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ABSTRACT: Growing conditions and processing technologies to which soybeans (SB) are exposed have an effect on digestibilities of AA found in the resultant soybean meals (SBM). This study evaluated SBM from five major SB-producing countries (Argentina, Brazil, China, India, and the United States). An industry representative in each country collected samples of unprocessed SB and SBM subjectively determined to be of high, intermediate, or low quality. The SB from each country were processed into SBM under uniform conditions in the United States. Five experiments (each examining the three SBM and the SB processed in the United States from a single country) were conducted to determine true ileal AAd digestibilities. In addition, a standard SBM purchased on the open market in the United States was used in all experiments as a control. Data from pigs fed a low-protein casein diet in each study were used to calculate true AA digestibilities. Pigs were fitted with simple T-cannulas at the terminal ileum and allotted to treatments in Latin square design experiments. Duplicate experiments were conducted at the University of Illinois and at The Ohio State University. Within each country comparison, pigs fed the SBM processed in the U.S. from SB grown in the five countries had lower ($P < 0.05$) true total amino acid (TAA) digestibilities than did pigs fed any of the SBM prepared within the country of origin, except the United States. This indicates that processing conditions used at the U.S. pilot plant were not ideal when using SB from other countries. True TAA digestibilities of the diets containing the high-, intermediate-, and low-quality SBM did not differ, except for China, where the low-quality SBM (83.5%) had a lower ($P < 0.05$) digestibility than the intermediate- (89.6%) or high- (89.0%) quality meals. Soybean meal produced in Argentina (average, 87%) and Brazil (average, 82%) had lower ($P < 0.05$) true TAA digestibilities than did the standard SBM (91%), indicating that the processing plants in those countries may produce a less digestible SBM than that available on the open market in the United States.

Key Words: Amino Acid, Digestibilities, Soybean Meal, Swine

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Introduction

Soybean meal (**SBM**) accounts for approximately 62% of the protein sources used in animal diets (ASA, 2002). The U.S. has been the leader in world soybean (**SB**) production, supplying approximately 42% of the world's SB; however, SB production in other countries has increased in recent years. Brazil had the second highest SB production (24% of the world crop), followed by Argentina (16%), China (8%), and India (3%). The world SB crop was valued at $12.28 billion in 2001 (ASA, 2002). Even though the U.S. is the leading SB producer, it is third in SBM export, supplying 16% of the world export market, behind Argentina (35%) and Brazil (25%; ASA, 2002).

Studies have shown compositional differences of both SB (Grieshop and Fahey, 2001) and SBM (Baize, 1997; Grieshop et al., 2003) within and among geographic regions of the world. These differences in composition could potentially result in different amino acid digestibilities of SBM; however, little research has been done comparing the digestibility of SBM produced throughout the world. This information is critical when determining the quality of SBM for the animal. In this experiment, SB and three qualities of SBM were obtained from five major SB-producing countries (Argentina, Brazil, China, India, and the United States). The SB were processed into SBM in the United States. Five experiments (each examining SBM from one of the

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countries) were conducted to determine true AA digestibilities of these SBM. All five trials were replicated at the University of Illinois, Urbana-Champaign (**UIUC**), and The Ohio State University, Columbus (**OSU**), using the same experimental design and treatments.

Materials and Methods

Soybean Meals

An approximately 450-kg sample of whole SB was collected from each of five countries (Argentina, Brazil, China, India, and United States) by an American Soybean Association representative within each country. Both a low- and a high-quality SB were obtained from India. The low-quality SB was grown under conditions of high rainfall and potential flooding, whereas the high-quality SB was grown under more conventional rainfall conditions. These SB were processed into SBM in the United States under standardized processing conditions at the Texas A&M University pilot processing plant. Each of the SB samples was cracked using Ferrel Ross cracking rolls (Ferrel Ross, Oklahoma City, OK) with a gap setting of 0.13 cm. Then, the cracked SB were dehulled using the Kice Aspirator (Kice Industries, Wichita, KS). This was followed by screening through a Smico vibratory screener (Simco Manufacturing Co. LLC, Oklahoma City, OK) to remove whole beans and large hull particles. After this, the SB were heated to 65.6 to 76.7°C in a French stack cooker and flaked using Bauer flaking rolls. Then, the flakes were extracted using a Crown Model 2 extractor (Crown Iron Works Co., Minneapolis, MN) with hexane solvent at ambient temperature. Next, the hexane solvent was removed and toasting was completed in the Crown desolventizer/toaster (**DT**) that contained three different trays (top, middle, and bottom), which were set at the same bed depth for each SB. Efforts were made to maintain similar temperatures in the Crown DT.

In addition, three samples of at least 250 kg of SBM from the same five countries were collected by an American Soybean Association representative located in that country, where the meals were subjectively evaluated to be of high, intermediate, or low quality. Characteristics used to determine quality varied but included criteria such as color, protein content, and/or processor history. No data were available on processing conditions used to prepare the meals or the genetic varieties of the SB. Also, a control source of SBM prepared in the United States was purchased on the open market in Ohio and used as a standard for comparison. Soybean meal from this source had been used in previous digestibility studies and its nutrients had been shown to be highly digestible.

The SBM prepared from the whole SB obtained in each country and the various quality level SBM were delivered to the feed mill at The Ohio Agricultural Research and Development Center, Wooster, where the SBM was ground to a relatively similar particle size, and samples were collected for analysis. The SBM was stored in a cool location until the animal experiments were performed. The chemical composition of the SBM used in this experiment is reported in Table 1.

Diets

The ingredient composition of the experimental semipurified diets is presented in Table 2. One diet contained enzyme-hydrolyzed casein at a 5% level (as-fed basis) as the sole protein source and was included to enable the calculation of true AA digestibilities. The sole source of protein in the other diets was the treatment SBM from each source. Each experiment used diets containing SBM from a single country. The treatments in each experiment included the SBM processed in the United States from SB originating from the country, and the low-, intermediate-, and high-quality SBM from the same country, along with the standard U.S. SBM. These diets were formulated to contain 17% CP (DM basis). All other ingredients in the diet were highly available, purified nutrient sources. A mycotoxin-binding agent (MTB-100 Alltech, Lexington, KY) was included in all diets, even though all SBM tested negative for the presence of mycotoxins. In addition, all diets contained 0.5% chromic oxide as a digestibility marker; however, at OSU, the chromic oxide concentration was decreased to 0.4% of the diet for the experiments using SBM from India, with cornstarch added to make up the difference. All diets were formulated to meet or exceed the vitamin and mineral requirements of growing pigs according to NRC (1998). Any N-containing material arriving at the ileum of pigs fed the casein diet was assumed to be endogenous secretions as the casein itself was assumed to be 100% digestible (Chung and Baker, 1992). Diets were mixed at both locations within 2 wk of start of an experiment.

