Determining the Productive Energy of Soybean Meal Relative to Corn and Feed-grade Amino Acids[1]

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Summary

A total of 2,153 finishing pigs (PIC 337 × 1050; initially 63.6 ± 1.03 lb) were used in a 112-d growth study to determine the productive energy of soybean meal (SBM) relative to corn and feed-grade amino acids. Pens of pigs were blocked by initial BW and allotted to one of four dietary treatments in a randomized complete block design. There were 26 or 27 pigs per pen and 20 pens per treatment across two barns. Soybean meal NE value used in diet formulation was 947 kcal/lb (78% NE of corn; NRC, 2012)[4]. The four treatments consisted of a diet containing a low level of SBM and added feed-grade amino acids (Low SBM), and three diets with a 3.37 (Med-Low SBM), 6.69 (Med-High SBM), and 10% (High SBM) increase in SBM compared to the Low SBM diet and decreased feed-grade amino acids. The High SBM diet did not contain feed-grade L-lysine. Treatment diets were fed in four phases. Pigs were weighed and feed disappearance was measured every 14 d to determine ADG, ADFI, F/G, and caloric efficiency (CE). From d 0 to 56, increasing SBM decreased (linear, $P < 0.05$) ADG and ADFI, with no effect on F/G. From d 56 to 112, increasing SBM tended (linear, $P < 0.10$) to decrease ADG but there was no effect on ADFI. As a result, F/G worsened (linear, $P = 0.050$) as dietary SBM increased. From d 0 to 112, there was a decrease (linear, $P < 0.05$) in ADG and ADFI as SBM level increased, but there was no effect on F/G. Caloric efficiency improved (linear, $P < 0.05$) as SBM level increased, suggesting a greater NE concentration than initially estimated. Increasing SBM decreased (linear, $P < 0.05$) carcass ADG and worsened (linear, $P < 0.05$) carcass F/G, but there was no effect on carcass CE. Increasing SBM decreased (linear, $P < 0.05$) HCW and carcass yield. Backfat depth and percentage lean were lowest and greatest, respectively, (quadratic, $P < 0.05$) for pigs fed the intermediate SBM levels. There was an increase (linear, $P < 0.05$) in pig removals with increasing SBM but no treatment effect on mortality. However, when combined, removals and mortality were increased (linear, $P < 0.05$) as SBM level increased. The

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

results of this study suggest that when using caloric efficiency, SBM is estimated to contain 93.5% on a liveweight basis or 83.9% on a carcass weight basis of the NE of corn.

Introduction

Soybean meal (SBM) is the primary plant-based protein source used in swine diets in the United States. The NE content of SBM has been reported as 947 kcal/lb, which is 78% of NE content of corn (NRC, 2012). However, there has been considerable debate regarding the appropriate NE value to use in formulation based on recent research. Net energy can be measured using calorimetry studies. However, feeding increasing levels of a test ingredient and using the differences in caloric efficiency (CE) to estimate the net energy (or productive energy) content relative to a known ingredient, such as corn, is a more practical approach. If the energy estimate of the test ingredient is accurate, CE should remain the same as the test ingredient's level increases. Changes in CE with increasing amounts of an ingredient is an indicator of over- or under-estimating the energy content of the ingredient. Previous research has observed improved pig performance with increasing SBM and has estimated the NE of SBM to be greater than 78% the NE of corn.[5] However, the diets containing high levels of feed-grade amino acids and low soybean meal in previous trials may have been deficient in nitrogen or one or more essential amino acids. Therefore, the current study used lower inclusion rates of feed-grade amino acids to ensure that other essential amino acids and nitrogen intake were not limiting over the range of soybean meal levels fed. The objective of this study was to determine the productive energy of soybean meal relative to corn and feed-grade amino acids.

