Nutritional value of soybean meal produced from conventional, high-protein, or low-oligosaccharide varieties of soybeans and fed to broiler chicks[1]

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ABSTRACT Three experiments were conducted to determine the feeding value to broiler chicks of soybean meal (SBM) produced from high-protein (SBM-HP), low-oligosaccharide (SBM-LO), or conventional (SBM-CV) varieties of soybeans. The 3 SBM contained 54.9, 53.6, and 47.5% CP, respectively. The standardized digestibility (SDD) of amino acids (AA) in the 3 ingredients was measured using a precision-fed rooster assay with cecectomized Single Comb White Leghorn roosters. Results indicated that the SDD of AA was not different among the 3 sources of SBM, with the exception that the SDD of Lys in SBM-HP tended to be greater ($P = 0.07$) than that in SBM-CV. In the second experiment, a precision-fed rooster assay was used to measure the concentration of TME_n in each source of SBM. Results indicated that the TME_n in SBM-HP was greater ($P < 0.001$) than those in SBM-LO and SBM-CV (3,104 vs. 2,984 and 2,963 kcal/kg of DM). A 14-d growth performance experiment was also conducted using 120 Ross 308 male commercial broiler chicks (mean initial BW = 102.6 g) that were allotted to a completely randomized design. There were 5 chicks/pen and 8 replicate pens/diet. Three corn- and SBM-based diets were formulated based on the data for digestible AA and TME_n that were measured in the previous experiments. Each source of SBM was used in 1 diet, but because of the greater concentrations of digestible AA in SBM-HP and SBM-LO than in SBM-CV, the inclusion of SBM-HP and SBM-LO were 31.21 and 32.60%, respectively, whereas an inclusion of 38.21% SBM-CV was used. There were no differences among the 3 diets for BW gain or feed efficiency, which indicated that the reduced inclusion rates of SBM-HP and SBM-LO compared with SBM-CV were not detrimental to broiler chick growth performance. It was concluded that, compared with SBM-CV, SBM-HP and SBM-LO are needed in lower concentrations in diets fed to broiler chicks because these 2 sources of SBM have a greater nutritional value than does SBM-CV.

Key words: amino acid, broiler chick, high-protein soybean meal, low-oligosaccharide soybean meal, nitrogen-corrected true metabolizable energy

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INTRODUCTION

Soybeans can be fed to poultry as soybean meal (**SBM**) that is produced when the defatted flakes are ground. New varieties of soybeans with increased protein concentration or reduced concentrations of oligosaccharides compared with conventional soybeans have recently been identified. The concentration of CP in high-protein SBM (**SBM-HP**) is greater than that in conventional SBM (**SBM-CV**) and the standardized ileal digestibility of amino acids (**AA**) in SBM-HP is similar to the digestibility of AA in SBM-CV when fed to growing pigs (Baker and Stein, 2009). Because of the greater concentration of AA in SBM-HP than in SBM-CV, greater quantities of digestible AA are provided in the SBM from high-protein varieties than in SBM produced from conventional soybeans (Baker and Stein, 2009). The digestible energy and ME in SBM-HP are also similar to the digestible energy and ME in SBM-CV when fed to pigs (Baker and Stein, 2009). The digestibility of AA and the concentration of ME in SBM-HP fed to broiler chicks have, however, not been measured.

The concentrations of stachyose and raffinose are lower in low-oligosaccharide SBM (**SBM-LO**) than in SBM produced from other varieties of soybeans (Baker and Stein, 2009). The digestibility of AA in SBM-LO is, however, not different from the digestibility of AA in SBM-CV when fed to growing pigs, which indicates that there are no detrimental effects to AA digestibility of removing the oligosaccharides (Baker and Stein, 2009). Soybean meal produced from low-oligosaccharide vari-

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eties of soybeans contained 7 to 9% more ME when fed to poultry (Parsons et al., 2000), but the digestibility by chickens of AA in SBM-LO has not been measured.

The objective of this research was, therefore, to measure the TME_n and AA digestibility values by roosters fed SBM-HP, SBM-LO, and SBM-CV. The second objective was to measure the growth performance of growing broiler chicks fed diets based on each of the 3 sources of SBM.

