Nutritional evaluation of new reduced oligosaccharide soybean meal in poultry

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ABSTRACT The nutritional values of a novel reduced-oligosaccharide soybean meal (SBM-RO) and conventional SBM (SBM-CV) were evaluated and compared in 4 experiments. The first experiment was a TME$_n$ assay with conventional roosters. The second experiment was a precision-fed cecectomized rooster assay that was conducted to determine TME$_n$ and amino acid (AA) digestibility. The third experiment was a standardized ileal AA digestibility assay, in which broiler chicks were fed semi-purified diets containing 20% protein (from only the test ingredient) for 17 to 21 d of age and ileal digesta were collected on d 21. The fourth experiment was a growth performance trial (7 to 20 d of age) where broiler chicks were fed corn-SBM diets (adequate in all AA) containing 38.84% SBM-RO or SBM-CV. The protein content (100% DM basis) of the SBM-CV and SBM-RO was 51.9 and 54.8%, respectively. The gross energy of the 2 SBM was similar. The TME$_n$ values in both conventional roosters and cecectomized roosters were significantly higher ($P < 0.05$) for SBM-RO than for SBM-CV (difference was approximately 200 kcal/kg of DM). Amino acid digestibility in cecectomized roosters was not different between SBM-CV and SBM-RO, with the exception of Trp, Ala, Asp, and Cys (SBM-RO > SBM-CV, $P < 0.05$). No significant differences between the SBM were found for AA digestibility in the standardized ileal AA digestibility assay. In the growth performance trial (experiment 4), the corn-SBM diet containing SBM-RO yielded significantly higher feed efficiency than the diet containing SBM-CV ($P < 0.001$). The results indicated that the SBM-RO contains higher ME than the SBM-CV and that digestibility of AA in SBM-RO is similar to SBM-CV.

Key words: soybean meal, oligosaccharide, metabolizable energy, amino acid digestibility, poultry

2013 Poultry Science 92:1830–1836
http://dx.doi.org/10.3382/ps.2012-02856

INTRODUCTION

Soybean meal (**SBM**) has been a dominant protein source in the US poultry feed industry since the 1950s. It is extensively used because of its high protein and energy content, its excellent amino acid (**AA**) quality and composition, as well as its high availability of AA (Stein et al., 2008). Dehulled SBM is the most commonly used SBM. It is an especially good source of lysine and tryptophan. Also, due to its low fiber content relative to other oilseed meals, the ME level of SBM of 2,711 kcal/kg on a DM basis for poultry is 11 to 25% greater than that of other oilseed meals (Stein et al., 2008). However, SBM has a lower ME value than the prediction from its gross energy (**GE**) for poultry. The latter is partially due to the low digestibility of the oligosaccharides in SBM, which can potentially lead to a large energy loss and also a possible dilution of energy and other nutrients in the diet (Stein et al., 2008). The oligosaccharides account for approximately 11% of the DM of SBM (Coon et al., 1988). The α-1,6 linkages of the raffinose-saccharides cannot be broken down by endogenous enzymes in the small intestine of poultry due to the absence of α-1,6-galactosidase (Gitzelmann and Auricchio, 1965), and therefore these carbohydrates are unable to pass through the intestinal wall. In addition, if the concentration of these oligosaccharides is high in the digestive tract, they may cause fluid retention and increase the digesta flow rate, leading to an adverse effect on the absorption and utilization of nutrients (Wiggins, 1984). Leske et al. (1991) suggested that the oligosaccharides can cause reduced transit time, which leads to reduced fiber digestion and thus a lower than expected TME$_n$ value. The TME$_n$ of soy protein concentrate was reported to be significantly decreased by stachyose and raffinose inclusion in a dose-dependent manner (Leske et al., 1993).

Removal of the oligosaccharides from SBM may increase the fiber fermentation, as well as the extent of digestion of other nutrient-providing components, be-

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Received October 25, 2012.
Accepted February 17, 2013.

