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Quality of US Soybean Meal Compared to the Quality of Soybean Meal from Other Origins

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Abstract Quality of soybeans and soybean meals (SBM) from non-US and US origins were compared. The US SBM was more consistent with higher digestibility (by KOH solubility), lower fiber and better quality of protein (by essential amino acid levels) than SBM of other major export origins (Argentina, Brazil and India). Protein quality carried through from whole soybeans to SBM, for a given origin. While the protein content was higher for the SBM from Brazil, the percentage of total digestible amino acids was highest for the SBM from the US and China. The US SBM had the highest content (total) of five essential amino acids for both poultry and swine feed uses, which when coupled with higher digestibility, would give US meal an advantage in rations balanced on amino acids. The mean particle size for all SBM from all origins was within the desirable range specified by nutritionists. The US soybeans were lower in protein than Brazilian soybeans, but higher than Argentine soybeans. The crude protein disadvantage of US soybeans was offset by higher concentrations of the essential amino acids in the lower protein soybeans. The US soybeans were lower in oil content than soybeans from either of the South American origins. Average protein and oil contents of US soybeans were consistent with the 2003 and 2004 annual soybean quality surveys. The US SBM held an advantage in digestibility and concentration of key amino acids in all three studies.

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Introduction

The large variation in the world environmental conditions in which soybeans are grown combined with the differences in varieties and agricultural practices create soybeans with varying quality parameters. Furthermore, the differences in meal processing conditions such as moisture, temperature and drying time result in soybean meals with different composition and quality parameters. Traditionally, United States has been the dominant supplier in the global soybean market but the South American (Brazil and Argentina combined) market share of soybeans increased from 34% in 1999 to 42% in 2004 [1].

The comparative quality of soybeans and soybean meals (SBM) from the United States and other origins has been studied. Grieshop and Fahey [2] determined that soybeans from China had a higher crude protein (42.14%) and a lower lipid concentration (17.25%) than those from Brazil (CP = 40.86%, lipid = 18.66%) and US (CP = 41.58%, lipid = 18.70%) on a dry matter basis. Moizuddin [3] and Park [4], in separate studies, found that SBM samples from EU and US had the highest level of protein and the lowest level of fiber compared to SBM from India, Brazil, Argentina and China.

Studies conducted by Batal et al. [5] and Araba and Dale [6] reported a growth depression when chicks consumed under-processed SBM with protein solubility in KOH (alkaline) higher than 85% [5] and when they consumed meal that had protein solubility less than 70% (over-processed) [6]. Moizuddin [3] found that the KOH solubility values were within the acceptable range of 80–85% for

SBM samples from EU, US and China while SBM samples from Brazil had an average KOH solubility value of 80%, which would not leave much allowance for deterioration during storage and shipping.

Amino acids (AA) determine the species-specific feeding value. Lysine, methionine, threonine, cysteine and tryptophan are five key amino acids that are essential for both swine and poultry nutrition. Moizuddin [3] reported that the lysine content of SBM from US and EU were consistently higher compared to SBM from other origins. The relative percentage of lysine in protein was higher in SBM from the US and EU. The SBM from the US over the surveyed years were reported to be highest in quantity and protein quality. Karr-Lilienthal et al. [7] reported 87% true digestibility in Argentine SBM, 82% in Brazilian SBM and 91% in US SBM. Digestibility differences magnify differences in measured protein quality.

The objectives of this work were to survey the quality of 2004 crop soybeans and SBM from non-US and US origins and to compare current results with data reported from previous studies.

Experimental Procedures

Sample Procurement

The American Soybean Association representatives collected 500–1,000 g soybean and SBM samples from locations in eight countries. Samples were shipped to the Grain Quality Laboratory at Iowa State University in quart Ziploc freezer-quality bags. Samples were identified by the date of collection, country of origin, country of production (SBM), location of collection, vessel or other container identification (if possible), and sampling method (if possible or known). Samples from flowing meal or soybeans were requested but the actual sampling methods were not generally provided. The number and location of the soybean and SBM samples obtained for this investigation is summarized in Tables 1, 2, respectively.

Compositional Analysis

Individual soybean and SBM samples were mixed and divided into four fractions using an electric grain divider (Gamet Rotary Divider, Gamet Seedburo Inc, Chicago, USA). The methods of sample handling, preparation and analysis are described in flowcharts of Figs. 1, 2.

