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Effects of Increasing Levels of Soybean Meal in Nursery Diets on Growth Performance and Fecal Characteristics of 22- to 60-lb Pigs[1]

Jamil E. G. Faccin, Robert D. Goodband, Mike D. Tokach, Joel M. DeRouchey, Jordan T. Gebhardt,[2] and Jason C. Woodworth

Summary

Two experiments were conducted to determine the effects of increasing soybean meal (SBM) on late nursery pig performance. In Exp. 1, a total of 266 pigs (241 × 600 DNA; initially 22.2 ± 0.37 lb) were used in a 21-d trial with 14 replicate pens per treatment and 4 to 5 pigs per pen. Pens of pigs were randomly assigned to 1 of 4 dietary treatments which were corn-based with SBM levels of 25.0, 28.9, 32.5, or 36.2%. In Exp. 2, a total of 340 pigs (241 × 600 DNA; initially 29.8 ± 0.40 lb) were used in a 21-d trial with 14 replicate pens per treatment and 4 to 5 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments which were corn-based with SBM levels of 25.0, 28.9, 32.5, or 36.2, or 40.0%. In both experiments, at weaning, pigs were distributed into pens based on body weight, gender, sow parity, and age. Before the start of the experimental period, pigs were fed a phase 1 followed by a phase 2 control diet. After 21 and 26 d for Exp. 1 and 2, respectively, pens of pigs were randomly allotted to treatments in a randomized complete block design with BW as the blocking factor. An addition of SBM replaced feed-grade amino acids (AAs) to form experimental diets and all diets were formulated to be nearly isocaloric with SBM NE considered to be 100% of corn NE. Dietary additions of feed-grade AA were adjusted to meet or exceed AA requirements in relation to Lys for Ile, Met, Cys, Thr, Trp, and Val. Diets were fed in meal form. In Exp. 1, increasing SBM from 25.0 to 36.2%, decreased ADG (linear, $P = 0.012$), ADFI (linear, $P < 0.001$), and final BW (linear, $P = 0.021$) with the greatest change occurring when SBM increased from 28.9 to 32.5%. No evidence for difference was observed for F/G ($P = 0.729$). In Exp. 2, starting with a heavier initial weight, increasing SBM from 25.0 to 40.0%, decreased ADFI (linear, $P = 0.017$) with the greatest change occurring when SBM increased from 32.5 to 36.2%. However, no evidence for difference ($P \geq 0.198$) was observed for ADG, final BW, and F/G. This study showed that when pigs were fed high levels of SBM starting from 22 lb in the nursery period, pig performance was negatively affected. However, delaying the use of elevated SBM levels until pigs reach 30 lb resulted in reduced feed intake without impacting growth or feed efficiency. Thus, feeding up to 28.9% SBM for nursery pigs starting at 22 lb does not compromise performance, and starting pigs on higher SBM diets when pigs are closer to 30 lb did not affect ADG or F/G.

[1] The authors appreciate the United Soybean Board for partial financial support.

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Introduction

Soybean meal (SBM) is the main plant-protein source used in swine diets primarily due to its high digestibility, amino acid profile, and consistent processing that removes anti-nutritional factors.[3] Feed-grade amino acids have been used worldwide aiming to meet pigs' amino acid requirements, reduce dietary crude protein, and decrease diet cost. However, with the recent Renewable Fuels Initiative, soybean oil is expected to be in record demand by the fuel energy industry. Consequently, there could be record amounts of SBM produced, which is speculated to be associated with a lower cost. As a result, there will be the potential opportunity for increased usage of SBM in swine diets. This might be a unique situation where SBM will replace a portion of the feed-grade amino acids in swine diets. With this opportunity for an increased supply of more economical SBM, there is a need to reevaluate the maximum amount of SBM that can be included in late nursery diets without negatively influencing performance. Therefore, the objective of this study was to evaluate different levels of SBM in late nursery diets on growth performance.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in these experiments conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS. Each pen (4 × 4 ft) was equipped with a 4-hole dry self-feeder, and a nipple waterer to provide *ad libitum* access to feed and water.

