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Relationship of soybean and soybean meal quality

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Relationship of soybean and soybean meal quality

by

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Signatures have been redacted for privacy

Dedication

This work would not have been possible without the extreme patience of my major professor Dr. Charles R. Hurburgh and my beloved wife Qudsia F. Aleem and the endless support and prayers from my parents (Mohammad Moizuddin and Rokeya Khatoon).

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CHAPTER I

GENERAL INTRODUCTION

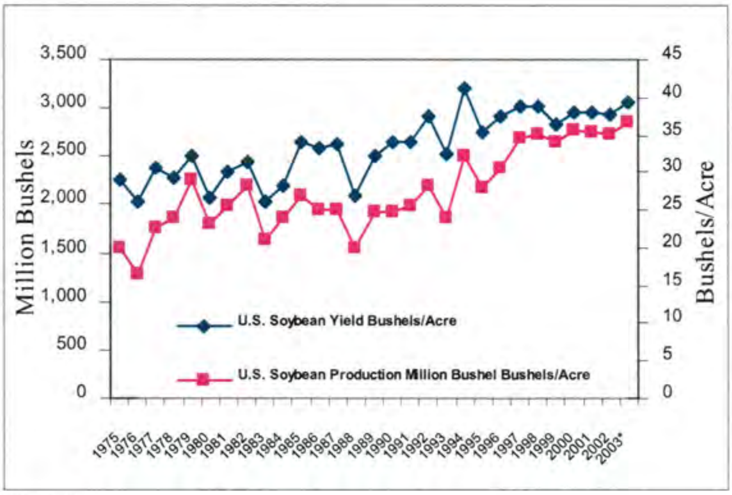
HISTORICAL PERSPECTIVE

For the past 5000 years, soybeans (Glycine max) have been used by people in China and the Pacific Rim countries. Soybeans were introduced into the United States around 1804, and first grown by U.S. farmers as crop in 1829. It was George Washington Carver's discovery a hundred years later in 1904 about the bean's valuable protein and oil that changed the soybean from a forage crop to what is now often referred as "the miracle crop" (1).

Soybeans are a primary provider of plant protein and vegetable oil (2). The plant is a legume in the same family as peas and alfalfa. It is planted in late spring and harvested in early fall. The plants flower and produce 60-80 pods, each containing two or three seeds. The seeds are high in protein and oil. A 60 pound bushel of soybeans generally yields about 11 pounds of soybean oil and 48 pounds of 44% protein soybean meal (soymeal or SBM) (3).

In 1929, the U.S. was producing 9 million bushels of soybeans. By 1940, the production had grown to 78 million bushels harvested from 5 million acres, making the U.S. a major exporter of soybeans and soybean products. By the 1950's, soybean meal was marketed as a low cost, high protein feed ingredient, and this exponentially increased livestock and poultry production in the United States. Figure 1 follows the growth of soybeans and soybean yield in the U.S. from 1975 to 2003 (4, 5). The U. S. Department of Agriculture has forecasted the 2003 soybean production at 2.9 billion bushels, which is five percent higher from 2002, but down one percent from 2001. An average yield of 39.4 bushels per acre was estimated based on the crop in early August this year.

Figure 1: U.S. soybean products 1975 - 2003

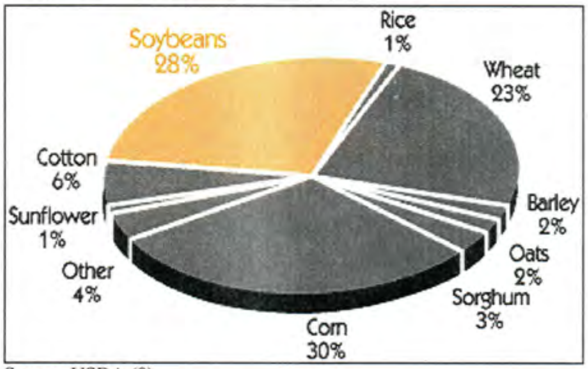


(*) Projection

SOURCE: USDA (4, 5)