Soybeans

One fraction of each soybean sample was sent to Eurofins Scientific, Inc. (Des Moines, IA, USA) to be analyzed for moisture, protein (combustion), oil and free fatty acids (FFA) using the American Oil Chemists' Society (AOCS) official methods Ac 2–41 (revised 1997), Ba 4e-93 (revised 2003), Ba 3-38 (revised 1997) and Ac 5-41 (revised 2000), respectively [8]. The second fraction was ground and sent to University of Missouri-Columbia Experiment Station Laboratories for analysis of 23 amino acids using Association of Official Analytical Chemists official method AOAC 982.30E [9]. The remaining two fractions were combined and scanned in near infrared instruments (Foss Infratec 1229, Foss Infratec 1241 and NIRSys 6500) (Foss North America, Eden Prairie, MN, USA) for moisture, protein, oil and fiber to validate US calibrations for these factors. After scanning, the samples were retained under refrigeration at 4 °C at the Grain Quality Lab.

Soybean Meal

One fraction of each SBM sample was sent to Eurofins Scientific, Inc. (Des Moines, IA, USA). The SBM samples were analyzed for moisture, protein (combustion), oil, fiber, ash and nitrogen solubility index (NSI) using AOCS methods Ba 2a-38 (revised 2003), Ba 4e-93 (revised 2003), Ba 3-38 (revised 1997), Ba 6-84 (revised 1997), Ba 5a-49 (revised 1997) and Ba 11-65 (revised 1997), respectively [8]. The SBM samples were also analyzed for (1) non-protein-nitrogen (NPN), (2) mold count, and (3) protein solubility by KOH method using (1) AOAC method 941.04, (2) AACC method 42–50 [10], and (3) AOAC 971.09, respectively. The protein content for SBM was also analyzed using AOCS method Ba 4d-90 [8] as a part of the NSI test.

The analysis of second fraction of SBM samples was the same as that of the second fraction of soybean samples. The third fraction of SBM samples was used for particle size analysis using Ro-tap style shaker (W. S. Tyler, Mentor, OH, USA). Fourteen sieves were used for particle size determination that ranged from 53 to 4,760 μm. The geometric mean diameter and the standard deviations were calculated using American Society of Agricultural Engineers standard method S319.2 [11]. The last fraction was scanned in near infrared instruments (Foss Infratec 1229, Foss Infratec 1241 and NIRSys 6500) (Foss North America, Eden Prairie, MN, USA) for moisture, protein, oil and fiber to validate previous calibrations for these factors. After scanning, the samples were retained under refrigeration at 4 °C at the Grain Quality Lab.

The digestible limiting amino acid (DLAA) content was calculated for both swine and poultry nutrition as: DLAA = limiting amino acid × KOH protein solubility.

Table 1 Quality of soybeans by origin (13% moisture basis)

Characteristic	USA	Brazil	Argentina	Other	Range
Number of samples	55	35	19	6	
Protein (%)[a]	34.8 B	35.5 A	33.3 C	36.0 A	(27.3–39.6)
Amino acids (% of soybeans)					
Lysine	2.22	2.22	2.16	2.38	(2.05–2.53)
Methionine	0.48	0.47	0.47	0.5	(0.42–0.55)
Threonine	1.33	1.34	1.34	1.37	(1.23–1.45)
Cysteine	0.53	0.51	0.51	0.56	(0.44–0.64)
Tryptophan	0.47	0.48	0.48	0.47	(0.30–0.61)
Five key amino acids (sum)[b]	5.03 AB	5.01 B	4.95 B	5.27 A	(4.52–5.46)
TAA (%)[c]	33.76	34.67	34.67	35.48	(31.04–38.44)
Oil (%)[d]	18.2 C	19.5 A	19.1 AB	18.5 C	(15.7–20.9)
FFA % of oil[e]	1.1 B	1.3 A	1.0 BC	0.7 C	(0.4–2.4)

[a, b, d, e] Mean in the rows having the same letter are not significantly different ($p = 0.05$)

[c] *TAA* total amino acids

Comparison with Previous Studies

The soybeans and SBM quality data from this survey were compared to similar data from previous studies done at Grain Quality Laboratory at IOWA State University. The soybean data was compared to the US annual soybean quality surveys from 2003 [12] and 2004 [13] crop years. The SBM data was compared to the studies done in 1995–1999 by Moizzudin [3] to compare the quality of SBM in the US and world market and the global SBM sampling and analysis project done by John Baize and Associates [14] in 1999. As in the current study, SBM samples were collected by American Soybean Association representatives in different countries. The samples were shipped to the Grain Quality Laboratory at IOWA State University where they were analyzed for various quality factors. Soybean samples were not used for these studies. A summary for overall averages of SBM composition of the past years was prepared for the major export origins of US, Brazil, Argentina and India.