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cause of a slower transit time. This may also create a better cecal environment for the microbial hydrolyzation, and thus improve the nutritional value of the SBM for poultry (Coon et al., 1988). Many approaches have been evaluated to improve the nutritional value of SBM, including ethanol extraction (Coon et al., 1990), adding exogenous enzymes (Irish et al., 1995), and developing genetically improved SBM lines (Parsons et al., 2000; Baker et al., 2011). Because the nutritional characteristics of genetically reduced-oligosaccharide SBM can vary from company to company depending on the genetic line, geographic location, and specific technique used to reduce oligosaccharides, it is important to determine the nutritional values of each individual SBM. The present study was conducted to determine the TME_n value, AA digestibility, and growth performance response of a new genetically reduced-oligosaccharide SBM in poultry. We hypothesized that the reduced-oligosaccharide SBM can provide improved TME_n, AA digestibility, and growth performance in broiler chicks in comparison with conventional SBM.

MATERIALS AND METHODS

Nutrient Analysis

Four experiments were conducted to compare the nutritional value of the reduced-oligosaccharide SBM (**SBM-RO**) with that of conventional SBM (**SBM-CV**). Two sources of SBM (SBM-CV and SBM-RO) were used in these experiments. These SBM were obtained from the United Soybean Board (Chesterfield, MO) and had been solvent extraction-processed under commercial conditions by POS Biosciences, Saskatoon, Canada. All experimental protocols were reviewed and approved by the Institutional Animal Care and Use Committee. The 2 sources of SBM were analyzed for GE using bomb calorimetry (model 6300, Parr Instruments, Moline, IL). Dry matter (method 934.01; AOAC International, 2006), AA (method 982.30; AOAC International, 2006), nitrogen and CP (method 990.03; AOAC International, 2006), ether extract (method 996.06; AOAC International, 2006), sucrose, stachyose, raffinose (Janauer and Englmaier, 1978), acid detergent fiber (method 973.18; AOAC International, 2006), neutral detergent fiber (Holst, 1973), trypsin inhibitor (method 22-46; AACC International, 2006), urease pH change (method 22-90; AACC International, 2006), KOH protein solubility (Parsons et al., 1991), and protein dispersibility index (method 46-24; AACC International, 2006) were analyzed at the University of Missouri Experiment Station Field Laboratory, Columbia.

TME_n Assay with Conventional Roosters (Experiment 1)

The TME_n of the 2 sources of SBM were determined using a precision-fed rooster assay with conventional Single Comb White Leghorn roosters. Forty intact roosters were housed individually in 22.5 × 36 cm cages with raised wire floors in an environmentally controlled room. A 16L:8D cycle was provided, and water was accessible at all times. The roosters were fasted for 26 h to empty the gastrointestinal tract of all dietary residues. Then, 20 conventional roosters were tube-fed 30 g of SBM-CV and another 20 were tube-fed 30 g of the SBM-RO. The roosters were then returned to individual cages, and all excreta (feces + urine) were collected for 48 h. The excreta and feed samples were freeze-dried, ground, and analyzed for GE and nitrogen as described above. The TME_n value for each source of SBM was calculated as described by Parsons et al. (1982).

TME_n and Standardized AA Digestibility Assay with Cecectomized Roosters (Experiment 2)

In experiment 2, 40 cecectomized Single Comb White Leghorn roosters were used to determine the TME_n and AA digestibility of the 2 sources of SBM using a precision-fed rooster assay. The TME_n was assessed in cecectomized roosters (in addition to conventional roosters) to evaluate the effect of microbial fermentation of undigested carbohydrates or fiber in the ceca for the 2 types of SBM. Cecectomy was performed according to the procedures described by Parsons (1985). The housing and methods for determining TME_n were the same as those used in experiment 1. The excreta and feed samples were also analyzed for AA at the University of Missouri–Columbia, and standardized AA digestibility values were calculated. Basal endogenous AA losses were estimated using roosters that had been fasted for 48 h.

