Advantages of Higher Soybean Meal Diets for Pigs

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Summary

Crystalline amino acids (AA) are widely used in diets for pigs to either lower the concentration of soybean meal (SBM) in the diets or to balance the AA profile of other protein sources including high protein corn protein. However, results of recent experiments demonstrated that even when diets are balanced for all indispensable AA, the excess levels of Leu in corn protein results in reduced growth performance of pigs. This is likely due to interactions between Leu and Val, Ile, and Trp and it is, therefore, possible to partly restore the lost performance obtained for diets with corn protein if extra Val, Ile, and Trp, is included. However, it appears that pigs fed diets based on corn and SBM have better growth performance than those fed corn protein and crystalline AA. It has also not been possible to demonstrate that low crude protein diets that contain crystalline AA instead of some of the SBM have greater net energy than diets based only on corn and soybean meal. It therefore appears that SBM may provide benefits to pigs in addition to the AA that are provided from SBM.

Introduction

Utilization of feed-grade crystalline amino acids (**CAA**) and the increased availability of grain co-products and alternative feed ingredients have led to replacement of soybean meal (**SBM**) in diets for pigs. One reason for the success of using CAA at the expense of SBM is that diets containing CAA have a lower concentration of crude protein (**CP**) compared with SBM-based diets. There is a common conception in the industry that diets with lower concentration of CP have greater net energy (**NE**) compared with diets with greater CP. As a consequence, it is believed that diets based on CAA contain more NE than diets based on SBM. However, this perception is based on theoretical calculations and there is no scientific evidence to support this. As a matter of fact, in a few experiments where diets based on CAA were compared with diets without CAA and with more SBM, it was not possible to demonstrate a difference in NE (Noblet et al., 2001; Munoz, 2020). However, these experiments were not specifically designed to determine the effects of replacing SBM by CAA and the perception that diets based on CAA contain more NE is therefore still widespread.

In recent years, high protein corn co-products (**HPCP**) that contain between 40 and 50% CP have been developed. It is therefore possible to formulate diets containing corn co-products as a protein source, but such diets will contain more than twice as much Leu as recommended. Leucine is an indispensable AA that stimulates the catabolism of branched-chain amino acids (**AA**) in the liver (Harper et al., 1984). However, if pigs are fed diets with excessive Leu, degradation of not only Leu, but also Val and Ile, may increase because of the stimulating effects of Leu or its metabolite on branched-chain AA degrading enzymes (Wiltafsky et al., 2010). Therefore, excess dietary Leu may result in an imbalanced supply of branched-chain AA by increased degradation of Val and Ile and thus reduce pig feed intake, protein synthesis, and growth performance (Gatnau et al., 1995; Wiltafsky et al., 2010; Kwon et al., 2019).

Therefore, the objective of this contribution was to investigate the effects of using SBM in pig diets on the growth performance of pigs and concentration of NE in diets.

Effects of using SBM in diets fed to growing pigs

Effects of excess Leu from HPCP on growth performance of pigs

An experiment was conducted to test the hypothesis that excess Leu from corn protein will result in negative effects on the growth performance of growing pigs and that crystalline $_{L}$-Val, $_{L}$-Ile, or $_{L}$-Trp will alleviate the negative ef-

Table 1. Growth performance and plasma urea nitrogen (PUN) of growing pigs fed experimental diets[1,2]

Item[3]	SBM diet	High-protein corn product diets								SEM	*P*-value
		Basal (no CAA)	+ Ile	+ Val	+ Trp	+ Ile, Val	+ Ile, Trp	+ Val, Trp	+ Ile, Val, Trp		
Body weight, kg											
d 1	28.7	28.5	28.7	28.7	28.4	28.5	28.7	28.5	28.5	0.83	0.969
d 28	55.3[a]	50.7[b]	50.7[b]	51.0[b]	50.7[b]	50.2[b]	50.0[b]	52.6[ab]	51.3[b]	1.35	< 0.001
ADG, g/d	950[a]	793[b]	785[b]	797[b]	797[b]	776[b]	760[b]	862[ab]	813[b]	28.8	< 0.001
ADFI, g/d	1,816[a]	1,621[b]	1,623[b]	1,650[ab]	1,704[ab]	1,617[b]	1,683[ab]	1,758[ab]	1,695[ab]	57.7	0.034
G:F	0.53	0.49	0.48	0.48	0.47	0.48	0.45	0.49	0.48	0.015	0.079
PUN, mg/dL											
d 1	9.0	7.6	8.3	8.3	8.0	7.4	8.0	8.3	8.1	0.45	0.486
d 14	7.9	8.0	7.6	8.9	7.5	8.5	7.8	8.8	7.4	0.71	0.773
d 28	12.0[a]	8.1[b]	8.6[b]	8.1[b]	8.8[ab]	7.6[b]	8.3[b]	8.3[b]	7.8[b]	0.76	0.004
HS, µg/mL	0.193	0.149	0.183	0.178	0.191	0.180	0.183	0.201	0.188	0.013	0.070
Trp, µmol/L	60.5[ab]	28.4[c]	43.9[bc]	40.2[bc]	61.6[ab]	45.9[bc]	62.3[ab]	79.9[a]	59.4[ab]	7.04	< 0.001