Animals and diets

Two experiments were conducted to determine the effects of increasing SBM on late nursery pig performance. In Exp. 1, a total of 266 pigs (241 × 600 DNA; initially 22.2 ± 0.37 lb) were used in a 21-d trial with 14 replicate pens per treatment and 4 to 5 pigs per pen. Pens of pigs were randomly assigned to 1 of 4 dietary treatments (Table 1) which were corn-based containing 25.0, 28.9, 32.5, or 36.2% SBM. In Exp. 2, a total of 340 pigs (initially 29.8 ± 0.40 lb) were used in a 21-d trial with 14 replicate pens per treatment and 4 to 5 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments which were corn-based containing 25.0, 28.9, 32.5, or 36.2, or 40.0% SBM. In both experiments, at weaning, pigs were distributed into pens based on body weight, gender, sow parity, and age. After 21 and 26 d for Exp. 1 and 2, respectively, pens of pigs were randomly allotted to treatments in a randomized complete block design with BW as the blocking factor.

The treatments were formed by replacing feed grade AAs with increasing dietary SBM, and all diets were formulated to be nearly isocaloric with SBM NE considered to be 100% of corn NE.[4] Dietary additions of feed-grade AA were adjusted to meet or exceed AA requirements in relation to Lys for Ile, Met, Cys, Thr, Trp, and Val. Diets were fed in meal form.

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[3] Pettigrew, J. E., K. T. Soltwedel, J. C. Miguel, and M. F. Palacios. 2017. Soybean Meal Information Center Fact Sheet: Soybean Use - Swine. Soybean Meal Inf. Cent. Available at: https://www.soymeal.org/resources/soybean-use-swine.

[4] Cemin, H.S., Williams, H.E., Tokach, M.D., Dritz, S.S., Woodworth, J.C., DeRouchey, J.M., Goodband, R.D., Coble, K.F., Carrender, B.A., Gerhart, M.J. Estimate of the energy value of soybean meal relative to corn based on growth performance of nursery pigs. J Animal Sci Biotechnol 11, 70 (2020). https://doi.org/10.1186/s40104-020-00474-x

Pen weights and feed disappearance were measured on d 0 (corresponding to d 21 and 26 post-weaning for Exp. 1 and 2, respectively), 7, 14, and 21 to determine ADG, ADFI, and F/G. Fecal samples for the determination of fecal dry matter and scores were collected on d 7 and 21. Fecal samples were collected from the same three medium weight pigs in each pen on both collection days. After collection, fecal samples were dried at 55°C (131°F) in a forced air oven for 48 h and the ratio of dried to wet fecal weight determined the fecal dry matter. Fecal scores were assigned by the same observer based on a 5-point scale, with 1 = watery feces; 2 = unformed feces; 3 = soft feces; 4 = firm formed feces; and 5 = hard feces.

Statistical analysis

Data were analyzed using the GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Inc., Cary, NC) in a randomized complete block design with pen serving as the experimental unit. The statistical model considered fixed effects of dietary treatment, linear and quadratic contrasts, and random effect of the block. Contrasts were used to test for linear and quadratic responses between different SBM levels. Fecal dry matter and fecal score were analyzed as repeated measures representing multiple observations in each pen over time. Pens were included in the model as random intercepts to account for subsampling attributed to the multiple observations on each day. Soybean meal, day, and the associated interactions were considered fixed effects within the statistical model. For fecal score, data were analyzed as categorical outcomes using a generalized linear mixed model with a multinomial response distribution using a cumulative logit link function. Data were summarized using the FREQ procedure and reported as the percentage of observations within each fecal score category by treatment and day. Results from the experiment were considered significant at $P < 0.05$ and marginally significant between $P > 0.05$ and $P \leq 0.10$.

Results and Discussion

In Exp. 1, for the overall 21-d period, increasing SBM from 25.0 to 36.2% (Table 2) in the diets, decreased ADG (linear, $P = 0.012$), ADFI (linear, $P < 0.001$), and final body weight (linear, $P = 0.021$) with the greatest change occurring when SBM increased from 28.9 to 32.5%. No evidence for difference was observed for F/G ($P = 0.729$). In Exp. 2, for the overall 21-d period, increasing SBM from 25.0 to 40.0% in the diets decreased (linear, $P = 0.017$) ADFI with the greatest change occurring when SBM increased from 32.5 to 36.2%. However, no evidence for difference was observed for ADG ($P = 0.295$), final BW ($P = 0.441$), and F/G ($P = 0.198$).