Standardized Ileal Amino Acid Digestibility Experiment (Experiment 3)

A standardized ileal AA digestibility (**SIAAD**) assay was conducted using semi-purified diets that contained 20% protein from only SBM-CV or SBM-RO. A total of 100 Ross 308 male commercial broiler chicks were obtained from a hatchery and fed a nutritionally complete corn-SBM starter diet until 17 d of age. This diet was formulated to meet all of the NRC (1994) nutrient requirements. On d 18 after hatching, all chicks were weighed, wing banded, and assigned to treatment groups so that their initial weights were similar among the groups. From 18 to 21 d of age, 10 replicate groups of 5 chicks were fed each of 2 semi-purified diets containing 20% protein from either SBM-CV or SBM-RO as the only source of protein (Table 1). Feed and water were provided for ad libitum consumption. At the conclusion of the experiment (d 21), all chicks were weighed and euthanized using CO_2 gas. The ileal diges-

Table 1. Composition of diets containing conventional soybean meal (SBM-CV) or reduced oligosaccharide soybean meal (SBM-RO)

Item (%, unless otherwise indicated)	Diet	
	SBM-CV	SBM-RO
SBM-CV	42.30	—
SBM-RO	—	40.20
Cornstarch	26.60	27.65
Dextrose	26.60	27.65
Dicalcium phosphate	1.00	1.00
Limestone	1.30	1.30
Vitamin premix[1]	0.20	0.20
Mineral premix[2]	0.15	0.15
Sodium chloride	0.35	0.35
$NaHCO_3$	0.30	0.30
K_2CO_3	0.50	0.50
Choline chloride (60%)	0.30	0.30
Chromic oxide	0.40	0.40
Calculated analysis		
Protein	20.0	20.0
ME (kcal/kg)	2,929	2,952
Ca	1.0	1.0
Available P	0.5	0.5
Lys	1.3	1.3
Met	0.3	0.3
Cys	0.3	0.3
Thr	0.8	0.8

[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 from $MnSO_4{\cdot}H_2O$; iron, 75 mg from $FeSO_4{\cdot}H_2O$; 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.

ta samples (from Meckel's diverticulum to the ileo-cecal junction) were collected, freeze-dried, and analyzed for AA and chromium. Chromic oxide was used as a digesta marker to calculate AA digestibility. Standardized AA digestibility was calculated using the AA excretion of chicks fed an N-free diet as the basal endogenous correction as described by Adedokun et al. (2008).

Broiler Growth Performance (Experiment 4)

The fourth experiment was a growth performance trial using diets that contained equal amounts of SBM-CV and SBM-RO. A total of 160 Ross 308 male commercial broiler chicks was fed a nutritionally complete corn-SBM starter diet for 7 d. This diet was fed in mash form and was formulated to meet all NRC (1994) nutrient requirements. On d 7 posthatch, all chicks were weighed, wing banded, and assigned to treatment groups so that their initial weights were similar among the groups. Chicks were randomly allotted to 2 diets in a completely randomized design with 5 chicks per group and 16 replicate groups per diet. Chicks were housed in battery cages with raised wire floors in an environmentally controlled room. Water was provided ad libitum. From 7 to 20 d of age, chicks were fed each of 2 diets containing 38.84% of SBM-CV or SBM-RO (Table 2). Each diet was formulated to contain 2,985 kcal of TME_n/kg, 1.10% Met + Cys, 1.40% Lys, and 1.0% Thr. These 2 diets were supplemented with DL-Met, L-Lys·HCl, and L-Thr so that both diets contained the same levels of these AA that exceeded the breeder recommendations. The latter was done to ensure that any growth performance differences obtained between the 2 diets were due to energy and not AA. At the conclusion of the experiment (d 20), all chicks were weighed, and data for body weight gain, feed intake, and feed efficiency were calculated.

Table 2. Composition of diets containing conventional soybean meal (SBM-CV) or reduced oligosaccharide soybean meal (SBM-RO) used in the chick growth performance trial (as-fed basis), experiment 4

Item (%, unless otherwise indicated)	Diet	
	SBM-CV	SBM-RO
Corn	55.64	55.77
SBM	38.84	38.84
Soybean oil	1.00	1.00
Limestone	1.20	1.20
Dicalcium phosphate	1.60	1.60
Sodium chloride	0.40	0.40
DL-Met	0.32	0.30
L-Lys HCl	0.11	0.03
L-Thr	0.07	0.04
Mineral mix[1]	0.15	0.15
Vitamin mix[2]	0.20	0.20
Choline chloride	0.10	0.10
OptiPhos phytase[3]	0.025	0.025
Bacitracin MD[4]	0.042	0.042
Chromic oxide	0.30	0.30
Calculated analysis		
Protein	23.9	24.8
ME (kcal/kg)	2,985	2,985
Ca	0.9	0.9
Available P	0.4	0.4
Lys	1.4	1.4
Met	0.7	0.7
Cys	0.4	0.4
Thr	1.0	1.0

[1] Provided per kilogram of complete diet: manganese, 75 mg from $MnSO_4{\cdot}H_2O$; iron, 75 mg from $FeSO_4{\cdot}H_2O$; 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.

