Improving the U.S. Position in World Soybean Meal Trade

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Abstract

In order to improve the value of U.S. soybean meal in trade markets, problems with quality must be corrected. This can only be achieved by creating appropriate incentives for producers, improving the accuracy of meal protein and amino acid testing, and gaining acceptance for composition tests as pricing criteria. A study of various data sources and physical soybean meal samples found that U.S. soybean meal was more consistent and of higher feeding value than was soybean meal from several other exporting countries. Common near-infrared analyzers can provide useful measures of composition for pricing. Amino acid levels as a quality measure can be tracked from the whole soybean into soy meal. Continuing integrated analysis could produce a dramatic reorientation of high and low soybean and soybean meal value in the marketplace.

Key words: animal feed, soybean composition, soybean meal, soybean quality, market value, pricing incentives.

IMPROVING THE U.S. POSITION IN WORLD SOYBEAN MEAL TRADE

Background

Soybean meal is produced from the extraction of oil from whole soybeans. It is a widely traded, high protein animal feed concentrate. Meal quality and acceptance are directly linked to properties and processing conditions of input soybeans.

U.S. soybeans usually contain less protein and oil than do Brazilian beans. Soybeans from northern regions (including Iowa) within the United States trade at lesser prices than do southern and central beans, again because of well-documented composition differences. Table 1, generated from a 10-year survey of U.S. soybeans, demonstrates the variation in U.S. soybean quality, with an associated impact on processing. These problems cannot be corrected without an incentive to producers who choose superior genetics and cultural practices. Although protein and oil content of soybeans can be measured reliably and quickly at country elevators, the market has been slow to accept composition tests as pricing criteria. Domestic processors, representing 70 percent of soybean consumption, cite the lack of premiums for meal protein as the primary reason for not pricing raw soybeans by composition. Also cited is an uncertainty about accuracy of meal protein testing. Feed users generally agree that increased protein, if consistent, is of value but they add that the amino acid profile is really the key to protein.

Soybean meal is priced at either 44 percent (with hulls) or 48 percent (dehulled) protein content, with no premium for exceeding specifications. Soybean oil revenue is dependent only on volume extracted, but usually any gain in oil percentage is accompanied by a 2:1 loss in protein percentage. Therefore, pricing to increase oil alone would be a net loss because as soon as the high oil soybeans became low enough in protein, the basic contract protein could not be guaranteed. This situation is depicted in Figure 1 (Huck, Winborn, and Hurburgh 1998). The three state averages shown are 10-

year composition averages for a low protein state (Minnesota), an average protein state (Illinois), and a high protein state (Mississippi).

As long as domestic processors can meet the contract protein guarantees, based on averages, there is no incentive to reward higher protein beans. For this to change, meal protein must be tested at the point of sale with price adjusted accordingly. No amount of publicity or discussion about soybean composition will cause any tangible action until processors face meal sales incentives that reward them for purchasing beans based on composition. Farmers will not capture any of the estimated 10–30 cents per bushel value-added from improved soybean composition (based on protein alone) without a pricing structure for meal composition.

Protein analysis is only the first step in describing meal quality. Animal geneticists and plant breeders know that protein digestibility, amino acid levels, and other compounds less readily measured than protein or oil will eventually be of prime market importance. Crude composition analysis is a logical starting point because the measurement technology is available. However, rapid analysis of amino acids and other low-level compounds need to follow.

In world markets, both soybeans and soybean products are traded commodities. Clearly, the sale of products is of higher value to the United States, in terms of the amount of processor margin between input soybean costs and market value of products per unit of soybeans. Table 2 shows the falling percentage of U.S. soybean meal production exported as meal. The export of meat, which increases domestic meal consumption, is a higher-valued alternative method of increasing soybean price but requires a relatively affluent buyer. The increased export of soybean meal is an intermediate step in adding value, especially attractive to emerging customers who are without indigenous processing capacity.

The U.S. share of world soybean meal trade has been falling, diverting to South America. Figure 2 shows these trends and indicates that a much greater percentage of competitors' soybeans are exported as meal relative to that of the United States.

To reverse this trend, and to simultaneously increase the value of domestically utilized meal (and thus input soybeans), the following must be in place:

- accurate, universally available capability to measure first soybean meal moisture, protein, fiber, and oil, then amino acids, other trace nutrients, and digestibility;
- a domestic pricing structure to accommodate variations in meal composition and value;
- a comprehensive understanding of meal quality from various origins, with a nutritional assessment of those differences.

This research was intended to be a first step in the process. As the project developed, working objectives were modified somewhat.

Objectives

The following objectives were identified and prioritized:

1. Compile a world and U.S. soybean meal quality database.
2. Estimate the accuracy with which near-infrared (NIR) technology can measure soybean meal quality.
3. Begin an assessment of amino acid and protein digestibility as related to meal value and measurement. Define additional research needed.
4. Summarize available data relating meal quantity and quality to soybean composition, and project availability of higher quality meals.

Materials and Methods

Objective 1: Compile Meal Quality Database

With the assistance of a survey project funded by the United Soybean Board (USB), samples of soybean meal were collected in world markets. Collection of 500-1,000 gram samples was completed between January and May 1997 by American Soybean Association representatives in 14 countries. U.S. samples were obtained from selected feed mills, elevators, and processors. The existing database for 1995 U.S. soy meal samples was included for comparison purposes. Samples were shipped to Iowa State University.