For fecal DM in Exp. 1 (Table 3), there was an SBM × day interaction (linear, $P = 0.030$) where on d 7 as SBM level increased, fecal DM linearly decreased ($P = 0.006$), but this effect was not observed on d 21 ($P = 0.812$). When considering only the treatment's main effects, regardless of the day, a tendency (linear, $P = 0.073$) for lower fecal DM was found as SBM level increased in the diet. Additionally, regardless of the treatment, pigs had lower ($P < 0.001$) fecal DM on d 7 than d 21. For fecal score (Figure 1), there was no evidence of SBM × day interaction ($P \geq 0.479$) or SBM level effect within either of the days ($P \geq 0.140$). Also, no evidence for differences was observed for the main effects of treatment ($P = 0.175$) and day ($P = 0.168$). For fecal DM in Exp. 2, no SBM × day interaction was found ($P > 0.180$), and on both d 7 and 21, increasing the inclusion rate of SBM in the diet resulted in a reduction (linear, $P = 0.046$) of fecal dry matter. Similar to Exp. 1, feces on d 7 were looser than on d 21 ($P < 0.001$). For

fecal score (Figure 2), there was no evidence of an SBM × day interaction ($P \geq 0.352$). However, fecal scores followed the results of DM, and as SBM increased, the frequency of unformed and watery feces increased on d 7 (linear, $P = 0.015$), and a tendency for a similar pattern was observed on d 21 (linear, $P = 0.093$). A day effect was also observed ($P = 0.032$) with a higher frequency of unformed and firm feces on d 7 than 21.

In conclusion, the study demonstrated that the initial starting weight of nursery pigs fed high levels of SBM impacts the responses observed. The negative impact on growth and feed efficiency was more pronounced when high inclusion levels of SBM were used when pigs had an initial starting weight of 22 lb (Exp. 1). However, when the starting weight was approximately 30 lb (Exp. 2), only feed intake was reduced, without any consequences in growth or feed efficiency. Also, increasing the levels of SBM reduced fecal DM more markedly a week after the transition to high SBM diets compared to 3 weeks after the start of treatment feeding.

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

	Soybean meal, %				
Item	**25.0%**	**28.9%**	**32.5%**	**36.2%**	**40.0%[2]**
Ingredients, %					
Corn	69.50	66.05	62.73	59.36	55.88
Soybean meal, 46% CP[3]	25.02	28.86	32.53	36.20	40.04
Soybean oil	1.00	1.00	1.00	1.00	1.00
Calcium carbonate	0.73	0.75	0.75	0.78	0.78
Monocalcium P, 21% P	1.10	1.05	1.00	0.95	0.90
Salt	0.60	0.60	0.60	0.60	0.60
L-Lys-HCl	0.65	0.53	0.42	0.30	0.18
DL-Met	0.28	0.24	0.21	0.18	0.14
L-Trp	0.09	0.07	0.05	0.03	---
L-Thr	0.30	0.25	0.20	0.15	0.10
L-Val	0.25	0.19	0.13	0.06	---
L-Ile	0.09	0.03	---	---	---
Vitamin-premix with phytase[4]	0.25	0.25	0.25	0.25	0.25
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Calculated analysis					
SID AA, %					
Lys	1.30	1.30	1.30	1.30	1.30
Ile:Lys	56	56	59	64	69
Leu:Lys	106	113	120	127	134
Met:Lys	40	39	38	37	35
Met and Cys:Lys	60	60	60	60	60
Thr:Lys	65	65	65	65	65
Trp:Lys	20.6	20.6	20.6	20.6	20.6
Val:Lys	73	73	73	73	73
SID Lys:NE, g/Mcal	4.88	4.89	4.89	4.90	4.90
NE, kcal/lb	1,208	1,206	1,205	1,204	1,203
Ca, %	0.65	0.66	0.66	0.67	0.68
STTD P, %	0.47	0.47	0.47	0.47	0.47
CP, %	19.0	20.2	21.5	22.7	24.0
NDF, %	8.4	8.4	8.4	8.4	8.4

[1] Soybean meal was assumed to have 100% NE as corn.
[2] Treatment with 40.0% SBM was only used in Exp. 2.
[3] CP = crude protein.
[4] 567 FTU/lb phytase with an expected STTD P release of 0.12% (Ronozyme HiPhos GT 2700; DSM Nutritional Products, Parsippany, NJ).

