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Is Caloric Efficiency an Accurate Method to Estimate Soybean Meal Net Energy in Nursery Pigs?

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Summary

A total of 4,730 pigs (PIC 337 × L 42) were used in a 20-d study to determine if the caloric efficiency (CE) method is an accurate predictor of soybean meal (SBM) NE in nursery pigs. Pigs were blocked by sow source, entry date, and initial BW (initially 26.5 ± 0.87 lb) and allotted to one of 12 dietary treatments in a randomized complete block design. The twelve treatments were arranged in a 3 × 4 factorial with main effects of SBM NE relative to corn used in diet formulation (80, 100, or 120%) and SBM level (26, 30, 34, or 38%). The same diet was used for each treatment containing 26% SBM, and this served as the base within each SBM NE level. There were 30 to 35 pigs per pen. There were 32 replications of the base treatment and 12 replications of the remaining nine treatments across two rooms. Pens of pigs were weighed, and feed disappearance was measured at the beginning and at the end of the study to determine ADG, ADFI, F/G, and CE. On d 21, following the completion of the growth study, a blood sample was collected from five pigs (two barrows and three gilts) per pen (84 pens; 420 pigs total) to determine serum urea nitrogen. Pigs were fasted for approximately 12 h prior to sample collection. To test SBM level × SBM NE in formulation interactions, the 30, 34, and 38% SBM level treatments were used. No SBM level × SBM NE in formulation interactions were observed. A tendency for a quadratic effect of SBM level was observed ($P < 0.10$) for ADG, where ADG tended to increase as SBM level increased from 26 to 34% but decreased as SBM level further increased to 38%. A quadratic effect of SBM level was observed ($P < 0.05$) for ADFI, where ADFI remained constant as SBM levels increased from 26 to 34% but decreased as SBM level increased to 38%. Thus, F/G improved linearly ($P < 0.05$) as the SBM level increased. To test simple effects of SBM level within SBM NE in formulation, all four SBM level treatments were used. A quadratic effect of SBM level within the 80% SBM NE in formulation was observed ($P < 0.05$) for ADG and ADFI, where ADG and ADFI increased as SBM level increased from 26 to 34% but decreased as SBM level increased to 38%. A linear effect of SBM level was observed ($P < 0.05$) for F/G within all three formulation strategies, where F/G improved as SBM level increased within each formulation strategy. Caloric

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efficiency improved (linear, $P < 0.001$) with increasing SBM level within each of the formulation strategies. The improvement in F/G appears to be a response to the SBM level rather than SBM NE itself. Thus, the CE method may not be an accurate method of predicting SBM NE in nursery pigs.

Introduction

The NE content of soybean meal (SBM), the primary plant-based protein source used in swine diets in the United States, is 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.

Calorimetry studies can be used to determine the NE of an ingredient, but the method is expensive and very few facilities are available to conduct this kind of research. However, a more practical approach is 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. 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 are 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% of the NE of corn.[3] However, the question remains as to whether improved performance can be solely attributed to energy or if other factors may be involved. Previous studies have used only one NE value for SBM in diet formulation. Therefore, the current study used increasing SBM levels within three different SBM NE value estimates used in diet formulation. The objective of this study was to determine if the caloric efficiency method is an accurate predictor of SBM NE in nursery pigs.

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 at a commercial research facility in southern Minnesota. Each pen was equipped with a five-hole stainless steel dry self-feeder and a bowl waterer for *ad libitum* access to feed and water. Diets were manufactured at the Hubbard Feeds feed mill (Mankato, MN) and were in meal form. Daily feed additions to each pen were accomplished using a robotic feeding system (DryExact Pro; Big Dutchman North America, Holland, MI) that recorded feed deliveries for individual pens.

A total of 4,730 nursery pigs (PIC 337 × L 42) were used in a 20-d study. Pigs were blocked by sow source, entry date, and initial BW (26.5 ± 0.87 lb) and allotted to one of 12 dietary treatments in a randomized complete block design. There were 30 to 35 pigs per pen.