Animals

Each university's animal care and use committee approved experimental procedures before experiment initiation. Crossbred pigs (PIC 326 sire line × C22 dams; PIC, Franklin, KY at UIUC and [Yorkshire × Landrace] × Duroc at OSU) were used as the test animals. Initial weights of the pigs averaged 35 kg at UIUC and 30 kg at OSU. Pigs at both locations were surgically fitted with a simple T-cannula at the distal ileum according to procedures adapted from Sauer et al. (1983). A period of 7 d was allowed for surgical recovery of the pigs before starting the experiment. The pigs were housed individually in galvanized metal (at UIUC) or stainless steel (at OSU) metabolism crates in temperature-controlled rooms. Water was available free choice via a low-pressure drinking nipple.

Experimental Design

Pigs were initially randomly assigned to diets using a 6 × 6 (7 × 7 for India) Latin square design with a 7-

Table 1. Chemical composition of a standard U.S. soybean meal, soybean meal prepared from soybeans grown in five different countries but processed under uniform conditions in the United States, and soybean meals of varying qualities from five different countries

	Item, % DM basis[a]							
Soybean meal[b]	DM	OM	CP	Fat	TDF	TEAA	TNEAA	TAA
Standard SBM	91.0	92.5	53.1	4.1	21.2	24.2	28.0	52.2
Argentina								
Soybean	95.4	92.3	47.4	4.4	23.7	21.5	24.3	45.7
Low	89.2	92.6	50.1	5.9	22.5	22.8	26.2	49.0
Intermediate	88.1	92.3	50.8	4.6	24.8	23.3	26.7	50.0
High	88.1	92.8	51.3	4.7	19.0	24.0	27.5	51.4
Brazil								
Soybean	95.8	93.3	57.0	4.4	19.7	25.0	29.3	54.3
Low	89.8	93.0	51.8	4.5	23.8	23.6	27.7	51.2
Intermediate	89.1	93.2	52.7	4.5	23.3	23.5	27.2	50.7
High	89.8	93.4	52.3	4.7	22.4	24.1	28.0	52.1
China								
Soybean	96.1	92.8	58.5	4.6	20.1	25.4	29.8	55.2
Low	90.1	93.5	48.8	3.9	24.2	22.0	25.7	47.6
Intermediate	88.1	93.9	50.7	3.4	21.0	22.6	26.2	48.8
High	88.5	93.5	52.9	3.5	19.4	25.0	28.7	53.7
India								
Soybean, low	96.9	92.3	54.6	5.6	20.7	24.3	28.4	52.8
Soybean, high	96.3	92.9	57.8	2.9	18.6	23.9	30.1	54.0
Low	89.5	90.8	51.7	3.9	23.4	24.2	27.8	52.0
Intermediate	89.2	91.0	51.6	3.3	21.6	22.4	26.4	48.8
High	90.3	92.6	59.5	3.6	17.0	27.1	31.6	58.7
United States								
Soybean	96.1	92.9	53.2	4.1	24.1	24.3	27.6	51.8
Low	89.2	92.9	54.2	3.2	18.4	23.9	27.3	51.1
Intermediate	89.4	91.8	51.1	5.3	18.4	23.9	27.5	51.4
High	89.3	92.6	55.4	3.7	17.5	25.4	29.1	54.4

[a]Fat = acid hydrolyzed fat; TDF = total dietary fiber; TEAA = total essential AA; TNEAA = total nonessential AA; TAA = total AA.
[b]Soybean = SBM prepared in the United States from soybeans (SB) grown in the five countries; Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.

d test period for each treatment. During each period, d 1 to 5 constituted the diet adaptation phase, and d 6 and 7 consisted of ileal digesta collection. Pigs were fed twice daily at 12-h intervals for both diet adaptation and collection phases. The quantity of feed (as-fed basis) provided each day during the first period was calculated on the basis of $0.09 \times$ kg $BW^{0.75}$, but equalized for animals within each experimental weekly period. The feeding level was increased by approximately 150 g in each subsequent period to account for the increased nutrient needs due to growth of the pigs.

Sampling Procedures

Ileal effluent was collected continuously for the same two 12-h intervals on d 6 and 7 of each period. Digesta were collected by attaching polyethylene tubing (5×25 cm; Rand Materials Handling Equipment Co., Inc., Pawtucket, RI) to the cannula barrel with a cable tie. The tubing was changed and emptied at least once every hour. Ileal digesta samples were frozen at −20°C to limit microbial activity and N loss until the end of collection. At the end of each collection day, ileal samples were thawed, pooled by pig, and a subsample was taken for lyophilization.

Chemical Analyses

Subsamples of the SBM, diets, and ileal digesta were ground through a 2-mm screen using a Wiley Mill (Thomas-Wiley, Swedesboro, NJ). At UIUC, SBM, feed, and ileal samples were analyzed for DM and ash concentrations according to AOAC (1995). Fat content of the SBM and diets was determined by acid hydrolysis (AACC, 1983), followed by ether extraction according to Budde (1952). Crude protein was determined from LECO nitrogen values (AOAC, 1995). Individual diets mixed at OSU were not analyzed for chemical composition, but each SBM sample was analyzed for AA.

Ileal samples collected at both sites were analyzed for chromium and AA concentrations at the University of Missouri Experiment Station Chemical Laboratories to eliminate variation between laboratories. Chromium was measured in diet and ileal samples by atomic absorption spectrophotometry after wet ashing in hydrochloric acid (AOAC, 1995). Diets, SBM, and ileal samples were analyzed for AA content using a Beckman 6300 AA analyzer (Beckman Coulter, Inc., Fullerton, CA) according to AOAC (1995).

Table 2. Ingredient composition (%) of experimental diets (as-fed basis) fed to pigs[a]

	SBM[b]					
Diet	Standard	SB	Low	Intermediate	High	Cornstarch
Casein[c]	—	—	—	—	—	61.50
Standard	35.00	—	—	—	—	38.25
Argentina						
Soybean	—	38.30	—	—	—	34.95
Low	—	—	37.50	—	—	35.75
Intermediate	—	—	—	37.50	—	35.75
High	—	—	—	—	37.10	36.15
Brazil						
Soybean	—	31.50	—	—	—	41.75
Low	—	—	36.00	—	—	37.25
Intermediate	—	—	—	36.50	—	36.75
High	—	—	—	—	36.10	37.15
China						
Soybean	—	30.00	—	—	—	43.25
Low	—	—	38.75	—	—	34.50
Intermediate	—	—	—	37.70	—	35.55
High	—	—	—	—	36.50	36.50
India						
Soybean, low	—	30.50	—	—	—	42.75
Soybean, high	—	30.50	—	—	—	42.75
Low	—	—	36.50	—	—	36.75
Intermediate	—	—	—	37.00	—	36.25
High	—	—	—	—	31.50	41.75
United States						
Soybean	—	33.30	—	—	—	39.95
Low	—	—	35.40	—	—	37.85
Intermediate	—	—	—	37.00	—	36.25
High	—	—	—	—	34.50	38.75

