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Effects of Increasing Soybean Meal Levels on Growth Performance and Carcass Characteristics of Pigs in Grower and Late-Finishing Phases[1]

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Summary

Four experiments were conducted to determine the effects of increasing soybean meal (SBM) on grower and late-finishing pig performance. In Exp. 1, a total of 615 pigs (initially 95.2 ± 1.51 lb) were used in a 28-d trial with 14 replicate pens per treatment and 8 to 10 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments which were corn-based with soybean meal levels of 19.1, 22.6, 26.3, 29.9, or 33.5%. In Exp. 2, a total of 615 pigs (initially 225.5 ± 3.42 lb) were used in a 30-d trial with 14 replicate pens per treatment and 8 to 10 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments which were corn-based with soybean meal levels of 11.2, 14.2, 17.2, 20.2, or 23.2%. In both experiments, treatments were assigned in a completely randomized design and soybean meal inclusion was increased, replacing feed grade amino acids to form the treatments. For Exp. 1, increasing SBM increased (linear, $P = 0.038$) ADG and improved ($P < 0.001$) feed efficiency, with the greatest change from increasing SBM from 19.1 to 22.6%. For late-finishing pigs (Exp. 2), no differences ($P > 0.10$) were observed for any growth performance or carcass criteria. Experiments conducted in a second series were conducted with the same basic procedures as Exp. 1 and 2, but all diets contained DDGS, and were conducted in a commercial facility. In Exp. 3, a total of 1,080 pigs (initially 86.1 ± 1.72 lb) were used in a 28-d trial with 10 replicate pens per treatment and 27 pigs per pen. Pens of pigs were assigned to 1 of 4 dietary treatments which were corn-20% DDGS-based and soybean meal was added at 18.2, 23.5, 28.9, or 34.3%. For Exp. 4, a total of 1,080 pigs (initially 225.2 ± 2.50 lb) were used in a 33-d trial with 10 replicate pens per treatment and 27 pigs per pen. Pens of pigs were assigned to 1 of 4 dietary treatments which were corn-10% DDGS-based with soybean meal levels of 9.5, 13.5, 17.5, or 21.5%. When DDGS was included in the diet, no differences ($P > 0.10$) were observed for any growth performance criteria for early- or late-finishing pigs. In conclusion, increasing levels of SBM (up to 33.5% of the diet) in grower pig diets linearly improved ADG and feed efficiency in corn-soybean meal-based diets. However, when DDGS was included in the diet, pig performance was not affected when SBM ranged from 18.2 to 34.3%. For late-finishing

[1] Funding, in part, was provided by the United Soybean Board.

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pig diets, increasing the SBM from approximately 10 to 23% in diets with or without DDGS did not result in any changes in growth and carcass parameters. These results suggest that high levels of SBM in the diet (no feed-grade amino acids) are well tolerated and do not negatively affect pig growth.

Introduction

It is common for swine diets to be formulated with increasing amounts of feed-grade AA and corn co-products such as DDGS as partial or complete replacements for SBM due to widespread availability and lower cost. With the recent Renewable Fuels Initiative, soybean oil is expected to be in record demand by the fuel energy industry. Consequently, there will be record amounts of soybean meal produced, which is speculated to result in inexpensive SBM. 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 likely 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 swine diets without negatively influencing performance. Therefore, this study aimed to determine the maximum allowable amount of soybean meal that can be added to grower and late-finishing diets that are formulated without or with DDGS.

Procedures

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. The study was conducted at the Kansas State University Swine Teaching and Research Center in Manhattan, KS (Exp. 1 and 2) and at a commercial research-finishing site in southwest Minnesota (Exp. 3 and 4). The barns were totally enclosed and environmentally regulated (Exp. 1 and 2), and naturally ventilated and double-curtain-sided (Exp. 3 and 4). Each pen was equipped with a 2-hole (Exp. 1 and 2) and 5-hole (Exp. 3 and 4) stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water.

