Soybean meal or crystalline amino acids in diets for growing pigs: Impact on diet net energy, pig growth performance, and nitrogen retention

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Summary

The net energy of soybean meal has been estimated directly or indirectly in a number of recent experiments in the United States and other countries. In all experiments, without exception, it has been concluded that soybean meal contains more net energy than currently indicated in official feed ingredient tables. The reason for the greater net energy in soybean meal compared with current book values is likely that the digestible energy in soybean meal is underestimated in feed ingredient tables and the retention of nitrogen in modern genotypes of pigs is greater than in older genotypes, which results in a greater net energy of the protein fraction in soybean meal. As a consequence, a net energy value of soybean meal of at least 90% and maybe 100% of the net energy of corn can be assumed, which means that there is no measurable increase in net energy of diets if soybean meal is replaced by corn and crystalline amino acids.

Introduction

The use of crystalline amino acids (**AA**) in diets for pigs has gradually increased over the last few decades due to the availability of more AA at competitive prices. Because soybean meal (**SBM**) is the most commonly used source of AA in diets for pigs in the United States, the increased use of crystalline AA has reduced the need for inclusion of SBM in diets. Indeed, as a common grower diet is formulated with none, 3, 4, or 5 crystalline AA, the inclusion rate of SBM in a grower diet is reduced from 34.5 to 18.75% (Table 1). In terms of growth performance, protein deposition, and carcass quality, it has generally been considered of no consequence if the AA were furnished by SBM or by other sources of AA as long as requirements for digestible AA were met. However, use of crystalline AA instead of SBM usually reduces diet crude protein concentration, and therefore also reduces nitrogen excretion, and it has been generally accepted that lower protein diets are beneficial for intestinal health and also contain more net energy (**NE**) than diets based on only corn and SBM. However, some of these assumptions are not based on strong scientific evidence, and results of recent research have left doubts about some of the previously assumed effects of using crystalline AA instead of SBM in diets for pigs.

The NE of SBM and other ingredients are usually calculated using prediction equations based on digestible nutrients in the ingredient or based on the concentration digestible energy (**DE**) corrected for nutrient concentrations (Noblet et al., 1994; NRC, 2012). In these prediction equations it is assumed that the NE value of crude protein is much lower than the energy value of starch and ingredients high in crude protein, therefore, have lower calculated NE than ingredients high in starch. As a consequence, the NE of SBM is assumed to be much lower than the NE of corn but results of recent research in the United States and other countries have failed to verify that the NE of SBM is much lower than in corn.

There is, therefore, a need for reviewing the assumptions that SBM in diets for growing pigs can be reduced without negative consequences for growth performance and protein retention and that NE in low-SBM diets is greater than in diets based only on corn and SBM. It is the objective of the current contribution to review and discuss results of some recent experiments conducted at the University of Il-

Table 1. Influence of crystalline AA on diet concentration of soybean meal in a typical diet for growing pigs

Item	Dietary protein, %			
	20.0	16.4	15.4	13.4
Ingredient, %				
Ground corn	60.40	70.27	71.40	75.11
Soybean meal	**34.50**	**24.00**	**22.80**	**18.75**
Soybean oil	2.50	2.50	2.50	2.50
L-Lys-HCl	-	0.32	0.35	0.47
DL-Met	-	0.08	0.09	0.12
L-Thr	-	0.08	0.10	0.15
L-Trp	-	-	0.01	0.03
L-Val	-	-	-	0.07
Vitamins, minerals	2.60	2.75	2.75	2.80
Analyzed nutrient, %				
Dry matter	88.49	89.73	88.16	88.55
Crude protein	20.02	16.36	15.38	13.40
Gross energy	3,976	3,936	3,924	3,963
Indispensable amino acids				
Arg	1.25	0.94	0.98	0.93
His	0.50	0.40	0.41	0.39
Ile	0.85	0.69	0.69	0.65
Leu	1.58	1.35	1.39	1.32
Lys	1.07	1.09	1.08	1.11
Met	0.28	0.28	0.31	0.36
Phe	0.95	0.77	0.79	0.75
Thr	0.70	0.63	0.67	0.64
Trp	0.34	0.23	0.26	0.25
Val	0.92	0.75	0.75	0.80

Table 2. Growth performance and carcass characteristics of pigs fed diets containing different levels of crude protein[1]

