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Effects of Extruded-Expelled Soybean Meal and Benzoic Acid on Growth Performance, Carcass Characteristics, and Carcass Iodine Value of Finishing Pigs[1]

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Summary

A total of 2,162 pigs (PIC 1050 × DNA 600; initially 69.2 ± 4.9 lb) were used in a 109-d finishing trial to evaluate the effects of extruded-expelled soybean meal (EESBM) and benzoic acid on growth performance, carcass characteristics, and carcass iodine value. Pigs were randomly allotted to 1 of 4 treatments with 27 to 28 pigs per pen and 20 pens per treatment. Dietary treatments were arranged in a 2 × 2 factorial with main effects of soybean meal source and benzoic acid. Diets contained either conventional soybean meal (SBM) or extruded-expelled soybean meal (EESBM; Lester Feed and Grain, Lester, IA) with or without 0.25% VevoVitall (DSM Products; Parsippany, NJ), a source of benzoic acid. The EESBM was analyzed to be 43.2% CP and 7.73% fat (acid hydrolysis). Experimental diets were not balanced for energy, but rather formulated to the same SID Lys:ME ratio and fed based on a feed budget from d 0 to 109 in 6 phases. Overall (d 0 to 109), there were no interactions between soybean meal source and benzoic acid addition. There was a main effect of soybean meal source where pigs fed conventional SBM had greater ($P = 0.01$) ADFI compared to pigs fed EESBM without influencing ADG, resulting in improved ($P < 0.001$) F/G. Also, pigs fed diets without benzoic acid had greater ($P = 0.02$) ADFI compared to pigs fed diets that contained benzoic acid without influencing ADG, resulting in pigs fed benzoic acid having improved ($P = 0.01$) F/G. When evaluating caloric efficiency, pigs fed diets containing benzoic acid had improved ($P < 0.001$) caloric efficiency compared to pigs fed diets without benzoic acid, with soybean meal source not having any impact. For carcass characteristics, pigs fed EESBM had increased ($P < 0.001$) carcass fat iodine value compared to pigs fed conventional SBM. For economics, there was a main effect of soybean meal source where pigs fed EESBM had a higher ($P \leq 0.002$) feed cost per pig placed in the low and high feed cost scenarios. There were no differences in revenue per pig placed in the low or high revenue scenarios regardless of soybean meal source or the inclusion of benzoic acid. Pigs fed conventional SBM had a higher ($P \leq 0.02$) income over feed cost (IOFC) compared to

[1] Funding, wholly or in part, was provided by The National Pork Board.

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pigs fed EESBM in the high feed cost, high revenue; high feed cost, low revenue; and low feed cost, low revenue scenarios. In summary, replacing conventional SBM with EESBM improved feed efficiency, but due to increased feed cost without influencing gain, it was less economical as measured by IOFC. Also, the addition of benzoic acid improved feed efficiency but did not improve IOFC.

Introduction

High feed ingredient costs have increased interest in strategies to improve feed efficiency in pigs. The extrusion-expelling process results in a soybean meal with a greater fat content compared to conventionally processed soybean meal. This has the potential to improve growth performance in finishing pigs. With current and future projected soybean meal pricing, producers may have an opportunity to lower feed costs with the use of extruded-expelled soybean meal.[4]

Acidifiers, such as benzoic acid, lower the pH of the gastrointestinal tract. The reduction in pH can potentially lead to improved nutrient digestion and growth performance.[5] There is currently little research to demonstrate and understand the effects of benzoic acid on growth performance in finishing pigs under a commercial setting. Therefore, the objective of this trial was to evaluate the effects of extruded-expelled soybean meal (EESBM) compared to conventional SBM with or without benzoic acid on growth performance, carcass characteristics, and carcass fat iodine value.