[a-b]Means within a row without a common superscript letter differ ($P < 0.05$).
[1]Each least squares mean represents 8 observations.
[2]Data are from Kwon et al. (2023).
[3]ADG = average daily gain; ADFI = average daily feed intake; CAA = crystalline amino acids; G:F = gain to feed ratio; HS = hypothalamic serotonin; SBM = soybean meal.

fects of excess dietary Leu (Kwon et al., 2023). A basal diet based on corn and a HPCP was formulated. Two levels of crystalline L-Ile (0 or 0.10%), 2 levels of crystalline L-Val (0 or 0.10%), and 2 levels of crystalline L-Trp (0 or 0.05%) were added to the basal diet for a total of 8 diets. A SBM diet based on corn and SBM was also used in addition to the 8 diets. A total of 288 growing pigs [initial body weight (**BW**): 28.6 kg; SD = 2.5] were randomly assigned to 9 dietary treatments in a 28-day growth performance experiment. Pigs were housed in pens with partly slatted concrete floors and average daily gain (**ADG**), average daily feed intake (**ADFI**), and gain to feed ratio (**G:F**) were calculated. Blood samples were collected and analyzed for plasma urea nitrogen (**PUN**). After blood collection, all pigs were euthanized and the hypothalamus was collected for serotonin analysis.

Results (Table 1) indicated that final BW and ADG of pigs fed the SBM diet were greater ($P < 0.05$) than for pigs fed all other diets, except pigs fed the diet with the addition of both L-Val and L-Trp. Average daily feed intake of pigs fed the SBM diet was greater ($P < 0.05$) compared with the diet containing HPCP and no CAA and the diet containing HPCP and Ile. Gain to feed ratio of pigs and hypothalamic serotonin tended ($P < 0.10$) to be different among dietary treatments, but pairwise comparisons were not significant. There was no difference among dietary treatments for PUN on d 1 or d 14, but on d 28, PUN of pigs fed the SBM diet was greater ($P < 0.05$) than that of pigs fed all other diets except the diet supplemented with L-Trp. Pigs fed the basal diet had lower ($P < 0.05$) free Trp in plasma compared with pigs fed all other diets except for pigs fed the diets with added Val, Ile, or Val and Ile.

It was concluded that pigs fed the SBM diet had better growth performance than pigs fed the diets containing HPCP. The combination of Val and Trp supplementation may be beneficial for preventing detrimental effects of excess Leu on growth performance of pigs.

Effects of excess Leu from HPCP and use of CAA on growth performance and intestinal tract function of weanling pigs

A follow-up experiment was conducted to test the hypothesis that the use of HPCP without or with CAA affects the growth performance and intestinal tract function of weanling pigs (Mallea et al., 2023). A two-phase feeding program was used. A total of 320 weanling pigs (initial BW: 6.1 kg; SD = 0.7) were randomly assigned to 10 dietary treatments. A SBM diet based on corn and SBM was formulated and a basal diet was formulated based on corn and 10% HPCP. Another basal diet was formulated based on corn and 20% HPCP. Two levels of crystalline L-Ile (0 or 0.10%), 2 levels of crystalline L-Val (0 or 0.10%), and 2 levels of crystalline L-Trp (0 or 0.05%) were added to the basal diet with 20% HPCP for a total of 8 diets. Pigs were housed in pens with fully slatted plastic floors and ADG, ADFI, and G:F were calculated. Fecal scores were assessed visually. Blood samples were collected from one pig in each pen and analyzed for PUN, total protein, albumin, peptide YY (**PYY**), and immunoglobulin G (**IgG**). Ileal tissue samples were also collected and villus height, crypt depth, and lamina propria thickness were measured.