[2] 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.

[3] OptiPhos phytase supplied 500 phytase units per kg of diet. Obtained from JBS United, Sheridan, IN.

[4] Bacitracin Methylene Disalicylate. Provided 27.7 mg/kg. Obtained from Pfizer Animal Health, Madison, NJ.

Statistical Analysis

Data for TME_n, AA digestibility, and growth performance were analyzed by ANOVA using the SAS system (SAS Institute, 1990) for complete randomized designs. Statistical significance of differences among individual treatment means were assessed using the least significant difference test. Each individual rooster was the experimental unit for all TME_n and rooster AA digestibility calculations, whereas the pen or group of chicks was the experimental unit in the SIAAD and broiler growth performance trials. A P-value of 0.05 was used to assess differences among means.

RESULTS AND DISCUSSION

Nutrient Composition

Nutrient compositions of the SBM-CV and SBM-RO on a DM basis are presented in Table 3. The CP content was increased from 51.9% for SBM-CV to 54.8% for SBM-RO. The concentration of sucrose was 8.02% in SBM-CV, but it was much higher in SBM-RO (15.73%, DM basis). The concentration of stachyose and raffinose were 5.16 and 1.01% in SBM-CV, respectively, but were decreased greatly to 0.40 and 0.35% in SBM-RO, respectively. Although the CP and carbohydrate levels varied, the GE of the 2 SBM was similar. As expected based on the higher CP level, SBM-RO had higher levels of almost all AA in comparison with SBM-CV.

The decrease in the concentrations of stachyose and raffinose in SBM-RO was expected because SBM-RO was produced from a genetically selected variety that has low concentrations of oligosaccharides. The increased CP and AA concentrations in SBM-RO compared with SBM-CV concur with previous data for another reduced oligosaccharide SBM (Baker and Stein, 2009; Baker et al., 2011). From the compositional data, it seems likely that genetic selection for reducing oligosaccharides in soybeans may result in an increase in CP and sucrose. This is consistent with the study of Parsons et al. (2000).

Table 3. Analyzed energy and nutrient composition of soybean meal produced from conventional (SBM-CV) or reduced-oligosaccharide (SBM-RO) varieties of soybeans (100% DM basis)

	Ingredient	
Item[1]	SBM-CV	SBM-RO
Gross energy (kcal/kg)	4,643	4,690
CP (%)	51.9	54.8
Ether extract (%)	1.20	0.95
NDF (%)	11.57	7.97
ADF (%)	6.69	4.25
Sucrose (%)	8.02	15.73
Stachyose (%)	5.16	0.40
Raffinose (%)	1.01	0.35
Trypsin inhibitor (TIU/g)	2,759	2,160
Urease activity (units of pH change)	0.00	0.03
KOH protein solubility (%)	71.36	74.13
Protein dispersibility index (%)	20.12	25.23
Indispensable amino acid (%)		
Arg	3.72	4.14
His	1.38	1.42
Ile	2.42	2.44
Leu	4.00	4.09
Lys	3.30	3.46
Met	0.70	0.72
Phe	2.61	2.68
Thr	1.97	2.03
Trp	0.70	0.72
Val	2.56	2.64
Dispensable amino acid (%)		
Ala	2.18	2.27
Asp	5.73	6.03
Cys	0.83	0.86
Glu	9.07	9.35
Pro	2.81	2.90
Ser	2.19	2.28
Tyr	1.89	1.89

[1] Samples analyzed at the University of Missouri Experiment Station Field Laboratory, Columbia.

