles (DDGS) on nursery pig growth performance. In Exp. 1, a total of 600 pigs (PIC C-29 × 359, initially 14.7 lb) were used in a 42-d growth study. Diets contained increasing amounts of soybean hulls (0, 3, 6, 9, or 12%) in either corn-soybean meal or corn-soybean meal-DDGS–based diets (15 and 30% DDGS for Phases 1 and 2, respectively). Pigs were blocked by initial pen weight, gender, and room location, with 10 pigs per pen and 6 replications per treatment. Overall (d 0 to 42), soybean hulls × DDGS interactions (quadratic, $P < 0.05$) were observed for F/G and caloric efficiency on an ME and NE basis. Increasing soybean hulls worsened F/G quadratically ($P < 0.03$) when added to diets without DDGS but linearly ($P < 0.01$) when added to diets with DDGS. Caloric efficiencies improved on an ME and NE basis (quadratic, $P < 0.04$) with increasing soybean hulls in diets without DDGS but did not influence caloric efficiency when added to diets containing DDGS. Adding DDGS to the diet decreased ($P < 0.04$) ADG and ADFI but tended to improve ($P < 0.06$) F/G. Adding soybean hulls to diets containing DDGS further reduced (quadratic, $P < 0.05$) ADG and tended to reduce (quadratic, $P < 0.08$) ADFI, whereas adding soybean hulls to diets without DDGS had no effect on ADG or ADFI.

In Exp. 2, 304 pigs (PIC, 337 × 1050, initially 25.7 lb) were used in a 21-d study. The 8 diets were arranged in a 2 × 4 factorial with increasing soybean hulls (0, 5, 10, or 15%) in either corn-soybean meal or corn-soybean meal-DDGS–based diets (20% DDGS). Pigs were balanced by initial BW and randomly allotted to 1 of 8 dietary treatments with 9 replications per treatment. Overall (d 0 to 21), no soybean hull × DDGS interactions were observed. Increasing soybean hulls tended to worsen (linear, $P < 0.07$) F/G but improved (linear, $P < 0.008$) caloric efficiency on an ME and NE basis. In contrast to the first experiment, the greatest negative effect on F/G (linear, $P < 0.04$) came from adding soybean hulls to diets without DDGS. Adding DDGS to the diets had no effect on growth performance.

These data indicate that feeding up to 15% soybean hulls in diets for nursery pigs does not affect growth rate or feed intake, but worsens F/G and improves caloric efficiency.

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The improvement in caloric efficiency indicates that published energy values underestimate the energy content of soybean hulls. The influence of DDGS in the diet on the response to soybean hulls varied between trials, indicating that further research is needed to understand potential interactions between high-fiber ingredients such as soybean hulls and DDGS on growth performance and caloric efficiency of nursery pigs.

Key words: DDGS, growth, nursery pig, soybean hulls

Introduction

Soybean hulls are a co-product from solvent extraction processing of whole soybeans and are available to be used in swine diets in the Midwest; however, because soybean hulls are a high-fiber, bulky ingredient with a low energy value (corn NE = 1,202 kcal/lb; soybean hulls NE = 455 kcal/lb; INRA 20045), they may be an underutilized ingredient. A previous study at Kansas State University demonstrated that 5% soybean hulls could be included in conventional corn-soybean–based nursery diets with no negative effects on growth performance, whereas including 10% or greater resulted in decreased performance (see Goehring et al., "The Effects of Soybean Hulls on Nursery Pig Growth Performance" p. 127). The objective of these studies was to evaluate increasing levels of soybean hulls (up to 15%) in diets with or without DDGS on growth performance and caloric efficiency of nursery pigs.

Procedures

The K-State Institutional Animal Care and Use Committee approved the protocols used in these experiments. Experiment 1 was conducted at the Cooperative Research Farm's Swine Research Nursery (Sycamore, OH), which is owned and managed by Kalmbach Feeds, Inc. Experiment 2 was conducted at the K-State Segregated Early Weaning Research Facility in Manhattan, KS.