Item	High-protein	Medium-protein	Low-protein	SEM	P-value
Initial weight, kg	9.67	9.61	9.64	-	-
Final weight, kg	138.49	140.07	137.77	2.02	0.920
Average daily feed intake, kg	2.49	2.49	2.47	0.05	0.715
Average daily gain, kg	0.97	0.98	0.96	0.01	0.929
Gain:Feed	0.39	0.39	0.39	0.01	0.567
Fat thickness, cm	2.29	2.86	2.76	0.338	0.075
Loin eye area, cm^2	60.27	58.05	53.65	0.015	0.058

[1]Diets were fed in a 5-phase sequence from approximately 10 to 138 kg. Within each phase, high protein diets were formulated without crystalline AA, medium protein diets were formulated with crystalline lysine, methionine, and threonine, and the low protein diets were formulated with crystalline lysine, methionine, threonine, tryptophan, and valine.

linois to determine the impact of reducing SBM in diets for growing pigs.

Impact of dietary soybean meal and crystalline amino acids on growth performance and nitrogen retention

In two recent experiments, growth performance and nitrogen balance of pigs fed diets with different levels of crude protein and crystalline AA were determined to test the hypothesis that reducing diet concentration of SBM has no negative impact on growth performance or nitrogen balance as long as diets are fortified with crystalline AA to meet minimum requirements for digestible AA. In Exp. 1, three dietary sequences were fed to pigs from around 10 kg to market weight at around 138 kg. There were five dietary phases from 10 to 25 kg, 25 to 50 kg, 50 to 75 kg, 75 to 100 kg, and from 100 to 138 kg. Within each phase, all diets were formulated as high-, medium-, or low-protein diets, but all diets within the same phase met the same minimum requirements for standardized ileal digestible AA (NRC, 2012). Within each phase, diets were formulated either without crystalline AA, with 3 crystalline AA (i.e., Lys, Met, and Thr), or with 5 crystalline AA (i.e., Lys, Met, Thr, Trp, and Val). As the concentration of crystalline AA was increased, the concentration of SBM in the diets was reduced. As an example, in diets fed from 25 to 50 kg, SBM was included in the diets at 32.75, 22.40, or 16.00% to yield diets containing 20.0, 16.0, or 14.0% crude protein, respectively.

Results demonstrated that there were no differences among treatments in overall growth performance from 10 to 138 kg (Table 2). Likewise, there were no differences in loin quality traits, belly quality, or backfat color. There was, however, a tendency ($P < 0.10$) for a reduction in loin eye area and there was also a tendency ($P < 0.10$) for an increase in back fat thickness as dietary crude protein was reduced. The tendency for a reduced loin eye area indicates that pigs fed the low-protein sequence of diets, while being able to maintain growth performance, were not able to maintain the same protein synthesis as pigs fed the diet sequence with greater protein concentration. A follow-up experiment was, therefore, conducted to test the hypothesis that pigs fed low protein diets have reduced nitrogen retention compared with pigs fed diets with greater protein intake even if diets are balanced for digestible AA. The same diets as used in phase 1 of the growth performance experiment were used in the nitrogen retention experiment and pigs had an initial body weight of 17.75 kg when they were placed in metabolism crates and fed experimental diets for 12 days with urine and feces being collected for 4 days after a 7-day adaptation period. Results of this experiment indicated that although nitrogen retention as a percentage of nitrogen intake increased ($P < 0.001$) as dietary crude protein was reduced, the total daily nitrogen retention calculated as gram per day was reduced (linear, $P < 0.001$) as the protein level was reduced (Table 3). It is likely that it is the reduced daily nitrogen retention that is the reason for the reduced loin eye area that was observed in the growth performance experiment. Thus, results of both experiments indicated that even when diets are carefully formulated to meet the same concentrations of digestible indispensable AA, protein synthesis is not always maintained in the low-protein diets.