All samples were measured for moisture, protein, oil, and fiber content using American Oil Chemists' Society (AOCS) Official Methods Ba 4e-93 (revised 1995), Ba 3-38 (revised 1993), Ba 6-84 (revised 1995), and Ba 2a-38 (revised 1993), respectively at

Woodson-Tenent, Inc., in Des Moines, Iowa. Samples were also scanned in five NIR analyzers, to develop calibrations for the above factors (and moisture). Urease activity was also measured as an indicator of the presence of trypsin inhibitor using AOCS Method (Ba 9-58 [revised 1993]).

Selected samples (designated by the USB) were analyzed for potassium hydroxide (KOH) protein solubility as a measure of protein digestibility, and for their amino acid profile as a measure of protein quality. We added U.S. samples to the amino acid group.

Objective 2: Assess Near-Infrared Technology

A basic calibration (one unit per brand, room temperature samples) was derived for each of five NIR brands. All are intended for use in processor laboratory situations, with four of the five designed for elevator use as well.

Calibrations were taken for moisture, protein, oil, and fiber content. Amino acid calibrations are in progress using additional samples generated from subsequent research. The amino acid chemistry data are quite costly compared to the basic proximate analyses. All the samples were used for calibration; outliers were then removed and documented. Cross-validation was used to estimate the accuracy of the NIR units on future samples. Of particular interest was the ability (or inability) of NIR to cover samples from all origins and expeller processes as well as from solvent process meal.

Objective 3: Assess Amino Acid Values

Standard estimates of amino acid levels in soybeans and soybean meal were compiled from various published sources. A summary was completed for lysine, methionine, cysteine, and tryptophan content, as these are the amino acids most likely to be limiting in animal diets. These were compared to the data obtained from domestic and world market meals.

Several indexes were developed to describe relative amino acid levels. The tracking of amino acid quantities was added to the Iowa State processing model SPROC, which is widely used to calculate process outputs/values from soybeans of varying composition. Digestibility was included as a multiplier to the protein and amino acid percentages. Conceivably, a digestibility increase could improve amino acid availability enough that a given amino acid could become surplus rather than limiting.

Objective 4: Summarize Meal Quality and Availability Data

Data from previous soybean surveys and variety trials were used to estimate the present and potential distribution of higher protein meals. The effect of amino acid correlation with protein was also estimated. The projected impact of variety selection based on composition was included. The source data for this objective originated entirely from other projects.

Results and Discussion

Meal Quality Database

Table 3 shows the quality of soybean meal by point of sampling. Contractual specifications for each sample were not known; however, U.S. soybean meal was notably higher in protein and lower in fiber than meals received from various other origins. Overall, there was significant variation in the quality of soybean meal in world markets.

Table 4 shows the quality of soybean meal by point of processing origin, and probably by soybean origin, especially for the United States and Latin American countries. Again, U.S. meal was significantly lower in fiber content, and among the highest in protein content. Notably, Brazilian meal, originating from soybeans with proven higher protein and oil content, was not superior to U.S. meal. Brazilian meal was pelletized, but pellet quality was generally poor and uneven.

Urease activity, expressed in pH rise under the conditions of the test, indirectly indicates the presence of a trypsin inhibitor in soybean meal. Only one sample failed to meet the criteria of below 0.2 for feed application.

There were clear visual differences in the samples, indicating different chemical values. Samples from India and China, among the highest in fiber, contained obvious bits of fibrous material other than soybean hulls. The expelled samples were noticeably more yellow and slicker, because of their higher residual oil content. Overall, the U.S. samples had the best particle size consistency and visual appeal.

Contract specifications were not given, but Table 5 shows a comparison of the samples to U.S. 44 percent and 48 percent standard specifications. A 0.5 percent point allowance for low protein and a 0.3 percent point allowance for fiber were used. These are the allowances in the National Oilseed Processors Association trading rules for meal.

Samples were counted only once, at the highest quality meal for which they would qualify.

The data show that few non-U.S. samples would qualify as high-protein meal in U.S. markets; as low protein meal the quality varied considerably. It is noteworthy that the failure to meet the fiber specification disqualified a majority of Brazilian samples as high protein meal. Worldwide processors are not producing uniform products; this introduces risk into the trade of a commodity. The U.S. samples were much more consistent, even though the source soybeans originated from a wide geographic area with proven variations in composition.

Table 6 shows the quality aspect of protein in soybean meal, amino acid make-up, and digestibility (protein solubility). U.S. samples were among the highest in limiting amino acids and KOH protein solubility. They also were more consistent in KOH protein solubility, as indicated by the smaller standard deviation compared to samples from other countries.

Near-Infrared Analysis

Calibrations for moisture, protein, oil, and fiber were developed for the near-infrared analyzers listed in Table 7. Only the solvent-extracted samples were used because an analysis of the spectral data showed expeller meal to be very different from solvent meal. Inclusion of expeller meal would have increased the error in calibration and thus had to be measured on a separate calibration.

Performance was comparable. Surprisingly, the unit with the least spectral capability, Foss Grainspec, was very similar to the others if not slightly better. The range divided by the SECV is often used as an evaluation statistic; all these calibrations were greater than 10 in this ratio, which means good quantification was possible, despite the wide range of sample origins. Protein was the most difficult factor to measure, followed by fiber. Most of the outliers excluded from calibration were for high-fiber samples.

Amino Acid Values

Table 8 shows several standard estimates of amino acid composition for soybean meal, compared to the data collected in the survey samples and from other sources. U.S.

samples compared very favorably with samples from other origins and were somewhat better than published values.