[a]All diets contained 20.0% sucrose, 3.0% dicalcium phosphate, 2.0% corn oil, 1.4% K_2CO_3, 0.6% limestone, 0.5% Cr_2O_3, 0.35% salt, 0.3% vitamin premix (provided per kilogram diet: 2,000 IU of vitamin A; 300 IU of vitamin D_3; 20 IU of vitamin E; 1.0 mg of vitamin K [menadione]; 4 mg of thiamine; 15 mg of niacin; 4 mg of riboflavin; 12 mg of pantothenic acid; 15 μg of vitamin B_{12}; 2 mg of pyridoxine; 0.1 mg of d-biotin; 0.5 mg of folic acid; and 0.60 g of choline), 0.1% MTB-100 (Alltech, Lexington, KY), and 0.05% trace mineral mix (provided per kilogram diet: 90 mg of Fe [ferrous sulfate]; 5 mg of Mn [manganese oxide]; 8 mg of Cu [copper sulfate]; 20 mg of I [potassium iodate]; 21 mg of Se [sodium selenite]; and 90 mg of Zn [zinc sulfate]).

[b]Standard = common source of soybean meal (SBM) from the United States; Soybean = SBM prepared in the United States from soybeans (SB) grown in the five countries; Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.

[c]Casein diet used in all experiments contained the following ingredients: 20.0% sucrose, 5.0% casein, 5.0% Solka-floc (Int. Fiber Corp., North Tonawanda, NY), 3.0% dicalcium phosphate, 2.0% corn oil, 1.4% K_2CO_3, 0.6% limestone, 0.5% Cr_2O_3, 0.4% salt, 0.3% vitamin premix (see Footnote a), 0.15% MgO, 0.1% MTB-100, and 0.05% trace mineral mix (see Footnote a).

Calculations

When calculating nutrient digestibilities by pigs fed at UIUC, analyzed Cr and AA values of the diets were used, whereas calculated values for Cr and AA in the diet were used for calculation of AA digestibilities of pigs fed at OSU. These techniques resulted in similar digestibility values. Upon completion of the experiment, diets mixed at OSU were analyzed for AA concentrations. Because analyzed concentrations were similar to calculated concentrations, the calculated values were used to more accurately reflect the concentration incorporated into the diet.

Apparent ileal nutrient digestibility (AD) values were calculated according to the following formula:

$$AD = 100 - [(N_D/N_F) \times (Cr_F/Cr_D) \times 100]$$

where N_D is the nutrient concentration present in ileal digesta, N_F is the nutrient concentration in feed, Cr_F is the Cr concentration in feed, and Cr_D is the Cr concentration in ileal digesta.

To calculate true ileal digestibilities of CP and AA, endogenous nutrient losses (ENL) were calculated according to Moughan et al. (1992) using the following equation:

$$ENL = N_D \times (Cr_F/Cr_D)$$

In each experiment, values for the pig fed the casein diet during each period were used to calculate the ENL for all pigs within the same period. Finally, true digestibility (TD) values were calculated using the following equation:

$$TD = AD + [(ENL/N_F) \times 100]$$

Table 3. Chemical composition of semipurified diets fed to ileal cannulated pigs at the University of Illinois

Diet[b]	Nutrient[a] DM	OM	CP	Fat	Lysine	Threonine	Methionine	TEAA	TNEAA	TAA
Casein	92.6	94.1	4.94	2.9	0.39	0.21	0.14	2.8	2.8	5.5
Standard SBM	91.7	93.7	16.8	4.3	1.06	0.66	0.23	8.1	8.6	16.7
Argentina										
Soybean	94.9	94.2	15.6	4.1	1.06	0.68	0.23	8.4	8.4	16.8
Low	92.6	94.3	16.1	4.1	1.04	0.66	0.23	8.2	8.6	16.7
Intermediate	92.3	92.2	17.8	4.0	1.00	0.61	0.21	7.6	8.2	15.8
High	92.2	93.8	16.5	3.5	1.02	0.64	0.22	8.1	8.2	16.3
Brazil										
Soybean	94.2	93.9	16.4	4.0	0.79	0.51	0.17	6.4	6.9	13.2
Low	92.2	94.7	16.9	4.6	0.89	0.58	0.20	7.2	7.8	15.0
Intermediate	91.8	94.4	13.1	4.6	0.83	0.52	0.18	6.5	7.1	13.6
High	92.4	93.8	17.1	4.8	0.85	0.52	0.18	6.6	7.0	13.6
China										
Soybean	92.9	95.1	18.1	3.8	0.91	0.55	0.20	7.4	7.6	15.0
Low	91.4	92.9	16.8	4.3	0.96	0.60	0.24	7.6	7.8	15.4
Intermediate	92.3	91.6	15.9	3.6	1.08	0.66	0.26	8.7	8.9	17.6
High	93.5	92.2	14.4	4.6	0.99	0.58	0.24	7.8	7.9	15.7
India										
Soybean, low	95.4	92.5	16.2	3.9	1.03	0.63	0.24	8.0	8.6	16.7
Soybean, high	95.4	92.5	14.3	4.8	1.07	0.66	0.22	8.3	9.0	17.3
Low	92.0	91.8	15.5	3.4	1.06	0.63	0.22	8.3	8.5	16.8
Intermediate	92.7	92.7	14.4	3.6	1.06	0.65	0.22	8.4	8.6	17.0
High	93.2	92.8	13.4	3.2	1.14	0.72	0.24	9.2	9.6	18.8
United States										
Soybean	93.3	94.6	16.8	4.0	0.97	0.62	0.21	7.7	8.3	16.0
Low	92.4	94.6	15.0	4.1	0.93	0.58	0.21	7.3	7.6	14.9
Intermediate	92.5	93.5	16.2	4.3	0.96	0.59	0.22	7.5	7.9	15.3
High	92.0	94.2	16.8	3.7	1.08	0.65	0.24	8.4	8.6	17.9

[a]Fat = acid hydrolyzed fat; TEAA = total essential AA; TNEAA = total nonessential AA; TAA = total AA.
[b]Soybean = SBM prepared in the United States from soybeans (SB) grown in the five countries; Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.

Statistics

Data were analyzed as a Latin square using the mixed models procedure of SAS (SAS Inst., Inc., Cary, NC). For the analyses of data collected at UIUC only (CP digestibilities), the model contained the fixed effect of diet and the random effects of pig and period.