Table 2. Effects of increasing soybean meal levels on the growth performance of phase 3 nursery pigs[1]

	Soybean meal, %						*P* =	
Item	**25.0**	**28.9**	**32.5**	**36.2**	**40.0[2]**	**SEM**	**Linear**	**Quadratic**
Exp. 1								
BW, lb								
d 0	22.2	22.2	22.2	22.2	---	0.37	0.956	0.990
d 21	48.4	50.5	46.6	46.7	---	0.83	0.021	0.189
d 0 to 21								
ADG, lb	1.25	1.31	1.15	1.17	---	0.035	0.012	0.569
ADFI, lb	1.89	1.89	1.74	1.72	---	0.035	< 0.001	0.742
F/G	1.51	1.45	1.53	1.49	---	0.025	0.975	0.729
Exp. 2								
BW, lb								
d 0	29.8	29.9	29.8	29.9	29.8	0.40	0.572	0.538
d 21	61.9	62.5	62.4	61.6	61.3	0.88	0.441	0.487
d 0 to 21								
ADG, lb	1.53	1.54	1.56	1.50	1.50	0.030	0.295	0.478
ADFI, lb	2.33	2.29	2.31	2.24	2.22	0.035	0.017	0.800
F/G	1.52	1.49	1.48	1.49	1.48	0.020	0.198	0.379

[1] A total of 266 and 340 pigs for experiments 1 and 2, respectively, were used in a 21-d trial. Each pen had 4 to 5 pigs and each treatment had 14 replicate pens. Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing synthetic amino acids inclusion.
[2] Treatment with 40.0% SBM was only used in Exp. 2.

Table 3. Main effects of SBM levels within days on nursery pig fecal dry matter[1]

	Soybean meal level, %[2]						P =	
Fecal DM, %	**25.0**	**28.9**	**32.5**	**36.2**	**40.0[3]**	**SEM**	**Linear**	**Quadratic**
Exp. 1[4]								
d 7	20.6	20.1	19.6	17.5	---	0.40	0.006	0.317
d 21	21.3	21.8	20.8	21.7	---	0.40	0.962	0.812
Exp. 2[5]								
d 7	20.8	19.6	18.7	17.0	16.6	0.43	< 0.001	0.832
d 21	22.0	21.3	22.5	19.3	19.9	0.43	0.046	0.644

[1] A total of 340 pigs were used in two 21-d trials in 56 pens. Each pen had 4 to 5 pigs and each treatment had 14 replicate pens. Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing synthetic amino acids inclusion.
[2] Feces from three piglets from each pen were taken in plastic bags on d 7 and 21, individually weighed, and dried to measure fecal dry matter.
[3] Treatment with 40.0% SBM was only used in Exp. 2.
[4] SBM × day, linear $P = 0.030$, quadratic $P = 0.344$; Day, $P < 0.001$.
[5] SBM × day, linear $P = 0.180$, quadratic $P = 0.377$; Day, $P < 0.001$.