In Exp. 1, a total of 600 pigs (PIC C-29 × 359, initially 14.7 lb BW) were used in a 42-d growth trial. Pens of pigs were blocked by initial pen weight, gender, and room location. Each treatment had 10 replications (pens) with 10 pigs per pen. 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 fed a common pelleted starter diet for 3 d; thus, d 0 of the experimental period was d 3 postweaning. A 2-phase experimental diet series was used with treatment diets fed from d 0 to 14 for Phase 1 and d 14 to 42 for Phase 2. The treatments included diets containing 0, 3, 6, 9, or 12% finely ground soybean hulls (408 μ) in either corn-soybean meal or corn-soybean meal-DDGS–based diets (15 and 30% DDGS for Phases 1 and 2, respectively). Proximate analysis was conducted by Ward Laboratories, Inc. (Kearny, NE) on the soybean hulls before diet formulation and on the DDGS (Tables 1 and 2). All diets within each phase were formulated on a common standardized ileal digestible (SID) lysine concentration (Tables 3 and 4). The SID lysine levels fed were selected based on the required level for the diets without soybean hulls. Thus, the SID lysine:energy ratio increased as soybean hulls were added to the diet. All

[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.

Phase 1 diets contained 4% fish meal and 10% spray-dried whey. Individual pen weight and feed disappearance were measured on d 0, 7, 14, 21, 28, 35, and 42 to determine ADG, ADFI, and F/G.
All treatment diets were fed in meal form, and the soybean hulls were ground at the K-State Grain Science Feed Mill through a 1/16-in. screen and shipped to Kalmbach Feeds, Inc. for diet manufacturing. Feed samples were collected from each feeder during each phase and combined for a single composite sample of each treatment per phase.

In Exp. 2, a total 304 pigs (PIC, 337 × 1050, initially 25.7 lb) were used in a 21-d growth trial. Pigs were weighed and allotted to 1 of 8 treatments arranged in a 2 × 4 factorial with main effects of DDGS (0 or 20%) and soybean hulls (0, 5, 10, and 15% with 4 or 5 pigs per pen and 9 pens per treatment. Pigs were provided unlimited access to feed and water by way of a 4-hole dry self-feeder and a cup waterer in each pen (5 ft × 5 ft). All diets were fed in in meal form from d 0 to 21 (Table 5). Average daily gain, ADFI, and F/G were determined by weighing pigs and measuring feed disappearance on d 0, 7, 14, and 21. Soybean hulls and DDGS samples were collected and submitted to Ward Laboratories, Inc. for analysis. Feed samples were collected from each feeder and combined for a single composite sample.

In both studies, data were analyzed using the PROC MIXED procedure of SAS (SAS Institute, Inc., Cary, NC) with pen as the experimental unit. Contrasts were used to test for soybean hulls × DDGS interactions, main effects of DDGS, and linear and quadratic effects of increasing soybean hulls in both non-DDGS and DDGS diets. Results were considered significant at $P \leq 0.05$ and considered a trend at $P \leq 0.10$.

Results and Discussion

The analyzed nutrient levels of the soybean hulls used in both experiments were similar to those used in diet formulation, with the exception of a lower Ca value in the soybean hulls for Exp. 2. Analyzed nutrient levels of the DDGS differed, with less CP and fat in the DDGS in Exp. 2 than in Exp. 1. Soybean hulls in diets with and without DDGS reduced the bulk densities of the diets (Table 6) and increased the crude fiber and NDF content (Tables 3, 4, and 5).

For the overall period (d 0 to 42) in Exp. 1, soybean hulls × DDGS interactions (quadratic $P < 0.05$; Table 7) were observed for F/G and caloric efficiency on an ME and NE basis. Increasing soybean hulls worsened F/G quadratically ($P < 0.03$) when added to diets without DDGS and linearly ($P < 0.01$) when added to diets with DDGS. Caloric efficiencies improved on an ME and NE basis (quadratic, $P < 0.04$) with increasing soybean hulls in diets without DDGS but did not influence caloric efficiency when added to diets containing DDGS. Including DDGS in diets decreased ($P < 0.04$) ADG and ADFI and tended to improve ($P < 0.10$) F/G and caloric efficiency on an ME basis but not on an NE basis. Increasing soybean hulls in diets containing DDGS further reduced (quadratic, $P < 0.05$) ADG and tended to decrease (quadratic, $P < 0.08$) ADFI, whereas adding soybean hulls to diets without DDGS had no effect on ADG or ADFI. No significant differences were observed in weight on d 42; nevertheless, pigs fed the diet containing 12% soybean hulls and DDGS were 6.4 lb lighter than pigs fed 12% soybean hulls in diets without DDGS.