Animals and diets

Four experiments were conducted to determine the effects of increasing levels of SBM in grower and late-finishing pigs. In Exp. 1, a total of 615 pigs (initially 95.2 ± 1.51 lb) were used in a 28-d trial with 14 replicate pens per treatment and 8 to 10 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments (Table 1) which were corn-based with soybean meal levels of 19.1, 22.6, 26.3, 29.9, or 33.5%. In Exp. 2, the same 615 pigs (initially 225.5 ± 3.42 lb) were re-allotted and used in a 30-d trial with 14 replicate pens per treatment and 8 to 10 pigs per pen. Pens of pigs were randomly assigned to 1 of 5 dietary treatments (Table 2) which were corn-based with soybean meal levels of 11.2, 14.2, 17.2, 20.2, or 23.2%. In Exp. 3, a total of 1,080 pigs (initially 86.1 ± 1.72 lb) were used in a 28-d trial with 10 replicate pens per treatment and 27 pigs per pen. Pens of pigs were assigned to 1 of 4 dietary treatments (Table 3) which were corn-20% DDGS-based and soybean meal was added at 18.2, 23.5, 28.9, or 34.3%. For Exp. 4, a total of 1,080 pigs (initially 225.2 ± 2.50 lb) were used in a 33-d trial with 10 replicate pens per treatment and 27 pigs per pen. Pens of pigs were assigned to 1 of 4 dietary treatments (Table 4) which were corn-10% DDGS-based and soybean meal levels of 9.5, 13.5, 17.5, or 21.5%. In all experiments, treatments were assigned in a completely randomized design and soybean meal inclusion was increased replacing feed-grade AAs to form the treatments.

All diets were formulated to be nearly isocaloric with SBM NE considered to be 100% of corn NE.[3] Diets with the highest and the lowest amount of SBM were formulated and the intermediate diets were obtained through blends of the low and high diet. Dietary additions of feed grade AA were adjusted to meet or exceed AA requirements in relation to Lys for Ile, Met and Cys, Thr, Trp, and Val. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) able to record feed deliveries for individual pens. Pigs were weighed every 14 d to determine ADG, ADFI, and F/G.

In Exp. 4, the three heaviest pigs in each pen were selected and marketed on d 14 of the study, but not included in the final pen carcass data. In Exp. 2 and 4, on the last day of the trial, final pen weights were obtained, and pigs were tattooed with a pen identification number and transported to a packing plant for carcass data collection. Carcass measurements included HCW, loin depth, backfat, and percentage lean. Percentage lean was calculated from a plant proprietary equation. Carcass yield was calculated by dividing the pen average HCW by the pen average final live weight obtained at the farm.

Statistical analysis
Data were analyzed using the GLIMMIX procedure of SAS (v. 9.4, SAS Institute, Inc., Cary, NC) in a completely randomized design with pen serving as the experimental unit and the initial BW serving as a covariate when it reduced the Bayesian Information Criteria by at least 2 units. The statistical model considered fixed effects of dietary treatment, linear and quadratic contrasts. In Exp. 2 and 4, hot carcass weight served as a covariate for the analysis of backfat, loin depth, and lean percentage. 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, no differences ($P > 0.10$) were observed for BW and ADFI; however, increasing SBM increased ADG (linear, $P = 0.038$) and improved feed efficiency (linear, $P < 0.001$), with the greatest change occurring when SBM increased from 19.1 to 22.6% (Table 5). However, with the inclusion of DDGS in the diet (Exp. 3; Table 6), no differences ($P \geq 0.32$) were observed for any growth performance criteria.

For the late-finishing pigs, no differences ($P \geq 0.12$) were observed for any growth performance criteria when increasing SBM in either corn (Table 7) or corn-DDGS-based (Table 8) diets. Additionally, no differences ($P \geq 0.13$) were observed for any carcass characteristic when increasing SBM in diets with or without DDGS (Exp. 2 and 4).