Statistical Analysis

All the analytical results for soybeans were expressed as 13% moisture basis. The SBM results were expressed as 12% moisture basis. The data was sorted based on country of origin and country of collection. The SBM from UAE, Indonesia, Malaysia, Philippines and Korea were pooled under one category named “Asia” and SBM from Mexico, Guatemala, El Salvador, Panama, Costa Rica, Trinidad, Barbados and Paraguay were pooled under another category called “Others” because there were very few samples available from these countries individually. Sample means, standard deviations, and minimum and maximum values were determined by country of origin. The means were evaluated by least significant difference method (LSD, $p = 0.05$). The data was statistically analyzed using JMP 5.1 software (SAS Institute Inc., Cary, NC, USA).

Results and Discussion

Soybean Quality

Table 1 shows the compositional comparison of soybean samples by country of origin. Soybean samples from Brazil and Others had the highest protein content. The protein content of US soybeans were significantly lower than those from Brazil and Others and significantly higher than those from Argentina ($p = 0.05$). The protein content was the lowest for soybeans from Argentina.

The soybean samples from Brazil and Argentina had the highest oil content. The oil content of soybeans from US was significantly lower than those from Brazil and Argentina and was not significantly different than those from Others ($p = 0.05$).

The free fatty acid (FFA) content is an indicator of chemical change in soybean oil and estimates the degree of hydrolytic rancidity of oil. According to NOPA [15] specifications, the maximum allowable FFA content is 0.75% in crude degummed soybean oil, 0.10% in once refined soybean oil and 0.05% in fully refined soybean oil. Shipments exceeding specifications are discounted according to NOPA rules. Generally, a FFA content of 1% or higher leads to a poor oil quality. High values of FFA content can occur when soybeans are stored at high temperatures (such as on a long ocean voyage) and in broken beans.

The mean FFA content of soybean samples from all origins except Others was higher than 1%. Soybeans from Others had an average FFA content of 0.68%. The FFA content was the highest for the soybeans from Brazil and lowest for the soybeans from Others and Argentina. The

Table 2 Quality of soybean meal by origin (12% moisture basis)

Characteristic	USA	Argentina	Brazil	India[a]	Asia[a]	China	Other[a, b]	Range
N	40	44	22	17	14	5	8	
Protein (%) [c]	47.5 B	46.0 D	48.8 A	46.6 CD	47.4 BC	46.3 BCD	47.8 ABC	(42.7–51.1)
Amino acids (%)[d]								
Lysine (%)	3.01	2.89	3.00	2.87	2.99	3.00	3.06	(2.64–3.19)
Methionine (%)	0.65	0.62	0.64	0.59	0.65	0.63	0.69	(0.50–0.73)
Threonine (%)	1.81	1.73	1.82	1.74	1.79	1.83	1.84	(1.56–1.98)
Cysteine (%)	0.70	0.68	0.70	0.63	0.70	0.70	0.76	(0.51–0.82)
Tryptophan (%)	0.68	0.67	0.70	0.66	0.68	0.66	0.74	(0.46–0.85)
Five key AA (sum)	6.86	6.59	6.86	6.48	6.82	6.82	7.08	(6.02–7.29)
Five AA % of protein[e]	14.4 A	14.3 BC	14.1 AB	13.9 C	14.4 A	14.7 ABC	14.8 A	
TAA (%)[f]	45.12	44.41	47.16	45.18	46.25	45.60	46.93	(40.66–49.95)
DTAA (%)[g]	39.58	37.45	39.29	38.91	39.88	40.27	40.90	(32.76–45.49)
Digestible five key AA coefficient %	6.01	5.55	5.71	5.58	5.88	6.02	6.17	(4.71–6.64)
DLAA[h] (S) (%)[i]	4.83	4.46	4.60	4.53	4.71	4.85	4.92	(3.84–5.34)
DLAA (P) (%)[j]	4.80	4.42	4.54	4.48	4.68	4.82	4.87	(3.77–5.28)
KOH solubility (%)[k]	87.7 A	84.3 B	83.3 B	86.1 AB	86.2 AB	88.3 AB	87.1 AB	(70.4–93.4)
Oil (%)[l]	1.2 C	1.7 A	1.6 AB	1.1 C	1.4 BC	1.2 BC	1.2 BC	(0.5–2.6)
Fiber (%)[m]	4.2 B	4.4 B	4.5 B	6.7 A	4.2 B	6.1 A	3.7 B	(2.8–7.7)
Ash (%)[n]	6.5 B	6.6 B	6.2 C	7.3 A	6.4 BC	6.5 B	6.5 B	(5.3–8.7)
NSI (%)[p]	14.1 BC	13.9 C	12.6 D	15.7 A	14.9 ABC	15.9 AB	15.2 AB	(9.6–23.4)
Non-protein nitrogen (%)	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	<1.0	–
Ammonia (%)	–	–	–	–	–	–	–	–
Mold count (cfu/g)	377[q]	507	1,803	3,191	179	158	1,135	(10–220,000)
Particle size (μm)[r]	1,070 AB	1,074 AB	1,088 AB	1,262 C	1,138 B	1,131 B	1,019 A	(688–1,621)