Procedures

General

The Kansas State University Institutional Animal Care and Use Committee approved the protocol used in this experiment. This experiment was conducted at a commercial research facility located in southwest Minnesota (Pipestone Nutrition; Edgerton, MN). Pigs were housed in a temperature-controlled wean-to-finish facility. Each pen (22.4 × 8.3 ft) contained 1 nipple waterer and a 4-hole dry self-feeder to allow for *ad libitum* access to feed and water. Pigs were allowed approximately 6.9 ft^2/pig.

Animal treatment and structure

A total of 2,162 pigs (PIC 1050 × DNA 600; initially 69.2 ± 4.9 lb) were used in a 109-d finishing trial. There were 27 or 28 pigs per pen and 20 pens per treatment. On d 0, pens were blocked by location in the barn and randomly allotted to 1 of 4 dietary treatments. A similar number of barrows and gilts were placed in each pen. Dietary treatments were arranged in a 2 × 2 factorial with main effects of soybean meal source and benzoic acid. Diets contained either conventional soybean meal (SBM) or extruded-expelled soybean meal (EESBM; Lester Feed and Grain, Lester IA) with or without the inclusion of VevoVitall (DSM Products; Parsippany, NJ), a source of benzoic acid added at 0.25% (Table 2). Pens of pigs and feed disappearance were measured on d 0, 13, 28, 51,

[4] 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. Journal of Animal Science: 79:1280-1287. doi: 10.2527/2001.7951280x.

[5] Warner, A. J., J. M. DeRouchey, M. D. Tokach, J. C. Woodworth, R. D. Goodband, and J. T. Gebhardt. 2021. Effects of calcium carbonate level with or without benzoic acid on weanling pig growth performance, fecal dry matter, and blood calcium and phosphorus concentrations. Kansas Agricultural Experiment Station Research Reports: Vol. 7: Issue 11. doi:10.4148/ 2378-5977.8184.

62, 82, 90, 98, and 109 to determine ADG, ADFI, and F/G. Pigs were individually ear tagged with LeeO ear tags at the start of the trial. On d 88 and 96, eight of the heaviest pigs per pen were weighed individually and transported to a commercial packing plant (WholeStone Farms, Fremont, NE) for processing and determination of carcass characteristics. The remaining pigs were marketed at the conclusion of this trial on d 109 and transported to WholeStone Farms for carcass characteristic collection. A fat sample was taken from the belly from one barrow per pen per marketing event and included all three layers of fat. Analysis of iodine value was conducted using near-infrared spectroscopy (NIR) at WholeStone Farms.

Diet preparation

Experimental diets were fed in 6 different phases. Pigs were fed on a feed budget with phases 1, 2, 3, 4, and 5 provided at 42, 93, 108, 110, and 100 lb per pig, respectively. Phase 6 was provided for the remainder of the study. Digestible AA levels for EESBM were assumed at 2.39% for Lys, 1.52% for Thr, 0.53% for Trp, 1.77% for Ile, 1.85% for Val, 0.54% for Met, 0.54% for Cys, and 2.90% for Leu. The ME of conventional SBM was assumed at 1,309 kcal/lb and ME value for EESBM was assumed at 1,650 kcal/lb. All nutrients were formulated to meet or exceed NRC (2012)[6] requirement estimates. Lysine HCl was formulated to remain very similar across all treatments within phase to allow the SBM source to be used to help balance the dietary SID Lys level. All diets were corn-soybean meal-based and were fed in meal form. Diets were manufactured at the Spronk Brothers Feed Mill (Edgerton, MN).

Chemical analysis

Diet samples for each treatment were collected at the end of each phase. Samples from each room for each treatment were then combined to create a composite sample and analyzed for proximate analysis (Midwest Laboratories; Omaha, NE). A separate composite sample was sent for amino acid analysis (Ajinomoto; Chicago, IL). Conventional SBM and EESBM were collected weekly from the feed mill and analyzed for proximate analysis and amino acid analysis (Midwest Laboratories; Omaha, NE).