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[3] 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

In conclusion, increasing levels of SBM (up to 33.5% of the diet) in grower pig diets improved ADG and feed efficiency in corn-soybean meal-based diets, but not when 20% DDGS was included in the diet. For late-finishing diets, increasing SBM from 9.5 to 23.2% in diets with or without DDGS did not statistically result in any change in growth or carcass parameters. Soybean meal levels higher than what are typically used today can be used in grower and finisher diets without negative effects on performance. Final diet costs will dictate the formulation strategy that is most economical to use.

Table 1. Diet composition (as-fed basis, Exp. 1)

	Soybean meal, %	
Item	**19.1**	**33.5**
Ingredients, %		
Corn	77.44	64.25
Soybean meal, 46% CP[1]	19.06	33.45
Calcium carbonate	0.90	0.90
Monocalcium P, 21% P	0.80	0.60
Salt	0.50	0.50
L-Lys-HCl	0.45	---
DL-Met	0.14	---
L-Trp	0.06	---
L-Thr	0.19	---
L-Val	0.11	---
L-Ile	0.06	---
Vitamin premix with phytase[2]	0.15	0.15
Trace mineral premix	0.15	0.15
Calculated analysis		
SID AA, %		
Lys	1.00	1.00
Ile:Lys	60	78
Leu:Lys	125	160
Met:Lys	37	29
Met and Cys:Lys	60	59
Trp:Lys	21.0	23.2
Thr:Lys	65	67
Val:Lys	72	85
SID Lys:NE, g/Mcal	3.82	3.83
NE, kcal/lb[3]	1,186	1,184
Ca, %	0.62	0.63
STTD P, %	0.39	0.39
Chemical analysis, %		
CP, %	16.3	21.3
NDF, %	8.6	8.6

[1]CP = crude protein.
[2]Ronozyme 2700 (DSM Nutritional Products, Inc, Parsippany NJ) provided an assumed 0.13% release of STTD P with 567 FTU/lb inclusion in the final diet.
[3]Soybean meal was assumed to have 100% NE as corn.

Table 2. Diet composition (as-fed basis, Exp. 2)

	Soybean meal, %	
Item	**11.2**	**23.2**
Ingredients, %		
Corn	86.23	75.14
Soybean meal, 46% CP[1]	11.20	23.19
Calcium carbonate	0.75	0.75
Monocalcium P, 21% P	0.30	0.12
Salt	0.50	0.50
L-Lys-HCl	0.38	---
DL-Met	0.06	---
L-Trp	0.05	---
L-Thr	0.14	---
L-Val	0.06	---
L-Ile	0.05	---
Vitamin premix with phytase[2]	0.15	0.15
Trace mineral premix	0.15	0.15
Calculated analysis		
SID AA, %		
Lys	0.75	0.75
Ile:Lys	61	82
Leu:Lys	144	182
Met:Lys	34	33
Met and Cys:Lys	60	67
Trp:Lys	21.0	23.4
Thr:Lys	67	70
Val:Lys	72	91
SID Lys:NE, g/Mcal	2.85	2.85
NE, kcal/lb[3]	1,193	1,192
Ca, %	0.45	0.46
STTD P, %	0.28	0.28
Chemical analysis, %		
CP, %	13.1	17.3
NDF, %	8.6	8.6

[1]CP = crude protein.
[2]Ronozyme 2700 (DSM Nutritional Products, Inc, Parsippany NJ) provided an assumed 0.13% release of STTD P with 567 FTU/lb inclusion in the final diet.
[3]Soybean meal was assumed to have 100% NE as corn.

Table 3. Diet composition (as-fed basis, Exp. 3)