Materials and Methods

The protocol used in this experiment was approved by the Kansas State University Institutional Animal Care and Use Committee. The study was conducted in two barns at a commercial research finishing site in southwest Minnesota. The barns were naturally ventilated and double-curtain-sided with totally slatted floors. Each pen was equipped with a 5-hole stainless steel dry self-feeder and a bowl waterer for ad libitum access to feed and water. All diets were manufactured at the Hord Farms West Feed Mill (Pipestone, MN) and were in mash form. Daily feed additions to each pen were accomplished using a robotic feeding system (FeedPro; Feedlogic Corp., Wilmar, MN) that recorded feed deliveries for individual pens.

A total of 2,153 pigs (PIC 337 × 1050; initially 63.6 ± 1.03 lb) were used in a 112-d growth trial. Pigs were housed in mixed-gender pens with 26 or 27 pigs per pen across two barns. Pens of pigs were blocked by initial BW and allotted to one of four dietary treatments in a randomized complete block design with 20 pens per treatment. Soybean meal NE value used in diet formulation was 947 kcal/lb (78% NE of corn; NRC, 2012). The four treatments consisted of a diet containing a low level of SBM and added feed-grade amino acids (Low SBM) and three diets with 3.37 (Med-Low SBM), 6.69 (Med-High SBM), and 10% (High SBM) increase in SBM level compared to the Low SBM diet and decreased added feed-grade amino acids (Tables 1 to 4). The High SBM

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diet did not contain feed-grade L-lysine. Treatment diets were fed in four phases. Pigs were weighed and feed disappearance was measured every 14 d to determine ADG, ADFI, and F/G. Caloric efficiency (CE) was determined on an NE basis and was calculated by multiplying total feed intake × energy content of the diet (kcal/lb) and dividing by total gain.

Three weeks prior to the end of the study, the four heaviest pigs in each pen were selected and marketed. The remaining pigs at the end of the study were tattooed with the specific pen identification number and marketed at a commercial abattoir (JBS Swift, Worthington, MN) for collection of carcass yield, backfat depth, loin depth, percentage lean, and hot carcass weight for each individual carcass.

Representative diet samples were collected and stored at -4°F until analysis for dry matter (DM) and crude protein (CP) in duplicate in the Kansas State University Swine Laboratory.

Data analysis

Experimental data were analyzed using the lmer function in R Studio (Version 4.2.2, R Core Team, Vienna, Austria) with pen serving as the experimental unit in a randomized complete block design within each of the two experimental barns. For all data, treatment served as a fixed effect within the statistical model, with the cross product of barn and block serving as a random effect. For carcass characteristics, pen was included as a random effect, and HCW was used as a covariate for all responses other than itself. Fixed effects were tested using the joint tests function in R, and treatment means were estimated using the emmeans function. Linear and quadratic contrasts were constructed with decreasing levels of SBM. Total removals and mortality data were analyzed assuming a binomial distribution with a logit link function. Results were considered significant at $P \leq 0.05$ and marginally significant at $P \leq 0.10$.

Results and Discussion

From d 0 to 56, increasing SBM decreased (linear, $P < 0.05$) ADG and ADFI but had no effect on F/G. From d 56 to 112, there was a tendency (linear, $P < 0.10$) for a decrease in ADG as SBM level increased but no effect on ADFI. As a result, F/G worsened (linear $P = 0.050$) as SBM level increased. From d 0 to 112 (overall), increasing SBM decreased (linear, $P < 0.05$) ADG and ADFI, but there was no effect on F/G. Caloric efficiency improved (linear, $P < 0.05$) as SBM level increased, indicating the NE of SBM (78% NE of corn; NRC, 2012) was underestimated in initial diet formulation.