Table 4. TME_n of conventional soybean meal (SBM-CV) and reduced-oligosaccharide soybean meal (SBM-RO) in cecectomized and conventional roosters[1]

Item	Cecectomized TME_n (kcal/g of DM)	Conventional TME_n (kcal/g of DM)
SBM-CV	2.560^b	2.775^b
SBM-RO	2.755^a	3.003^a
Pooled SEM	0.029	0.018

[a,b] Means within a column with no common superscript letters are different ($P < 0.05$).

[1] Data are means of 20 roosters per treatment.

TME_n Values

The TME_n of SBM-RO was significantly greater ($P < 0.05$) than SBM-CV both in cecectomized roosters and conventional roosters (Table 4). The difference was approximately 200 kcal/kg of DM. The latter difference in TME_n values for SBM-CV and SBM-RO agrees with previously published values (Parsons et al., 2000). Perryman and Dozier (2012) also recently reported that AME_n values for 2 reduced oligosaccharide SBM were higher than a control SBM in broiler chickens. The increased TME_n for SBM-RO can be attributed partially to the reduction of the concentrations of raffinose and stachyose, which cannot be digested in the small intestine due to a lack of endogenous α-(1,6)-galactosidase in poultry. Part of the increase was probably also due to the increased level of highly digestible CP and sucrose (Sibbald, 1986) in SBM-RO, and decreased levels of poorly digestible ADF and NDF. Therefore, the poorly digested oligosaccharides and fiber were replaced by more highly digestible CP and sucrose.

The TME_n values were higher for conventional roosters than for cecectomized roosters for both SBM. Coon et al. (1990) reported that the digestibility of raffinose and stachyose based on excreta collection were significantly higher than ileal digestibility in roosters. This indicates that due to the absence of galactosidase in the small intestine of poultry, most of the raffinose and stachyose are fermented by bacteria in the ceca and colon. The latter may at least partially explain the difference in TME_n between cecectomized and conventional roosters for SBM-CV. However, there was also a large difference in TME_n between bird types for SBM-RO, indicating that other carbohydrates in the SBM were probably digested or fermented in the ceca of conventional roosters.

Table 5. Standardized amino acid digestibility coefficients (%) for conventional soybean meal (SBM-CV) and reduced-oligosaccharide soybean meal (SBM-RO) in cecectomized roosters[1]

	Ingredient			
Amino acid (%)	SBM-CV	SBM-RO	SEM	P-value
Indispensable amino acid				
Arg	90.3	91.2	0.63	0.292
His	90.4	90.8	0.46	0.549
Ile	90.8	91.8	0.48	0.133
Leu	90.6	91.3	0.47	0.292
Lys	89.0	88.9	0.61	0.834
Met	91.9	92.3	0.50	0.646
Phe	91.2	91.6	0.47	0.549
Thr	87.1	88.1	0.56	0.248
Trp	96.4^{b}	97.2^{a}	0.18	0.006
Val	87.2	88.3	0.64	0.233
Dispensable amino acid				
Ala	86.8^{b}	89.2^{a}	0.57	0.006
Asp	89.2^{b}	90.5^{a}	0.40	0.028
Cys	81.5^{b}	85.0^{a}	1.03	0.025
Glu	92.3	93.0	0.38	0.230
Pro	90.0	91.0	0.56	0.206
Ser	88.7	89.7	0.57	0.217
Tyr	90.5	91.4	0.45	0.132

[a,b] Means within a row with no common superscript letters are different ($P < 0.05$).

[1] Data are means of 20 roosters per treatment.

AA Digestibility

No differences were observed between the 2 sources of SBM for digestibility of any indispensable AA, with the exception of Trp (SBM-RO > SBM-CV, $P = 0.006$; Table 5). For dispensable AA, there were significant differences in the digestibility of only Ala, Asp, and Cys, with the SBM-RO having higher digestibility ($P < 0.05$) than the SBM-CV. No significant differences between the SBM were found for AA digestibility in the SIAAD assay (Table 6).