Based on the results in Exp. 1, soybean hulls × DDGS interactions occurred for F/G and caloric efficiencies. Feed efficiency worsened with the addition of soybean hulls due to a decrease in dietary energy; however, the improvement in caloric efficiency in diets without DDGS indicates that the energy value of soybean hulls is underestimated by published values when used at low levels in the diet. Contrary to previous research, levels up to 12% soybean hulls could be used without negative effects on ADG and ADFI. Furthermore, DDGS reduced ADG and ADFI but improved F/G while not affecting NE efficiency; therefore, the objective of Exp. 2 was to further evaluate the inclusion of soybean hulls up to 15% with or without DDGS to better understand the interaction of high-fiber ingredients and the impact on ME and NE efficiency.

Contrary to Exp.1, no soybean hulls × DDGS interactions were observed ($P > 0.25$) for the overall data (d 0 to 21) in Exp. 2. Increasing soybean hulls tended to worsen (linear, $P < 0.07$) F/G, but caloric efficiency improved (linear, $P < 0.008$) on an ME and NE basis, suggesting the published energy value for soybean hulls is undervalued. Increasing soybean hulls in diets without DDGS worsened (linear, $P < 0.04$) F/G, but adding DDGS had no effect on growth performance or caloric efficiency on an ME and NE basis.

In conclusion, soybean hulls are a low-energy, low bulk density ingredient that can be used in nursery pig diets up to 5% without affecting feed efficiency or up to 15% of the diet with no changes in gain or feed intake. The improvement in caloric efficiency when soybean hulls were added to the diet suggests that the energy value of soybean hulls is underestimated by published values. A numerical decrease in growth rate was evident when pigs were fed the 30% DDGS with 12% soybean hulls, which could be due to the diet reaching a fiber and NDF level that does not allow pigs to eat enough to meet their energy requirement, potentially due to increased gut fill. These studies suggest that more research is needed to fully understand the influence of combining high levels of high-fiber ingredients and the mechanisms for the decreased growth rate.

Table 1. Chemical analysis of soybean hulls (as-fed basis)

Item	Exp. 1	Exp. 2
Nutrient, %		
DM	91.40	91.71
CP	10.1 (12.2)[1]	13.4 (12.2)
ADF	42	25.2
NDF	58.3	51.2
Crude fiber	34.3 (33.3)	31.8 (33.3)
Ca	0.66 (0.52)	0.11 (0.52)
P	0.10 (0.15)	0.17 (0.15)
Bulk density, lb/bu[2]	37.72	40.25

[1] Values in parentheses indicate those used in diet formulation.

Table 2. Chemical analysis of dried distillers grains with solubles (as-fed basis)

Item	Exp. 1	Exp. 2
Nutrient, %		
DM	91.01	90.77
CP	26.3 (27.2)[1]	29.5 (27.2)
ADF	13.3	16.1
NDF	25.5	27.5
Crude fiber	9.3	8.1
Fat (oil)	11.8 (10.7)	8.7 (10.7)
Ca	0.07 (0.03	0.04 (0.03)
P	0.85 (0.71)	0.87 (0.71)

[1] Values in parentheses indicate those used in diet formulation.

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

		Phase 1[2]									
	DDGS, %:[3]	0					15				
Item	Soybean hulls, %:	0	3	6	9	12	0	3	6	9	12
Ingredient											
Corn		55.23	52.53	49.76	47.06	44.28	43.14	40.36	37.65	34.95	32.25
Soybean meal, 46.5% CP		28.19	27.92	27.73	27.46	27.27	25.54	25.35	25.08	24.81	24.54
Soybean hulls		--	3.00	6.00	9.00	12.00	--	3.00	6.00	9.00	12.00
DDGS		--	--	--	--	--	15.00	15.00	15.00	15.00	15.00
Select menhaden fish meal		4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00	4.00
Spray dried whey		10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
Monocalcium P, 21% P		0.50	0.50	0.50	0.50	0.50	0.15	0.15	0.15	0.15	0.15
Limestone		0.83	0.80	0.76	0.72	0.69	1.00	0.98	0.95	0.91	0.88
Salt		0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCl		0.230	0.228	0.223	0.220	0.215	0.260	0.255	0.253	0.250	0.248
L-threonine		0.123	0.128	0.133	0.138	0.143	0.050	0.055	0.060	0.065	0.070
L-tryptophan		0.130	0.133	0.135	0.138	0.138	0.088	0.090	0.093	0.095	0.098
Ronozyme CT (10,000)[4]		0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