The twelve treatments were arranged in a 3 × 4 factorial design with main effects of SBM NE relative to corn used in the diet formulation (80, 100, or 120%) and SBM level (26, 30, 34, or 38%). The same diet was used for each treatment containing

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26% SBM, and this served as the base within each SBM NE level. Altering the NE estimate for SBM in the 26% SBM level diet set the dietary NE used within each SBM NE formulation strategy to determine whether dietary fat needed to be added to or removed from the diet to maintain dietary NE as the SBM level increased in the diet. Across the three formulation strategies, SID Lys, AA:Lys ratios, STTD P, and Ca:P were maintained. There were 32 replications of the base treatment and 12 replications of the remaining nine treatments across two rooms. Complete diet samples were collected from each feeder, pooled, ground to reduce the particle size, and stored at -4°F until they were submitted for complete proximate analysis in duplicate (University of Missouri Agricultural Experiment Station Chemical Laboratory, Columbia, MO). Pens of pigs were weighed, and feed disappearance was measured at the beginning and at the end of the study to determine ADG, ADFI, and F/G. Caloric efficiency 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.

On d 21, following the completion of the growth study, a blood sample was collected from five pigs (two barrows and three gilts) from 21 pens of the base treatment and seven pens per treatment of the remaining nine treatments (84 pens; 420 pigs total) to determine serum blood urea nitrogen (BUN). Pigs were fasted approximately 12 h prior to sample collection.

Statistical analysis

Experimental data were analyzed as a randomized complete block design with pen as the experimental unit and weight block as a random effect. Initial BW was included in the model as a covariate for all growth responses other than itself. The main effects of SBM level and SBM NE in formulation, as well as their interactions, were tested. To test the main effects of SBM level, all four SBM level treatments were used, but to test the interaction and main effects of SBM NE in formulation, the 30, 34, and 38% SBM level treatments were used. Linear and quadratic contrasts were constructed with increasing SBM levels, and SBM NE estimates used in diet formulation. Linear and quadratic simple effects of SBM level within each of the three SBM NE formulation strategies were tested using all four SBM level treatments. Serum BUN data were analyzed in a similar manner, with microtiter plate serving as a random effect and pen serving as a random effect to account for subsampling multiple pigs within pens. Data were analyzed using the lmer package of R (version 4.2.2 (2022-10-31)). Results were considered significant with $P \leq 0.05$ and were considered marginally significant with $P \leq 0.10$.

Results and Discussion

From d 0 to 20, using the 30, 34, and 38% SBM level treatments, no SBM level × SBM NE formulation strategy interactions were observed. Using all four SBM level treatments to test main effects of SBM level, a tendency for a quadratic effect of SBM level was observed ($P < 0.10$) for ADG, where ADG tended to increase as the SBM level increased from 26 to 34% but decreased as SBM level further increased to 38%. A quadratic effect of SBM level was observed ($P < 0.05$) for ADFI, where ADFI remained constant as the SBM level increased from 26 to 34% but decreased as SBM level further increased to 38%. As a result, there was a linear effect of SBM level observed ($P < 0.05$) for F/G, where F/G improved as SBM level increased. Using all four SBM level treatments within each formulation strategy, a quadratic effect of SBM level within the 80% SBM NE formulation strategy was observed ($P < 0.05$) for ADG and ADFI, where

ADG and ADFI increased as SBM level increased from 26 to 34% but decreased as SBM level further increased to 38% resulting in a similar impact on d 20 BW. A linear effect of SBM level was observed ($P < 0.05$) for F/G within all three formulation strategies, where F/G improved as SBM level increased within each formulation strategy. A tendency for a linear effect of SBM level was observed ($P < 0.10$) for ADG within the 100% SBM NE formulation strategy and for ADFI within the 120% SBM NE formulation strategy, where ADG tended to increase within the 100% formulation as SBM level increased, and ADFI tended to decrease within the 120% formulation as SBM level increased.