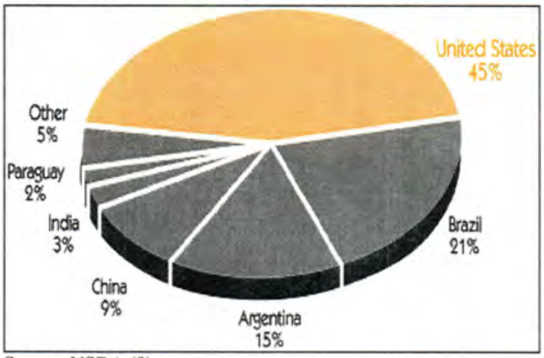
Today, soybeans are grown in at least 30 states, making the soybean crop the second largest in cash sales and the first in value of crop exports from the United States. As much as 28% of the agricultural land was used to grow soybean in 2000, the percent of growing area used by other crops in U.S. are shown in Figure 2. Figure 3 shows the world soybean production in year 2000, of which U.S. producing 45% of the world's soybean and as shown in Figure 4, 54% of the exported soybean in the world came from the United States. The world's three largest soybean producing countries are the United States, Brazil and Argentina producing over 80% of the world's soybeans. Yet the United States' share of the world market for all soy commodities has been declining; soybean share, down 50%, soybean oil share, down 66%, and the SBM share down 70% between 1977 and 2001 (6). All the while, the South American production and market share have been increasing at a faster rate than that of the United States (Figure 5) (2). USDA reported that between 1998/99 and 2002/03 world production of soybean meal increased 23% (7). The U.S. share of world SBM production has declined, from 31.8% to 26.7%, and the South American and Asian shares have increased. Asia's largest gain was from China, increasing production by 4.5%. In 2002/03, the E.U. remained the largest importer of soybean meal, purchasing over 19.1 million tons or 41% of the world imports (7).

Figure 2: U.S. crop area planted 2000



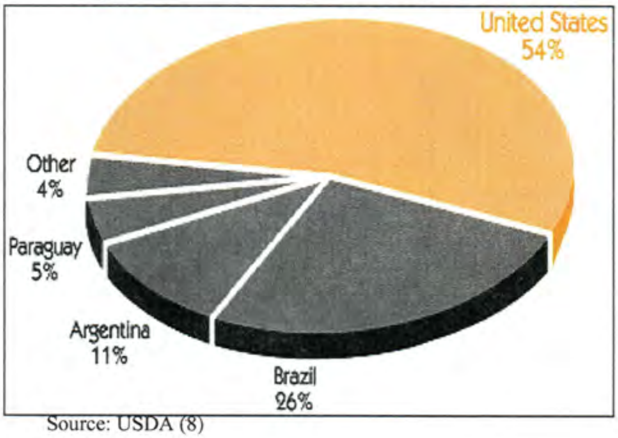
Source: USDA (8)

Figure 3: World soybean production 2000



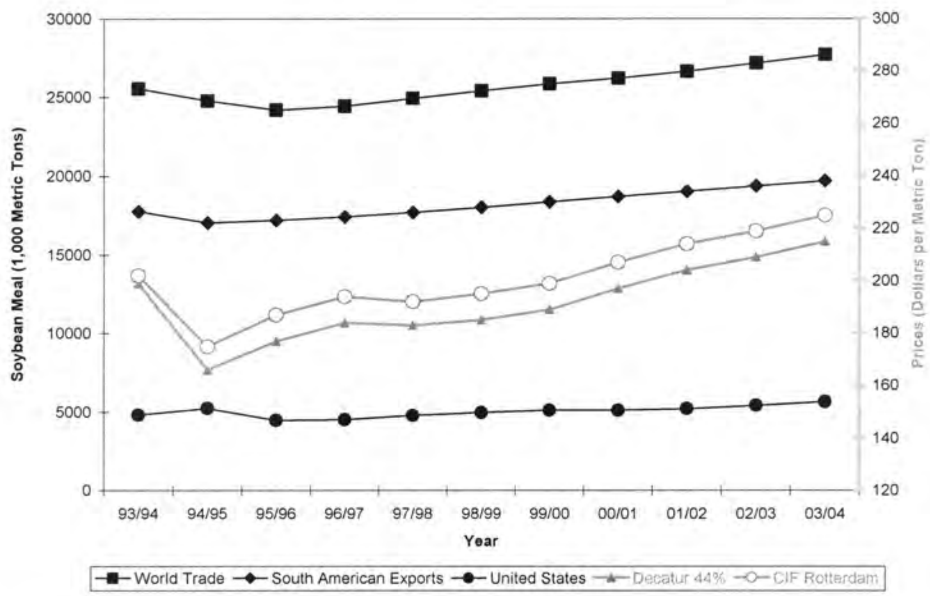
Source: USDA (8)

Figure 4: World soybean exports 2000



Source: USDA (8)

Figure 5: Soybean meal exports and prices in world markets



Source: USDA (2)

MARKET VALUE OF SOYBEANS AND SBM

In 2003, the U.S. Department of Agriculture estimated that about 74 million acres of land were used to grow soybeans, producing 2.9 million bushels (bushel = 60 lbs). An average price paid to the farmer will range $4.55 to $5.55 per bushel. This translates the value of the crop to be ~$14 billion. For the same year, the U.S. will export ~$6 billion worth of soybeans and soybean products. Eighty percent of domestically used edible fats and oil comes from U.S. soybeans.

