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Allison K. Blomme
Kansas State University, ablomme@k-state.edu

Haley K. Wecker
Kansas State University, haley27@k-state.edu

Mike D. Tokach
Kansas State University, mtokach@k-state.edu

See next page for additional authors

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Estimating the Net Energy Value of Expelled, Extruded Soybean Meal When Fed to Nursery Pigs

Allison K. Blomme, Haley K. Wecker, Mike D. Tokach,[1] Jason C. Woodworth,[1] Charles R. Stark, and Chad B. Paulk

Summary

Solvent-extracted soybean meal (SSBM) is typically used as the primary protein source in swine diets in the United States. Mechanically extracted or expelled soybean meal (MSBM) typically has increased concentrations of fat and decreased concentrations of essential AA compared to SSBM, but MSBM has been demonstrated to have improved AA digestibility. This study aimed to estimate the NE value of MSBM relative to SSBM and to determine its effects on growth performance of late nursery pigs. A total of 297 pigs (241 × 600, DNA) were weaned (BW 11.2 lb) and placed into 60 pens (2 rooms of 30 pens) with 5 pigs per pen balanced by gender and weaning weight. Pigs were fed a common diet for 21 days. Then, pens of pigs (BW 20.7 lb) were randomly assigned to one of five treatments to provide 12 replications per treatment. Treatments consisted of increasing amounts of MSBM replacing SSBM in the diet (0, 25, 50, 75, and 100%). All diets were fed for 28 days and were formulated to 1.30% standardized ileal digestible lysine, and met or exceeded NRC[2] recommendations for Lys:AA, Ca, and P. The SSBM has an NRC[2] NE value of 946 kcal/lb and the 0% MSBM diet was formulated to 1091 kcal/lb and NE was not balanced between diets. Analyzed values for CP, ether extract, crude fiber, and total Lys for the SSBM were 47.28%, 0.47%, 3.80%, and 3.00%, respectively, while the MSBM contained 47.41%, 6.88%, 5.32%, and 2.99% respectively. The MSBM had increased values for KOH solubility and trypsin inhibitor (83.62 and 7026 TIU/g, respectively) compared to the SSBM (73.05 and 3011 TIU/g, respectively) while urease activity was similar between the two (0.03 vs. 0.02 Δ pH, respectively). Data were analyzed using PROC GLIMMIX (SAS v. 9.4) with pen as the experimental unit and room as the blocking factor. There was no evidence of differences in ADG and ADFI in pigs fed diets with increasing concentrations of MSBM. Pigs fed diets with increasing concentrations of MSBM had improved (linear, $P < 0.001$) F/G and caloric efficiency on an NE basis. In conclusion, using caloric efficiency to estimate NE of the MSBM relative to SSBM, MSBM was estimated to have a value of 123% of SSBM NE or 1,164 kcal/lb. This increase in NE resulted in improved feed efficiency of nursery pigs.

[1] Department of Animal Sciences and Industry, College of Agriculture, Kansas State University.

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

Introduction

Oil is extracted from soybeans using either solvent or mechanical extraction. Soybean meal is a byproduct of the soy oil extraction process. For solvent extraction, soy oil is primarily extracted with the use of a hexane mixture running through soybean flakes that had previously been cracked and dehulled. This process is capable of removing up to 97.5% of the oil contained in soybeans, leaving as little as 0.5% of oil in the remaining meal.[3] Because of the efficiency of the solvent extraction process, this is commonly used in soybean crush facilities. For the mechanical extraction process, the oil is extracted using an expeller press. The expeller presses the extruded soybeans through a horizontal shaft using a screw. As the flakes travel through the expeller, their compression increases because the volume of the shaft decreases. Oil is allowed to escape from the expeller while the resulting soybean meal remains. The expeller process leaves about 5 to 8% oil content in the mechanical extracted soybean meal it produces.[4] Because of the mechanical nature of the expelling process, soybeans may or may not be dehulled prior to oil extraction.