Before combining the data from both locations, the interaction of location and diet was examined. Because this effect was not significant, data were combined, and location was included as a random effect. For data collected at both sites (AA digestibilities), the model included the fixed effect of diet and the random effects of location, pig within location, and period within location. Least squares means were separated using *F*-test protected LSD, with an alpha level of 0.05 used to determine statistical significance.

Results and Discussion

Quality characteristics (low, intermediate, high) of the SBM within each country were subjectively assessed in different ways before this experiment. Low, intermediate, and high quality designations for SBM from Argentina, China, and India were based primarily on CP concentrations, with the high-quality SBM having the highest CP concentration. Color and physical appearance also were used when categorizing the quality of the SBM from India. In the United States, both processing technologies employed at the plant and chemical compositional data of SBM from previous years at each of the processing plants were used to assess SBM quality. The processing plant history, as well as where the SB were grown, were used to assign quality designations to the Brazilian SBM samples, with the low-quality SBM originating from a new SBM processing plant.

Chemical Composition of Diets Fed at UIUC

The chemical composition of diets prepared and fed to ileal-cannulated pigs at UIUC is presented in Table 3. Dry matter and OM concentrations of all diets were similar, ranging from 91.4 to 95.4% and 91.6 to 95.1%, respectively. All SBM-containing diets had CP concentrations close to the formulated 17% dietary concentration except for the diets containing the intermediate-quality SBM from Brazil (13.1%), the high-quality SBM from China (14.4%), nearly all of the Indian SBM (13.4 to 15.5%), and the low-quality U.S. SBM (15.0%). All

Table 4. Endogenous losses (g/kg DMI) of nitrogen and amino acids at the terminal ileum[a]

Item	Mean	Range (min–max)[b]	SEM
Nitrogen	2,943.8	1,759.1–5,186.6	148.9
Essential AA			
Arginine	492.4	191.4–1,415.3	35.5
Histidine	210.9	110.8–557.8	10.4
Isoleucine	569.2	330.2–1,015.5	21.3
Leucine	671.8	342.0–1,855.1	38.6
Lysine	472.2	118.2–1,387.4	29.5
Methionine	132.4	75.1–302.9	5.5
Phenylalanine	351.3	171.3–1,154.7	25.8
Threonine	645.2	388.5 – 1,362.9	25.8
Tryptophan	134.4	40.9–340.7	7.3
Valine	618.2	377.4–1,419.7	26.6
Nonessential AA			
Alanine	1,481.5	261.9–5,752.9	218.4
Aspartic Acid	954.8	523.8–3,075.2	60.3
Cystine	201.5	122.7–624.7	13.5
Glutamic acid	1,858.2	1,143.9–5,378.0	93.6
Glycine	1,153.8	378.3–3,657.6	82.3
Proline	3,012.3	376.1–11,976.3	382.6
Serine	789.7	495.5–1,187.0	22.6
Tyrosine	323.5	151.1–851.8	19.3
TEAA[c]	4,297.9	2,427.7–10,165.0	208.1
TNEAA[d]	9,785.5	3,656.7–21,975.4	545.9
TAA[e]	14,207.3	6,084.4–30,766.2	713.8

[a]For nitrogen, n = 30; for all AA, n = 60.
[b]Minimum to maximum.
[c]TEAA = total essential AA.
[d]TNEAA = total nonessential AA.
[e]TAA = total AA.

diets were formulated based on a subsample of the SBM included in that diet. The lower CP concentrations found in these diets could be due to variation in mixing, as well as to variation in the composition of the SBM samples themselves. Because only a small sample was taken initially from each batch of SBM shipped, there may have been some differences in the CP content of the SBM compared with the analyzed values for the subsample. Acid hydrolyzed fat concentrations ranged from 3.2 to 4.8%. Amino acid composition of the diets reflected the AA composition of the SBM.

In general, pigs remained healthy and consumed their meals throughout the experiments. In cases in which the pigs did not consume their meals or became ill, they were removed from the trial and replaced with one of the additional cannulated pigs to ensure that digestibilities estimates were based on healthy animals.

Endogenous nitrogen and AA losses are reported in Table 4. The mean endogenous losses of N and AA were similar to those reported by Dilger et al. (2004). There was a large range of endogenous losses when comparing all five experiments conducted at both locations, but there was limited variation within each experiment. In general, endogenous AA losses for experiments conducted at OSU were lower than for those conducted at UIUC. A similar trend was noted by van Kempen et al. (2002). Mean endogenous losses were higher in the current study than those noted by Smiricky et al. (2002) and Traylor et al. (2001), but mean values from these studies fell within the range of endogenous losses noted in the current study.

Soybean Meal from Argentina

True ileal digestibilities by pigs fed SBM produced in Argentina are presented in Table 5. Pigs fed the SBM produced from Argentinean SB had lower ($P < 0.05$) true digestibilities of CP than did pigs fed the standard SBM from the United States, and pigs fed the standard SBM had the highest ileal true CP digestibilities. Although the CP digestibilities were numerically lower for the three Argentinean SBM samples, only the low-quality SBM produced in Argentina was significantly less digestible than the standard SBM produced in the United States. There were no differences in CP digestibilities among the different quality SBM produced in Argentina.

Pigs fed the SBM produced from Argentinean SB had the lowest ($P < 0.05$) true ileal digestibilities for all AA measured (Table 4). There were no differences in AA digestibilities by pigs fed the low-, intermediate-, or high-quality SBM produced in Argentina. Pigs fed the standard SBM had higher ($P < 0.05$) digestibilities of cysteine and glycine than did pigs fed the SBM produced in Argentina, higher digestibilities of arginine, lysine, and aspartate than pigs fed the low- and high-quality SBM produced in Argentina, and higher digestibilities of histidine than the low- and intermediate-quality SBM from Argentina.

The true digestibility coefficients of proline from pigs fed the intermediate- and high-quality SBM from Argentina and the standard SBM were over 100%. This is perhaps the result of an overestimation of endogenous proline loss and, thus, an overestimation of true proline digestibility. Use of a low-protein casein diet to estimate endogenous losses perhaps may result in mobilization of glutamine from muscle, which can be metabolized into glutamate for use by the enterocytes to synthesize ammonia, citrulline, and proline (de Lange et al., 1989).

Total essential AA (**TEAA**) digestibilities were similar for all three qualities of SBM produced in Argentina and the standard SBM, whereas total nonessential AA (**TNEAA**) and total AA (**TAA**) digestibilities were lower ($P < 0.05$) for the SBM produced in Argentina compared with the standard SBM.