Any amino acid increases in soybean meal must arise from amino acid improvements in the input soybeans. The relative amino acid content (any amino acid as a percentage of total protein) is unchanged by oil removal and is a useful measure of both soybean and soybean meal quality. Assuming that meal is blended to a market target protein level, relative amino acid levels will distinguish higher- and lower-valued meals.

Tests of 1997 crop whole soybeans indicated that relative amino acid values were higher in lower protein U.S. beans than in higher protein beans. This result should be investigated because the lower protein western Corn Belt soybeans could produce better soybean meal even though the nominal crude protein levels are lower for these soybeans.

Amino acid levels can be tracked from whole soybeans into meal. This is important because an amino acid analysis on whole soybeans can be carried forward to a value calculation for extracted meal. The Iowa State University processing model SPROC (Brumm and Hurburgh 1990) was modified to predict meal amino acid levels as well as protein, oil, and fiber levels. Table 9 shows example results, based on the range of amino acid data for whole soybeans, except for #6, which is a concept example of amino acids sharply elevated at the expense of total protein. The conclusion is that lower protein soybeans do not necessarily yield lower aggregate values, depending on what species of livestock is to be fed. This is an important finding for growers and processors in naturally protein-deficient areas and provides opportunities for market targeting to mitigate the climatic problem. Development of this concept would be an important follow-up to this project.

Availability of Meal

The long-term national soybean quality database was used to estimate availability of meal at various protein levels. Amino acids were not included because the relationship between protein and relative amino acids is not sufficiently documented to be predictive. Amino acid values were not measured for these samples. Table 10 reports the results.

Overall, about 8 percent of U.S. soybeans could not make high protein meal, and nearly 25 percent would make meal in excess of high protein standards. The predicted percentage over 48.5 percent protein was nearly the same as the meal survey data (Table 5) indicated.

The impact of the previous suggestion concerning amino acids–protein relationships could be significant because the meal from protein-deficit states is more likely to originate from low protein soybeans. While processors in those areas may have to accept either lower protein meal or smaller outputs of meal within specifications, this meal may have higher feeding value per unit by virtue of higher levels of essential amino acids. The penalty structure for protein on meal does not consider this possibility. A 1 percentage point increase in the lysine ratio (the share of protein that is lysine) would produce approximately 0.25 lb of additional lysine per bushel of soybeans, an added value of about $0.50/bu at today's amino acid prices ($2.00/lb). This would offset at least a 1 percentage point decline in crude protein, even if the protein decline would take meal protein below 47.5 percent.

A 1993 study (IAHEES 1993) proposed that dramatic increases in lysine or methionine could have large value to meal users. This study did not examine the interrelationships of amino acids and protein in rations, nor did it consider the impact on cost and the environment from overfeeding nitrogen from nonessential amino acids. Doubling either lysine or the sulfur containing amino acids, even at the expense of reduced total protein, is likely to produce significant net increases in value ($1.00–$2.00/bu), which can be captured by sophisticated meal users and produced even in areas where there is high soybean yield yet a chronic climate-induced protein deficit. It is clear that an integrated study of animal performance, various available feedstocks, and agronomic possibilities could yield major rewards system-wide.

Summary

From the various data sources and the physical sampling of soybean meal, the following summary points are drawn.

- Meal of U.S. origin was more consistent and of higher feeding value (more digestible, lower in fiber, often higher in protein, and having better quality protein) than meal of other origins. This is an important and useful marketing advantage for the United States.
- Common NIR analyzers can measure the proximate analysis of meal with the following relative accuracy, expressed as a data range divided by the standard

error of prediction (versus reference):

Moisture	24–32
Protein	17–21
Oil	34–43
Fiber	15–18

A relative accuracy of 15 is considered excellent for useful quantification.

- Amino acid levels can be tracked from whole soybeans into soybean meal. Analysis of soybean samples shows that reduced total protein (e.g., in northern growing areas) does not necessarily mean reduced feeding value of meal even at lower nominal protein levels. Likewise, soybean modifications that sharply increase limiting amino acids, even at the expense of total protein, may be best directed toward protein deficit areas.
- An integrated study of animal performance, multiple feedstuffs, and agronomic/genetic possibilities has the potential to dramatically reorient high and low soybean and soybean meal values in the marketplace.