For serum BUN, using all four SBM level treatments to test main effects of SBM level, a linear effect of SBM level was observed ($P < 0.001$), where BUN increased as the SBM level increased. Using all four SBM level treatments within each formulation strategy, a linear effect of SBM level within each of the formulation strategies was observed ($P < 0.001$) for BUN, where BUN increased as SBM level increased within each formulation strategy.

Caloric efficiency within each formulation strategy was plotted (Figure 1). Caloric efficiency improved (linear, $P < 0.001$) with increasing SBM level within each of the formulation strategies. However, the greatest improvement was observed within the 120% formulation strategy, indicating that SBM NE was underestimated the most at 120% of corn NE in diet formulation. Additionally, the improvement in F/G appears to be a response to SBM level rather than the SBM NE itself. Thus, the CE method may not be the most accurate method of predicting SBM NE in nursery pigs.

Acknowledgments

Appreciation is expressed to Hubbard Feeds (Mankato, MN) and Alltech (Nicholasville, KY) for technical support of this project.

Table 1. Composition of experimental diets[1]

	SBM NE, % of corn NE											
	80				100				120			
Item SBM level, %:	26	30	34	38	26	30	34	38	26	30	34	38
Ingredient, %												
Corn	68.28	64.15	60.01	55.88	68.28	64.60	60.92	57.24	68.28	65.02	61.75	58.49
Soybean meal (47.7% CP)	26.00	30.00	34.00	38.00	26.00	30.00	34.00	38.00	26.00	30.00	34.00	38.00
Corn oil	1.60	2.10	2.60	3.10	1.60	1.65	1.70	1.75	1.60	1.23	0.87	0.50
Calcium carbonate	0.73	0.75	0.76	0.78	0.73	0.75	0.76	0.78	0.73	0.75	0.76	0.78
Monocalcium phosphate	1.10	1.05	1.00	0.95	1.10	1.05	1.00	0.95	1.10	1.05	1.00	0.95
Sodium chloride	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60	0.60
L-Lys-HCl	0.62	0.50	0.37	0.25	0.62	0.50	0.37	0.25	0.62	0.49	0.37	0.24
DL-Met	0.25	0.21	0.18	0.14	0.25	0.21	0.17	0.13	0.25	0.21	0.17	0.13
L-Thr	0.29	0.24	0.18	0.13	0.29	0.24	0.18	0.13	0.29	0.24	0.18	0.13
L-Trp	0.07	0.05	0.02	---	0.07	0.05	0.02	---	0.07	0.05	0.02	---
L-Val	0.21	0.14	0.07	---	0.21	0.14	0.07	---	0.21	0.14	0.07	---
L-Ile	0.08	0.05	0.03	---	0.08	0.05	0.03	---	0.08	0.05	0.03	---
Vitamin premix	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Trace mineral premix	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08	0.08
Selenium premix	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05	0.05
Phytase[2]	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02
Total	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

continued

Table 1. Composition of experimental diets[1]