MATERIALS AND METHODS

General

All experimental protocols were reviewed and approved by the Institutional Animal Care and Use Committee at the University of Illinois. Three sources of SBM were used in these experiments (Table 1). The SBM were produced from high-protein, low-oligosaccharide, or conventional varieties of soybeans. Samples were processed at the Zeeland Farm Services processing plant (Zeeland Farm Services, Zeeland, MI), which is an industry-sized crushing plant that uses crushing techniques typical of the soybean industry. Soybeans were processed in a 3-stage process. In the first stage, soybeans underwent cleaning, drying, conditioning, cracking, removal of hulls, more cracking, and then flaking. In the second stage, soybeans underwent oil extraction using hexane solvent, which was subsequently removed by distillation. In the third stage, flakes were toasted, desolventized, dried, cooled, and ground into SBM.

The 3 sources of SBM were analyzed for sucrose, raffinose, and stachyose (Janauer and Englmaier, 1978), DM (method 930.15; AOAC International, 2005), CP (method 990.03; AOAC International, 2005), ADF (method 973.18; AOAC International, 2005), NDF (Holst, 1973), Ca (method 978.02; AOAC International, 2005), P (method 946.06; AOAC International, 2005), trypsin inhibitors (method Ba 12-75; AOCS, 1998), and ether extract (method 920.39; AOAC International, 2005). They were also analyzed for gross energy using bomb calorimetry (Model 6300, Parr Instruments, Moline, IL) and for AA on a Hitachi Amino Acid Analyzer (Model No. L8800, Hitachi High Technologies America, Inc., Pleasanton, CA), using ninhydrin for postcolumn derivatization and norleucine as the internal standard. Before analysis, samples were hydrolyzed with 6 *N* HCl for 24 h at 110°C (method 982.30, alternative 3;

Table 1. Analyzed energy and nutrient composition of soybean meal (SBM) produced from high-protein (SBM-HP), low-oligosaccharide (SBM-LO), or conventional (SBM-CV) varieties of soybeans (as-fed basis)[1]

	Ingredient		
Item	SBM-HP	SBM-LO	SBM-CV
DM (%)	88.7	88.7	87.5
Gross energy (kcal/kg)	4,503	4,254	4,454
CP (%)	54.86	53.63	47.47
Ether extract (%)	0.76	0.96	1.48
Ca (%)	0.34	0.33	0.24
P (%)	0.73	0.68	0.67
Neutral detergent fiber (%)	5.04	4.96	6.68
Acid detergent fiber (%)	3.54	3.09	3.91
Sucrose (%)	4.27	7.35	7.05
Stachyose (%)	4.97	1.38	4.61
Raffinose (%)	0.93	0.18	0.93
Trypsin inhibitor activity (trypsin inhibitor U/mg)	4.50	3.50	3.20
Indispensable amino acid (%)			
Arg	4.27	4.05	3.56
His	1.44	1.35	1.25
Ile	2.54	2.41	2.25
Leu	4.35	4.10	3.76
Lys	3.56	3.33	3.14
Met	0.78	0.71	0.68
Phe	2.89	2.72	2.48
Thr	2.13	1.96	1.83
Trp	0.78	0.72	0.69
Val	2.64	2.50	2.36
Dispensable amino acid (%)			
Ala	2.34	2.18	2.07
Asp	6.42	6.00	5.40
Cys	0.78	0.73	0.65
Glu	10.31	9.51	8.54
Gly	2.31	2.14	2.00
Pro	2.72	2.42	2.36
Ser	2.57	2.36	2.10
Tyr	2.01	1.84	1.70

[1]Data are based on the analysis of 1 sample of each source of SBM.

AOAC International, 2005). Methionine and Cys were determined as methionine sulfone and cysteic acid, respectively, after cold performic acid oxidation overnight before hydrolysis (method 982.30, alternative 1; AOAC International, 2005). Tryptophan was determined after NaOH hydrolysis for 22 h at 110°C (method 982.30; AOAC International, 2005).

AA Digestibility

Amino acid digestibility in the 3 sources of SBM was measured using a precision-fed rooster assay with cecectomized Single Comb White Leghorn roosters (68 wk old). Twelve roosters were cecectomized according to the procedure described by Parsons (1985). Birds were housed individually in 22.5 × 36 cm cages with raised wire floors in an environmentally controlled room. A 16-h light and 8-h dark cycle was provided, and water was accessible at all times. The 12 roosters were allotted to the 3 SBM sources in a completely randomized design with 4 birds per source of SBM. After a 24-h feed withdrawal, birds were precision-fed 30 g of their assigned source of SBM via crop intubation. Excreta samples were collected for 48 h after intubation by using plastic collection trays placed under each rooster.

The basal endogenous losses of AA were measured from additional roosters that were deprived of feed for 48 h. Plastic collection trays were placed under each rooster to collect excreta. Excreta samples were lyophilized and finely ground before chemical analysis.