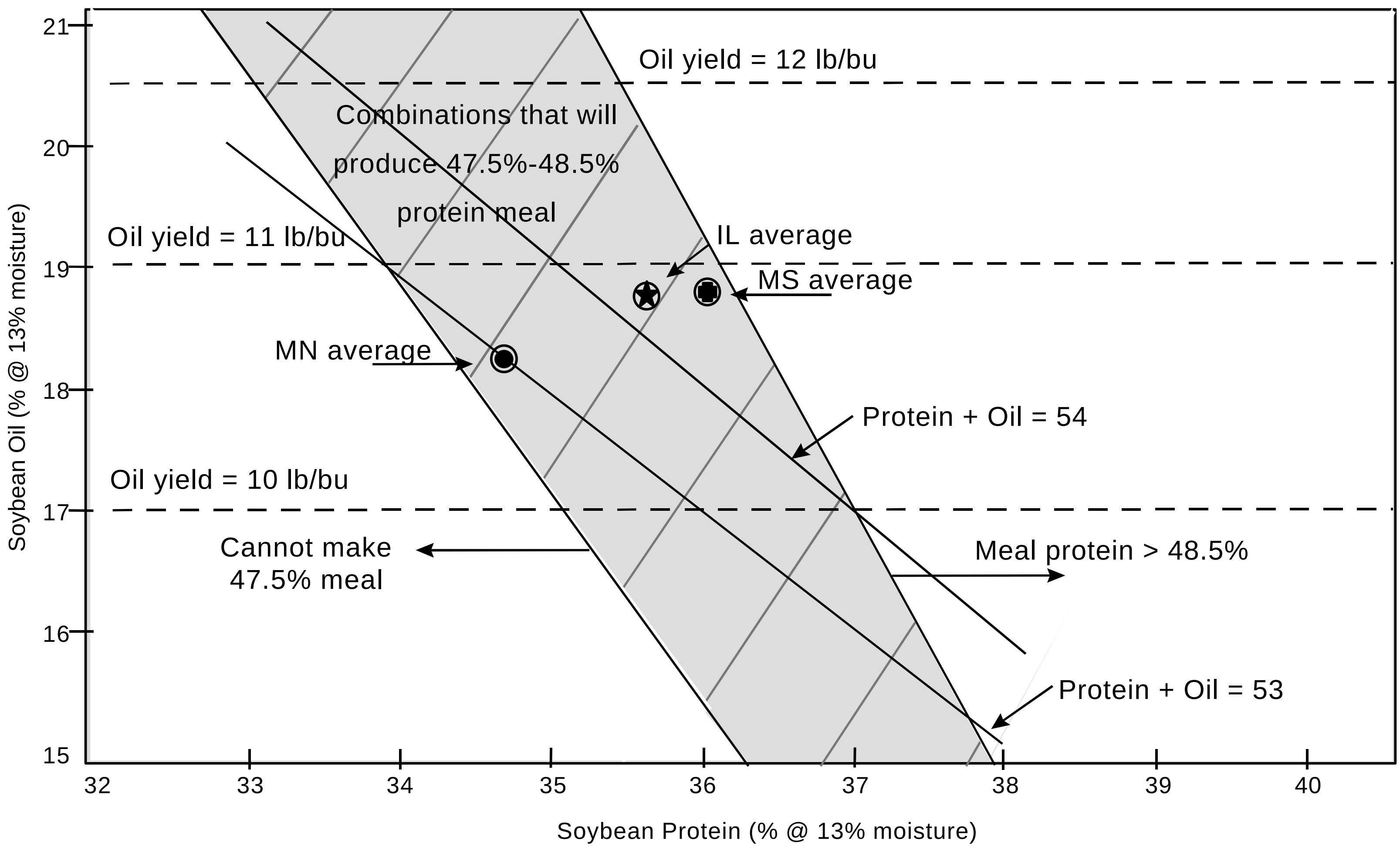
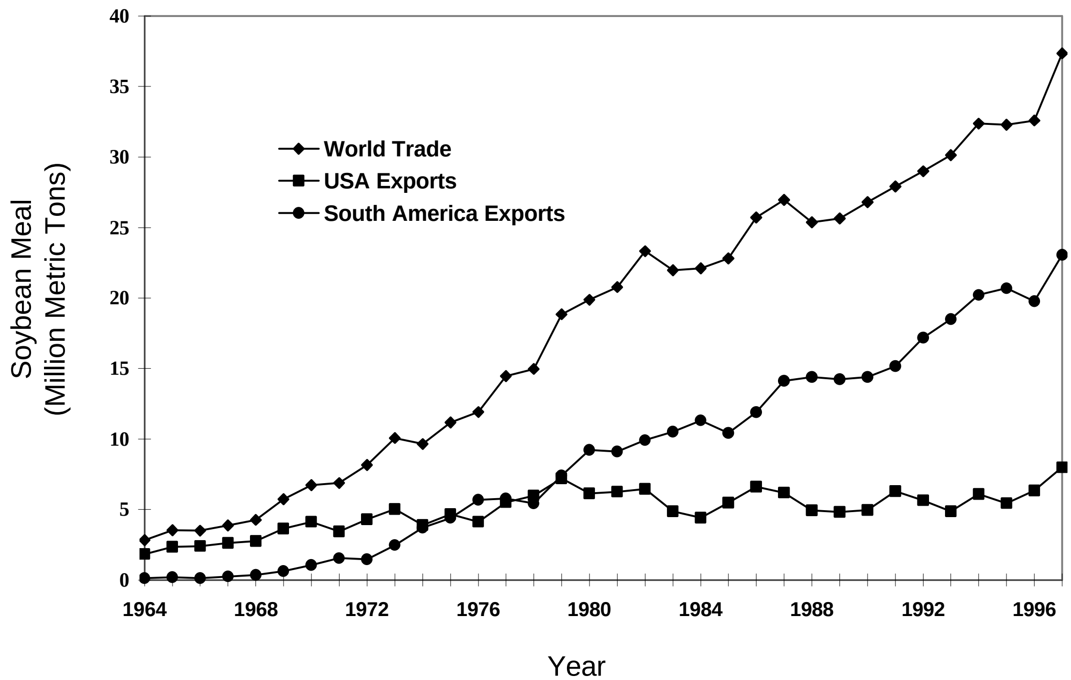


FIGURE 1. Protein and oil combinations that will produce 47.5 percent to 48.5 percent protein meal



Source: USDA, Economic Research Service

FIGURE 2. Soybean meal exports in world markets

TABLE 1. State-by-state variation in soybean quality and process yields, 1986–96 (ranges in parentheses)