Results (Table 2) indicated that the inclusion of 10 or 20% HPCP in diets reduced ($P < 0.05$) final BW on d 28 and

Table 2. Growth performance of weanling pigs fed the experimental diets[1,2]

Item[2]	SBM diet	10% HPCP	20% HPCP								SEM	P-value
			-	+ Ile	+ Val	+ Trp	+ Ile, Val	+ Ile, Trp	+ Val, Trp	+ Ile, Val, Trp		
BW, kg												
d 1	6.33	6.29	6.34	6.33	6.30	6.32	6.30	6.32	6.31	6.29	-	-
d 14	7.43	7.27	7.35	7.21	7.35	7.2	7.35	6.97	7.40	7.43	0.35	0.979
d 28	14.23^{a}	12.58^{bcd}	12.07^{cd}	11.89^{cd}	13.03^{abc}	11.93^{cd}	12.60^{bcd}	11.44^{d}	13.00^{abc}	13.78^{ab}	0.55	0.009
ADG, g/d												
Phase 1	78	70	72	63	75	63	75	47	78	81	9	0.280
Phase 2	486^{a}	380^{cde}	337de	334de	405^{bc}	338de	375^{cde}	319^{e}	400^{bcd}	453^{ab}	24	< 0.001
Overall	282^{a}	225^{cd}	205^{cde}	199de	240^{bc}	200^{cde}	225^{cd}	183^{e}	239^{bc}	267^{ab}	14	< 0.001
ADFI, g/d												
Phase 1	142	137	136	138	141	136	149	119	146	158	10	0.245
Phase 2	662^{a}	550^{cd}	503^{cde}	488de	572^{bcd}	500^{cde}	550^{cd}	442^{e}	578^{abc}	647^{ab}	34	< 0.001
Overall	402^{a}	343^{b}	319^{bc}	313^{bc}	357^{ab}	318^{bc}	350^{ab}	280^{c}	362^{ab}	402^{a}	19	< 0.001
G:F												
Phase 1	0.55	0.49	0.53	0.45	0.52	0.46	0.49	0.36	0.52	0.52	0.06	0.180
Phase 2	0.73	0.69	0.67	0.69	0.71	0.67	0.68	0.73	0.70	0.70	0.03	0.347
Overall	0.70	0.65	0.64	0.64	0.67	0.62	0.64	0.66	0.66	0.66	0.02	0.154

[1]Data are least square means of 8 observations per treatment.
[2]Data were from Mallea et al. (2023).
[3]ADFI = average daily feed intake; ADG = average daily gain; BW = body weight; G:F = gain to feed ratio; HPCP = high protein corn co-products.

ADG and ADFI in phase 2 and for the entire experimental period compared with the SBM diet. Final BW of pigs fed the 20% HPCP diet with the 3 CAA was greater ($P < 0.05$) compared with the 20% HPCP diet containing no CAA, the HPCP diets with Ile, Trp, or Ile and Trp. Average daily gain and ADFI in phase 1 were not affected by dietary treatment. However, the ADG of pigs fed the 20% HPCP diets with the 3 CAA was greater ($P < 0.05$) in phase 2 and for the overall experiment compared with the 10% and 20% HPCP diets with no CAA and the 20% HPCP diets with Ile, Trp, Ile and Val, or Ile and Trp. Pigs fed the 20% HPCP diet with the 3 CAA had greater ($P < 0.05$) ADFI in phase 2 and for the overall experiment than pigs fed diets with 10 or 20% HPCP containing no CAA or the HPCP diets with Ile, Trp, or Ile and Trp. Gain:feed was not affected by dietary treatment. In phase 2 and overall, fecal scores (Table 3) were reduced ($P < 0.05$) if HPCP was used instead of SBM. No differences among experimental diets were observed for PUN, total protein, albumin, peptide YY, or IgG on d 14 (data not shown) and for total protein, peptide YY, and immunoglobulin G on d 28. Plasma urea N of pigs fed the SBM diet on d 28 was greater ($P < 0.05$) compared with the HPCP diets supplemented with Ile, Val, Val and Trp, or Ile, Val, and Trp. Albumin in plasma was greater ($P < 0.05$) in pigs fed the SBM diet than in pigs fed the HPCP diets supplemented with Ile, Trp, Ile and Val, Ile and Trp, or Val and Trp, but was not different from pigs fed the two HPCP diets with no CAA and the HPCP diets supplemented with Val or Ile, Val, and Trp. Ileal villus height, crypt depth, villus height to crypt depth ratio, and lamina propria thickness, as well as microbial protein, concentrations of VFA and ammonium in feces were not affected by dietary treatments (data not shown).