Economic analysis

For economic analysis, gain per pig placed, total feed cost per pig, revenue, and income over feed cost were calculated using 4 different low and high revenue and feed cost scenarios. Feed cost per lb of gain was calculated by dividing feed cost per pig by the total weight gained using a low and high feed cost scenario. Revenue per pig placed was determined by total gain times the dressing percentage (0.75) and then multiplied by a carcass price of $0.55 for the low revenue scenario and $0.95 for the high scenario. Income over feed cost was calculated by using the low or high revenue per pig placed minus the low or high feed cost per pig placed. The following ingredient costs were used for the low cost scenario: corn = $3.36/bu ($120/ton); soybean meal = $280/ton; EESBM = $340/ton; DDGS = $160/ton; and benzoic acid = $1.15/lb. For the high cost scenario, the following ingredient costs were used: corn = $6.72/bu ($240/ton); soybean meal = $420/ton; EESBM = $500/ton; DDGS = $260/ton; and benzoic acid = $1.15/lb.

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[6] National Research Council. 2012. Nutrient Requirements of Swine: Eleventh Revised Edition. Washington, DC: The National Academies Press. doi:10.17226/13298.

Statistical analysis

Data were analyzed using the GLIMMIX procedure of SAS OnDemand for Academics (SAS Institute, Inc., Cary, NC) in a randomized complete block design with pen as the experimental unit and location as the blocking factor. Treatments were considered a fixed effect and block as a random effect. The interaction and main effects of soybean meal source and benzoic acid inclusion were analyzed. The model for mortality and removal data specified a binomial distribution. Differences between treatments were considered significant at $P \leq 0.05$ and marginally significant at $0.05 < P \leq 0.10$.

Results and Discussion

For the proximate analysis, conventional SBM had higher CP and lower fat (acid hydrolysis) compared to EESBM. For the amino acid analyses, conventional SBM had collectively higher amino acid values compared to EESBM, with the exception of Cys and Pro (Table 1). In the complete diet analysis, diets had similar CP levels within phase (Table 2). As expected, fat levels were higher in diets containing EESBM compared to diets containing conventional SBM.

There were no interactions between soybean meal source and benzoic acid for any growth response criteria. Thus, only main effects will be discussed. From d 0 to 51, pigs fed EESBM had greater ($P = 0.01$) ADFI and improved ($P < 0.001$) F/G compared to pigs fed conventional SBM (Table 3). There was no effect of soybean meal source on ADG. Pigs fed diets without benzoic acid had greater ($P \leq 0.005$) ADG and ADFI compared to pigs fed diets containing benzoic acid. Pigs that were fed diets containing benzoic acid had improved ($P < 0.001$) F/G compared to pigs fed diets without benzoic acid.

From d 51 to 109, pigs fed conventional SBM had greater ($P = 0.06$) ADFI compared to pigs that were fed EESBM. Pigs fed EESBM had improved ($P < 0.001$) F/G compared to pigs fed conventional SBM. There was a tendency for an increase ($P = 0.06$) in ADG in pigs fed diets containing benzoic acid compared to pigs fed diets without benzoic acid. There were no main effects for benzoic acid on ADFI or F/G during this period.

Overall (d 0 to 109), pigs fed conventional SBM had greater ($P = 0.01$) ADFI compared to pigs fed EESBM without influencing ADG. Therefore, pigs fed EESBM had improved ($P < 0.001$) F/G compared to pigs fed conventional SBM. Also, pigs fed diets without benzoic acid had greater ($P = 0.02$) ADFI compared to pigs fed diets that contained benzoic acid without influencing ADG. As a result, pigs fed benzoic acid had improved ($P = 0.01$) F/G compared to pigs fed diets without benzoic acid.

There were no main effects for soybean meal source or benzoic acid on removals, mortality, or total removals and mortality for the duration of the study (Table 3).