			Soybeans		Products			Variability of components as measured by average standard deviation	
Region	**State**	**n (1-year total)**	**Protein (%)**	**Oil (%)**	**Meal (lb/bu)**	**Meal Protein (%)**	**Oil (lb/bu)**	**Protein (% pts)**	**Oil (% pts)**
WCB	IA	2571	35.1	18.4	42.7	48.0	10.8	1.14	0.70
	KS	319	35.3	18.4	42.9	48.2	10.8	1.20	0.33
	MN	1277	34.9	18.2	42.5	47.9	10.6	1.10	0.67
	MO	1057	35.6	18.5	43.1	48.4	10.8	1.29	0.78
	ND	182	34.4	18.3	42.2	47.3	10.7	1.27	0.75
	NE	867	34.7	18.7	42.4	47.9	10.9	1.19	0.62
	SD	323	34.6	18.3	42.2	47.8	10.7	1.15	0.74
		6590	35.06 (28.4-40.8)	18.42 (12.1-22.1)	42.7 (38.6-48.8)	48.0 (39.5-53.2)	10.8 (6.9-13.0)	1.27	0.78
ECB	IL	3147	35.4	18.7	42.9	48.3	10.9	1.29	0.79
	IN	1305	36.0	18.3	43.5	48.6	10.7	1.16	0.70
	MI	317	36.0	17.8	43.6	48.4	10.4	1.28	0.73
	OH	1218	36.1	18.1	43.6	48.5	10.6	1.22	0.66
	WI	78	35.6	18.2	43.2	48.2	10.6	1.11	0.61
		6065	35.67 (30.4-40.7)	18.40 (15.2-20.6)	43.2 (39.1-46.9)	48.4 (43.2-52.8)	10.7 (8.4-12.6)	1.32	0.82
MDS	AR	429	35.9	18.2	43.4	48.4	10.6	1.44	0.83
	KY	206	35.9	18.2	43.5	48.5	10.6	1.14	0.71
	LA	179	36.3	18.9	43.3	49.2	11.0	1.33	0.73
	MS	373	36.0	18.7	43.3	48.8	10.9	1.35	0.84
	OK	21	34.8	18.6	42.4	47.8	10.9	1.05	0.98
	TN	140	35.8	18.2	43.4	48.4	10.6	1.22	0.87
	TX	25	34.9	18.5	42.3	48.0	10.8	1.65	0.74
		1373	35.90 (30.6-40.4)	18.43 (15.3-21.4)	43.3 (39.1-46.3)	48.6 (41.2-52.7)	10.8 (8.9-12.6)	1.39	0.86
SE	AL	59	36.3	18.6	43.2	49.2	10.9	1.65	0.94
	FL	14	37.0	18.5	43.7	49.8	10.8	2.11	0.54
	GA	34	36.6	18.5	43.6	49.4	10.8	1.34	0.91
	NC	109	36.1	18.3	43.5	48.7	10.7	1.39	0.84
	SC	47	36.2	18.5	43.3	49.1	10.8	1.67	0.87
		263	36.27 (30.4-40.7)	18.50 (15.2-20.6)	43.4 (39.7-46.4)	49.1 (42.7-53.5)	10.8 (8.8-12.1)	1.67	0.97
EC	DE	36	36.4	17.9	43.9	48.8	10.5	1.32	0.97
	MD	100	36.2	18.2	43.7	48.8	10.6	1.19	0.67
	NJ	28	36.2	18.4	43.6	48.8	10.7	0.97	0.89
	PA	18	35.4	18.3	43.0	48.3	10.7	1.60	0.66
	VA	51	36.4	18.0	44.0	48.8	10.5	1.15	0.67
		233	36.25 (32.1-40.1)	18.13 (15.2-20.6)	43.7 (39.7-46.4)	48.7 (46.4-52.7)	10.7 (8.8-12.1)	1.27	0.79
Averages	U.S.							1.38	0.84
	Within Region							1.38	0.84
	Within State							1.30	0.76

Notes: Soybean quality basis 13 percent moisture. Process yields and quality basis 12 percent moisture.

TABLE 2. Percentage of U.S. soybeans exported as soybean meal

Year	Soybean Production (TMT)[a]	Soybean Exports (TMT)	Soy Meal Exports (TMT)	Shares (%) Exported As	
				Soybeans	Soy Meal[b]
1980	48921	19712	6154	40.3	17.6
1982	59610	24634	6499	41.3	15.2
1984	50644	16279	4426	32.1	12.2
1986	52868	20600	6617	39.0	17.5
1988	42152	14355	4937	34.1	16.3
1990	52416	15161	4962	28.9	13.2
1992	59612	20944	5653	35.1	13.2
1994	68493	22810	6094	33.3	12.4
1996	64837	23999	6345	37.0	13.7

[a] Thousand metric tons.
[b] Calculated based on the assumption that one bushel of soybeans produces 43 lbs of meal.