Table 3. Nitrogen balance of pigs fed diets containing different levels of crude protein[1]

Item	High-protein	Medium-protein	Low-protein	SEM	P-value
Feed intake, kg/d	1.00	0.99	1.03	-	-
N intake, g/d	36.68[a]	29.53[b]	27.36[c]	0.64	<0.001
N excretion in feces, g/d	4.06[a]	3.48[ab]	3.14[b]	0.43	<0.001
N excretion in urine, g/d	8.39[a]	4.33[b]	2.96[b]	0.48	<0.001
Absorbed N, g/d	32.60[a]	26.06[b]	24.25[bc]	0.54	<0.001
Retained N, g/d	24.11[a]	21.81[ab]	21.19[b]	0.69	<0.001
ATTD of N, %	88.89	88.24	88.46	1.30	0.606
N retention, % intake	66.03[b]	73.56[a]	77.64[a]	2.31	<0.001
N retention, % absorbed	74.16[b]	83.32[a]	87.76[a]	1.74	<0.001

[1]Diets were fed to pigs with an initial body weight of 17.5 kg. High protein diets were formulated without crystalline AA, medium protein diets were formulated with crystalline lysine, methionine, and threonine, and the low protein diets were formulated with crystalline lysine, methionine, threonine, tryptophan, and valine.

To further investigate the impact of reducing dietary crude protein and SBM on growth performance, carcass composition, and nitrogen balance, two additional experiments were conducted. The same diets were used in both experiments. A control diet was formulated based on corn and SBM without any crystalline AA. This diet met all nutrient requirements for growing pigs (NRC, 2012). Three additional diets were formulated by reducing the inclusion rate of SBM and adding 3 crystalline AA (i.e., Lys, Met, Thr); 4 crystalline AA (i.e., Lys, Met, Thr, Trp); or 5 crystalline AA (i.e., Lys, Met, Thr, Trp, Val) to the diet. Concentrations of standardized ileal digestible indispensable AA were at or above requirements (NRC, 2012) in all diets, but the concentration of crude protein was reduced from 20.0% to 16.4, 15.4, and 13.4%, respectively, by including 3, 4, or 5 crystalline AA in the diets. In the growth performance experiment, 176 growing pigs (initial body weight: 32.2 ± 4.2 kg) were used. On d 1, 16 pigs were randomly chosen and euthanized and the composition of nutrients and energy in the body of these pigs was determined. The remaining 160 pigs were allotted to the four diets using a randomized complete block design. There were 4 pigs per pen (2 gilts and 2 barrows) and 10 replicate pens per diet. Diets were provided to pigs on an *ad libitum* basis for 28 d. At the conclusion of the experiment, one pig in each pen that had a BW that was closest to the pen average was slaughtered after an overnight fast. To determine body composition, the pig body was partitioned into three parts (i.e., carcass, blood, and viscera). The weight of each part was recorded and samples from each part were then analyzed for fat and nitrogen. By subtracting the concentration of nutrients in the 16 pigs that were sacrificed at the beginning of the experiment from the weight of each nutrient in the pigs sacrificed at the end of the experiment, body retention of lipid and nitrogen during the experimental period was calculated. Results indicated that average daily gain and average daily feed intake were not affected by dietary treatments, which resulted in no differences in gain to feed ratio (Table 4). Retained protein, lipid,

Table 4. Growth performance and deposition of protein, fat, and energy in growing pigs[1,2]

Item	Dietary protein, %				SEM	Contrast *P*-value	
	20.0	16.4	15.4	13.4		Linear	Quadratic
Initial BW, kg (on d 1)	32.17	32.29	32.20	32.18	-	-	-
Final BW, kg (on d 29)	61.31	60.64	60.62	61.70	2.20	0.908	0.378
ADG, kg/d	1.04	1.01	1.02	1.06	0.04	0.912	0.339
ADFI, kg/d	2.12	2.21	2.15	2.23	0.07	0.133	0.914
G:F	0.493	0.460	0.473	0.474	0.014	0.296	0.275
Protein deposition, g/d	125.85	119.56	123.27	114.11	9.96	0.259	0.722
Lipid deposition, g/d	137.29	138.13	121.86	123.06	15.09	0.224	0.748
Energy deposition, Mcal/d	1.95	2.04	1.88	1.75	0.17	0.146	0.113
Energy intake, Mcal/d	8.41	8.68	8.42	8.85	0.29	0.184	0.609
Energy efficiency for growth[3], %	22.78	23.39	22.26	19.57	1.54	0.088	0.083
Blood urea N, mg/dL	16.10	10.30	8.10	5.00	0.93	< 0.001	0.886
Bacteria protein in colon, µg/g	963.14	817.07	868.43	710.05	74.30	0.030	0.700

[1]Data are least square means of 10 observations for all treatments.
[2]The diet with 20.0% crude protein was based on corn and soybean meal and no crystalline AA, but in diets contianing 16.4, 15.4, or 13.4% crude protein, the inclusion of soybean meal was reduced and lysine, methionine, and threonine; lysine, methionine, threonine, and tryptophan; or lysine, methionine, threonine, tryptophan, and valine were included to maintain equal concentrations of digestible indispensable AA.
[3]Energy efficiency for growth (%) was calculated by dividing energy deposition by energy intake and multiplying by 100.