It was concluded that using HPCP instead of SBM in diets for weanling pigs has a negative effect on growth performance, but ileal morphology, microbial protein, and fecal VFA and ammonium were not affected. The detrimental effect on growth performance of pigs fed HPCP-based diets was partially ameliorated with the supplementation of Ile, Val, and Trp.

Determination of net energy in low protein diets containing CAA and normal protein diets fed to growing pigs

This experiment was conducted to test the hypothesis that NE in diets is not increased by increasing CAA in diets fed to group-housed pigs (Lee et al., 2023). First, a diet based on corn and SBM, minerals, and vitamins was formulated; this diet contained no CAA. Then, a normal protein diet was formulated based on corn and SBM, minerals, and vitamins and crystalline Lys, Met, and Thr; this diet was similar to a typical diet used in the industry. Four additional diets were formulated by reducing CP by 1, 2, 3, or 4% units compared with the normal-CP diet containing three CAA. Therefore, a total of six diets were used. A total of 24 growing pigs (initial BW: 29.9 kg; SD = 2.4) were randomly allo-

Table 3. Fecal score and plasma characteristics of pigs[1,2]

Item[3]	SBM diet	10% HPCP	20% HPCP								SEM	*P*-value
			-	+ Ile	+ Val	+ Trp	+ Ile, Val	+ Ile, Trp	+ Val, Trp	+ Ile, Val, Trp		
Fecal score[4]												
Phase 1	2.42	2.25	2.12	2.03	2.17	2.03	2.51	2.08	2.21	2.11	0.21	0.295
Phase 2	1.67[a]	1.44[b]	1.23[c]	1.23[c]	1.21[c]	1.37[bc]	1.26[bc]	1.26[bc]	1.21[c]	1.33[bc]	0.13	0.001
Overall	2.05[a]	1.84[abc]	1.67[bc]	1.63[c]	1.75[bc]	1.70[bc]	1.89[ab]	1.67[bc]	1.71[bc]	1.72[bc]	0.14	0.030
d 28												
PUN, mg/dL	6.25[a]	4.62[abc]	4.50[abc]	4.00[bcd]	3.62[cd]	5.00[abc]	4.62[abc]	5.62[ab]	2.59[d]	2.37[cd]	0.66	0.006
Total protein, mg/dL	4.82	4.86	4.68	4.71	4.83	4.75	4.60	4.66	4.62	4.80	0.10	0.390
Albumin, mg/dL	3.18[a]	3.12[ab]	2.97[abcde]	2.85[cde]	3.03[abcd]	2.83[de]	2.72[e]	2.86[bcde]	2.82[de]	3.11[abc]	0.09	0.009
PYY, ng/mL	2.69	2.72	2.79	2.75	2.96	2.72	2.96	3.16	2.95	2.94	1.03	0.971
Ig G, mg/mL	6.59	4.59	4.61	5.64	4.59	4.93	4.68	4.70	4.71	3.91	0.91	0.679

[1]Data are least square means of 7 to 8 observations per treatment.
[2]Data were from Mallea et al. (2023).
[3]PUN = plasma urea nitrogen; immunoglobulin G = IgG; peptide YY = PYY.
[4]Fecal scores were visually assessed every other day by 2 independent observers for 28 days. Fecal score: 1, normal feces; 2, moist feces; 3, mild diarrhea; 4, severe diarrhea; and 5, watery diarrhea.

cated to six calorimeter chambers in the Swine Calorimeter Unit at the University of Illinois. There were four pigs per chamber. The six chambers were allotted to six diets using a 6 × 6 Latin square design with six periods. Therefore, there were six replicate chambers per diet. The O_2 consumption and CO_2 and CH_4 production were measured and fecal and urine samples were collected for 6 days. Fasting heat production (**FHP**) was also determined. Diets and ground fecal samples and lyophilized urine samples were analyzed for gross energy (**GE**) and urine samples were analyzed for N.