TABLE 3. Quality of soybean meal samples collected in world markets, by point of sampling

		Fiber % (12% mb)				Protein % (12% mb)				Oil % (12% mb)				Urease Activity (pH rise)			
Country	**n**	**AVG**	**S.D.**	**Min.**	**Max.**	**AVG**	**S.D.**	**Min.**	**Max.**	**AVG**	**S.D.**	**Min.**	**Max.**	**AVG**	**S.D.**	**Min.**	**Max.**
China	9	5.85	0.40	5.29	6.80	45.00	1.02	43.31	47.05	1.61	0.30	0.94	2.07	0.07	0.01	0.04	0.08
Colombia	10	4.70	1.21	3.45	7.66	46.65	1.47	43.26	48.72	1.36	0.57	0.64	2.69	0.04	0.02	0.03	0.10
Germany	12	5.62	1.39	3.48	7.62	45.70	1.97	42.56	47.93	1.18	0.45	0.59	1.85	0.03	0.00	0.03	0.04
Greece	2	7.70	2.09	5.61	9.79	41.89	1.11	40.78	43.00	1.86	0.91	0.95	2.77	0.04	0.00	0.03	0.04
Hungary	3	6.23	0.53	5.49	6.69	46.44	0.81	45.29	47.02	1.33	0.27	0.98	1.64	0.09	0.06	0.04	0.17
Indonesia	13	5.69	1.47	3.55	7.09	47.02	1.62	43.58	49.46	1.30	0.27	0.93	1.75	0.05	0.03	0.03	0.13
Japan	11	5.40	1.69	2.97	8.50	46.54	1.43	44.03	48.78	1.30	0.40	0.60	1.97	0.04	0.01	0.04	0.07
Korea	7	5.53	0.91	3.95	6.64	46.04	0.56	42.30	46.81	1.63	0.39	0.97	2.30	0.03	0.01	0.03	0.05
Mexico	3	4.08	0.67	3.21	4.82	47.15	0.49	46.50	47.68	0.63	0.06	0.56	0.71	0.10	0.01	0.08	0.11
Philippines	10	4.21	1.03	3.37	6.44	48.16	0.89	46.58	49.41	1.51	0.25	1.16	1.92	0.04	0.00	0.04	0.05
Portugal	5	6.42	0.44	5.90	7.08	44.25	1.05	43.54	46.34	1.42	0.11	1.30	1.58	0.03	0.00	0.03	0.04
Romania	1	6.64	—	—	—	43.95	—	—	—	1.64	—	—	—	0.04	—	—	—
Slovenia	2	6.44	0.07	6.37	6.51	46.14	0.06	46.08	46.19	1.64	0.04	1.60	1.68	0.03	0.00	0.03	0.03
Spain	4	5.81	0.32	5.78	6.09	44.65	0.65	43.89	45.31	1.33	0.09	1.20	1.43	0.03	0.00	0.03	0.03
Thailand	7	6.25	0.74	5.24	7.61	47.00	1.05	45.46	49.18	1.40	0.57	1.03	2.74	0.07	0.06	0.22	0.08
Turkey	3	4.96	1.23	3.37	6.35	46.56	1.78	44.35	48.71	1.36	0.35	1.10	1.86	0.04	0.01	0.03	0.06
U.S. (1995)[b]	46	5.41	1.97	3.01	12.18	45.27	2.56	37.82	48.67	1.23	0.58	0.72	4.67	0.06	0.06	0.03	0.38
U.S.	11	3.57	0.41	3.00	4.52	48.10	1.12	45.99	49.51	1.24	0.34	0.94	2.08	0.04	0.02	0.00	0.08
U.S. (expelled)	12	5.29	0.27	4.83	5.67	40.18	2.15	34.62	42.55	9.44	3.02	6.23	17.36	—	—	—	—
Venezuela	6	3.69	0.50	3.36	4.78	48.05	0.49	47.48	48.84	0.99	0.21	0.67	1.33	0.04	0.02	0.03	0.07
All	177	5.28	1.55	2.97	12.18	45.75	2.59	34.62	49.51	1.87	2.24	0.56	17.36	0.05	0.04	0.00	0.38

Note: Unless otherwise stated, samples were collected January through May 1997.
[a] Countries where soybean meal samples were collected.
[b] Collected in 1995.

TABLE 4. Quality of soybean meal samples collected in world markets, by point of origin