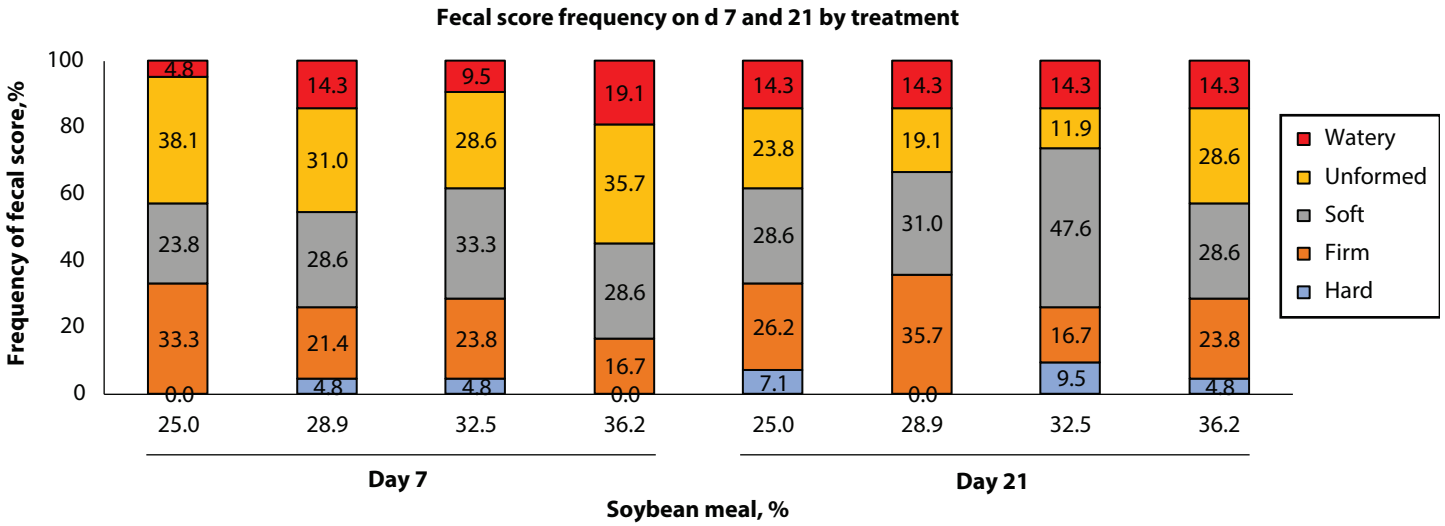

Figure 1. Fecal score frequency on d 7 and 21 by SBM level (Exp. 1). A total of 266 pigs were used with 4 or 5 pigs per pen. Each bar represents 42 observations representing 3 pigs in 14 pens per treatment. Fecal scores were assigned by a single observer based on a 5-point scale, with watery, unformed, soft, firm, and hard feces. Frequency was determined by the number of each fecal score over the total number of observations of each treatment. SBM × day, linear, *P* = 0.479; quadratic, *P* = 0.949; SBM d 7: linear, *P* = 0.140; quadratic, *P* = 0.439; SBM d 21: linear, *P* = 0.647; quadratic, *P* = 0.504; Day, *P* = 0.168.

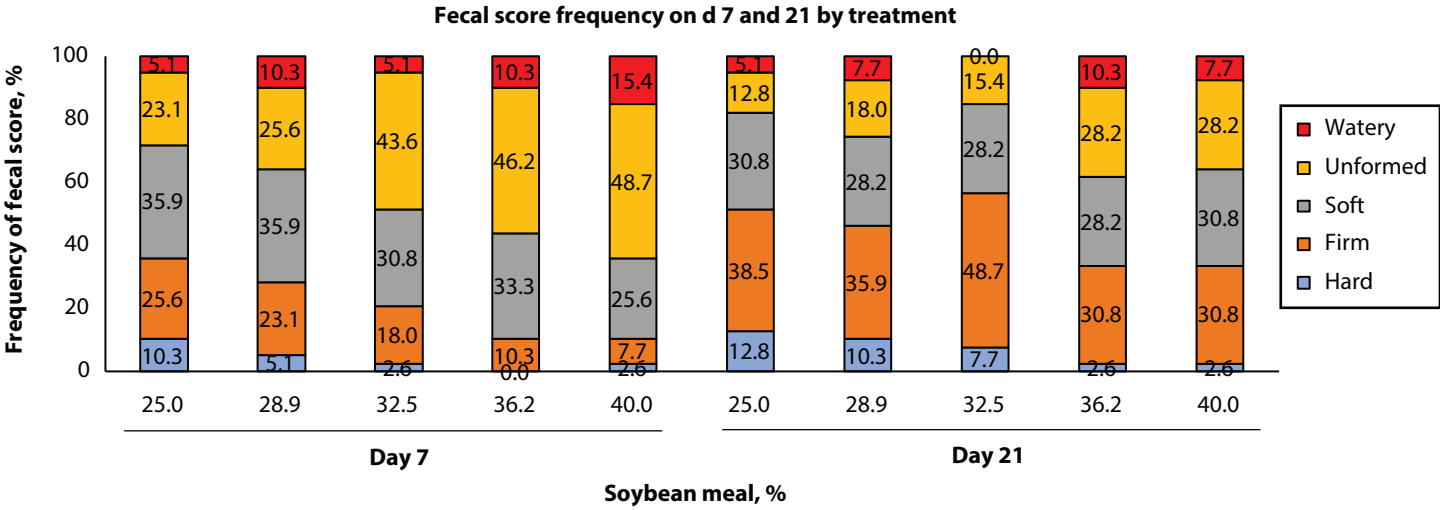

Figure 2. Fecal score frequency on d 7 and 21 by SBM level (Exp. 2). A total of 340 pigs were used with 4 or 5 pigs per pen. Each bar represents 42 observations representing 3 pigs per pen and 14 pens per treatment. Fecal scores were assigned by a single observer based on a 5-point scale, with watery, unformed, soft, firm, and hard feces. Frequency was determined by the number of each fecal score over the total number of observations of each treatment. SBM × day, linear, *P* = 0.352; quadratic, *P* = 0.550; SBM d 7: linear, *P* = 0.015; quadratic, *P* = 0.826; SBM d 21: linear, *P* = 0.093; quadratic, *P* = 0.718; Day, *P* = 0.032.