Results (Table 4) indicated that feed intake, fecal and urine GE output, the ATTD of dry matter and GE, total heat production (**THP**), FHP, and retained energy were not different between pigs fed the two normal-CP diets. Respiratory quotient (**RQ**) of pigs fed the normal-CP diet without CAA was less (P = 0.045) compared with the normal-CP diet with CAA. Concentrations of digestible energy (**DE**) and metabolizable energy (**ME**) in the normal-CP diet without CAA were greater ($P < 0.05$) than in the normal-CP diet with CAA, but there was no difference in concentration of NE between the two normal-CP diets. Feed intake, GE intake, and fecal GE output of pigs were linearly (P = 0.044) increased by reducing CP in diets, but reducing CP in diets did not affect the ATTD of dry matter and GE or urine GE excretion by pigs. Total heat increment, FHP, retained energy, and concentrations of DE, ME, and NE were not affected by reducing CP in diets containing CAA.

Discussion

The growth performance of both growing pigs and weanling pigs was negatively affected by the use of HPCP compared with diets containing SBM. One of the primary limitations of using corn co-products is its relatively high fiber concentration, which leads to reduced nutrient utilization in pigs (Woyengo et al., 2014). Excessive dietary Leu that is supplied by including corn protein is also cause for concern, as it stimulates the breakdown of branched-chain AA in skeletal muscle and liver (Harper et al., 1984). The increased Leu results in an increased production of the Leu metabolite, α-keto isocaproate, which also increases the secretion of branched-chain α-keto acid dehydrogenase enzyme complex that catalyzes the branched-chain AA (Wiltafsky et al., 2010). It is likely that it is the excess Leu that resulted in reduced growth performance of pigs fed diets containing HPCP (Kwon et al., 2019).

Levels of PUN are mostly influenced by the quantities and balance of AA that are absorbed by pigs (Nyachoti et al., 2006). The reason for the increased PUN in growing and weanling pigs fed the SBM diets compared with pigs fed the HPCP diets is likely a result of greater ADFI for pigs fed the SBM diet. In addition, PUN is often used as a response criterion in AA requirement studies because it responds rapidly to changes in dietary AA concentration and to changes in AA utilization efficiency in pigs (Coma et al., 1995). The reduced PUN that was observed as CAA was supplemented to the HPCP diets is likely a result of increased availability of Ile and Val, which ameliorated the imbalance among AA for protein synthesis that was caused by excessive Leu.

Ileal morphology, microbial protein, and fecal VFA and ammonium productions may vary depending on the composition of diets and it is possible that they are changed in pigs fed diets containing SBM or HPCP. Diets containing higher CP may increase the size and thickness of the intestinal villi of pigs because more AA need to be digested

Table 4. Effects of reducing crude protein (CP) on apparent total tract digestibility (ATTD) of dry matter (DM) and gross energy (GE) and concentrations of digestible energy (DE), metabolizable energy (ME), and net energy (NE) in diets and total heat production (THP) and fasting heat production (FHP) from group-housed pigs[1,2]

Item[3] Dietary CP	Normal		Low, CP reduction[4] (% unit)					Contrast *P*-value[5]		
	No CAA[3]	3 CAA	-1	-2	-3	-4	SEM	Normal	Linear	Quadratic
Feed intake, kg/d	2.79	2.70	2.73	2.88	2.95	2.89	0.19	0.520	0.044	0.442
Fecal GE output, kcal/d	1,267	1,247	1,275	1,289	1,352	1,313	78	0.712	0.078	0.547
ATTD of DM, %	89.65	89.73	89.72	90.18	89.88	90.14	0.26	0.801	0.141	0.783
ATTD of GE, %	88.00	87.79	87.75	88.14	87.82	87.93	0.31	0.565	0.664	0.662
Urine GE output, kcal/d	213	182	181	187	174	173	29	0.154	0.575	0.714
THP, kcal/BW$^{0.6}$/d	384	375	378	376	390	377	20	0.544	0.621	0.704
FHP, kcal/ BW$^{0.6}$/d	223	220	235	218	238	221	17	0.834	0.878	0.481
Retained energy, kcal/BW$^{0.6}$/d	411	399	406	432	478	433	43	0.755	0.100	0.405
Respiratory quotient, fasted	0.66	0.64	0.63	0.64	0.64	0.67	0.03	0.136	0.112	0.217
Respiratory quotient, fed	0.99	1.03	1.01	1.05	1.05	1.04	0.04	0.045	0.199	0.444
Energy in diets, kcal/kg										
GE	3,846	3,802	3,800	3,788	3,785	3,787	-	-	-	-
DE	3,384	3,337	3,335	3,339	3,324	3,330	12	0.004	0.381	0.932
ME	3,310	3,272	3,269	3,273	3,266	3,271	10	0.012	0.891	0.909
NE	2,646	2,605	2,663	2,631	2,665	2,634	47	0.413	0.559	0.392