continued

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

		Phase 1[2]									
	DDGS, %:[3]	0					15				
Item	Soybean hulls, %:	0	3	6	9	12	0	3	6	9	12
Calculated analysis											
Standardized ileal digestible (SID) amino acids, %											
Lysine		1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32	1.32
Isoleucine:lysine		63	62	62	62	62	65	65	65	65	65
Leucine:lysine		128	127	126	125	124	143	142	141	140	139
Methionine:lysine		35	35	35	35	36	32	32	32	32	33
Met & Cys:lysine		58	58	58	58	58	58	58	58	58	58
Threonine:lysine		65	65	66	66	65	65	65	65	65	65
Tryptophan:lysine		17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Valine:lysine		69	69	69	68	68	73	73	73	72	72
Total lysine, %		1.46	1.47	1.47	1.48	1.49	1.49	1.49	1.50	1.51	1.52
ME, kcal/lb		1,504	1,484	1,463	1,443	1,422	1,507	1,486	1,466	1,445	1,425
SID lysine:ME, g/Mcal		3.98	4.05	4.13	4.21	4.29	3.97	4.05	4.12	4.20	4.28
CP, %		21.9	21.9	22.0	22.0	22.0	23.7	23.7	23.7	23.8	23.8
Crude fiber, %		2.3	3.2	4.2	5.1	6.0	1.9	2.9	3.8	4.7	5.7
ADF, %[5]		3.1	4.2	5.3	6.4	7.6	5.0	6.2	7.3	8.4	9.5
NDF, %[6]		7.8	9.2	10.6	12.0	13.5	11.6	13.0	14.4	15.8	17.2
Ca, %		0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80	0.80
P, %		0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64	0.64
Available P, %		0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46	0.46

[1] A total of 600 nursery pigs (PIC C-29 × 359, initially 14.7 lb) were used in a 42-d growth trial with 6 replications per treatment.
[2] Phase 1 diets were fed from d 0 to 14.
[3] DDGS: dried distillers grains with solubles.
[4] Ronozyme CT (10,000) (International Nutrition, Omaha, NE), providing 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 (Institut National de la Recherche Agronomique), 2004. All other values taken from NRC, 1998.

Table 4. Phase 2 diet composition (Exp. 1, as-fed basis)[1]

		Phase 2[2]									
	DDGS, %:[3]	0					30				
Item	Soybean hulls, %:	0	3	6	9	12	0	3	6	9	12
Ingredient											
Corn		63.94	61.03	58.35	55.60	52.93	39.74	36.98	34.20	31.44	28.73
Soybean meal (46.5% CP)		32.71	32.67	32.40	32.21	31.94	27.34	27.15	26.96	26.77	26.50
Soybean hulls		--	3.00	6.00	9.00	12.00	--	3.00	6.00	9.00	12.00
DDGS		--	--	--	--	--	30.00	30.00	30.00	30.00	30.00
Monocalcium P (21% P)		1.05	1.05	1.05	1.05	1.05	0.35	0.35	0.35	0.35	0.35
Limestone		0.95	0.89	0.83	0.77	0.71	1.35	1.30	1.28	1.23	1.20
Salt		0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix		0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix		0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCl		0.333	0.323	0.320	0.315	0.313	0.395	0.390	0.385	0.380	0.378
L-threonine		0.130	0.138	0.145	0.150	0.158	0.005	0.008	0.010	0.013	0.015
L-tryptophan		0.125	0.130	0.135	0.138	0.140	0.048	0.050	0.053	0.055	0.058
Ronozyme CT (10,000)[4]		0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019	0.019
Total		100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0

continued

Table 4. Phase 2 diet composition (Exp. 1, as-fed basis)[1]