The results of the current study indicate that digestibility of AA in SBM-RO is similar or slightly higher than in SBM-CV. Perryman and Dozier (2012) reported no consistent differences for AA digestibility values between reduced oligosaccharide SBM and control SBM in broiler chickens although the reduced oligosaccharide SBM had higher digestible AA concentrations due to a higher protein and AA content. Baker and Stein (2009) have reported no difference in AA digestibility among 3 different sources of SBM (SBM-high protein, SBM-low oligosaccharides, and SBM-CV) in a standardized ileal

Table 6. Standardized ileal digestibility coefficients of amino acids (%) for conventional soybean meal (SBM-CV) and reduced-oligosaccharide soybean meal (SBM-RO) fed to 18- to 21-d-old broiler chicks[1]

	Ingredient			
Item (%)	SBM-CV	SBM-RO	SEM	P-value
Indispensable amino acid				
Arg	90.1	89.3	1.04	0.591
His	99.2	97.8	1.14	0.412
Ile	85.1	84.0	1.27	0.438
Leu	85.2	83.3	1.34	0.333
Lys	86.0	84.5	1.69	0.553
Met	85.7	83.3	2.14	0.444
Phe	86.5	84.5	1.15	0.232
Thr	82.5	79.8	1.56	0.231
Trp	84.2	84.6	1.24	0.793
Val	83.2	81.6	1.48	0.470
Dispensable amino acid				
Ala	84.2	82.7	1.54	0.489
Asp	84.9	83.4	1.03	0.319
Cys	81.3	79.3	1.48	0.344
Glu	90.0	87.6	0.98	0.171
Gly	82.3	81.3	1.44	0.621
Pro	86.8	85.1	1.03	0.267
Ser	86.9	83.5	1.39	0.102
Tyr	86.6	84.5	1.27	0.255

[1] Data are means of 10 replicate groups of 5 chicks per treatment.

Table 7. Growth performance from d 7 to 20 d posthatch for broiler chicks fed diets containing conventional soybean meal (SBM-CV) or reduced-oligosaccharide soybean meal (SBM-RO)[1]

	Diet			
Item	SBM-CV	SBM-RO	Pooled SEM	P-value
BW gain (g)	557^{a}	566^{a}	5.4	0.218
Feed intake (g)	724^{a}	702^{b}	5.1	0.005
G:F (g/kg)	769^{b}	807^{a}	5.1	<0.0001

[a,b] Means within a row with no common superscript letters are different ($P < 0.05$).

[1] Values are means of 16 replicate groups of 5 broiler chicks per treatment.

digestibility assay for pigs. These observations suggest that the AA digestibility coefficient values of SBM-CV can be used when formulating diets for broiler chicks if SBM-RO is used. Consequently, as AA in both SBM can be absorbed to the same degree, less SBM is needed in the diet if SBM-RO is used instead of SBM-CV because SBM-RO contains higher levels of digestible AA (similar AA digestibility with higher AA concentrations).

Broiler Growth Performance

No significant difference was observed between treatments for BW gain of the chicks ($P > 0.05$; Table 7). However, the feed intake for the SBM-RO treatment was significantly lower ($P < 0.05$) than for the SBM-CV treatment. Therefore, the diet containing SBM-RO yielded significantly higher feed efficiency than the diet containing SBM-CV ($P < 0.0001$). The reduced feed intake and increased feed efficiency obtained for the SBM-RO diet suggest that the SBM-RO contained a higher ME_n level than the SBM-CV. These results are not in agreement with Baker et al. (2011), who reported no differences in growth performance between chicks fed diets containing a SBM-LO and SBM-CV. Irish et al. (1995) reported that broiler chickens fed a diet containing an ethanol-extracted reduced oligosaccharide SBM had significantly poorer weight gains and feed efficiencies ($P < 0.05$) than chicks fed SBM-CV, possibly because the diet containing the ethanol-extracted SBM was less palatable due to the higher maize starch content. In the current study, the SBM-RO did not adversely affect the weight gain of broiler chicks as was observed earlier for ethanol-extracted SBM. In summary, for the current study, the improved feed efficiency obtained with the SBM-RO diet in experiment 4 combined with the higher TME_n values obtained with both conventional and cecectomized roosters indicate that the SBM-RO has increased ME_n compared with SBM-CV.

ACKNOWLEDGMENTS

This study was supported by a grant from the United Soybean Board (Chesterfield, MO).

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