Table 5. Nitrogen balance, apparent total tract digestibility (ATTD) of energy, and concentrations of energy in experimental diets fed to growing pigs, as-fed basis[1,2]

Item	Dietary protein, %				SEM	Contrast *P*-value	
	20.0	16.4	15.4	13.4		Linear	Quadratic
Intake							
Feed, kg/d	1.07	1.07	1.08	1.11	0.04	0.375	0.523
N, g/d	34.39	28.13	26.65	23.70	0.93	< 0.001	0.622
Nitrogen excretion							
Fecal nitrogen, g/d	4.57	3.79	4.23	4.23	0.22	0.241	0.082
Urine nitrogen, g/d	6.76	4.04	3.46	1.93	0.47	< 0.001	0.999
N balance							
N absorbed, g/d	29.83	24.33	22.43	19.47	0.88	< 0.001	0.895
N retained, g/d	23.06	20.30	18.96	17.54	0.59	< 0.001	0.892
N retention, % intake	67.09	72.05	71.26	73.89	1.31	< 0.001	0.686
Biological value, % absorbed[3]	77.28	83.41	84.73	90.02	1.53	< 0.001	0.336

[1]Data are least square means of 10 observations for all treatments.
[2]The diet with 20.0% crude protein was based on corn and soybean meal and no crystalline AA, but in diets containing 16.4, 15.4, or 13.4% crude protein, the inclusion of soybean meal was reduced and lysine, methionine, and threonine; lysine, methionine, threonine, and tryptophan; or lysine, methionine, threonine, tryptophan, and valine were included to maintain equal concentrations of digestible indispensable AA.
[3]Biological value was calculated by dividing nitrogen retained (g/d) by nitrogen absorbed (g/d) and multiplying by 100.

and energy were also not significantly affected by dietary treatment, but energy efficiency tended to decrease (quadratic, $P < 0.10$) as dietary protein was reduced. In the nitrogen balance experiment using the same four diets as in the growth performance experiment, 40 growing pigs (initial body weight: 20.5 ± 2.4 kg) were allotted to a randomized complete block design with four diets and 10 replicate pigs per diet for a total of 10 replicate pigs per diet. Pigs were housed individually in metabolism crates and fecal and urine samples were collected quantitatively for 5 days after 7 days of adaptation. Results indicated that daily nitrogen intake was reduced (linear, $P < 0.001$), and daily nitrogen in feces tended (quadratic, $P < 0.10$) to be reduced as dietary protein was reduced (Table 5). Daily nitrogen excretion in urine was also reduced (linear, $P < 0.001$) as dietary protein decreased. However, although nitrogen retention calculated as percentage of intake increased (linear, $P < 0.001$), absorbed nitrogen and retained nitrogen calculated as gram per day were reduced (linear, $P < 0.001$) as dietary protein decreased.

Combined, results of the above four experiments indicate that although growth performance can be maintained in diets based on corn, crystalline AA, and reduced levels of SBM, nitrogen retention, and therefore, protein synthesis appears to be compromised, which will result in reduced carcass leanness. These observations are in agreement with results by Kerr and Easter (1995) and Le Belego and Noblet (2002) who also observed reduced nitrogen retention of pigs fed diets with reduced concentrations of SBM. Likewise, reduced carcass leanness was also observed as dietary crude protein was reduced although growth performance was not changed (Kerr et al., 1995).