[a] Samples (one each) from Trinidad, India, Malaysia excluded because of very high oil (8.0, 18.2, and 20.3%, respectively)

[b] Other: Barbados, Costa Rica, El Salvador, Guatemala, Panama, Paraguay, Trinidad, Mexico

[f] *TAA* total amino acids

[g] *DTAA* digestible total amino acids

[h] *DLAA* digestible limiting amino acids

[i] *DLAA* (S) digestible limiting amino acids for swine: lysine, threonine and tryptophan

[j] *DLAA* (P) digestible limiting amino acids for poultry: methionine, lysine and threonine

[q] Two samples from one collection point (Turkey) with over 200,000 cfu/g removed from average

[c, d, e, k, l, m, n, p, r] Mean in the rows having the same letter are not significantly different ($p = 0.05$)

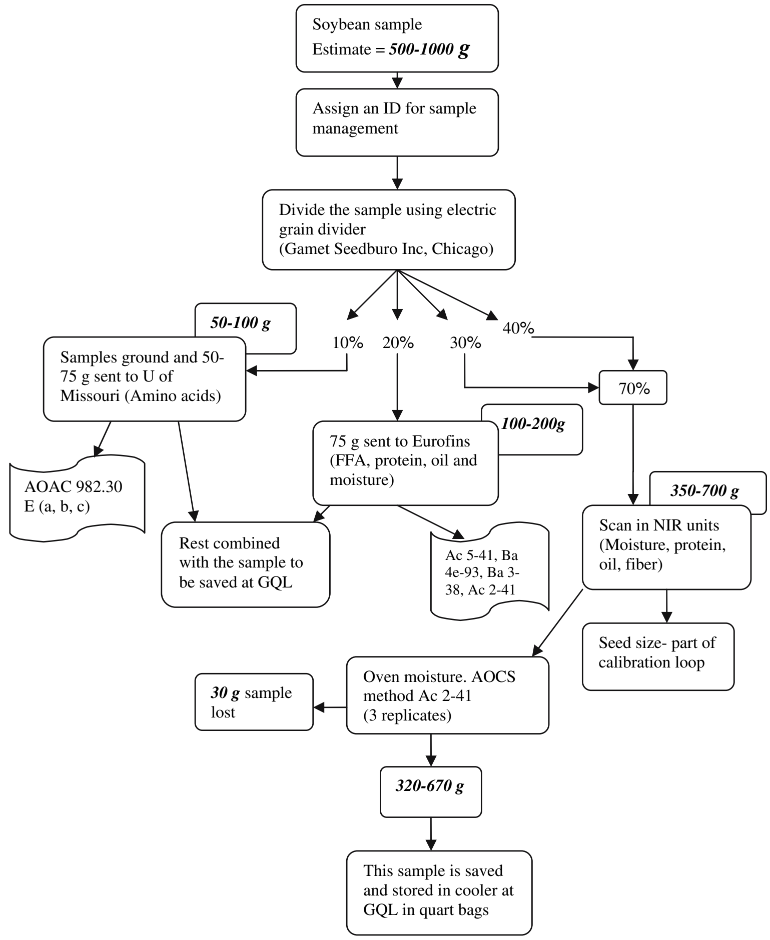
FFA content of samples from US was significantly lower than those from Brazil but significantly higher than Others ($p = 0.05$).