Excreta from all the roosters were analyzed for CP and AA as described for the 3 sources of SBM. The standardized digestibility (**SDD**) of AA was calculated using the method described by Sibbald (1979). Data for SDD of AA in the 3 sources of SBM were analyzed by ANOVA using the GLM procedure in SAS (SAS Institute Inc., Cary, NC). The significance of differences among individual treatments was assessed using the least significant difference test. The rooster was the experimental unit for all calculations, and an α-value of 0.05 was used to assess differences among means.

TME_n Experiment

In the second experiment, TME in the 3 sources of SBM was measured using a precision-fed rooster assay with conventional Single Comb White Leghorn roosters (68 wk old). Twelve intact roosters were housed individually in 22.5 × 36.0 cm cages with raised wire floors in an environmentally controlled room. A 16-h light and 8-h dark cycle was provided and water was accessible at all times. The 12 roosters were allotted to the 3 SBM sources in a completely randomized design with 4 birds per source of SBM. After a 24-h feed withdrawal, birds were precision-fed 30 g of their assigned source of SBM via crop intubation. Excreta samples were collected for 48 h after intubation as described for the AA experiment. Excreta samples were lyophilized and analyzed in duplicate for gross energy using bomb calorimetry (Model 6300, Parr Instruments). The instrument was standardized using benzoic acid, and TME_n in each source of SBM was calculated as described by Parsons et al. (1992). Data were analyzed as described for the AA experiment.

Growth Performance Experiment

A growth assay was conducted using diets that contained SBM-HP, SBM-LO, and SBM-CV. The objective of this experiment was to confirm that chick performance was not compromised when the inclusion rate of SBM-HP or SBM-LO was reduced compared with SBM-CV as long as diets were formulated to the same concentration of TME_n and SDD AA. A total of 120 Ross 308 male commercial broiler chicks were fed a corn- and SBM-based starter diet for 7 d. This diet was formulated to contain 3,159 kcal of TME, 23.68% CP, 1.30% Lys, 0.89% Thr, 0.94% Met + Cys, 1.07% Ca, and 0.50% bioavailable P. All other nutrients in the pretest diet were included at levels that met or exceeded NRC (1994) requirements. On d 8 posthatch, chicks (mean initial BW = 102.6 g) were randomly allotted to 3 diets in a completely randomized design with 5 chicks per pen and 8 replicate pens per diet (Table 2). Chicks were housed in battery cages with raised wire floors in an environmentally controlled room. Water and artificial light were provided at all times. The 3 diets included 1 diet with each source of SBM. Diets were formulated based on data for SDD and TME_n that were measured in the AA and the TME_n experiments. Each diet was formulated to contain 3,240 kcal of TME_n/kg, 23% CP, 0.88% SDD Met + Cys, and 1.20% SDD Lys. Soybean oil was used to equalize concentrations of TME_n among the 3 diets, and all diets were analyzed for DM, gross energy, CP, ether extract, and AA as described for the 3 sources of SBM. All chicks were weighed at the start of the experiment and at the conclusion of the experiment 14 d later. At the conclusion of the experiment, data for BW gain, feed intake, and feed efficiency were calculated. Data were analyzed as described for the AA experiment.

RESULTS

Nutrient Composition

The concentrations of CP and Lys were 54.86 and 3.56, 53.63 and 3.33, and 47.47 and 3.14% in SBM-HP, SBM-LO, and SBM-CV, respectively (Table 1). The concentration of sucrose was 4.27% in SBM-HP, but sucrose concentrations were 7.35 and 7.05% in SBM-LO and SBM-CV, respectively. The concentrations of stachyose and raffinose were 1.38 and 0.18% in SBM-LO, but were 4.97 and 0.93% in SBM-HP and 4.61 and 0.93% in SBM-CV, respectively. However, the concentration of ether extract was 1.48% in SBM-CV, but only 0.76 and 0.96% in SBM-HP and SBM-LO, respectively.

AA Digestibility and TME_n Values

No differences were observed among the 3 sources of SBM in values for SDD of any of the indispensable AA, with the exception that a tendency ($P = 0.07$) was observed for a greater SDD of Lys in SBM-HP than in SBM-CV (Table 3). For the dispensable AA, no differences among the 3 sources were observed. The TME_n in SBM-HP was greater ($P < 0.05$) than in SBM-LO and SBM-CV (3,104 vs. 2,984 and 2,963 kcal/kg of DM, respectively), but the values for SBM-LO and SBM-CV were not different.