Soybean Meal from Brazil

Pigs fed the SBM produced from the Brazilian SB had greater than 20 percentage units lower true digestibilities of CP than did pigs fed the SBM processed in Brazil (Table 6). The low-quality Brazilian-produced SBM had a lower ($P < 0.05$) CP digestibility than the standard SBM produced in the United States. There were no differences in true CP digestibilities of the different quality SBM from Brazil. As regards AA di-

Table 5. True ileal crude protein and amino acid digestibilities (%) by pigs fed semipurified diets containing soybean meals prepared in Argentina or prepared from soybeans grown in Argentina and processed under uniform conditions in the United States

	Soybean meal source[a]					
Item	Soybean	Low	Intermediate	High	Standard	SEM[b]
Crude protein[c]	73.3[g]	82.1[h]	84.4[hi]	84.1[hi]	90.0[i]	2.8
n	12	12	12	11	12	
Essential AA						
Arginine	83.8[g]	92.4[h]	93.7[hi]	92.7[h]	95.5[i]	1.23
Histidine	77.4[g]	87.8[h]	88.5[h]	88.6[hi]	91.4[i]	1.12
Isoleucine	75.8[g]	88.9[h]	88.8[h]	89.2[h]	90.0[h]	1.21
Leucine	72.5[g]	86.1[h]	86.2[h]	86.2[h]	87.4[h]	1.14
Lysine	75.4[g]	86.0[h]	86.8[hi]	86.2[h]	90.2[i]	1.91
Methionine	81.9[g]	91.3[h]	91.1[h]	90.9[h]	92.1[h]	0.97
Phenylalanine	73.1[g]	86.7[h]	86.7[h]	86.3[h]	87.8[h]	1.08
Threonine	79.4	92.6	82.9	83.0	85.8	1.72
Tryptophan	73.1[g]	89.0[h]	90.2[h]	89.3[h]	92.0[h]	1.35
Valine	72.9[g]	86.3[h]	86.5[h]	86.4[h]	88.2[h]	1.33
Nonessential AA						
Alanine	71.5[g]	84.2[h]	84.5[h]	83.8[h]	86.3[h]	1.68
Asparate	70.2[g]	82.9[h]	83.5[hi]	82.6[h]	87.0[i]	1.4
Cysteine	61.7[g]	76.3[h]	78.6[h]	77.6[h]	85.1[i]	2.41
Glutamate	77.4[g]	86.3[h]	88.2[h]	86.3[h]	91.5[h]	1.86
Glycine	61.3[g]	75.7[h]	80.4[h]	79.3[h]	88.0[i]	3.71
Proline	87.1[g]	98.1[g]	113.7[h]	110.9[h]	120.7[h]	20.42
Serine	74.4[g]	89.1[h]	89.8[hi]	89.8[hi]	92.8[i]	1.85
Tyrosine	77.6[g]	88.0[h]	88.7[h]	88.2[h]	90.3[h]	1.13
TEAA[d]	74.5[g]	87.5[h]	88.0[h]	86.8[h]	90.3[h]	1.82
TNEAA[e]	73.2[g]	85.3[h]	88.2[h]	86.3[h]	92.7[i]	3.48
TAA[f]	73.7[g]	86.2[h]	87.9[hi]	86.4[h]	91.3[i]	2.42

[a]Soybean = SBM prepared in the United States from Argentinean soybeans (SB); Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.
[b]SEM = pooled standard error of the mean.
[c]Crude protein digestibility calculated using only data from pigs fed at the University of Illinois at Urbana-Champaign; n = 6 for all treatments.
[d]TEAA = total essential AA.
[e]TNEAA = total nonessential AA.
[f]TAA = total AA.
[g,h,i]Within a row, means without a common superscript letter differ, $P < 0.05$.

gestibilities, pigs fed the SBM produced from the Brazilian SB had the lowest ($P < 0.05$) true ileal digestibilities of all AA measured, with digestibility coefficients of at least 20 percentage units less for pigs fed this diet compared with all other diets. Pigs fed the standard SBM had higher ($P < 0.05$) digestibilities of isoluecine, leucine, lysine, methionine, phenylalanine, threonine, and valine than pigs fed the SBM from Brazil. Pigs fed the intermediate- and high-quality SBM from Brazil had higher ($P < 0.05$) true ileal digestibilities of isoleucine than pigs fed diets containing the low-quality SBM. Pigs fed the high-quality SBM had higher ($P < 0.05$) true valine digestibilities than pigs fed diets containing the low-quality SBM, whereas pigs fed the intermediate-quality SBM had higher tryptophan digestibilities than pigs fed the low-quality SBM. For all other amino acids, there were no differences in digestibilities among the three qualities of Brazilian SBM. The true digestibility coefficients of proline were only slightly over 100% for the intermediate- and high-quality SBM from Brazil and the standard SBM. This result was probably due to an overestimation of endogenous proline losses. Pigs fed the standard SBM had higher ($P < 0.05$) TEAA, TNEAA, and TAA digestibilities than pigs fed the Brazilian SBM and there were no differences in digestibilities among the SBM of varying qualities produced in Brazil.

Soybean Meal from China

Pigs fed the SBM produced from Chinese SB had the lowest true CP digestibility (Table 7). Pigs fed the low-quality Chinese SBM had a lower ($P < 0.05$) CP digestibility than did pigs fed the intermediate, high, and standard SBM.

For all AA measured, pigs fed the SBM produced from Chinese SB had the lowest ($P < 0.05$) digestibilities, with coefficients at least 20 percentage units less than for the other treatments. The low-quality SBM from China had lower ($P < 0.05$) amino acid digestibilities than the intermediate- and high-quality SBM. The intermediate- and high-quality SBM from China and the standard SBM from the U.S. were similar in amino acid digestibilities, except for threonine, where the in-

Table 6. True ileal crude protein and amino acid digestibilities (%) by pigs fed semipurified diets containing soybean meals prepared in Brazil or prepared from soybeans grown in Brazil and processed under uniform conditions in the U.S.