Figure 3 shows the sum of five key amino acids (Threonine, Methionine, Tryptophan, Cysteine, Lysine) for soybeans from three origins as actual percentage by weight and as a percentage of crude protein. The percentage of amino acids present in protein may decrease when the protein content increases. The line representing the five key amino acids calculated as a percentage of crude protein in Fig. 3 has a negative slope for soybeans from US and Brazil indicating a decrease in amino acid concentrations as protein content of soybeans increases. In contrast, Argentine soybeans indicated an increase in amino acids concentration with an increase in protein content (Fig. 3).

Soybean Meal Quality

The compositional comparison of the SBM samples by country of origin is presented in Table 2. The SBM from Brazil and Other origins had the highest protein content whereas the samples from Argentina, China and India had the lowest protein content. The protein content of SBM from USA was significantly lower than that from Brazil,

Fig. 1 Soybean handling and analysis procedure



but was not significantly different from Asia, China and Others. The protein content of samples from India, China and Argentina was not significantly different from each other ($p = 0.05$).

The residual oil content was highest for the SBM samples from Argentina and Brazil and lowest in those from India, China and Others. The oil content of SBM from US was significantly lower than those from Argentina and Brazil ($p = 0.05$). Oil is extracted from soybeans under different processing conditions. These differences in processing conditions (such as temperature, moisture, residence time and fineness) may result in SBM of varying residual oil content.

The samples from India and China had the highest fiber content while those from Others, Asia and USA had the lowest fiber content. The fiber content of SBM samples from India and China was significantly different from the fiber content of US SBM while those from US, Asia, Argentina, Brazil and Others were not significantly different ($p = 0.05$).

The ash content was highest for the samples from India and lowest for the samples from Brazil. The ash content of SBM from India and China was significantly different from the ash content of US samples while the samples from US, Asia, Argentina and Others were not significantly different ($p = 0.05$). Higher ash in the samples from India was supported by the visual observation of more non-meal material in these samples.

The NSI estimates the extent of denaturation of proteins. This value was highest for the SBM from China and India and lowest for the samples from Brazil. The NSI content of SBM samples from India was significantly higher than those from US SBM while the samples from Brazil were significantly lower than those from US ($p = 0.05$). The NSI values ranging from 15–30% on a 12% moisture basis are recommended for both 44% protein and dehulled SBM. Only the SBM samples from China and India were in this range.

The protein solubility index determined by KOH method estimates protein digestibility of feed and is widely used to estimate the under or over-processing of SBM. Under and over-processing refers to inadequate or excessive heat treatment, respectively, than required. The recommended range for protein solubility index is 73–85% [16]. The SBM from all countries except Argentina and Brazil had protein solubility index higher than 85%