		Phase 2[2]									
	DDGS, %:[3]	0					30				
Item	Soybean hulls, %:	0	3	6	9	12	0	3	6	9	12
Calculated analysis											
Standardized ileal digestible (SID) amino acids,%											
Lysine		1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28	1.28
Isoleucine:lysine		61	62	61	61	61	66	66	66	66	66
Leucine:lysine		129	128	127	126	125	160	159	158	157	156
Methionine:lysine		33	33	34	34	35	29	29	29	29	29
Met & Cys:lysine		58	58	58	58	59	59	58	58	58	58
Threonine:lysine		63	63	63	63	63	63	63	63	63	63
Tryptophan:lysine		17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Valine:lysine		68	68	68	67	67	77	77	76	76	76
Total lysine, %		1.42	1.42	1.43	1.44	1.44	1.47	1.48	1.49	1.50	1.50
ME, kcal/lb		1,505	1,48	1,465	1,445	1,424	1,510	1,489	1,469	1,448	1,428
SID lysine:ME, g/Mcal		3.86	3.93	4.00	4.07	4.15	3.85	3.92	3.99	4.06	4.14
CP, %		21.13	21.23	21.25	21.29	21.31	24.67	24.71	24.75	24.79	24.80
Crude fiber, %		2.7	3.6	4.5	5.5	6.4	1.9	2.9	3.8	4.7	5.7
ADF, %[5]		3.6	4.7	5.8	6.9	8.1	7.5	8.6	9.7	10.9	12.0
NDF, %[6]		9.1	10.5	11.9	13.3	14.7	16.6	18.0	19.5	20.9	22.3
Ca, %		0.69	0.68	0.67	0.66	0.65	0.69	0.69	0.69	0.69	0.69
P, %		0.63	0.62	0.62	0.61	0.61	0.59	0.58	0.58	0.57	0.57
Available P, %		0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40	0.40

[1] A total of 600 nursery pigs (PIC C-29 × 359, initially 14.7 lb) were used in a 42-d growth trial with 6 replications per treatment.
[2] Phase 2 diets were fed from d 14 to 42.
[3] DDGS: dried distillers grains with solubles.
[4] Ronozyme CT (10,000) (International Nutrition, Omaha, NE), providing 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 (Institut National de la Recherche Agronomique), 2004. All other values taken from NRC, 1998.

Table 5. Diet composition (Exp. 2, as-fed basis)[1]

DDGS,%[2]	0				20			
Item Soybean hulls, %	0	5	10	15	0	5	10	15
Ingredient								
Corn	64.42	59.84	55.16	50.72	48.25	43.82	39.21	34.48
Soybean meal (46.5% CP)	32.08	31.73	31.47	30.97	28.55	28.05	27.71	27.52
Soybean hulls	-	5.00	10.00	15.00	-	5.00	10.00	15.00
DDGS	-	-	-	-	20.00	20.00	20.00	20.00
Monocalcium P (21% P)	1.05	1.05	1.05	1.05	0.6	0.6	0.6	0.6
Limestone	1.00	0.93	0.88	0.80	1.25	1.18	1.13	1.05
Salt	0.35	0.35	0.35	0.35	0.35	0.35	0.35	0.35
Vitamin premix	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15	0.15	0.15	0.15
L-lysine HCL	0.328	0.320	0.310	0.308	0.368	0.365	0.358	0.345
DL-methionine	0.125	0.130	0.140	0.150	0.043	0.045	0.053	0.060
L-threonine	0.125	0.123	0.125	0.130	0.065	0.070	0.073	0.075
Phyzyme 600[3]	0.125	0.125	0.125	0.125	0.125	0.125	0.125	0.125
Total	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Calculated analysis								
Standardized ileal digestible (SID) amino acids,%								
Lysine	1.26	1.26	1.26	1.26	1.26	1.26	1.26	1.26
Isoleucine:lysine	61	61	61	61	65	65	65	65
Leucine:lysine	129	128	127	125	151	149	147	146
Methionine:lysine	33	33	34	34	30	30	30	31
Met & Cys:lysine	58	58	58	58	58	58	58	58
Threonine:lysine	63	63	63	63	63	63	63	63
Tryptophan:lysine	17.5	17.5	17.5	17.5	17.5	17.5	17.5	17.5
Valine:lysine	68	68	67	67	74	74	73	73
Total lysine, %	1.39	1.41	1.42	1.43	1.43	1.44	1.46	1.47
ME, kcal/lb	1,503	1,458	1,413	1,368	1,506	1,461	1,416	1,371
SID lysine: ME, g/Mcal	3.80	3.92	4.05	4.18	3.80	3.91	4.04	4.17
CP, %	20.9	20.9	21.0	21.0	23.2	23.2	23.3	23.4
Crude fiber, %	2.7	4.2	5.8	7.3	2.2	3.7	5.3	6.8
ADF, %[4]	3.5	5.4	7.3	9.2	6.2	8.0	9.9	11.8
NDF, %[5]	9.0	11.4	13.7	16.1	14.1	16.4	18.8	21.1
Ca, %	0.70	0.70	0.70	0.70	0.70	0.70	0.70	0.70
P, %	0.62	0.61	0.61	0.60	0.60	0.59	0.58	0.58
Available P, %	0.42	0.42	0.42	0.42	0.42	0.42	0.42	0.42