	SBM NE, % of corn NE											
	80				100				120			
Item SBM level, %:	**26**	**30**	**34**	**38**	**26**	**30**	**34**	**38**	**26**	**30**	**34**	**38**
Calculated analysis												
Standardized ileal digestible (SID) amino acids, %												
Lys	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30	1.30
Ile:Lys	56	59	62	66	56	59	62	66	56	59	63	66
Leu:Lys	107	115	122	129	107	115	122	130	107	115	123	131
Met:Lys	38	37	35	34	38	37	35	34	38	37	35	34
Met and Cys:Lys	58	58	58	58	58	58	58	58	58	58	58	58
Thr:Lys	65	65	65	65	65	65	65	65	65	65	65	65
Trp:Lys	20	20	20	20	20	20	20	20	20	20	20	20
Val:Lys	71	71	70	70	71	71	71	70	71	71	71	71
His:Lys	33	36	39	42	33	36	39	42	33	37	40	43
Total Lys, %	1.43	1.44	1.45	1.46	1.43	1.44	1.45	1.46	1.43	1.44	1.45	1.46
NE, kcal/lb	1,157	1,157	1,157	1,157	1,220	1,220	1,220	1,219	1,283	1,283	1,284	1,284
SID Lys:NE, g/Mcal	5.10	5.10	5.10	5.10	4.83	4.83	4.83	4.84	4.60	4.59	4.59	4.59
CP, %	19.2	20.5	21.9	23.2	19.2	20.6	21.9	23.2	19.2	20.6	22.0	23.4
SID Lys:CP	6.76	6.33	5.94	5.61	6.76	6.33	5.93	5.59	6.76	6.31	5.91	5.56
Ca, %	0.65	0.66	0.67	0.68	0.65	0.66	0.67	0.68	0.65	0.66	0.67	0.68
STTD P, %	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48	0.48
Ca:P	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09	1.09
Analyzed composition, %[3]												
DM	88.4	88.1	88.7	88.3	88.4	88.2	88.2	88.4	88.4	88.4	88.2	88.1
CP	17.6	19.2	20.5	21.2	17.6	18.6	20.6	21.9	17.6	18.8	20.3	21.0
Crude fat	3.5	4.0	4.7	4.8	3.5	3.9	3.7	3.7	3.5	3.1	3.0	2.9
Crude fiber	2.4	2.1	2.3	2.4	2.4	2.6	2.9	2.8	2.4	3.3	2.9	3.2
Ash	5.0	5.2	5.3	5.6	5.0	4.9	5.3	6.0	5.0	5.1	5.2	5.2

[1] Diets were fed from d 0 to 20 of the study in meal form.
[2] Quantum Blue 5G (AB Vista, Plantation, FL) provided an estimated release of 0.12% STTD P with 567 FTU/lb.
[3] Complete diet samples were collected from each feeder, pooled, ground to reduce particle size, and stored at -4°F until they were submitted for complete proximate analysis in duplicate (University of Missouri Agricultural Experiment Station Chemical Laboratory, Columbia, MO).

Table 2. Effect of soybean meal (SBM) level within NE formulation strategy on nursery pig growth performance and blood urea nitrogen (BUN)[1]

	Base[2]	80			100			120				*P* = SBM level	
SBM NE, % of corn NE:													
Item[3] SBM level, %:	**26**	**30**	**34**	**38**	**30**	**34**	**38**	**30**	**34**	**38**	**SEM**	**Linear**	**Quadratic**
BW, lb													
d 20[4]	51.1	51.6	52.1	51.0	51.6	51.5	51.8	51.2	51.8	51.6	0.33	0.061	0.051
d 0 to 20													
ADG, lb[5]	1.21	1.22	1.24	1.20	1.23	1.22	1.24	1.20	1.23	1.22	0.014	0.172	0.069
ADFI, lb[6]	1.64	1.64	1.65	1.58	1.64	1.64	1.63	1.62	1.63	1.60	0.016	0.014	0.048
F/G[7]	1.36	1.33	1.33	1.32	1.34	1.34	1.32	1.35	1.33	1.31	0.009	< 0.001	0.915
Serum BUN, mg/dL[8,9]	3.92	5.33	6.79	8.23	5.09	6.13	8.01	5.12	6.50	8.88	0.491	< 0.001	0.143

SBM NE, % of corn NE:	**80**		**100**		**120**	
***P*-values[10] SBM level:**	**Linear**	**Quadratic**	**Linear**	**Quadratic**	**Linear**	**Quadratic**
d 20 BW	0.880	0.003	0.055	0.721	0.057	0.667
ADG	0.822	0.006	0.079	0.650	0.176	0.772
ADFI	0.005	0.007	0.628	0.650	0.062	0.531
F/G	< 0.001	0.455	0.001	0.995	< 0.001	0.583
Serum BUN	< 0.001	0.955	< 0.001	0.294	< 0.001	0.090