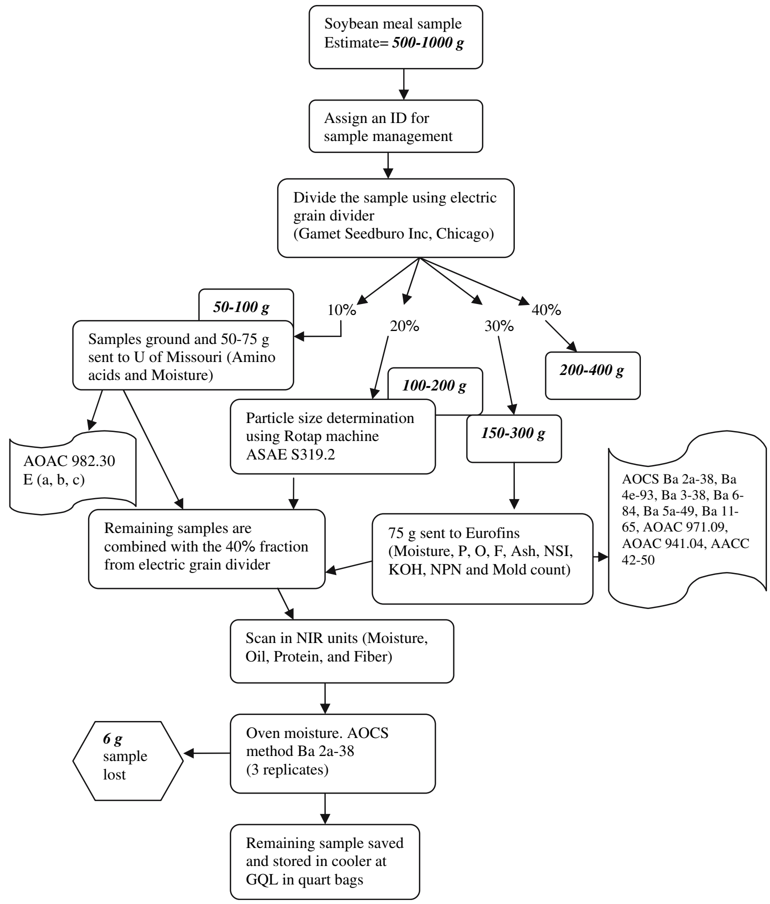


Fig. 2 Soybean meal handling and analysis procedure

suggesting that these meals were under-processed. The KOH value of SBM from the US was significantly higher than those from Brazil and Argentina while the samples from US, Asia, China, India and Others were not significantly different ($p = 0.05$). A positive correlation was expected between protein solubility index and the nitrogen solubility index, since over-processing of SBM will result in more denaturation of protein and hence, lower KOH protein solubility index and NSI. Of all the SBM samples tested, a positive correlation ($r = 0.49$) was found between KOH protein solubility and NSI.

Non-protein-nitrogen (NPN) sources such as urea and ammonia are sometimes utilized in ruminant rations low in protein [17]. The NPN sources increase the apparent protein content of SBM. Poisoning by ingestion of excess urea or other sources of NPN is usually acute, rapidly progressing, and fatal [18]. Non-protein-nitrogen (NPN) present in SBM indicates the presence of urea or ammonia in meal. One SBM sample from India failed the criteria of less than 1% NPN, with a value of 2.73 and 0.17% ammoniacal nitrogen present in meal.

Mold counts in feed is indicative of potential digestive and toxic problems. The average mold count was highest for the SBM of US origin and was lowest for the SBM from China. However, all samples were well within nutritional guidelines. There were two samples of US origin collected by Turkey and Japan ASA offices that had a mold count of over 200,000 cfu/g. This value was still lower than 1,000,000 cfu/g at which mold becomes viable and poses serious health hazards if fed to livestock [18].

Amino Acid Profile of SBM

The amino acids that an animal cannot synthesize from proteins fed and must be supplied within the feed are referred to as essential amino acids. The amino acids present in the lowest amount in a feed relative to their requirement by the animal are referred to as the limiting amino acids [19]. The limiting amino acids for swine are lysine, threonine and tryptophan and for poultry are methionine, lysine and threonine. The amino acid contents of SBM from different origins are shown in Table 2. The percentage of total amino acids (TAA) for SBM from Brazil was significantly higher than those from Argentina while TAA for SBM from Others were not significantly different ($p = 0.05$). The percentage of total digestible amino acids (TDAA) (KOH times TAA) for SBM from US was significantly higher than those from Argentina while TDAA