Increasing SBM decreased (linear, $P < 0.05$) carcass ADG and worsened (linear, $P < 0.05$) carcass F/G, but there was no effect on carcass CE. For carcass characteristics, there was a decrease (linear, $P < 0.05$) in HCW and carcass yield as SBM level increased. There was a SBM level effect (quadratic, $P < 0.05$) on backfat depth where backfat depth decreased from the Low SBM to the Med-High SBM level but increased from the Med-High SBM to the High SBM level. As a result, there was also a SBM level effect (quadratic, $P < 0.05$) on percentage lean where percentage lean increased from the Low SBM to the Med-High SBM level but decreased from the Med-High to the High SBM level. There was no effect ($P > 0.10$) of dietary treatment on loin depth.

There was an increase (linear, $P < 0.05$) in pig removals as SBM increased but no treatment effect ($P > 0.10$) on mortality. However, increasing SBM in the diet resulted in increased (linear, $P < 0.05$) combined removals and mortality.

An estimate of the NE of SBM was calculated by adjusting NE of SBM used in formulation (thus changing dietary NE) until CE for all treatments were equal. Using CE, SBM is estimated to contain 93.5% on a liveweight basis or 83.9% on a carcass weight basis of the NE of corn based on results of this study.

Together, these data help further elucidate the effect of SBM on growth performance of pigs and provide further evidence that productive energy is above the NE assumption of the NRC (2012).

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Table 1. Composition of phase 1 diets (as-fed basis)[1]

	Soybean meal			
Item	Low	Med-Low	Med-High	High
Ingredient, %				
Corn	69.39	66.36	63.32	60.29
Soybean meal, 47.7% CP	27.51	30.88	34.20	37.52
Monocalcium P, 21% P	0.65	0.63	0.60	0.55
Limestone	0.98	0.97	0.95	0.95
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine 55%	0.45	0.30	0.15	----
DL-Met	0.13	0.10	0.07	0.04
L-Trp	0.04	0.02	----	----
L-Val	0.05	----	----	----
Thr[2]	0.18	0.12	0.07	0.01
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Phytase[3]	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	1.10	1.10	1.10	1.10
Ile:Lys	62	67	72	78
Leu:Lys	132	140	147	154
Met:Lys	36	34	33	32
Met and Cys:Lys	60	60	60	60
Thr:Lys	66	66	66	66
Trp:Lys	21	21	21	23
Val:Lys	72	73	78	83
His:Lys	41	44	47	50
Total Lys, %	1.24	1.24	1.25	1.26
NE, kcal/lb	1,112	1,103	1,095	1,087
SID Lys:NE, g/Mcal	4.49	4.52	4.56	4.59
CP, %	19.4	20.6	21.7	22.9
Ca, %	0.60	0.60	0.60	0.60
STTD P, %	0.40	0.40	0.40	0.40
Ca:P	1.16	1.14	1.12	1.11
Analyzed values, %				
DM	86.4	86.1	86.4	86.1
CP	18.9	20.6	21.1	20.9

[1]Phase 1 diets were fed from approximately 60 to 105 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huvepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.13% STTD P for all the diets.

Table 2. Composition of phase 2 diets (as-fed basis)[1]

	Soybean meal			
Item	**Low**	**Med-Low**	**Med-High**	**High**
Ingredient, %				
Corn	75.80	72.79	69.79	66.74
Soybean meal, 47.7% CP	21.37	24.74	28.06	31.37
Monocalcium P, 21% P	0.50	0.45	0.38	0.34
Limestone	0.92	0.90	0.92	0.90
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine 55%	0.45	0.30	0.15	----
DL-Met	0.09	0.06	0.03	----
L-Trp	0.04	0.02	----	----
L-Val	0.04	----	----	----
Thr[2]	0.16	0.10	0.04	----
Vitamin-trace mineral premix	0.10	0.10	0.10	0.10
Phytase[3]	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.95	0.95	0.95	0.95
Ile:Lys	61	67	73	79
Leu:Lys	138	147	155	164
Met:Lys	34	33	31	30
Met and Cys:Lys	60	60	60	60
Thr:Lys	66	66	66	67
Trp:Lys	21	21	21	23
Val:Lys	72	74	80	86
His:Lys	42	45	49	52
Total Lys, %	1.07	1.08	1.09	1.10
NE, kcal/lb	1,131	1,122	1,114	1,106
SID Lys:NE, g/Mcal	3.81	3.84	3.87	3.90
CP, %	17.0	18.1	19.3	20.5
Ca, %	0.53	0.53	0.53	0.53
STTD P, %	0.35	0.35	0.35	0.35
Ca:P	1.16	1.14	1.14	1.12
Analyzed values, %				
DM	85.9	86.0	86.1	86.0
CP	15.3	16.9	17.6	18.8