[1] A total of 304 pigs (PIC, 337 × 1050, initially 25.7 lb) were used in a 21-d growth trial with 9 replications per treatment.
[2] DDGS: dried distillers grains with solubles.
[3] Phyzyme 600 (Danisco, Animal Nutrition, St. Louis, MO), providing 231 phytase units (FTU)/lb, with release of 0.10% available P.
[4] Soybean hulls ADF values taken from INRA (Institut National de la Recherche Agronomique), 2004. All other values taken from NRC, 1998.
[5] Soybean hulls NDF values taken from INRA (Institut National de la Recherche Agronomique), 2004. All other values taken from NRC, 1998.

Table 6. Bulk density of experimental diets (Exp. 2) (as-fed basis)[1]

		Treatments							
	DDGS, %:[2]	0				20			
Item	Soybean hulls, %:	0	5	10	15	0	5	10	15
Bulk density, lb/bu		58.2	56.7	54.1	49.7	54.5	51.7	49.2	50.3

[1] Diet samples collected from the tops of each feeder during each phase. Bulk density was not measured in Exp. 1.
[2] DDGS: dried distillers grains with solubles.

Table 7. The effects of soybean hulls in corn-soybean meal and corn-soybean meal-dried distillers grains with solubles (DDGS) nursery diets (Exp. 1)[1]

												Probability, *P*<			
	DDGS, %[2]:	-					+						Soy hulls w/out DDGS		Soybean hulls with DDGS	
Item	Soybean hulls, %:	0	3	6	9	12	0	3	6	9	12	SEM	Linear	Quadratic	Linear	Quadratic
d 0 to 42																
ADG, lb		1.25	1.20	1.21	1.22	1.24	1.19	1.20	1.22	1.18	1.09	0.036	0.99	0.28	0.08	0.05
ADFI, lb		1.89	1.85	1.89	1.93	1.88	1.75	1.77	1.87	1.83	1.68	0.070	0.81	0.93	0.74	0.08
F/G, lb[3]		1.51	1.54	1.56	1.58	1.51	1.48	1.47	1.53	1.55	1.53	0.024	0.47	0.03	0.01	0.46
Caloric efficiency[4]																
ME[3]		2,274	2,287	2,289	2,286	2,157	2,227	2,189	2,248	2,249	2,190	35.7	0.005	0.04	0.89	0.46
NE[3]		1,628	1,627	1,618	1,606	1,505	1,615	1,579	1,610	1,601	1,549	25.3	0.002	0.04	0.17	0.45
BW, lb																
d 0		14.7	14.4	14.5	14.7	14.7	14.6	14.6	14.7	14.5	14.5	0.92	0.89	0.84	0.91	0.95
d 42		67.2	64.8	65.4	66.7	66.9	64.4	65.2	66.0	64.3	60.5	2.36	0.88	0.51	0.25	0.19

[1] A total of 600 nursery pigs (PIC C-29 × 359, initially 14.7 lb) were used in a 42-d growth trial with 10 replications per pen.
[2] Phase 1 = 15% DDGS, Phase 2 = 30% DDGS.
[3] Soybean hulls level × DDGS interaction, quadratic, $P < 0.05$.
[4] Caloric efficiency is express as kcal/lb gain.