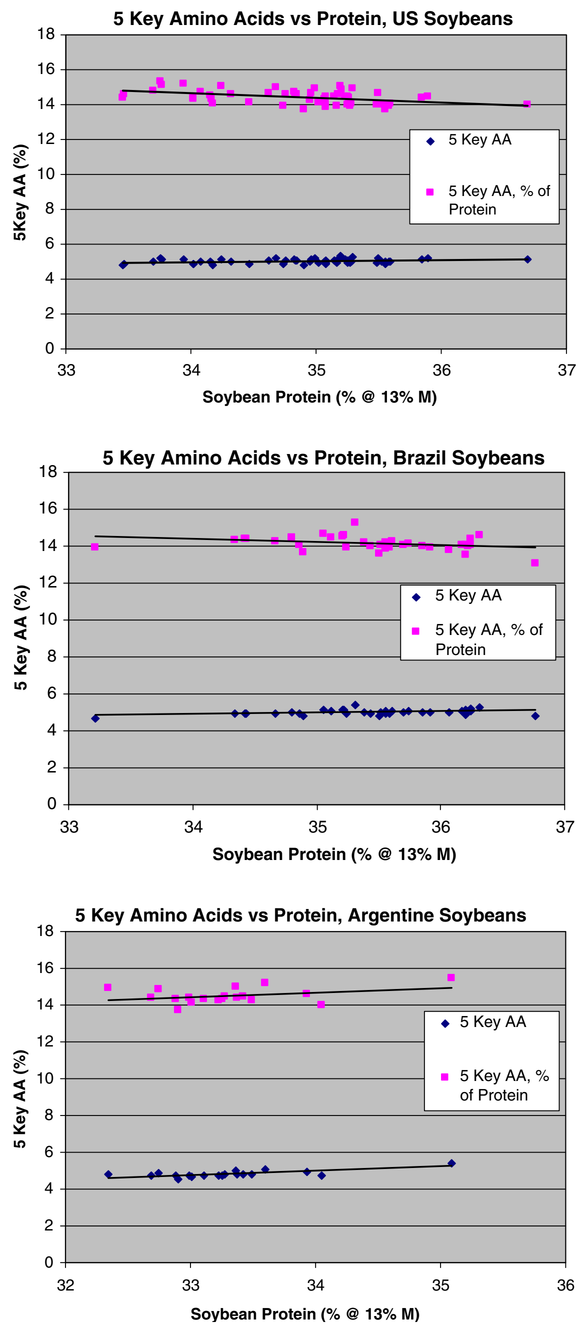


Fig. 3 Sum of five key amino acids of soybeans from different origins

for SBM from other countries were not significantly different ($p = 0.05$).

The percentage of the five limiting amino acids was the highest for SBM from Others, US and Brazil, and was the lowest for the SBM from Argentina and India. The limiting AA content of SBM from India and Argentina was significantly different from that of SBM from US while the samples from US, Others, Brazil, Asia and China were not significantly different ($p = 0.05$).

The percentage of digestible limiting amino acids (DLAA) for swine and poultry feed uses was the highest for SBM from Others, China, US and Asia and was the lowest for the samples from Argentina. The DLAA content of SBM from Brazil, India and Argentina was significantly lower than that of SBM from US while the samples from US, Others, Asia and China were not significantly different ($p = 0.05$).

The average lysine content in a 44 and 48% solvent extracted SBM is 2.90 and 2.96%, respectively, at 12% moisture [20]. The lysine content of all SBM samples from Argentina and India were below the published values. The tryptophan content of all SBM samples in the survey was above the published value of 0.60%.

The best amino acid profiles were in SBM from US while the poorest profiles were in SBM from Argentina. Although the total AA content was higher for SBM samples from Brazil than for the samples from US, the total digestible and digestible limiting AA content was higher for the SBM samples from US, Others and China. These samples had a higher DLAA as a percent of protein, therefore better protein quality.

Particle Size Analysis of SBM

Particle size of SBM is very important when the SBM is used in animal feed. Increased surface area for enzyme action improves efficiency of digestion and ultimately efficiency of body weight gain. The desired particle size for feed applications is between 250 and 1,700 μm, in a normal bell-shaped distribution [21]. Table 3 summarizes the particle size analysis data by country of origin. The mean particle size for the SBM from all origins was 1,120 μm, which is within the 250–1,700μm range specified for feed applications. There was a wide variation in the particle size of SBM across origins while the particle size within samples from the same origin was consistent. The mean particle size of SBM samples from China was more consistent than samples from other origins. The SBM samples from India had the poorest particle size distribution with highest

Table 3 Particle size of soybean meal by country of origin

Country of origin	Mean particle size (μm)	% in desired range (250 and 1,700 μm)
USA	1,070	84.1
Argentina	1,074	79.8
Brazil	1,088	83.7
India	1,262	65.5
China	1,131	88.1
Asia	1,138	91.1
Other	1,125	82.3

Table 4 Comparison of US soybean quality studies (13% moisture basis)

Study	Protein	Oil
This study[a]	34.8 A	18.2 A
2003 annual survey[b]	35.7 A	18.7 A
2004 annual survey[c]	35.2 A	18.7 A

[a, b, c] Mean in the rows having the same letter are not significantly different ($p = 0.05$)

mean particle size and lowest percentage of particles in the desirable range ($d = 1262$ µm, desirable % = 65.5). These samples also contained a large amount of foreign (clearly non-soybean) material.