	Soybean meal source[a]					
Item	Soybean	Low	Intermediate	High	Standard	SEM[b]
Crude protein[c]	51.4[g]	72.2[h]	78.9[hi]	77.4[hi]	87.9[i]	4.20
n	9	12	12	12	12	
Essential AA						
Arginine	63.6[g]	87.1[h]	91.7[hi]	90.7[hi]	95.2[i]	2.58
Histidine	57.1[g]	79.4[h]	82.6[h]	84.3[hi]	90.1[i]	3.01
Isoleucine	52.1[g]	80.5[h]	84.4[i]	85.7[i]	91.3[j]	2.94
Leucine	48.7[g]	78.0[h]	81.3[h]	82.1[h]	88.6[i]	3.18
Lysine	55.5[g]	76.7[h]	81.7[h]	81.6[h]	90.4[i]	3.29
Methionine	62.6[g]	84.5[h]	87.4[h]	88.0[h]	92.6[i]	2.72
Phenylalanine	49.7[g]	79.1[h]	82.0[h]	83.5[h]	89.1[i]	3.36
Threonine	50.1[g]	72.5[h]	76.7[h]	77.7[h]	86.8[i]	4.20
Tryptophan	57.6[g]	80.5[h]	87.1[i]	85.3[hi]	90.1[i]	4.94
Valine	47.8[g]	75.4[h]	80.0[hi]	81.4[i]	89.1[j]	4.69
Nonessential AA						
Alanine	52.8[g]	74.0[h]	77.3[h]	78.6[h]	87.2[i]	4.85
Asparate	51.1[g]	75.8[h]	79.1[h]	79.3[h]	88.1[i]	2.94
Cysteine	33.8[g]	64.2[h]	69.4[h]	69.5[h]	83.5[i]	7.69
Glutamate	57.7[g]	80.6[h]	83.7[h]	83.5[h]	92.2[i]	3.36
Glycine	38.2[g]	60.9[h]	69.5[h]	71.2[hi]	84.4[h]	6.75
Proline	60.4[g]	88.7[h]	102.6[h]	101.6[h]	101.1[h]	10.56
Serine	57.5[g]	81.4[h]	85.6[h]	85.9[h]	92.6[i]	2.05
Tyrosine	57.6[g]	80.3[h]	83.9[h]	84.8[h]	90.6[i]	4.92
TEAA[d]	54.6[g]	84.9[h]	85.3[h]	85.7[h]	92.0[i]	5.85
TNEAA[e]	54.2[g]	77.9[h]	82.9[h]	83.2[h]	90.8[i]	3.07
TAA[f]	53.5[g]	78.4[h]	83.1[h]	83.5[h]	90.8[i]	3.18

[a]Soybean = SBM prepared in the United States from Brazilian soybeans (SB); Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.
[b]SEM = pooled standard error of the mean.
[c]Crude protein digestibility calculated using only data from pigs fed at University of Illinois at Urbana-Champaign; n = 4 for SB treatment; n = 6 for all other treatments.
[d]TEAA = total essential AA.
[e]TNEAA = total nonessential AA.
[f]TAA = total AA.
[g,h,i,j]Within a row, means without a common superscript letter differ, $P < 0.05$.

termediate-quality Chinese SBM was more ($P < 0.05$) digestible than the standard U.S. SBM. The low-quality SBM from China also was similar in digestibility to the standard SBM for arginine, leucine, methionine, phenylalanine, and threonine. Proline digestibility coefficients were again slightly higher than 100% for the SBM from China and the standard SBM from the United States. In the case of true TEAA digestibility, the intermediate- and high-quality SBM from China and the standard SBM had higher ($P < 0.05$) digestibilities than the low-quality Chinese SBM, whereas for TNEAA and TAA digestibilities, the low-quality Chinese SBM was less digestible than the intermediate- or high-quality SBM, but similar to the standard SBM.

Soybean Meal from India

Pigs fed diets containing SBM processed from both the low- and high-quality SB from India had much lower ($P < 0.05$) true CP digestibilities than did pigs fed the other diets (Table 8). In fact, the digestibility coefficients for these SBM averaged over 30 percentage units less than that of the Indian SBM. There were no differences in true CP digestibility between the three qualities of Indian SBM, with all three having similar values to that of the standard SBM.

With regard to true ileal AA digestibilities, pigs fed the standard SBM and SBM processed in India had similar AA digestibilities. The digestibility values were similar for all three qualities of SBM processed in India. The SBM processed in the U.S. from both low- and high-quality Indian SB had much lower ($P < 0.05$) AA digestibilities than did the SBM produced in India. Proline digestibility coefficients were near 100% for the Indian SBM and the standard SBM. Pigs fed the three qualities of Indian SBM had similar TEAA, TNEAA, and TAA digestibilities compared with the standard SBM.

Soybean Meal from the United States

Pigs fed SBM produced from U.S. SB and the low-quality SBM had the lowest true CP digestibilities of all treatments tested (Table 9). Crude protein digest-

Table 7. True ileal crude protein and amino acid digestibilities (%) by pigs fed semipurified diets containing soybean meal prepared in China and prepared from soybeans grown in China and processed under uniform conditions in the United States

Item	Soybean meal source[a]					SEM[b]
	Soybean	Low	Intermediate	High	Standard	
Crude protein[c]	54.0[g]	78.1[h]	87.7[i]	86.2[i]	86.1[i]	2.42
n	10	12	12	12	12	
Essential AA						
Arginine	66.7[g]	89.7[h]	94.3[i]	93.3[hi]	93.0[hi]	2.20
Histidine	62.6[g]	83.8[h]	89.3[i]	89.1[i]	88.6[i]	2.77
Isoleucine	59.0[g]	84.8[h]	90.9[i]	90.2[i]	88.6[i]	1.91
Leucine	54.3[g]	82.9[h]	89.2[i]	87.9[i]	86.2[hi]	2.35
Lysine	60.3[g]	81.9[h]	87.4[i]	88.1[i]	87.7[i]	2.11
Methionine	62.3[g]	87.4[h]	91.4[hi]	92.8[i]	90.9[hi]	3.00
Phenylalanine	55.5[g]	82.7[h]	89.3[i]	87.9[i]	86.2[hi]	2.28
Threonine	55.4[g]	83.8[h]	89.9[i]	85.3[hi]	83.4[h]	4.90
Tryptophan	61.3[g]	86.9[h]	91.6[i]	91.0[i]	90.7[i]	2.18
Valine	58.4[g]	82.4[h]	89.4[i]	88.7[i]	86.4[i]	1.63
Nonessential AA						
Alanine	58.5[g]	78.8[h]	87.3[i]	86.7[i]	84.3[i]	2.24
Asparate	55.8[g]	78.4[h]	85.0[i]	85.2[i]	84.7[i]	2.60
Cysteine	48.7[g]	71.6[h]	79.7[i]	80.0[i]	79.3[i]	5.61
Glutamate	59.8[g]	82.7[h]	89.5[i]	87.1[i]	86.5[i]	2.69
Glycine	53.1[g]	74.3[h]	82.6[i]	81.7[i]	79.5[hi]	2.99
Proline	57.2[g]	101.0[h]	97.9[h]	107.2[h]	103.3[h]	12.77
Serine	53.6[g]	85.3[h]	91.1[i]	91.4[i]	90.1[hi]	3.28
Tyrosine	58.8[g]	83.9[h]	89.5[i]	89.8[i]	88.4[i]	3.95
TEAA[d]	59.5[g]	84.6[h]	90.3[i]	89.4[i]	88.2[i]	2.48
TNEAA[e]	55.7[g]	82.0[h]	88.0[i]	88.7[i]	87.0[hi]	2.23
TAA[f]	60.4[g]	83.5[h]	89.6[i]	89.0[i]	87.7[hi]	2.73

[a]Soybean = SBM prepared in the United States from Chinese soybeans (SB); Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.
[b]SEM = pooled standard error of the mean.
[c]Crude protein digestibility calculated using only data from pigs fed at University of Illinois at Urbana-Champaign; n = 6 for each treatment.
[d]TEAA = total essential AA.
[e]TNEAA = total nonessential AA.
[f]TAA = total AA.
[g,h,i]Within a row, means without a common superscript letter differ, $P < 0.05$.

ibilities of the standard SBM and the intermediate and high-quality U.S. SBM were similar.