Solvent-extracted soybean meal (SSBM) is typically used as the primary protein source in swine diets in the United States. Mechanically extracted or expelled soybean meal (MSBM) typically has decreased concentrations of essential AA compared to SSBM, but MSBM has been demonstrated to have improved AA digestibility. In addition, MSBM contains more oil which provides increased energy content of the diet.[2] Therefore, it is necessary to accurately quantify the energy content of MSBM for use in swine diets. The objective of this study was to determine differences in growth performance of pigs fed increasing amounts of two different sources of soybean meal (SSBM and MSBM), by using changes in caloric efficiency (CE) to estimate MSBM NE value.

Materials and Methods

The protocol used in this study was approved by the Kansas State University Institutional Animal Care and Use Committee. This experiment was conducted at the Kansas State University Swine Teaching and Research Center. Pens (4.00 × 4.99 ft) contained a three-hole dry self-feeder and one nipple waterer to provide *ad libitum* access to feed and water.

Animals and diets

Pigs (241 × 600, DNA, Columbus, NE) were weaned at 21 d of age with an average BW of 11.2 lb and assigned to pens with 5 pigs/pen balanced by gender and weight. All pigs were fed a common diet for 21 days until they weighed an average of 20.7 lb. At this time, pens of pigs were randomly assigned to 1 of 5 dietary treatments for a 28-d feeding trial. Pens were balanced by gender, BW, and location within the barn for a total of 60 treatment pens for 12 replications per treatment.

A total of 5 dietary treatments consisted of increasing amounts of MSBM (0, 25, 50, 75, and 100%) used to replace SSBM on a weight/weight basis. The MSBM was produced using the high shear dry extrusion-pressing procedure. The soybeans were dehulled to produce SSBM, but non-dehulled soybeans were used to produce MSBM. Representative samples of SSBM and MSBM were submitted to the Agricultural Experimental

[3] Andersen, G. E. 2011. Solvent Extraction. AOCS Lipid Library.

[4] Boeck, H. 2011. Expanding and Expelling. AOCS Lipid Library.

Station Chemical Laboratories (University of Missouri-Columbia, Columbia, MO) to be analyzed for available Lys, KOH solubility, trypsin inhibitor activity, and urease activity (Table 1). Also, representative samples of corn, SSBM, and MSBM were submitted for determination of total AA content, DM, CP, crude fiber (CF), ether extract (EE), Ca, and P.

Diets were formulated to exceed the NRC[2] requirement estimates for AA, Ca, and P and were not balanced for NE. Inclusion of feed-grade AA were used to balance AA between treatments (Table 2). Diets were provided in mash form. Feed disappearance and pen weights were recorded each week and were used to determine ADG, ADFI, F/G, and caloric efficiency (CE). Treatments, culls, and mortalities were recorded daily. The actual energy value of MSBM relative to SSBM was estimated based on CE, which was obtained by multiplying ADFI by kcal of NE per lb of diet (1,091 kcal/lb) and dividing by ADG. To obtain an energy estimate, the energy value of MSBM was adjusted for the slope of CE to be zero.

Chemical analysis

Representative diet samples were obtained from each treatment and stored at -4°F until analysis. Samples were analyzed for DM, CP, CF, and EE at Experiment Station Chemical Laboratories (Columbia, MO).

Statistical analysis

Data were analyzed as a generalized randomized complete block design with pen as the experimental unit and barn/room as the blocking factor using the PROC-GLIMMIX procedure of SAS (SAS Institute, Inc., Cary, NC). Single degree-of-freedom contrasts were constructed to test the linear and quadratic effects of increasing MSBM. Results were considered significant at $P \leq 0.05$, and marginally significant at $P \leq 0.10$.