Country	n	Fiber % (12% mb)				Protein % (12% mb)				Oil % (12% mb)				Urease Activity (pH rise)			
		AVG	S.D.	Min.	Max.	AVG	S.D.	Min.	Max.	AVG	S.D.	Min.	Max.	AVG	S.D.	Min.	Max.
Argentina	12	6.20	0.91	3.95	7.62	44.22	1.18	42.56	46.78	1.62	0.21	1.35	1.94	0.04	0.01	0.03	0.06
Bolivia	2	6.14	1.53	4.61	7.66	45.99	2.73	43.26	48.72	1.08	0.38	0.71	1.46	0.04	0.01	0.04	0.05
Brazil	25	5.45	1.18	3.37	6.97	46.94	1.55	43.58	49.46	1.48	0.31	0.60	1.97	0.04	0.01	0.03	0.06
China	4	4.60	1.68	1.73	5.97	45.75	0.91	44.88	47.05	2.55	1.91	0.94	5.78	0.07	0.01	0.06	0.09
Colombia	4	4.83	0.74	3.68	5.72	46.76	0.94	45.35	47.64	1.51	0.78	0.64	2.69	0.05	0.03	0.03	0.10
Germany	4	5.41	0.78	4.12	6.15	45.45	1.00	44.48	47.10	1.12	0.16	0.98	1.40	0.06	0.06	0.17	0.03
Greece	3	7.35	1.78	5.61	9.79	42.58	1.33	40.78	43.95	1.79	0.75	0.95	2.77	0.04	0.00	0.04	0.04
India	17	6.71	0.68	5.73	8.50	46.47	0.72	44.43	47.33	1.10	0.19	0.87	1.74	0.07	0.05	0.03	0.22
Japan	1	5.33	—	—	—	46.15	—	—	—	1.69	—	—	—	0.44	—	—	—
Korea	3	5.26	0.59	4.45	5.78	45.63	0.24	45.30	45.83	1.73	0.41	1.37	2.30	0.03	0.00	0.03	0.03
Mexico	3	4.51	0.31	3.21	4.82	47.47	0.21	46.50	47.68	0.66	0.05	0.56	0.71	0.11	0.00	0.08	0.11
Netherlands	3	3.72	0.17	3.48	3.86	46.61	0.20	46.40	46.87	0.60	0.01	0.59	0.61	0.03	0.00	0.03	0.03
Paraguay	2	4.15	0.63	3.53	4.78	48.63	0.21	48.42	48.84	0.75	0.08	0.67	0.83	0.03	0.00	0.03	0.03
Thailand	1	5.24	—	—	—	49.18	—	—	—	2.74	—	—	—	0.03	—	—	—
U.S. (1995)[b]	46	5.41	1.97	3.01	12.18	45.27	2.56	37.82	48.67	1.23	0.58	0.72	4.67	0.06	0.06	0.03	0.38
U.S.	34	4.14	1.17	2.97	7.08	47.27	1.76	43.31	49.51	1.34	0.30	0.94	2.08	0.04	0.02	0.00	0.09
U.S. (expelled)	12	5.29	0.27	4.83	5.67	40.18	2.15	34.62	42.55	9.44	3.02	6.23	17.36	—	—	—	—
Venezuela	2	3.55	0.02	3.53	3.58	47.51	0.03	47.48	47.54	1.21	0.12	1.09	1.33	0.05	0.02	0.03	0.07
All	178	5.15	1.66	2.97	12.18	45.83	2.92	34.62	49.51	2.09	2.67	0.60	17.36	0.05	0.03	0.00	0.22

Note: Unless otherwise stated, samples were collected 1996 through 1997.
[a] Countries where soybean meal was processed.
[b] Collected in 1995.

TABLE 5. Comparison of solvent-extracted soybean meal quality to U.S. standard specifications

		High Protein (%)		Low Protein (%)	
Protein spec		48.0		44.0	
Low limit		47.5		43.5	
Fiber spec		3.5		7.0	
High limit		3.8		7.3	
Country[a]	**n**	**Number Meeting**	**Number Over 48.5% Protein**	**Number Meeting**	**Number Over 44.5% Protein**
U.S. (1996)	34	18	8	15	18
U.S. (1995)	46	13	3	19	10
Argentina	11	0	0	7	4
Brazil	25	5	4	16	15
Colombia	4	0	0	4	4
Germany	4	0	0	4	4
India	17	0	0	14	13
Total	177	36	15	79	59

Notes: Only countries with more than three samples were reported. Expelled meal samples were not included. Samples were counted only once, as either high protein or low protein.
[a] Countries where soybean meal was processed.

TABLE 6. Limiting amino acids and KOH solubility of soybean meal samples collected in world markets, by point of origin

		Lysine(%)		Cysteine(%)		Methionine(%)		Tryptophan(%)		Non-protein[b]	KOH Solubility(%)[c]	
Country[a]	**n**	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**	**AVG**	**SD**	**(%)**	**AVG**	**SD**
Argentina	4	2.77	0.20	0.51	0.01	0.59	0.04	0.59	0.06	2.29	79.66	3.12
Brazil	7	2.94	0.13	0.50	0.08	0.58	0.03	0.64	0.05	1.74	83.43	1.53
China	4	2.82	0.05	0.53	0.02	0.60	0.02	0.57	0.06	1.75	84.80	3.74
India	6	2.81	0.19	0.54	0.04	0.60	0.04	0.61	0.05	2.23	83.66	2.73
Japan	1	2.94	—	0.56	—	0.63	—	0.66	—	1.29	82.47	—
Korea	1	2.93	—	0.54	—	0.62	—	0.70	—	1.22	86.20	—
Mexico	1	2.97	—	0.48	—	0.54	—	0.65	—	2.13	91.73	—
U.S. (1996)	13	3.03	0.13	0.58	0.08	0.63	0.03	0.61	0.10	2.04	86.45	1.96
Venezuela	2	3.05	0.00	0.54	0.01	0.58	0.02	0.57	0.06	0.59	83.34	4.85
All	39	2.91		0.53		0.60		0.62		1.70	84.64	4.56

[a] Countries where soybean meal was processed.
[b] Crude protein (%) – sum of amino acids (%).
[c] Indicator of protein digestibility.