Pigs fed the intermediate and high-quality U.S. SBM had AA digestibilities similar to that of the standard SBM. Pigs fed the low-quality U.S. SBM had lower ($P < 0.05$) digestibilities of histidine, isoluecine, lysine, methionine, threonine, valine, aspartate, cysteine, glutamate, and tyrosine than did pigs fed the standard SBM. There was no difference in AA digestibilities between the SBM of varying quality produced in the United States. The SBM produced from U.S. SB under standardized conditions at the pilot plant in the United States had lower ($P < 0.05$) digestibilities than the intermediate and high-quality U.S. SBM, but values were similar to those for the low-quality U.S. SBM for histidine, lysine, methionine, threonine, alanine, cysteine, glutamate, and tyrosine. Proline digestibility coefficients were at or above 100% for all treatments due to overestimation of endogenous proline losses. For true TEAA, TNEAA, and TAA digestibilities, all three qualities of U.S. SBM were similar to those of the standard SBM, with the SBM prepared at the pilot plant from U.S. SB being lower ($P < 0.05$).

In each experiment, pigs fed the SBM processed from SB grown in each country under standardized conditions at the U.S. pilot plant had much lower AA digestibilities than did pigs fed the SBM processed within each country, except for the U.S. SBM, where differences were not as great. In vitro protein quality characteristics of the SBM produced at the pilot plant indicated that some problems in processing might have occurred. All SBM except those produced from Argentinean and Brazilian SB had protein solubilities in KOH greater than 85%, so the resultant SBM may have been underprocessed. Urease values of SBM produced from Indian and Argentinean SB were at or above 0.2 pH unit changes, again indicating potential underprocessing.

Conditions used in SB processing can influence composition of the resultant SBM. For example, in a study by Grieshop et al. (2003), no differences in individual or TAA concentrations were noted in samples of SB from 10 U.S. processing plants. However, significant differences in individual and TAA concentrations were noted in the resultant SBM. These differences in processing conditions can result in differences in nutrient digestibilities (Sauer and Ozimek, 1986). The heating

Table 8. True ileal crude protein and amino acid digestibilities (%) by pigs fed semipurified diets containing soybean meals prepared in India or prepared from soybeans grown in India and processed under uniform conditions in the United States

	Soybean meal source[a]						
	Soybean						
Item	Low	High	Low	Intermediate	High	Standard	SEM[b]
Crude protein[c]	53.7[g]	48.5[g]	81.9[h]	82.2[h]	87.1[h]	86.5[h]	2.48
n	13	14	14	14	14	14	
Essential AA							
Arginine	65.3[g]	63.1[g]	91.9[h]	92.0[h]	93.6[h]	94.0[h]	2.25
Histidine	63.6[g]	62.1[g]	87.4[h]	87.1[h]	89.6[h]	90.7[h]	2.28
Isoleucine	57.7[g]	54.4[g]	87.2[h]	87.1[h]	90.1[h]	89.5[h]	2.28
Leucine	56.2[g]	52.9[g]	84.5[h]	84.3[h]	88.1[h]	87.5[h]	3.90
Lysine	65.2[g]	62.9[g]	88.1[h]	87.4[h]	89.0[h]	83.9[h]	3.45
Methionine	66.0[g]	61.6[g]	88.6[h]	88.1[h]	90.9[h]	90.9[h]	2.61
Phenylalanine	55.7[g]	51.6[g]	85.2[h]	85.1[h]	88.1[h]	87.3[h]	2.76
Threonine	57.1[g]	54.1[g]	80.7[h]	80.2[h]	83.7[h]	84.0[h]	1.95
Tryptophan	61.3[g]	60.8[g]	88.1[h]	86.7[h]	87.6[h]	89.4[h]	3.81
Valine	57.6[g]	55.0[g]	84.7[h]	84.2[h]	87.5[h]	87.8[h]	2.04
Nonessential AA							
Alanine	58.2[g]	55.8[g]	82.4[h]	81.8[h]	84.8[h]	85.2[h]	2.72
Asparate	57.5[g]	55.2[g]	84.0[h]	83.4[h]	85.2[h]	86.5[h]	1.85
Cysteine	52.7[g]	48.6[g]	77.4[h]	78.5[hi]	83.2[hi]	83.2[i]	2.05
Glutamate	30.1[g]	62.2[h]	86.9[i]	86.8[i]	88.6[i]	90.3[i]	7.62
Glycine	54.8[g]	54.9[g]	79.4[hi]	77.8[h]	82.1[hi]	83.8[i]	2.31
Proline	62.7[g]	60.2[g]	97.8[h]	100.1[h]	99.6[h]	101.1[h]	10.44
Serine	59.6[h]	54.1[g]	87.7[i]	86.6[i]	90.3[i]	90.7[i]	1.75
Tyrosine	59.6[g]	56.7[g]	86.3[h]	86.3[h]	89.3[h]	88.6[h]	3.60
TEAA[d]	58.4[g]	57.3[g]	86.7[h]	86.3[h]	89.1[h]	89.6[h]	2.34
TNEAA[e]	59.2[g]	58.6[g]	86.2[h]	85.9[h]	88.2[h]	89.5[h]	1.92
TAA[f]	58.9[g]	58.1[g]	86.4[h]	86.1[h]	88.7[h]	89.3[h]	1.85

[a]Soybean, Low = SBM prepared in the United States from low-quality Indian soybeans (SB); Soybean, High = SBM prepared in the United States from high-quality Indian SB; Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.
[b]SEM = pooled standard error of the mean.
[c]Crude protein digestibility calculated using only data from pigs fed at University of Illinois at Urbana-Champaign; n = 7 for each treatment.
[d]TEAA = total essential AA.
[e]TNEAA = total nonessential AA.
[f]TAA = total AA.
[g,h,i]Within a row, means without a common superscript letter differ, $P < 0.05$.

process is designed to denature any remaining antinutritional factors present in the SB. If proper temperatures are not reached, some antinutritional factors may not be destroyed (Araba and Dale, 1990). These antinutritional factors will lead to a decrease in digestibility of the SBM due to the presence of protease inhibitors. However, if temperatures used are too high, there can be some damage to nutrients in the SB, particularly lysine (Araba and Dale, 1990).