When evaluating caloric efficiency, pigs fed diets containing benzoic acid had improved ($P < 0.001$) caloric efficiency compared to pigs fed diets without benzoic acid with no differences between soybean meal sources. This suggests that our initial estimate of ME for the EESBM was accurate.

For carcass characteristics, pigs fed EESBM had increased ($P < 0.001$) carcass fat iodine value. Benzoic acid did not influence carcass fat iodine value.

For economics, there was a main effect of soybean meal source where pigs fed EESBM had a higher ($P \leq 0.002$) feed cost per pig placed in the low and high feed cost scenarios. There were no differences in revenue per pig placed in the low or high revenue scenarios regardless of soybean meal source or the inclusion of benzoic acid. Pigs fed conventional SBM had a higher ($P \leq 0.02$) IOFC compared to pigs fed EESBM in the high feed cost, high revenue; high feed cost, low revenue; and low feed cost, low revenue scenarios. It is recommended that producers utilize their own current ingredient prices to economically compare these dietary options.

In conclusion, replacing conventional SBM with EESBM improved feed efficiency but due to increased feed cost without influencing gain, it was less economical as measured by IOFC. Also, the addition of benzoic acid improved feed efficiency but did not improve IOFC.

Table 1. Composition of soybean meal sources

	SBM	EESBM
Chemical analysis,[1] %		
DM	87.29	94.89
CP	45.45	43.20
Fat (acid hydrolysis)	1.20	7.73
Amino acids,[2] %		
Ala	1.95	1.85
Arg	3.16	3.10
Asx	5.15	4.95
Cys	0.59	0.61
Glu	8.16	7.75
Gly	1.88	1.84
His	1.14	1.13
Ile	2.02	1.93
Leu	3.44	3.28
Lys	2.83	2.73
Met	0.61	0.59
Met + Cys	1.20	1.20
Phe	2.30	2.19
Pro	1.74	2.29
Ser	2.29	2.21
Thr	1.82	1.76
Trp	0.66	0.52
Tyr	1.33	1.31
Val	2.07	1.99

[1]A composite sample of each treatment diet was collected from the feeder and later submitted to Midwest Laboratories (Omaha, NE) for proximate analysis.
[2]A composite sample of each treatment diet was collected from the feeder and later submitted to Ajinomoto (Chicago, IL) for amino acid analysis.
SBM = soybean meal. EESBM = extruded-expelled soybean meal.

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

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		Phase 6	
Ingredient, %	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**
Corn	64.55	60.04	68.95	65.56	73.98	71.70	77.33	75.66	78.24	76.34	85.72	84.27
Soybean meal, 46% CP	22.60	---	18.35	---	13.50	---	10.30	---	9.65	---	12.35	---
Extruded expelled soybean meal, 43% CP[2]	---	27.04	---	21.67	---	15.74	---	11.94	---	11.55	---	13.75
Corn DDGS	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	---	---
Limestone	0.88	0.88	0.88	0.88	0.85	0.85	0.83	0.83	0.78	0.78	0.68	0.68
Monocalcium phosphate, 21%	0.34	0.35	0.32	0.33	0.28	0.28	0.22	0.23	0.13	0.13	0.32	0.33
Salt	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Lys-HCl	0.55	0.58	0.51	0.54	0.48	0.50	0.46	0.47	0.40	0.40	0.24	0.26
DL-Met	0.16	0.19	0.12	0.14	0.08	0.09	0.05	0.06	0.02	0.03	0.00	0.00
L-Trp	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.02	0.02	---	0.01
Thr[3]	0.24	0.24	0.21	0.21	0.19	0.19	0.16	0.16	0.14	0.13	0.08	0.08
L-Val	0.04	0.03	0.02	0.02	---	---	---	---	---	---	---	---
Vitamin and trace mineral premix	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10	0.10
Copper chloride	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03	0.03
Phytase[4]	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Benzoic acid[5]	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-	+/-
Total	100	100	100	100	100	100	100	100	100	100	100	100