Broiler Growth Performance Experiment

No differences were observed among treatments in the initial or final BW of the chicks (Table 4). Likewise, the average BW gain, feed intake, and G:F ratio values were not different among treatments.

DISCUSSION

Composition of Ingredients

The nutrient composition of SBM-CV concurs with published values (NRC, 1998). The increased AA concentration in SBM-HP compared with SBM-CV is in agreement with previous data (Baker and Stein, 2009).

Table 2. Composition of diets containing soybean meal (SBM) produced from high-protein (SBM-HP), low-oligosaccharide (SBM-LO), or conventional (SBM-CV) varieties of soybeans and used in the broiler growth performance experiment (as-fed basis)

	Diet		
Item	SBM-HP	SBM-LO	SBM-CV
Ingredient (%)			
Corn	61.64	59.36	52.74
SBM-HP	31.21	—	—
SBM-LO	—	32.60	—
SBM-CV	—	—	38.21
Soybean oil	2.75	3.60	4.76
Dicalcium phosphate	2.08	2.05	2.00
Limestone	1.17	1.17	1.17
Vitamin premix[1]	0.20	0.20	0.20
Mineral premix[2]	0.15	0.15	0.15
Salt	0.45	0.45	0.45
DL-Met	0.24	0.28	0.25
L-Lys·HCl	0.07	0.10	0.03
Bacitracin-methylene disalicylate premix[3]	0.04	0.04	0.04
Analyzed composition			
DM (%)	87.6	88.1	85.3
Gross energy (kcal/kg)	4,205	4,140	4,003
CP (%)	22.1	21.6	20.5
Ether extract (%)	6.2	5.1	4.9
Indispensable amino acid (%)			
Arg	1.48	1.49	1.41
His	0.59	0.55	0.54
Ile	0.92	0.94	0.89
Leu	1.76	1.75	1.71
Lys	1.27	1.28	1.22
Met	0.51	0.53	0.50
Phe	1.04	1.04	1.00
Thr	0.79	0.73	0.74
Trp	0.30	0.27	0.25
Val	1.02	1.05	1.00
Dispensable amino acid (%)			
Ala	1.02	0.99	0.97
Asp	2.22	2.13	2.07
Cys	0.32	0.30	0.31
Glu	3.59	3.75	3.70
Gly	0.89	0.87	0.85
Pro	1.17	1.17	1.16
Ser	0.90	0.79	0.82
Tyr	0.70	0.64	0.62

[1]Provided per kilogram of complete diet: retinyl acetate, 4,400 IU; cholecalciferol, 25 IU; DL-α-tocopheryl acetate, 11 IU; vitamin B_{12}, 0.01 mg; riboflavin, 4.41 mg; D-pantothenic acid, 10 mg; niacin, 22 mg; and menadione sodium bisulfite, 2.33 mg.

[2]Provided per kilogram of complete diet: manganese, 75 mg as $MnSO_4 \cdot H_2O$; iron, 75 mg as $FeSO_4 \cdot H_2O$; zinc, 75 mg from ZnO; copper, 5 mg from $CuO_4 \cdot 5H_2O$; iodine, 0.75 mg from ethylene diamine dihydroiodide; and selenium, 0.1 mg from Na_2SeO_3.

[3]Contributed 27.5 mg/kg of bacitracin methylene disalicylate.

Table 3. Standardized amino acid digestibility (%) and TME_n of soybean meal (SBM) produced from high-protein (SBM-HP), low-oligosaccharide (SBM-LO), or conventional (SBM-CV) varieties of soybeans and fed to cecectomized or conventional roosters in the amino acid digestibility and TME_n experiment, respectively (as-fed basis)[1]

	Ingredient				
Item	SBM-HP	SBM-LO	SBM-CV	SEM	*P*-value
Indispensable amino acid					
Arg	92.16	90.60	90.13	0.90	0.30
His	90.32	89.10	88.20	0.74	0.18
Ile	93.10	92.68	91.05	0.73	0.16
Leu	92.89	92.59	91.04	0.81	0.27
Lys	92.47	89.85	88.54	1.03	0.07
Met	93.15	92.51	91.56	0.66	0.28
Phe	93.90	92.83	91.48	0.76	0.13
Thr	89.84	89.30	89.00	0.96	0.83
Trp	97.66	97.28	97.87	0.42	0.61
Val	89.43	90.10	89.53	1.08	0.90
Dispensable amino acid					
Ala	90.47	89.70	87.80	0.82	0.11
Asp	92.31	92.38	91.30	0.63	0.44
Cys	86.34	85.85	87.19	1.03	0.66
Glu	94.82	94.20	93.65	0.52	0.33
Pro	93.01	93.46	92.32	0.77	0.59
Ser	92.80	93.37	93.26	1.04	0.92
Tyr	92.94	92.18	91.91	0.82	0.67
TME_n, (kcal/kg of DM)	3,104[a]	2,984[b]	2,963[b]	33	0.03

[a,b]Means within a row lacking a common superscript letter are different ($P < 0.05$).