	Soybean meal, %	
Item	**18.2**	**34.3**
Ingredients, %		
Corn	58.50	43.55
Soybean meal, 46% CP[1]	18.16	34.25
DDGS	20.00	20.00
Calcium carbonate	1.20	1.20
Monocalcium P, 21% P	0.55	0.33
Salt	0.50	0.50
L-Lys-HCl	0.50	---
DL-Met	0.10	---
L-Trp	0.05	---
Thr[2]	0.19	---
L-Val	0.09	---
Tribasic copper chloride	0.03	0.03
Phytase[3]	0.05	0.05
Vitamin-trace mineral premix	0.10	0.10
Calculated analysis		
SID AA, %		
Lys	1.10	1.10
Ile:Lys	58	82
Leu:Lys	145	180
Met:Lys	35	33
Met and Cys:Lys	60	65
Trp:Lys	19.8	23.4
Thr:Lys	65	71
Val:Lys	75	92
SID Lys:NE, g/Mcal	4.38	4.38
NE, kcal/lb[4]	1,140	1,139
Ca, %	0.61	0.62
STTD P, %	0.45	0.45
Chemical analysis, %		
CP, %	19.9	25.6
NDF, %	12.2	12.2

[1]CP = crude protein.
[2]Thr Pro, CJ America-Bio, Fort Dodge, IA.
[3]Optiphos Plus 2500 G (Huvepharma Inc. Peachtree City, GA) provided 567 units of phytase FTU/lb of diet with an assumed release of 0.13% STTD P.
[4]Soybean meal was assumed to have 100% NE as corn.

Table 4. Diet composition (as-fed basis, Exp. 4)

	Soybean meal, %	
Item	**9.5**	**21.6**
Ingredients, %		
Corn	77.99	66.66
Soybean meal, 46% CP[1]	9.49	21.57
DDGS	10.00	10.00
Calcium carbonate	0.95	0.95
Monocalcium P, 21% P	0.30	0.18
Salt	0.50	0.50
L-Lys-HCl	0.38	---
DL-Met	0.05	---
L-Trp	0.04	---
Thr[2]	0.14	---
L-Val	0.03	---
Tribasic copper chloride	0.03	0.03
Phytase[3]	0.02	0.02
Vitamin-trace mineral premix	0.10	0.10
Calculated analysis		
SID AA, %		
Lys	0.75	0.75
Ile:Lys	58	85
Leu:Lys	162	201
Met:Lys	36	37
Met and Cys:Lys	65	72
Trp:Lys	19.9	23.6
Thr:Lys	67	75
Val:Lys	75	97
SID Lys:NE, g/Mcal	2.91	2.91
NE, kcal/lb[4]	1,168	1,167
Ca, %	0.45	0.46
STTD P, %	0.32	0.34
Chemical analysis, %		
CP, %	14.3	18.6
NDF, %	10.6	10.5

[1]CP = crude protein.
[2]Thr Pro, CJ America-Bio, Fort Dodge, IA.
[3]Optiphos Plus 2500 G (Huvepharma Inc. Peachtree City, GA) provided 227 units of phytase FTU/lb of diet with an assumed release of 0.13% STTD P.
[4]Soybean meal was assumed to have 100% NE as corn.

Table 5. Effects of increasing soybean meal levels on growth performance of grower pigs (Exp. 1; no DDGS)[1]

	Soybean meal, %[2]						*P* =	
Item	19.1	22.6	26.3	29.9	33.4	SEM	Linear	Quadratic
BW, lb								
d 0	95.2	95.2	95.2	95.1	95.2	1.51	0.956	0.996
d 28	157.0	158.8	157.7	158.2	159.0	1.22	0.415	0.954
Day 0 to 28								
ADG, lb	2.20	2.27	2.23	2.26	2.28	0.042	0.038	0.747
ADFI, lb	4.77	4.81	4.71	4.69	4.76	0.069	0.471	0.456
F/G	2.17	2.12	2.11	2.08	2.09	0.019	< 0.001	0.089

[1]A total of 615 pigs were used in a 28-d trial with 8 to 10 pigs per pen and 14 replicate pens per treatment.
[2]Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing feed-grade amino acid inclusion and increasing crude protein (16.3, 17.5, 18.8, 20.0, and 21.3%, respectively).