Comparison with Previous Studies

Soybeans

The comparison of soybean quality from this survey with the previous US soybean crop annual quality studies is presented in Table 4. The average US protein and oil contents for 2003 were 35.7 and 18.7%, respectively (on a 13% moisture basis). The average US protein and oil contents for 2004 were 35.2 and 18.7%, respectively (on a 13% moisture basis). The average protein and oil contents for US soybeans were not significantly different for all the surveys ($p = 0.05$).

The US soybeans in this study were likely sourced from the western United States (exports to Asia, Mexico). These origins are normally lower than the national averages, in both protein and oil. If freight patterns that favor west coast shipments (in preference to the Gulf) persist, and if US domestic processors increase their programs to attract higher quality soybeans, the composition situation for exports is likely to continue.

Soybean Meal

Table 5 shows the comparison of SBM quality from this survey with quality reported in previous studies. The general quality rankings of SBM origin countries for the present study were similar to the previous studies. US meal held an advantage in digestibility and concentration of key amino acids in all three studies. Meals were reasonably equal in fiber content except for meal from India, which was higher. The 2004 SBM from US had higher protein solubility than samples from previous years. The protein content of the 2004 meals from Brazil were significantly higher than in previous years, from 46.7% in 1995–1999 survey to 48.8% in 2004. This may reflect Brazilian production expanding north, toward the equator. Protein quality as measured by the content of five key amino acids was similar to past years. The crude protein disadvantage of US SBM was offset by the better quality of protein combined with the higher protein solubility.

The US SBM was more consistent with higher digestibility, lower fiber and better protein quality than SBM from Argentina, Brazil and India. The US soybeans and SBM had higher concentrations of key amino acids despite originating from lower protein beans. The US soybean meal was higher in the five key amino acids content for both swine

Table 5 Comparison of soybean meal quality study results (12% moisture basis)[a]

	Origin	N	Protein (%)		Lys (%)		Cys (%)		Met (%)		5 key AA (% of P)	TAA (%)		KOH sol (%)	
2004	USA	40	47.5	B	3.01	A	0.70	B	0.65	A	14.4	45.12	AB	87.7	A
	Argentina	44	45.9	D	2.89	B	0.68	B	0.62	BC	14.3	44.41	B	84.3	BC
	Brazil	22	48.8	A	3.00	A	0.70	B	0.64	AB	14.1	47.16	AB	83.3	C
	India	18	46.6	CD	2.87	B	0.63	C	0.59	C	13.9	45.18	AB	86.1	AB
	Asia	15	47.4	BC	2.99	A	0.70	B	0.65	A	14.4	46.25	AB	86.2	AB
	China	5	46.3	BCD	3.00	A	0.70	AB	0.63	ABC	14.7	45.60	AB	88.3	A
	Other	9	47.8	ABC	3.05	A	0.76	A	0.69	A	14.8	46.73	AB	86.2	ABC
1995–-1999	USA	311	47.2	BC	2.98	A	0.69	A	0.65	A	14.3	46.01	A	85.0	A
	Argentina	70	45.5	D	2.80	B	0.62	B	0.61	B	14.0	43.90	C	79.9	BC
	Brazil	136	46.7	C	2.86	B	0.64	B	0.61	B	14.4	45.40	B	80.4	B
	India	143	47.5	B	2.84	B	0.64	B	0.63	AB	14.0	45.68	AB	76.3	C
Baize 1999	USA	16	47.7	A	3.00	A	0.74	A	0.68	A	14.5	46.06	A	83.4	A
	Argentina	10	45.0	C	2.84	B	0.67	B	0.62	B	14.3	43.95	B	76.2	C
	Brazil	14	46.9	AB	2.82	B	0.70	B	0.62	B	13.9	45.11	A	78.7	BC
	India	17	46.8	B	2.91	A	0.68	B	0.64	B	14.2	46.01	A	80.6	B

[a] Mean in the rows having the same letter are not significantly different ($p = 0.05$)

and poultry feed uses, which, when combined with higher digestibility, would give US meal an advantage in the diet rations balanced on the basis of amino acid requirements of the animals being fed. Thus, the key feeding value parameters were not necessarily decreased by an overall reduction in protein level. This can be used to the US advantage if the market recognizes amino acids rather than just crude protein as the indicator of feeding value.

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