Table 8. Main effects of soybean hulls and dried distillers grains with solubles (DDGS) (Exp. 1)[1]

	Soybean hulls, %						DDGS[2]			Probability, *P*<		
										Soybean hulls		
Item	0	3	6	9	12	SEM	-	+	SEM	Linear	Quadratic	DDGS
d 0 to 42												
ADG, lb	1.22	1.20	1.22	1.20	1.17	0.026	1.22	1.18	0.02	0.23	0.55	0.04
ADFI, lb	1.82	1.81	1.88	1.88	1.78	0.051	1.89	1.78	0.03	0.95	0.20	0.02
F/G	1.49	1.51	1.55	1.57	1.52	0.018	1.54	1.51	0.01	0.03	0.04	0.06
Caloric efficiency[3]												
ME	2,251	2,238	2,268	2,267	2,173	25.2	2,258	2,220	16.0	0.12	0.05	0.10
NE	1,622	1,603	1,614	1,603	1,527	17.7	1,597	1,591	11.3	0.002	0.05	0.73
BW, lb												
d 0	14.7	14.5	14.6	14.6	14.6	0.62	14.6	14.6	0.41	0.98	0.92	0.92
d 42	65.8	65.0	65.7	65.5	63.7	1.67	66.2	64.1	1.06	0.47	0.65	0.16

[1] A total of 600 nursery pigs (PIC C-29 × 359, initially 14.7 lb) were used in a 42-d growth trial with 10 replications per pen.
[2] Phase 1 = 15% DDGS, Phase 2 = 30% DDGS.
[3] Caloric efficiency is express as kcal/lb gain.

Table 9. The effects of soybean hulls in corn-soybean meal and corn-soybean meal-dried distillers grains with solubles (DDGS) diets (Exp. 2)[1]

	DDGS, %									Probability, $P<$			
	0				20					Soybean hulls w/out DDGS		Soybean hulls with DDGS	
Item Soybean hulls, %:	0	5	10	15	0	5	10	15	SEM[2]	Linear	Quadratic	Linear	Quadratic
d 0 to 21													
ADG	1.17	1.18	1.16	1.13	1.13	1.15	1.14	1.10	0.032	0.27	0.53	0.43	0.36
ADFI	1.81	1.82	1.83	1.82	1.78	1.80	1.79	1.75	0.053	0.82	0.82	0.61	0.50
F/G	1.54	1.54	1.59	1.61	1.57	1.57	1.57	1.59	0.027	0.04	0.58	0.61	0.64
Caloric efficiency[3]													
ME	2,319	2,262	2,273	2,253	2,365	2,317	2,250	2,234	38.7	0.27	0.62	0.007	0.66
NE	1,657	1,600	1,590	1,558	1,707	1,656	1,590	1,560	27.3	0.01	0.63	0.0001	0.68
BW, lb													
d 0	26.0	25.6	25.6	25.6	25.7	25.6	25.7	25.7	0.59	0.66	0.78	0.98	0.97
d 21	50.6	50.5	50.4	49.3	49.5	49.7	50.4	48.8	1.05	0.40	0.62	0.74	0.35

[1] A total of 304 pigs (PIC, 337 × 1050, initially 25.7 lb) were used in a 21-d growth trial with 9 replications per treatment.
[2] No soybean hulls × DDGS interactions, $P > 0.25$.
[3] Caloric efficiency is express as kcal/lb gain.

Table 10. Main effects of soybean hulls in corn-soybean meal and corn-soybean meal-dried distillers grains with solubles (DDGS) diets (Exp. 2)[1]

	Soybean hulls, %					DDGS			Probability, *P*<		
									Soybean hulls		
Item	0	5	10	15	SEM	0	20%	SEM	Linear	Quadratic	DDGS
d 0 to 21											
ADG	1.15	1.17	1.15	1.11	0.022	1.16	1.13	0.02	0.18	0.28	0.17
ADFI	1.79	1.81	1.81	1.78	0.036	1.82	1.78	0.03	0.85	0.52	0.26
F/G	1.56	1.56	1.57	1.60	0.018	1.57	1.58	0.01	0.07	0.47	0.74
Caloric efficiency[2]											
ME	2,342	2,289	2,261	2,244	25.8	2,277	2,291	18.3	0.008	0.50	0.59
NE	1,682	1,628	1,590	1,559	18.2	1,601	1,628	12.9	0.0001	0.53	0.15
BW, lb											
d 0	25.8	25.6	25.7	25.6	0.39	25.7	25.7	0.30	0.77	0.82	0.94
d 21	50.0	50.1	50.4	49.0	0.70	50.2	49.6	0.51	0.41	0.29	0.40

[1] A total of 304 pigs (PIC, 337 × 1050, initially 25.7 lb) were used in a 21-d growth trial with 9 replications per treatment.
[2] Caloric efficiency is express as kcal/lb gain.