Continued

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

	Phase 1		Phase 2		Phase 3		Phase 4		Phase 5		Phase 6	
Ingredient, %	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**	**SBM**	**EESBM**
Calculated analysis												
SID amino acids, %												
Lys	1.20	1.27	1.07	1.12	0.93	0.95	0.83	0.85	0.77	0.79	0.67	0.69
Ile:Lys	55	55	55	55	55	55	55	55	58	58	64	63
Leu:Lys	128	123	134	130	143	139	151	148	160	158	166	160
Met and Cys:Lys	58	58	58	58	58	58	58	58	58	58	60	58
Thr:Lys	63	63	63	63	64	64	64	64	65	65	66	66
Trp:Lys	17	17	17	17	17	17	17	17	17	17	17	17
Val:Lys	65	65	65	65	65	65	66	66	70	70	76	75
SID Lys:ME, g/Mcal	3.76	3.76	3.33	3.33	2.85	2.85	2.54	2.54	2.01	2.01	2.00	2.01
ME, kcal/lb	1,445	1,527	1,455	1,521	1,466	1,515	1,475	1,512	1,478	1,513	1,488	1,531
CP, %	19.02	19.57	17.34	17.76	15.42	15.66	14.16	14.31	13.90	14.17	13.01	13.00
Ca, %	0.60	0.60	0.58	0.58	0.55	0.55	0.52	0.52	0.48	0.48	0.48	0.48
Available P, %	0.30	0.30	0.29	0.29	0.28	0.28	0.26	0.26	0.24	0.24	0.24	0.24
Ca:P	1.99	2.00	2.00	2.01	2.00	2.00	2.00	2.00	2.01	2.01	2.00	2.01
Chemical analysis,[6] %												
CP	19.50	20.40	18.00	18.50	16.60	15.90	13.60	14.40	14.40	13.70	12.10	12.60
Fat (acid hydrolysis)	4.56	6.00	4.30	5.72	4.04	5.32	4.32	5.00	4.10	4.84	3.41	4.48

[1]Pigs were fed on a feed budget with phase 1, 2, 3, 4, and 5 provided at 42, 93, 108, 110, and 100 lb per pig, respectively. Phase 6 was provided for the remainder of the study.
[2]Lester Feed and Grain (Lester, IA).
[3]Thr Pro; CJ America Bio, Downers Grove, IL.
[4]Quantum Blue 5P (AB Vista, Marlborough, UK) was included at 2,000 FTU/kg and provided an estimated release of 0.12% for available P.
[5]VivoVitall (DSM Products, Parsippany, NJ) was added at 0.25%.
[6]A composite sample of each treatment diet was collected from the feeder and later submitted to Midwest Laboratories (Omaha, NE) for proximate analysis.
SBM = soybean meal. EESBM = extruded-expelled soybean meal.

Table 3. Main effects of extruded-expelled soybean meal and benzoic acid on growth performance, caloric efficiency, carcass characteristics, and carcass iodine value[1]