TABLE 7. Near-infrared characteristics and calibration statistics for solvent extracted soybean meal (n=172) (range in parentheses)

Statistic	Bruker Vectra 2800	NIRSystems 6500	Foss Infratec 1229, Flow-Feed	Foss Infratec 1221, Cuvette	Foss Grainspec
Instrument Properties					
Type of unit	**Interference monochromator, reflectance**	**Grating monochromator, reflectance**	**Grating monochromator, transmission**	**Grating monochromator, transmission**	**Fixed filter, transmission**
Number of wavelengths	1167	1050	100	100	33
Wavelength range (nm)	800-2856	400-2498	850-1050	850-1050	850-1050
Sample presentation	Cup	Cup	Flow	Cup	Flow
Sample size	100g	500g	500g	150g	500g
Moisture (5.2%-15.2%)					
Number of PLS factors	8	4	6	6	5
R^2	0.962	0.940	0.951	0.983	0.950
SECV[a]	0.31	0.40	0.41	0.38	0.42
Range/SECV	32	25	24	26	24
Outliers[b]	16	4	7	15	15
Protein (% as is moisture) (37.5%-49.9%)					
Number of PLS factors	10	4	6	7	6
R^2	0.963	0.922	0.950	0.963	0.960
SECV[a]	0.58	0.71	0.63	0.61	0.58
Range/SECV	21	17	20	20	21
Outliers[b]	38	25	25	35	23
Oil (% as is moisture) (0.6%-2.3%)					
Number of PLS factors	13	7	8	8	7
R^2	0.903	0.904	0.883	0.891	0.860
SECV[a]	0.15	0.15	0.19	0.17	0.19
Range/SECV	15	15	10	14	10
Outliers[b]	15	4	12	23	23
Fiber (% as is moisture) (3.0%-12.1%)					
Number of PLS factors	13	6	6	8	5
R^2	0.921	0.932	0.943	0.942	0.820
SECV[a]	0.57	0.55	0.55	0.51	0.58
Range/SECV	16	17	17	18	16
Outliers[b]	14	19	26	35	22

[a] Standard error of cross validation, single instrument calibrations.

[b] By spectra or poor chemistry.

TABLE 8. Published estimates and data for amino acid levels in soybean products (weight percentages basis 12 percent moisture)

	Lysine		TSAA[a]		Tryptophan	
Source	**Wt%**	**Relative %**	**Wt%**	**Relative %**	**Wt%**	**Relative %**
ISU-CES (1996)	2.97	6.40	1.38	2.97	0.67	1.45
NAS-NRC (1994)	3.05	6.43	1.38	2.91	0.67	1.42
NAS-NRC (1988)	2.95	6.23	1.38	2.93	0.74	1.56
Ensminger (1977)	2.89	6.15	1.33	2.83	0.68	1.46
Juergens (1993)	3.03	6.29	1.37	2.84	0.69	1.42
Biokawa (1995)	2.98	6.25	1.42	3.00	0.64	1.35
Feedstuffs (1997)	3.16	6.46	1.47	3.00	0.69	1.41
ISU-CES (1996)	2.84	6.45	1.15	2.61	0.63	1.43
NAS-NRC (1994)	2.69	6.11	1.28	2.91	0.74	1.68
NAS-NRC (1988)	2.90	6.59	1.18	2.68	0.69	1.57
Ensminger (1977)	2.27	5.60	1.26	3.11	0.66	1.63
Juergens (1993)	2.8	6.13	1.3	2.84	0.6	1.31
Feedstuffs (1997)	2.83	6.58	1.29	3.00	0.59	1.37
U.S. samples	3.03	6.60	1.21	2.64	0.61	1.33
Non-U.S. samples	2.90	6.48	1.12	2.23	0.62	1.39

[a] TSAA is total sulfur containing amino acids, methionine and cysteine.

TABLE 9. Example amino acid levels in high protein soybean meal as calculated by SPROC

	Soybean Composition[a]				Meal Composition[b]		
Case	Protein (%)	Oil (%)	Lysine (%)	Methionine (%)	Protein (%)	Lysine (%)	Methionine (%)
1	35	19	2.21	0.46	48.0	3.02	0.62
2	34	20	2.24	0.54	48.0	3.17	0.77
3	32	20.5	2.08	0.48	46.5	3.02	0.70
4	37	17	2.14	0.44	48.4	2.80	0.58
5	40	13	2.48	0.52	49.2	3.05	0.64
6	30	23	3.00	0.60	45.4	4.54	0.91

[a] Basis 13% moisture.
[b] Basis 12% moisture, maximum 3.5% fiber.

TABLE 10. Distribution of soybean product yields in samples from Minnesota, Illinois, Mississippi, and the United States, 1986–96

		Percentage of Samples From:			
Parameter	Level	Minnesota[a]	Illinois[b]	Mississippi[c]	United States
Meal yield (lb/bu)	Below 40	1.9	1.9	0.8	1.6
	40-41	11.9	8.8	4.8	7.7
	41-42	19.7	14.9	8.2	13.9
	42-43	27.0	20.1	14.4	19.6
	43-44	23.7	31.9	35.9	30.4
	44-45	12.3	19.1	31.6	21.8
	45-46	3.0	3.2	3.5	4.6
	Above 46	0.4	0.1	0.0	0.2
Meal Protein (%)	Below 45.5	1.7	0.7	0.8	0.9
	45.5-46.5	4.0	1.5	0.3	1.9
	46.5-47.5	9.4	4.3	1.3	4.9
	47.5-48.5[d]	77.1	67.5	50.5	67.7
	48.5-49.5	6.0	16.6	24.3	15.4
	49.5-50.5	1.2	7.3	15.6	6.7
	Above 50.5	0.5	2.1	7.2	2.5
Oil yield (lb/bu)	Below 9	1.3	0.1	0.0	0.4
	9-10	15.5	5.6	3.2	9.6
	10-11	44.4	45.5	51.1	50.7
	11-12	33.0	46.4	42.0	37.6
	Above 12	2.4	2.3	2.9	1.7

Notes: Meal values basis 12 percent moisture.
[a] Protein deficient state.
[b] "Average" protein state.
[c] Protein surplus state.
[d] Market target.

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