Theoretical and actual impact on net energy of using crystalline amino acids instead of soybean meal

According to current book values, the NE of soybean meal is much less than that of corn. As an example, on a dry matter basis, the NE of corn is 3,026 kcal/kg and the NE of soybean meal is 2,319 kcal/kg (NRC, 2012). The reason for this difference primarily is that the equation used to calculate NE assumes a large negative effect of crude protein on NE (Noblet et al., 1994; NRC, 2012). Indeed, the gross energy and the DE is greater in SBM than in corn (NRC, 2012), but because of the assumed negative effect of crude protein on NE, the calculated NE is only 77% of the NE of corn (Table 6). As illustrated in Table 1, the inclusion of corn will increase as dietary SBM is reduced, and concentrations of crystalline AA are increased in a diet. As a consequence of the assumed difference in NE between corn and SBM, the theoretical NE of a diet will increase if SBM is reduced, and the inclusion of corn is increased. However, in several recent experiments, the NE of SBM was greater than the value estimated by NRC (2012) and NE values ranging from 82 to 125% of the NE of corn have been reported (Li et al., 2017; Cemin et al., 2020; Lee et al., 2021). If those values are correct, it would be assumed that the theoretical increase in NE obtained by increasing corn and reducing SBM in a

Table 6. Comparison of gross energy, digestible energy, metabolizable energy, and net energy in corn and soybean meal, kcal/kg dry matter [1]

Item	Corn	Soybean meal
Gross energy	4,454	4,730
Digestible energy	3,908	4,022
Metabolizable energy	3,844	3,661
Net energy	3,026	2,319

[1] All values calculated from NRC (2012).

diet because of inclusion of crystalline AA may not be realized in practical diets. An experiment was, therefore, conducted to test the hypothesis that the negative effect on diet NE of using SBM in diets is less than calculated from current NRC (2012) values. A diet based on corn, SBM, and L-Lysine was formulated and 5 additional diets in which the concentration of SBM was gradually reduced and inclusion of crystalline AA was increased were also formulated. All diets were formulated to meet the AA requirement for pigs from 30 to 115 kg. The concentration of corn increased from 69.3 to 85.4% and the concentration of SBM was reduced from 27.0 to 9.4% as the inclusion of crystalline AA increased. Diets were fed to group housed and ad libitum fed pigs housed in calorimeter chambers and the concentration of NE was determined for each diet. Results indicated that there were no differences among diets in NE (Table 7) and the hypothesis that the NE of SBM is greater than previously thought was, therefore, confirmed. Indeed, because NE did not change as dietary corn increased and SBM was reduced, results indicated that the NE of SBM may be close to the NE of corn. It was also noted that the observed NE of all diets, regardless of the level of SBM in the diet, was greater than the calculated values, further indicating that SBM may contribute more NE to diets than calculated from current book values. This last observation is also in agreement with results of other recent experiments (Ochoa et al., 2024; Lee et al., 2024).

Table 7. Effects of dietary crude protein and reducing soybean meal and protein on calculated and measured concentrations of net energy in diets and measured total heat production and fasting heat production from group-housed pigs

Item Dietary crude protein, %:	16.4	14.6	12.7	11.6	10.6	9.6	SEM
Soybean meal, %:	27.0	19.1	16.7	14.2	11.8	9.3	
Energy in diets, kcal/kg							
Calculated net energy	2,500	2,546	2,561	2,575	2,588	2,600	-
Measured net energy[1]	2,646	2,605	2,663	2,631	2,665	2,634	47
Heat production, kcal/kg body weight$^{0.6}$ per day							
Total heat production[1]	384	375	378	376	390	377	20
Fasting heat production[1]	223	220	235	218	238	221	17

[1]There were no differences among diets on measured net energy, total heat production, or fasting heat production.

In the experiment referenced in Table 4, where four diets containing 20.0, 16.4, 15.4, or 13.4% crude protein were formulated by reducing SBM from 34.5 to 24.0, 22.8, or 18.8% and increasing corn and crystalline AA, the NE of each diet was also calculated using the comparative slaughter procedure. Results of this calculation demonstrated that NE of diets did not increase as the concentration of SBM was reduced and the determined NE of the diet based on corn and SBM and no crystalline AA was greater than the NE calculated from NRC (2012), which was also observed in the previous experiment (Cristobal et al., 2024a). Results of the second experiment, therefore, confirmed that the NE of SBM likely is close to the NE of corn when fed to group housed pigs allowed ad libitum intake of feed. These results are also in agreement with recent data from Ochoa et al. (2024) who also reported that the NE of a diet based on corn and SBM is greater than the value calculated from a theoretical prediction equation that assumes a large negative effect of diet crude protein on NE.