Results and Discussion

The analyzed values for corn were similar to expected values based on NRC,[2] but the SSBM had decreased ether extract (0.47%) compared to the expected value (1.52%) (Table 1). The MSBM had increased concentrations of EE, CP, and AA compared to reported values,[2] bringing it closer to the levels reported for SSBM, while maintaining a higher CF and EE content. The analyzed crude protein and amino acids concentrations were similar between the SSBM and MSBM. Trypsin inhibitor activity, KOH solubility, and urease activity were all lower for SSBM (85,360 TIU/oz, 73.05%, and 0.02 Δ pH, respectively) than in MSBM (199,184 TIU/oz, 83.62%, 0.03 Δ pH, respectively). Although the trypsin inhibitor activity was greater in the MSBM compared to the SSBM, it has also been established that soybean meals with a KOH between 73 and 88% and urease levels between 0.1 and 0.3 Δ pH are considered acceptable quality.[5] Therefore, quality measurements for both SSBM and MSBM were within acceptable ranges.

There was no evidence of difference in ADG or ADFI between pigs fed the dietary treatments (Table 3). However, increasing MSBM concentration of the diet improved (linear, $P = 0.001$) F/G and NE CE of pigs. Experimental diets were formulated to have similar concentrations or above the recommended concentration of standard ileal

[5] United Soybean Board. 2018. 2018 Soybean Meal Demand Assessment. Chesterfield. MO, USA.

digestible AA, Ca, and standardized total tract digestible P. Therefore, this improvement in F/G was likely caused by an increase in NE provided by MSBM. The difference in NE can be attributed to the increase in EE values. As expected, this indicates that more oil was retained during the expelling process compared to the solvent extraction process. The CE or "productive energy" was used to estimate the NE of a feed ingredient based on the known value of another. Calculating the NE content of the MSBM based on CE, estimates that MSBM (1,164 kcal/lb) reported herein is 217 kcal/lb greater than the NRC[2] NE value of SSBM (947 kcal/lb).

Extruded-expelled soybean meal used in this experiment had similar concentrations of CP and essential AA, and increased EE and CF compared to the solvent-extracted soybean meal. Late nursery pigs fed increasing concentrations of extruded-expelled soybean meal in comparison to solvent-extracted soybean meal did not demonstrate a difference in ADG or ADFI but did have improved F/G. Caloric efficiency was improved as the amount of extruded-expelled soybean meal increased. These results determined an NE estimate of 1,164 kcal/lb for extruded-expelled soybean meal.

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Table 1. Proximate analysis and total amino acid content of corn, solvent-extracted soybean meal (SSBM), and mechanically expelled soybean meal (MSBM), as-fed basis

Item, %	Corn	SSBM	MSBM
Dry matter	86.56	90.01	93.55
Crude protein	8.10	47.28	47.41
Crude fiber	1.78	3.80	5.32
Ether extract	2.54	0.47	6.88
Calcium	0.01	0.45	0.34
Phosphorus	0.26	0.67	0.64
KOH solubility	---	73.05	83.62
Trypsin inhibitor, TIU/g	---	3011	7026
Urease, Δ pH	---	0.02	0.03
AA			
Ala	0.55	2.00	1.99
Arg	0.37	3.36	3.46
Asp	0.53	5.28	5.41
Cys	0.17	0.68	0.74
Glu	1.48	8.56	8.70
Gly	0.32	1.97	2.01
His	0.22	1.24	1.25
Ile	0.30	2.31	2.33
Leu	0.87	3.62	3.63
Lys	0.27	2.99	3.05
Available Lys	---	2.93	2.96
Met	0.16	0.65	0.64
Phe	0.38	2.43	2.49
Pro	0.65	2.34	2.40
Ser	0.35	1.91	2.12
Thr	0.27	1.78	1.78
Trp	0.06	0.67	0.69
Tyr	0.18	1.67	1.69
Val	0.38	2.38	2.36

[a]A representative sample of each ingredient was obtained, homogenized, and submitted to the Agricultural Experimental Station Chemical Laboratories (University of Missouri-Columbia, Columbia, MO) for proximate and amino acid analysis.