[1]A total of 4,730 nursery pigs (PIC 337 × L 42, initially 26.5 ± 0.87 lb BW) were used in a 20-d study with 30-35 pigs per pen. There were 32 replications of the base treatment and 12 replications per treatment of the other nine treatments.
[2]The base treatment contained 26% SBM, with SBM NE estimated at 80, 100, or 120% of the NE of corn in diet formulation. This treatment was used as the starting point for all contrasts constructed.
[3]Initial BW was used as a covariate for all growth criteria.
[4]SBM NE linear, $P = 0.839$; SBM NE quadratic, $P = 0.513$.
[5]SBM NE linear, $P = 0.583$; SBM NE quadratic, $P = 0.211$.
[6]SBM NE linear, $P = 0.573$; SBM NE quadratic, $P = 0.087$.
[7]SBM NE linear, $P = 0.733$; SBM NE quadratic, $P = 0.675$.
[8]SBM NE linear, $P = 0.864$; SBM NE quadratic, $P = 0.135$.
[9]On d 21, following the completion of the growth study, a blood sample was collected from five pigs (two barrows and three gilts) from 21 pens of the base treatment and seven pens per treatment of the remaining nine treatments (84 pens; 420 pigs total) to determine serum blood urea nitrogen (BUN).
[10]There were no SBM level × SBM NE interactions observed ($P > 0.10$).

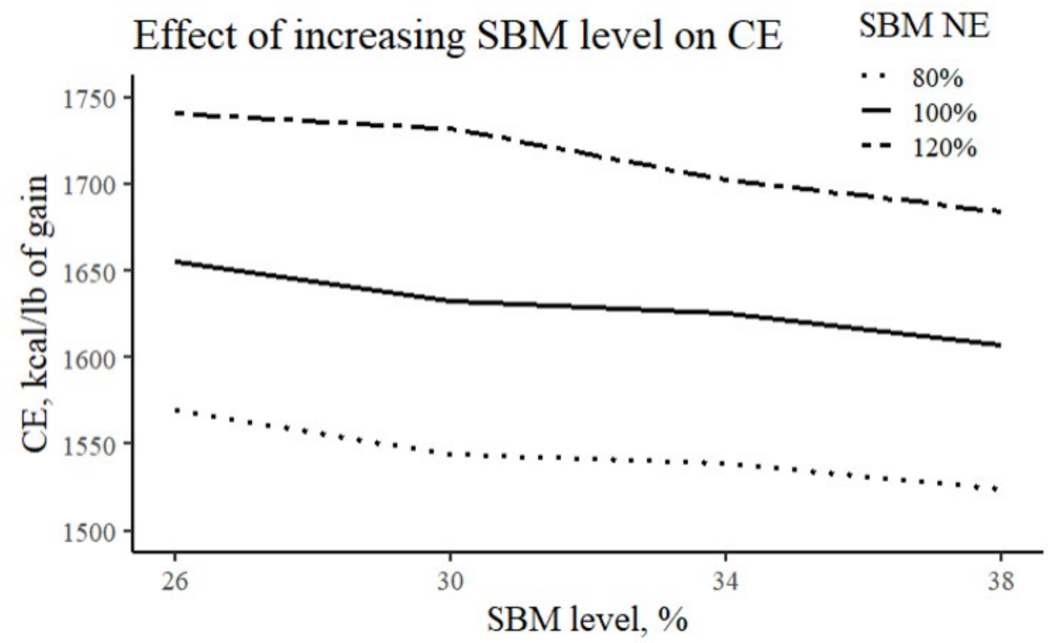

Figure 1. Effect of increasing soybean meal (SBM) level on caloric efficiency (CE) when SBM NE is estimated at 80, 100, or 120% of corn NE in diet formulation. For 80% SBM NE, slope = -3.55. 100% SBM NE, slope = -3.81. 120% SBM NE, slope = -4.98. Increasing SBM level within 80% SBM NE: linear, *P* < 0.001; quadratic, *P* = 0.508. Increasing SBM level within 100% SBM NE: linear, *P* < 0.001; quadratic, *P* = 0.999. Increasing SBM level within 120% SBM NE: linear, *P* < 0.001; quadratic, *P* = 0.610.