In 2000, the U.S. exported 990 million bushels of soybeans (54% of the globally traded soybeans) and 6.35 million metric tons of SBM (9). Other countries trading percentages are shown in Figure 4. The top ten countries that buy U.S. soybeans and soybean products are shown in Table-2, with the amount in $ million, earned from those trades.

Table 2: 2003 - Top ten U.S. export customers ($ Million)

Soybean Exports		Soybean Meal Exports		Soybean Oil Exports	
European Union	$1,143	Philippines	$166	Mexico	$39
China	$1008	Canada	$161	Korea	$34
Japan	$758	Indonesia	$69	India	$25
Mexico	$678	Dominican Republic	$65	Peru	$20
Taiwan	$385	Saudi Arabia	$63	Canada	$16
Korea	$259	Egypt	$50	Ethiopia	$10
Indonesia	$164	Turkey	$49	Jamaica	$8
Thailand	$145	Venezuela	$48	El Salvador	$8
Israel	$95	Japan	$47	Haiti	$8
Canada	$72	Algeria	$40	Nicaraqua	$7
All Others	$538	All Others	$404	All Others	$77
Total	$5,244	Total	$1,163	Total	$253

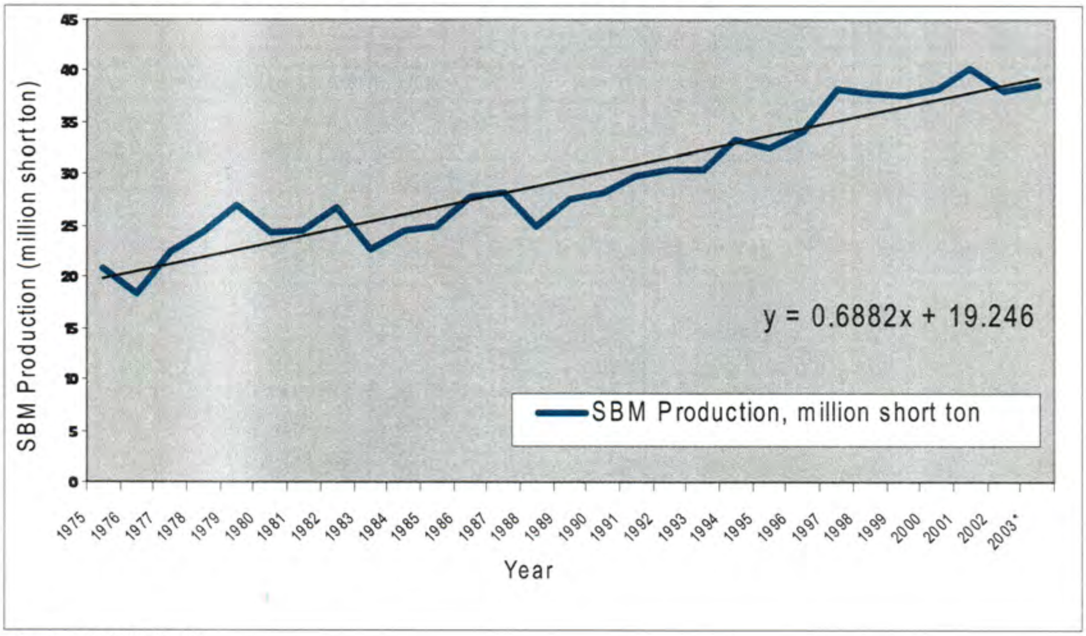
Source: USDA (8)

U.S. soybean meal production from 1975 to 2003 is shown in Figure 6 (10, 11). The SBM production for the past 30 years has followed a growth of 0.6 million metric ton per year. The world soybean meal export for the year 2000 is shown in Figure 7. Only 16% of the over 39 million short tons produced in the U.S. were exported. The rest was used domestically. Argentina and Brazil were first and second in soybean meal export quantity.

Nearly all U.S. soybeans are processed with solvent extraction (12). The two main products of solvent extraction are soybean meal, a high-protein ingredient for animal feeds, and crude soybean oil. Both are traded commodities on the Chicago Board of Trade. Soybean meal (or its precursor, defatted soybean flakes) can be further processed into soy flour and protein isolates, but the bulk of consumption is as soybean meal for animal feed.