Table 2. Ingredient composition of experimental diets, as-fed basis

	MSBM replacement of SSBM,[a] %				
Ingredient, %	0	25	50	75	100
Corn	63.72	63.74	63.75	63.76	63.80
Soybean meal, dehulled solvent extracted (46.5% CP)	32.50	24.37	16.25	8.13	---
Soybean meal, extruded-expelled	---	8.13	16.25	24.38	32.50
Calcium carbonate	0.95	0.95	0.95	0.95	0.95
Monocalcium P (21.5% P)	0.95	0.95	0.95	0.95	0.95
Salt	0.35	0.35	0.35	0.35	0.35
L-Lys-HCl	0.48	0.47	0.46	0.46	0.45
DL-Met	0.24	0.23	0.21	0.19	0.17
L-Thr	0.22	0.22	0.23	0.23	0.22
L-Trp	0.04	0.04	0.05	0.05	0.06
L-Val	0.12	0.12	0.12	0.12	0.12
Trace mineral premix	0.15	0.15	0.15	0.15	0.15
Vitamin premix[b]	0.25	0.25	0.25	0.25	0.25
Phytase[c]	0.03	0.03	0.03	0.03	0.03
Total	100	100	100	100	100
Calculated analysis, %					
SID AA, %					
Lys	1.35	1.35	1.35	1.35	1.35
Ile:Lys	57	56	56	56	56
Leu:Lys	116	118	120	122	124
Met:Lys	39	38	38	37	36
Met+Cys:Lys	60	60	60	60	60
Thr:Lys	65	65	65	65	65
Trp:Lys	19.5	19.5	19.5	19.5	19.5
Val:Lys	70	70	70	70	70
His:Lys	37	38	38	39	40
Net energy, kcal/lb	1091	---	---	---	---
CP, %	21.6	21.4	21.2	21.0	20.8
Crude fiber, %	2.5	2.5	2.4	2.4	2.3
Ca, %	0.72	0.72	0.72	0.72	0.72
Standardized digestible P, %	0.46	0.46	0.46	0.46	0.46
Analyzed values, %					
DM	88.36	88.76	89.09	89.40	89.83
CP	21.95	22.00	22.23	21.78	21.48
Crude fiber	2.48	2.38	2.57	2.82	2.45
Ether extract	1.39	1.50	1.98	2.62	3.05

[a]MSBM = mechanically expelled soybean meal. SSBM = solvent-extracted soybean meal. DM = dry matter. CP = crude protein.
[b]Premix contains a minimum of: vitamin A 750,000 IU/lb, vitamin D_3 300,000 IU/lb, vitamin E 8,000 IU/lb, vitamin B_{12} 6.0 mg/lb, menadione 600 mg/lb, riboflavin 1,500 mg/lb, d-pantothenic acid 5,000 mg/lb, and niacin 9,000 mg/lb.
[c]Ronozyme HiPhos (GT) 2700, 1,225,717 phytase FYT/lb, DSM Nutritional Products, Parsippany, NJ.

Table 3. Effects of increasing mechanically expelled soybean meal (MSBM) replacing solvent-extracted soybean meal on growth performance and caloric efficiency of pigs[a]

	Treatment, %MSBM						Probability, *P* <	
	0	25	50	75	100	SEM	Linear	Quadratic
BW, lb								
d 0	20.7	20.6	20.6	20.6	20.6	0.43	0.899	0.882
d 28	58.1	58.6	60.2	59.0	58.7	1.19	0.672	0.335
D 0 to d28								
ADG, lb	1.33	1.33	1.34	1.37	1.36	0.03	0.249	0.908
ADFI, lb	1.99	1.96	1.98	1.95	1.93	0.43	0.315	0.883
F/G	1.51	1.47	1.47	1.42	1.41	0.02	0.001	0.966
CE,[b] kcal/lb	1653	1616	1617	1558	1553	21.29	0.001	0.966

[a]A total of 297 pigs with an initial BW of 20.5 lb were used in a 28-d growth trial with 5 pigs per pen and 12 replicates per treatment.

[b]CE = caloric efficiency obtained by multiplying ADFI by kcal of NE of 0% diet (1091 kcal/lb) and dividing by ADG for each treatment.