Table 6. Effects of increasing soybean meal levels in diets containing DDGS on growth performance of grower pigs (Exp. 3; 20% DDGS)[1]

	Soybean meal, %[2]					*P* =	
Item	19.1	22.6	26.3	29.9	SEM	Linear	Quadratic
BW, lb							
d 0	86.1	86.2	86.1	86.2	1.72	0.993	0.988
d 28	147.7	147.1	147.8	146.5	2.24	0.776	0.886
Day 0 to 28							
ADG, lb	2.18	2.17	2.19	2.13	0.028	0.321	0.394
ADFI, lb	4.81	4.76	4.82	4.75	0.072	0.704	0.877
F/G	2.21	2.20	2.20	2.23	0.029	0.613	0.431

[1]A total of 1053 pigs were used in a 28-d trial with 27 pigs per pen and 9 or 10 replicate pens per treatment.
[2]Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing feed-grade amino acid inclusion and increasing crude protein (19.9, 21.8, 23.7, and 25.6%, respectively).

Table 7. Effects of increasing soybean meal levels on growth performance of late finishing pigs (Exp. 2; no DDGS)[1]

	Soybean meal, %[2]						*P* =	
Item	11.2	14.2	17.2	20.2	23.2	SEM	Linear	Quadratic
BW, lb								
d 0	225.5	225.5	225.4	225.7	225.6	3.42	0.964	0.981
d 30[3]	287.3	288.8	288.8	289.9	288.5	4.74	0.352	0.284
Day 0 to 30								
ADG, lb	2.05	2.11	2.11	2.13	2.09	0.159	0.411	0.179
ADFI, lb	6.11	6.21	6.19	6.12	6.11	0.789	0.758	0.406
F/G[3]	2.97	2.94	2.93	2.87	2.92	0.134	0.115	0.336
Carcass characteristics								
HCW, lb[3]	214.1	214.8	215.2	215.2	213.9	2.41	0.978	0.384
Yield, %	74.4	74.3	74.4	74.2	74.2	0.43	0.311	0.984
Backfat, in.	0.58	0.57	0.57	0.55	0.57	0.017	0.132	0.170
Loin depth, in.	2.65	2.66	2.64	2.67	2.66	0.057	0.707	0.809
Lean, %	56.2	55.9	56.0	56.3	55.9	0.21	0.727	0.990

[1]A total of 615 pigs were used in a 30-d trial with 8 to 10 pigs per pen and 14 replicate pens per treatment.
[2]Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing feed-grade amino acid inclusion and increasing crude protein (13.1, 14.1, 15.2, 16.2, and 17.3%, respectively).
[3]Initial BW was used as a covariate due to lower Bayesian Information Criteria.

Table 8. Effects of increasing soybean meal levels in diets with 10% DDGS on the growth performance and carcass characteristics of late finishing pigs (Exp. 4; 10% DDGS)[1]

	Soybean meal, %[2]					*P* =	
Item	9.5	13.5	17.5	21.5	SEM	Linear	Quadratic
BW, lb							
d 0	225.3	225.3	225.1	225.3	2.50	0.989	0.966
d 33[3]	278.4	279.3	277.2	279.0	2.99	0.964	0.875
Day 0 to 33							
ADG, lb	1.75	1.76	1.73	1.79	0.033	0.600	0.421
ADFI, lb	5.79	5.73	5.78	5.75	0.056	0.720	0.816
F/G	3.30	3.26	3.35	3.21	0.055	0.417	0.384
Carcass characteristics							
HCW, lb[3]	205.5	204.1	205.0	204.7	1.16	0.806	0.642
Yield, %	73.0	72.1	72.6	72.6	0.41	0.699	0.271
Backfat, in.	0.59	0.59	0.59	0.58	0.016	0.536	0.807
Loin depth, in.	2.46	2.47	2.45	2.48	0.024	0.695	0.690
Lean, %	57.1	57.2	57.1	57.4	0.24	0.449	0.706

[1]A total of 1,080 pigs were used in a 33-d trial with 27 pigs per pen and 10 replicate pens per treatment.
[2]Soybean meal NE was considered 100% of corn NE. Increasing levels of SBM resulted in decreasing feed-grade amino acid inclusion and increasing crude protein (14.3, 15.7, 17.2, and 18.6%, respectively).
[3]Initial BW was used as a covariate due to lower Bayesian Information Criteria.