Interest in the end-use value of soybeans is growing. In 1986, the U.S. Congress established that end-user value was a key objective of U.S. Grain Grades and Standards. New soybean quality tests or standards should be related to the value of products from solvent extraction processing (12).

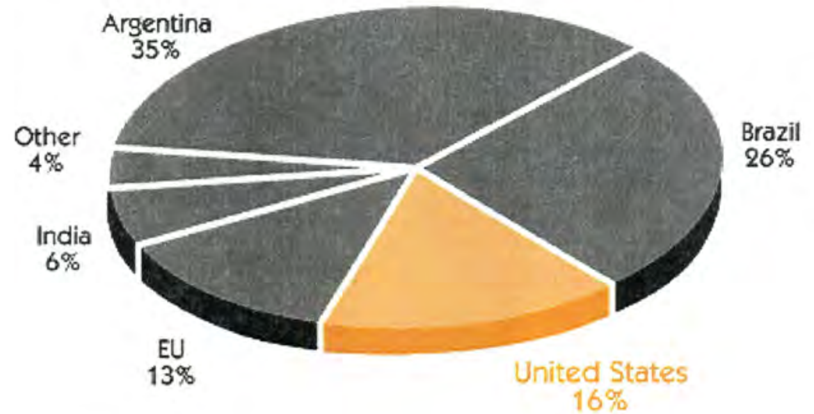
Figure 6: U.S. soybean meal production from 1975 – 2003



Source: USDA (9, 10)

*short ton = 0.907 metric ton

Figure 7: World soybean meal exports 2000



Source: USDA (7)

SOYBEAN PROCESSING

Soybeans are a versatile crop with many uses. Before they can be used in food, feed or industrial products, soybeans must be processed. A number of anti-nutritional factors have been identified in raw soybeans, but the ones of consequence are:

a. Trypsin and chymotrypsin inhibiters (inhibit protein digestion) (13, 14).
b. Phytohemagglutinins are proteins present in soybean that can agglutinate red blood cells in various species of animals (causes diarrhea by decrease digestibility of nitrogen-free extract. Resulting in interference with normal absorption of pancreatic amylase in the intestinal epithelium, therefore allowing the enzyme to be quickly eliminated in the feces) (15, 16).
c. Urease (this enzyme is of importance in poultry nutrition only as a guide for measuring the adequacy of processing. Urease in itself is not harmful to poultry. It is

of some concern in diets for ruminants as these diets quite often contain considerable urea.) (17).

d. Lipase and Lipoxygenase result in peroxidation and beany flavor, respectively.

Fortunately, anti-nutritional factors can be deactivated, modified or reduced through proper heat treatment. Since those inhibitors are proteins, caution must be taken to minimize the destruction of the oil seed protein.

There are several steps in the soybean-crushing process: **Dehulling**: Soybeans are cracked and the hulls are removed. **Solvent extraction**: The soybeans are flaked in special machines and moved to towers or tanks where they are soaked in solvent. This solvent (hexane) removes about 99 percent of the pure, crude soybean oil from the flake. **Toasting and Grinding**: After the oil is removed, the soybean flakes are cleaned toasted and ground. This produces the soybean meal, which contains 47-49 percent protein (Figure 8). During the same production, some hulls can be reintroduced to produce SBM at the lower protein content. **Refining**: The crude soybean oil may be refined depending on use. In the refining process, crude oil can be degummed, bleached, deodorized or hydrogenated with hydrogen gas. In "degumming," the fatty acid content of the oil is neutralized with a caustic acid to produce certain products (soap, for example). The oil also may be "bleached" by heating it with an absorbent clay material before it is "deodorized" through a vacuum steam-distillation process (Figure 8) (18). The addition of the hulls, the protein content of the SBM, and moisture percentages all play a critical role in determining economic values and are subject to regulation by federal and/or local government.

SOYBEAN MEAL TRADING RULES

SBM specifications have been established by trade agreement. Table 1 gives the National Oil Processors Association (19) specifications for solvent extracted SBM, and for dehulled SBM, officially described as either 44% or 48% protein. These specifications are only rough guides to the nutritive value of the meal. A more detailed version of trading rules covering both soybeans and soybean meal is in the appendix.