Reasons for increased net energy in soybean meal

There are two main reasons why SBM contains more NE than calculated from previously developed prediction equations. The first reason is that the digestible energy in SBM is greater than estimated in current book values. As an example, in an average of 22 sources of SBM, the DE was 239 kcal greater than NRC (2012), which was in agreement with results of previous experiments conducted at the University of Illinois (Sotak-Peper et al., 2015). A greater DE in SBM also results in a greater NE value and an increase in DE of 239 kcal per kg corresponds to an increase in calculated NE of approximately 170 kcal per kg.

The second reason for increased NE in SBM is that modern genotypes of pigs are more efficient in retaining nitrogen in the body than older genotypes. Indeed, one of the reasons for the assumed negative impact of diet crude protein on NE is that it has been assumed that growing pigs only retain between 45 and 50% of absorbed nitrogen in the body (Noblet et al., 2004). This estimate corresponds to a retention of 40 to 45% of consumed nitrogen and is in agreement with data published in the 1970's and 1980's (Gatel and Grosjean, 1992). However, as pig genetic companies have placed more emphasis on selection based on lean deposition, pigs have become more efficient in retaining nitrogen in the body, and later data indicated that pigs were able to retain between 50 and 60% of consumed nitrogen (Kerr and Easter, 1995; Otto et al., 2003). Recently, data from nitrogen balance experiments in which modern genotypes of pigs fed a corn-soybean meal-based diet without crystalline AA were used, pigs retained between 60 and 70% of consumed nitrogen (Corassa et al., 2024; Ochoa et al., 2024; Cristobal et al., 2024b). Thus, the genetics of pigs have become much more efficient in utilizing dietary nitrogen for protein synthesis and the quantities of AA that need to be deaminated with a subsequent excretion of nitrogen via the urea cycle is, therefore, less in modern genotypes of pigs than in older genotypes. Because deamination of AA and excretion of nitrogen are energy requiring processes, the theoretical energy contribution from dietary protein increases as nitrogen retention increases. As an example, if nitrogen retention increases from 45 to 70% of nitrogen intake, the NE of soybean meal will increase by approximately 165 kcal per kg. It is, therefore, likely that the increased nitrogen retention that is observed in modern genotypes of pigs contributes to the increased NE of SBM that has been consistently observed in experiments conducted in recent years.

If it is assumed that the increased DE of SBM results in an increased NE of 170 kcal per kg compared with current book values and that the greater capacity for nitrogen retention contributes and additional 165 kcal per kg, the increased NE of SBM due to these two factors is 335 kcal NE per kg. If this value is added to the current estimate for NE in SBM (i.e., 2,319 kcal per kg dry matter; Table 6), a NE of 2,654 kcal per kg dry matter is obtained, which corresponds to around 88% of the NE in corn. This value is in reasonable agreement with some recent estimates for NE in SBM (i.e., Li et al. 2017; Lee et al., 2021) and is also in agreement with observations that the NE of a corn-SBM diet is close to 100 kcal per kg greater than calculated (Ochoa et al., 2024; Lee et al., 2024). It is, however, noted that NE values estimated from the gain to feed ratio obtained in growth assays usually give greater estimates for NE in SBM (Cemin et al., 2020). The reason for this discrepancy is not completely clear but may be related to changes in body composition and body energy concentration that is not realized by simply determining gain to feed ratio of a group of growing pigs.

Conclusions

Results of numerous experiments conducted in recent years have demonstrated that the NE of SBM is greater than current book values. It is likely that this is a result of a greater concentration of DE in SBM than previously thought as well as a greater energy value of the protein fraction in SBM due to the greater nitrogen retention in modern genotypes of pigs compared with older genotypes. In experiments conducted to determine NE in SBM or in corn-SBM diets using indirect calorimetry or the comparative slaughter procedure, NE values for SBM between 90 and 100% of corn have been obtained, which is reasonably close to theoretical calculations of NE in SBM fed to modern genotypes of pigs. However, in a number of experiments conducted to calculate NE in SBM from the gain to feed ratio of pigs used in growth assays, the NE of SBM has been estimated to be between 100 and 125% of corn. Whereas these latter values may overestimate the NE of SBM because changes in body composition are not included in the estimates, it should be noted that in all experiments conducted to determine NE of SBM or in corn-SBM based diets, a greater NE than current book values has been obtained. Because no values less than current book values have been reported, it is unlikely that the values reported from recent experiments are due to normal random variations around a common mean value.

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