[1]Phase 2 diets were fed from approximately 105 to 160 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huvepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.13% STTD P for all the diets.

Table 3. Composition of phase 3 diets (as-fed basis)[1]

Item	Soybean meal			
	Low	Med-Low	Med-High	High
Ingredient, %				
Corn	80.29	77.23	74.22	71.13
Soybean meal, 47.7% CP	17.27	20.65	23.96	27.27
Monocalcium P, 21% P	0.25	0.25	0.20	0.15
Limestone	0.88	0.85	0.85	0.85
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine 55%	0.45	0.30	0.15	----
DL-Met	0.07	0.03	----	----
L-Trp	0.04	0.02	----	----
L-Val	0.03	----	----	----
Thr[2]	0.14	0.08	0.03	----
Vitamin-trace mineral premix	0.05	0.05	0.05	0.05
Phytase[3]	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.85	0.85	0.85	0.85
Ile:Lys	60	67	74	80
Leu:Lys	144	153	163	172
Met:Lys	34	32	30	32
Met and Cys:Lys	60	60	60	63
Thr:Lys	66	66	66	69
Trp:Lys	21	21	21	23
Val:Lys	72	75	82	88
His:Lys	42	46	50	54
Total Lys, %	0.96	0.97	0.98	0.99
NE, kcal/lb	1,146	1,137	1,128	1,120
SID Lys:NE, g/Mcal	3.37	3.39	3.42	3.44
CP, %	15.4	16.5	17.7	18.9
Ca, %	0.46	0.46	0.46	0.46
STTD P, %	0.30	0.30	0.30	0.30
Ca:P	1.18	1.14	1.13	1.12
Analyzed values, %				
DM	85.7	85.6	85.8	86.1
CP	14.1	14.7	16.5	17.8

[1]Phase 3 diets were fed from approximately 160 to 215 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huvepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.13% STTD P for all the diets.

Table 4. Composition of phase 4 diets (as-fed basis)[1]

	Soybean meal			
Item	**Low**	**Med-Low**	**Med-High**	**High**
Ingredient, %				
Corn	84.50	81.45	78.41	75.32
Soybean meal, 47.7% CP	13.18	16.56	19.88	23.18
Monocalcium P, 21% P	0.23	0.20	0.15	0.10
Limestone	0.82	0.80	0.80	0.80
Sodium chloride	0.50	0.50	0.50	0.50
Liquid lysine 55%	0.45	0.30	0.15	----
DL-Met	0.04	0.01	----	----
L-Trp	0.04	0.02	----	----
L-Val	0.02	----	----	----
Thr[2]	0.13	0.07	0.02	----
Vitamin-trace mineral premix	0.05	0.05	0.05	0.05
Phytase[3]	0.05	0.05	0.05	0.05
Total	100.00	100.00	100.00	100.00
Calculated analysis				
Standardized ileal digestible (SID) amino acids, %				
Lys	0.75	0.75	0.75	0.75
Ile:Lys	59	67	74	82
Leu:Lys	150	161	172	182
Met:Lys	33	31	31	33
Met and Cys:Lys	60	60	63	67
Thr:Lys	66	66	66	71
Trp:Lys	21	21	21	23
Val:Lys	72	77	84	91
His:Lys	43	47	51	56
Total Lys, %	0.85	0.86	0.87	0.87
NE, kcal/lb	1,157	1,149	1,140	1,132
SID Lys:NE, g/Mcal	2.94	2.96	2.98	3.00
CP, %	13.7	14.9	16.1	17.3
Ca, %	0.42	0.42	0.42	0.42
STTD P, %	0.28	0.28	0.28	0.28
Ca:P	1.15	1.12	1.11	1.10
Analyzed values, %				
DM	86.3	86.3	86.4	86.3
CP	12.9	14.7	15.3	16.3