Because SBM quality is affected by processing conditions, it is important that optimal processing conditions be defined; however, these conditions may not be the same for all SB varieties grown throughout the world. In this study, although digestibilities were low for all SBM produced at the pilot plant, they were much lower for the SBM produced from international SB than for that produced from the U.S. SB. This finding indicates that conditions used in SBM processing may need to be varied depending on the composition of the SB. Soybean composition varies depending on several factors including rainfall (Rose, 1988), temperature (Wolf et al., 1982), and photoperiod (Cure et al., 1982), all of which were different in the geographic regions sampled for our particular study.

Studies have shown substantial variation in composition of SB and SBM produced within a country. Grieshop and Fahey (2001) examined the variability in SB grown in Brazil, China, and the United States. They reported differences in CP and AA composition of SB grown within these countries as well as differences among the three countries. For example, CP concentrations ranged from 39 to 42% of DM for SB grown in different Brazilian states and 39 to 45% of DM for SB grown in different regions of the U.S. This variability in SB composition leads to variability in SBM composition as well. A survey of 55 U.S. SBM processing plants showed differences in CP, total dietary fiber, and acid-hydrolyzed fat concentrations among SBM based on the region of the United States in which the SB were grown and processed (Grieshop et al., 2003). Although no simi-

Table 9. True ileal crude protein and amino acid digestibilities (%) by pigs fed semipurified diets containing soybean meals prepared in the United States or prepared from soybeans grown in the United States and processed under uniform conditions in the United States

	Soybean meal source[a]					
Item	Soybean	Low	Intermediate	High	Standard	SEM[b]
Crude protein[c]	84.7[g]	82.5[g]	92.9[h]	94.0[h]	95.7[h]	4.57
n	11	12	12	12	12	
Essential AA						
Arginine	90.8[g]	94.6[h]	95.8[h]	95.7[h]	97.3[h]	2.11
Histidine	84.5[g]	88.5[gh]	92.1[h]	92.1[h]	94.2[i]	2.27
Isoleucine	80.1[g]	87.1[h]	90.4[hi]	91.2[hi]	93.0[i]	2.09
Leucine	78.9[g]	85.9[h]	89.9[h]	89.3[h]	91.6[h]	3.03
Lysine	82.8[g]	87.0[gh]	90.9[h]	90.6[h]	93.1[i]	2.71
Methionine	86.4[g]	89.9[gh]	92.7[hi]	93.2[hi]	93.7[i]	1.61
Phenylalanine	79.5[g]	86.4[h]	90.4[h]	89.5[h]	91.8[h]	2.96
Threonine	76.0[g]	81.9[gh]	86.8[hi]	86.7[hi]	89.6[i]	3.66
Tryptophan	79.8[g]	88.5[h]	92.6[h]	93.4[h]	94.4[h]	3.22
Valine	78.4[g]	84.8[h]	89.1[hi]	89.8[hi]	91.7[i]	2.61
Nonessential AA						
Alanine	79.1[g]	84.4[gh]	88.4[hi]	88.6[hi]	91.1[h]	3.83
Asparate	79.8[g]	86.2[h]	89.6[hi]	89.3[hi]	91.4[i]	3.75
Cysteine	72.7[g]	78.5[gh]	84.8[hi]	83.6[hi]	88.4[i]	3.79
Glutamate	85.9[g]	87.9[g]	90.0[gh]	90.5[h]	92.8[h]	2.57
Glycine	83.2	88.6	87.5	89.6	95.3	9.67
Proline	110.0	118.1	99.2	103.3	113.8	22.34
Serine	81.0[g]	87.5[h]	90.3[h]	90.5[h]	92.8[h]	2.83
Tyrosine	72.9[g]	87.8[gh]	91.8[hi]	91.5[hi]	93.3[i]	2.05
TEAA[d]	80.7[g]	88.0[h]	91.1[h]	92.7[h]	93.9[h]	3.34
TNEAA[e]	83.1[g]	89.7[h]	89.4[h]	91.1[h]	95.0[h]	5.40
TAA[f]	81.9[g]	88.7[h]	88.7[h]	91.0[h]	94.3[h]	4.24

[a]Soybean = SBM prepared in the United States from U.S. soybeans (SB); Low = low-quality SBM; Intermediate = intermediate-quality SBM; High = high-quality SBM.
[b]SEM = pooled standard error of the mean.
[c]Crude protein digestibility calculated using only data from pigs fed at University of Illinois at Urbana-Champaign; n = 6 for each treatment.
[d]TEAA = total essential AA.
[e]TNEAA = total nonessential AA.
[f]TAA = total AA.
[g,h,i]Within a row, means without a common superscript letter differ, $P < 0.05$.

lar survey for other countries has been published, it is safe to assume that similar amounts of variation exist in the SBM produced in these countries as well. Differences were noted in chemical composition of the SBM within a country for meals used in the current study. In fact, as SBM quality improved according to subjective indices, AA concentrations and protein solubility in potassium hydroxide increased, whereas total dietary fiber concentration decreased. These differences in SBM composition could lead to differences in quality and digestibility of SBM.

In the current study, few differences in true AA digestibilities were noted within a country. Only the low-quality SBM from China was less digestible than the intermediate- and high-quality SBM produced within this country. This corresponds with the in vitro protein quality assessment of these SBM. Urease values of less than 0.05 pH units, protein solubilities in KOH between 75 and 85% of CP, and protein dispersibility index values below 50% indicate properly processed SBM.

Differences in SBM composition do not necessarily correlate to differences in digestibility as noted by van Kempen et al. (2002), who compared digestibilities of SBM from four locations in the United States and SBM from one location in The Netherlands. The AA composition of the SBM varied among locations, both between the U.S. and the Netherlands and within the United States; however, there was little difference in AA digestibilities by swine.

The standard SBM was used in this study to compare SBM produced in other countries to a high-quality SBM available on the open market in the United States. In the case of true TAA digestibilities, the SBM from China, India, and the United States were similar in digestibility to the standard SBM, but the SBM from Argentina and Brazil were less digestible. It is important that the true digestibility of AA in SBM be accounted for when determining the ideal SBM for use in animal diets. The lower digestibilities noted for SBM from Argentina and Brazil will no doubt result in fewer AA reaching organ systems of the animal and could result in poorer growth performance. Argentina and Brazil currently lead the world in SBM exports, but indications from our experiment are that they may be exporting a SBM that is less digestible than those produced in other countries.

Implications

Low-, intermediate-, and high-quality soybean meals collected from five different countries differed in chemical composition, but few differences existed in true amino acid digestibilities by swine. When compared with a U.S. standard soybean meal known to be of high quality, the soybean meals produced in Argentina and Brazil were less digestible, whereas the soybean meals produced in China, India, and the United States were similar in digestibility. These differences in true amino acid digestibilities among countries might offer a competitive advantage to feed formulators/ swine producers with knowledge of the highest-quality soybean meals available on the market.

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