	SBM source				Benzoic acid[2]			
Item	**SBM**	**EESBM**	**SEM**	***P* =**	**None**	**Yes**	**SEM**	***P* =**
BW, lb								
d 0	69.3	69.0	1.03	0.58	69.2	69.1	1.03	0.85
d 51	171.8	171.8	1.55	0.99	173.3	170.2	1.55	0.03
Market weight	271.3	271.7	1.62	0.81	272.2	270.8	1.62	0.39
d 0 to 51								
ADG, lb	2.00	2.02	0.07	0.30	2.03	1.98	0.02	0.01
ADFI, lb	4.41	4.28	0.04	0.01	4.47	4.22	0.04	<0.001
F/G	2.21	2.12	0.01	< 0.001	2.20	2.13	0.01	< 0.001
d 51 to 109								
ADG, lb	2.05	2.06	0.02	0.37	2.04	2.07	0.02	0.06
ADFI, lb	6.42	6.32	0.04	0.06	6.34	6.41	0.04	0.14
F/G	3.14	3.07	0.02	< 0.001	3.11	3.09	0.02	0.33
Overall (d 0 to 109)								
ADG, lb	2.02	2.04	0.01	0.20	2.03	2.02	0.01	0.37
ADFI, lb	5.36	5.25	0.04	0.01	5.35	5.26	0.04	0.02
F/G	2.66	2.58	0.01	< 0.001	2.63	2.60	0.01	0.01
Removals, %	4.9	4.4	0.59	0.58	4.5	4.8	0.94	0.74
Mortality, %	3.7	3.3	0.60	0.60	3.7	3.3	0.60	0.60
Total removals and mortalities, %	8.6	7.8	0.84	0.48	8.2	8.1	0.74	0.94
Caloric efficiency, kcal ME/lb gain	3,902	3,910	15.4	0.62	3,934	3,878	15.4	< 0.001
Carcass characteristics								
HCW, lb	200.7	201.4	1.47	0.51	201.8	200.3	1.47	0.18
Yield, %	73.41	73.57	0.01	0.12	73.51	73.47	0.01	0.68
Iodine value	67.67	73.10	0.27	< 0.001	70.25	70.52	0.27	0.43

[1]A total of 2,162 pigs (initially 69.2 ± 4.9 lb) were used with 27 to 28 pigs per pen and 20 replications per treatment (40 replications per main effect) for a 109-day trial.

[2]VivoVitall (DSM Products, Parsippany, NJ) was added at 0.25%.

SBM = soybean meal. EESBM = extruded-expelled soybean meal.

Table 4. Main effects of extruded-expelled soybean meal and benzoic acid on economics[1]

	SBM source				Benzoic acid[2]			
Item	**SBM**	**EESBM**	**SEM**	***P* =**	**No**	**Yes**	**SEM**	***P* =**
Economics, $/pig placed								
Gain	190.45	191.57	1.78	0.63	191.14	190.88	1.78	0.91
Feed cost (Hi)[3]	70.44	73.18	0.65	0.002	71.67	71.95	0.65	0.74
Feed cost (Lo)[4]	42.86	45.03	0.39	< 0.001	43.59	44.30	0.39	0.17
Revenue (Hi)[5]	128.56	129.31	1.20	0.63	129.02	128.85	1.20	0.91
Revenue (Lo)[6]	78.56	79.02	0.73	0.63	78.85	78.74	0.73	0.91
IOFC (HiF-HiR)	58.12	56.13	0.67	0.02	57.35	56.90	0.67	0.58
IOFC (HiF-LoR)	8.12	5.84	0.31	< 0.001	7.17	6.79	0.31	0.26
IOFC (LoF-LoR)	35.70	34.00	0.41	0.001	35.26	34.44	0.41	0.11
IOFC (LoF-HiR)	85.70	84.28	0.86	0.20	85.43	84.55	0.86	0.42

[1]A total of 2,162 pigs (initially 69.2 ± 4.9) were used with 27 to 28 pigs per pen and 20 replications per treatment (40 replications per main effect) for a 109-day trial.
[2]VevoVitall, DSM Products, Parsippany, NJ.
[3]Feed cost (Hi): corn was valued at $6.72/bu ($240/ton); SBM at $420/ton, EESBM at $500/ton; DDGS at $260/ton; and benzoic acid at $1.15/lb.
[4]Feed cost (Lo): corn was valued at $3.36/bu ($120/ton); SBM at $280/ton, EESBM at $340/ton; DDGS at $160/ton; and benzoic acid at $1.15/lb.
[5]Revenue/pig placed (Hi) = (total gain/pig placed × 0.75) × $0.90.
[6]Revenue/pig placed (Lo) = (total gain/pig placed × 0.75) × $0.55.
SBM = soybean meal. EESBM = extruded-expelled soybean meal.