[1]Phase 4 diets were fed from approximately 215 to 290 lb.
[2]Thr Pro; CJ America-Bio, Downers Grove, IL.
[3]Optiphos (Huvepharma, Sofia, Bulgaria) was included at 1,251 FTU/kg providing an estimated release of 0.13% STTD P for all the diets.

Table 5. Effects of increasing soybean meal on growth performance and caloric efficiency relative to corn and feed-grade amino acids[1]

	Soybean meal					*P* =	
Item	Low	Med-Low	Med-High	High	SEM	Linear	Quadratic
BW, lb							
d 0	63.6	63.6	63.6	63.6	1.03	0.996	0.996
d 56	178.2	177.3	175.1	175.2	1.86	< 0.001	0.380
d 112	292.5	290.6	287.7	287.2	2.26	0.004	0.632
d 0 to 56							
ADG, lb	2.04	2.02	1.97	1.98	0.020	< 0.001	0.446
ADFI, lb	4.44	4.41	4.31	4.30	0.070	< 0.001	0.689
F/G	2.18	2.18	2.18	2.17	0.019	0.666	0.608
d 56 to 112							
ADG, lb	2.15	2.11	2.12	2.10	0.022	0.099	0.745
ADFI, lb	6.51	6.48	6.43	6.48	0.066	0.474	0.410
F/G	3.03	3.07	3.04	3.09	0.021	0.050	0.686
d 0 to 112							
ADG, lb	2.09	2.06	2.04	2.03	0.017	0.001	0.492
ADFI, lb	5.43	5.38	5.31	5.32	0.063	0.004	0.353
F/G	2.60	2.61	2.60	2.62	0.016	0.249	0.823
Caloric efficiency, kcal/lb gain	2,967	2,956	2,927	2,924	18.1	0.003	0.751
Carcass performance							
Carcass ADG, lb[2]	1.54	1.52	1.50	1.49	0.013	< 0.001	0.750
Carcass F/G[3]	3.52	3.54	3.53	3.57	0.022	0.016	0.467
Carcass CE, kcal/lb gain	4,016	4,008	3,972	3,991	24.6	0.146	0.423
Carcass characteristics							
HCW, lb	216.6	214.9	212.7	211.1	1.70	< 0.001	0.957
Carcass yield, %[4]	73.9	73.8	73.7	73.3	0.15	0.001	0.226
Backfat depth, in.[5]	0.67	0.64	0.63	0.65	0.011	0.094	0.012
Loin depth, in.[5]	2.69	2.69	2.68	2.68	0.020	0.663	0.756
Lean, %[5]	56.8	57.1	57.2	57.0	0.17	0.250	0.039
Removals, %	3.8	5.4	6.7	6.7	1.14	0.021	0.314
Mortality, %	1.1	2.4	0.6	2.8	0.71	0.410	0.300
Total removals and mortality, %	4.8	7.7	7.1	9.3	1.40	0.008	0.517

[1]A total of 2,153 pigs (PIC 337 × 1050; initially 63.6 ± 1.03 lb BW) were used in a 112-d growth study with 26 to 27 pigs per pen and 20 replicates per treatment across two barns.
[2]Carcass ADG = overall ADG × carcass yield.
[3]Carcass F/G = ADFI / carcass ADG.
[4]Carcass yield was calculated based on adjusted live weight. Adjusted live weight = (pen live weight – total weight of light and cull pigs) / (pen inventory – number of light and cull pigs).
[5]Data were analyzed using HCW as a covariate.