[1]Each least squares mean represents 6 observations except normal CP diet and diet containing -2% CP ($n = 5$).
[2]Data are from Lee et al. (2023).
[3]BW = body weight; CAA = crystalline amino acids; CP = crude protein.
[4]Dietary CP was reduced from the concentration of CP in the normal diet containing 3 CAA.
[5]Normal = normal CP diet without CAA vs. normal CP with CAA; linear = linear effects of reducing dietary protein; quadratic = quadratic effects of reducing dietary protein.

and absorbed by increasing surface area. However, diets containing high fiber may negatively impact ileal morphology by causing inflammation, villus atrophy, and reduced nutrient absorption. Productions of microbial protein, fecal VFA, and ammonium are a result of the fermentation of dietary fiber in the large intestine by gut microorganisms. Results from the study by Mallea et al. (2023) indicated that ileal morphology, microbial protein, and fecal VFA and ammonium productions were not changed by diets containing SBM or HPCP, which demonstrated that under the condition of this experiment, there were no major differences in fermentability or intestinal tract function by using SBM or HPCP in diets for pigs.

The greater RQ observed for pigs fed the normal-CP diet supplemented with CAA than for pigs fed the normal-CP diet without CAA is likely the result of the RQ for protein being lower than for carbohydrates. Because the normal-CP diet without CAA contained more SBM and thus a greater concentration of CP, the RQ in this diet was less compared with the normal-CP diet with CAA. Diets with a greater CP may lead to increased excretion of urine energy because of increased deamination of AA and thus increased urea production, which is the primary energy component in urine (Noblet et al., 2001).

Pigs fed diets containing AA close to the AA requirements would expend less energy on metabolizing AA to carbon skeletons and amino groups (Le Bellego et al., 2001; Brown-Brandl et al., 2004) than pigs fed diets with excess protein. Therefore, it was believed that if pigs were fed diets containing less SBM and greater CAA, the efficiency of ME would be increased. However, contrary to common belief in the industry that low-CP diets provide greater NE compared with high-CP diets, the results from the study by Lee et al. (2023) did not demonstrate an increased NE or an increased NE to ME ratio when dietary CP was reduced.

Concentrations of DE and ME in the normal-CP diet supplemented with three CAA were less than in the normal-CP diet without CAA. The differences in energy are attributed to the more corn and less SBM used in the normal-CP diet with three CAA, as corn contains less GE and DE than SBM. This difference resulted in the difference in ME in diets, but this was not observed for NE. Results from the study by Lee et al. (2023) also contradict the notion that the NE in corn is much greater than the NE in SBM because the inclusion of corn was increased and the inclusion of SBM was reduced as CP was reduced in diets. However, it has been reported that ME and NE in SBM are greater than published values (Sotak-Peper et al., 2015; Lee et al., 2021). The results of this study also indicated that the NE of SBM may be close to that in corn.

Conclusions

In conclusion, pigs fed the SBM diet had better growth performance than pigs fed the diets containing HPCP. The inclusion of CAA in the HPCP diets partially improved the growth performance of pigs, but did not fully replicate the results observed with SBM-based diets. Plasma urea N of pigs fed the SBM was greater than that of pigs fed the HPCP diets. Ileal morphology, microbial protein, and fecal VFA and ammonium productions were not changed by diets containing SBM or HPCP. Diets containing low protein (i.e., low SBM and high crystalline AA) did not increase the concentration of NE by group-housed pigs. Therefore, the common conception in the industry that diets with low protein have greater NE compared with diets with greater protein needs to be corrected.

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