[1]Data are means of 4 roosters per treatment.

The differences in the concentrations of stachyose and raffinose between SBM-LO and SBM-HP and SBM-CV were expected because SBM-LO was produced from a variety of soybeans that was selected for low concentrations of oligosaccharides. This decrease in oligosaccharides is also in agreement with previous data (Baker and Stein, 2009).

SDD of AA

The SDD of AA in SBM-CV was similar to those in previous data (Parsons et al., 2000). The SDD of AA in SBM-HP were comparable with values obtained for SBM produced from commercial soybeans (Edwards et al., 2000), but to our knowledge, the SDD of AA in SBM-LO has not been measured previously in poultry. The lack of a difference among the 3 meals in the SDD of AA agrees with data from pigs (Baker and Stein, 2009). Likewise, the standardized ileal digestibility values of AA in full-fat soybeans produced from high-protein and conventional varieties were not different when fed to pigs (Cervantes-Pahm and Stein, 2008). These observations indicate that the AA in SBM-HP and SBM-LO were absorbed to the same degree as AA in SBM-CV when fed to both pigs and chickens. Because of the greater concentrations of AA in SBM-HP and SBM-LO than in SBM-CV, these meals contained greater amounts of digestible AA than did SBM-CV. Consequently, less SBM needs to be added to the diet if SBM-HP or SBM-LO is used instead of SBM-CV. Another implication of these results is that digestibility values for AA obtained with SBM-CV can also be used in the formulation of diets for broiler chicks if SBM-HP or SBM-LO is used.

TME_n

The value for TME_n in SBM-CV that was obtained in this experiment was slightly greater than previously published values (NRC, 1994; Edwards et. al., 2000).

Table 4. Growth performance from d 8 to 21 posthatch of broiler chicks fed soybean meal (SBM) produced from high-protein (SBM-HP), low-oligosaccharide (SBM-LO), or conventional (SBM-CV) varieties of soybeans[1]

	Diet				
Item	SBM-HP	SBM-LO	SBM-CV	Least significant difference	Pooled SEM
Initial weight (g)	102.6	102.6	102.6	0.76	0.25
Final weight (g)	712.6	720.1	733.6	44.2	15.0
BW gain (g)	610.0	617.3	631.0	44.1	15.0
Feed intake (g)	807.8	813.9	840.3	46.8	15.9
G:F (g/kg)	755.1	758.6	750.8	32.2	10.9

[1]Values are means of 8 replicate groups of 5 broiler chicks per treatment.

However, in agreement with previous data (Edwards et al., 2000), a greater TME_n was observed in SBM-HP compared with SBM-CV. The reason for the increase in TME_n in SBM-HP compared with SBM-CV is most likely that the extra CP contributes energy to the meal and displaces poorly digestible ADF and NDF. The concentration of ME in SBM-HP was also greater than that in SBM-CV when these meals were fed to pigs (Baker and Stein, 2009). The concentration of TME_n was reported to be greater in SBM-LO than in SBM-CV (Parsons et. al. 2000), but the present data did not show this effect. It is possible that differences among varieties of soybeans were responsible for these differences among experiments. Nevertheless, the fact that SBM-LO had the same energy value as SBM-CV is consistent with recent observations in pigs (Baker and Stein, 2009).

Broiler Chick Growth Performance

The overall performance of the chicks was similar to data reported by Douglas and Parsons (2000). There were no differences in growth performance among chicks fed the different diets, although the diets containing SBM-HP and SBM-LO contained less SBM than the diet containing SBM-CV. This observation indicates that the data for AA concentrations and SDD that were measured in the AA experiment are correct. The implication of this observation is that less SBM will be needed if SBM-HP or SBM-LO is used in diets fed to broiler chicks.

In conclusion, SBM-HP and SBM-LO have a greater nutritional value in diets for broiler chicks because of the increased concentration of digestible AA, which reduces the quantity of SBM that is needed in the diet.

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