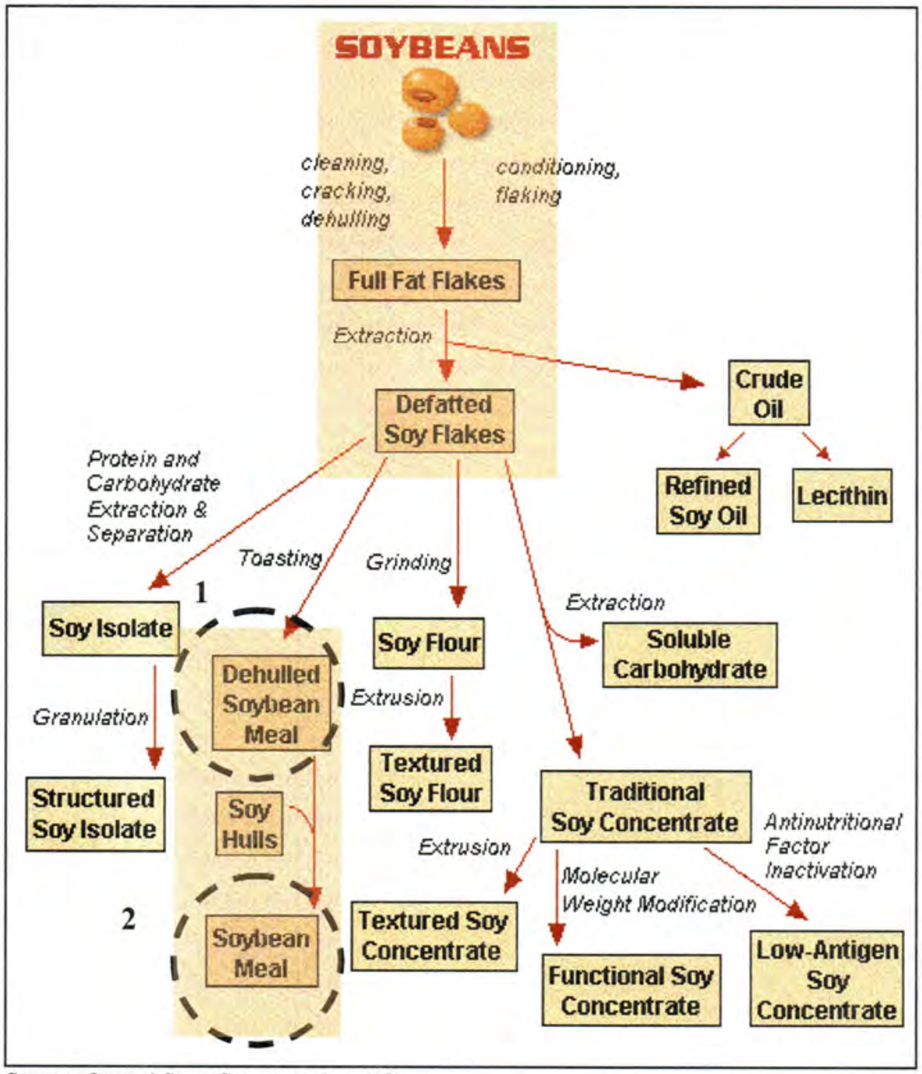
These rules have limited value when formulating diets. Diet formulation requires a balanced amino acid (AA) profile, particularly in the limiting AA for a particular species (for poultry, sulfur containing, for swine, lysine). Formulators, wanting to maximize the value of their raw material and minimize formula cost, often prefer to separate raw material beyond trader classifications. Common criteria of segregation are meal origin, supplier, and other quality characteristics combined with chemical composition.

Table 1: Specifications for solvent extracted and dehulled SBM (%)

	Min./Max.	Solvent extracted SBM	Dehulled SBM
Moisture	Max.	12.0	12.0
Protein	Min.	44.0	47.5 – 49.0
Fat	Min.	0.5	0.5
Crude Fiber	Max.	7.0	3.3 – 3.5
Anticacking agent	Max.	0.5	0.5

Source NOPA (19)

Figure 8: Soybean processing and some of its products.



Source: Central Soya Company, Inc. (18)

MARKET DEMAND FOR SOYBEAN MEAL

The world use of SBM in animal feed has grown steadily to 125 million metric tons in 2001 (2). A major driving force for growth has been recent outbreaks of hoof and mouth and the Bovine Spongiform Encephalopathy (mad cow disease) in Western European countries. Several EU countries have banned the use of animal protein in livestock feed, causing an increase in the use of vegetable protein meals in animal feed (20). Other European countries are in the process of or have passed legislation to restrict animal protein in feed, which will further increase the demand for plant protein. With the increased use of plant protein, the importance of protein quality and the methods used to control quality will increase. Protein quality is a major factor affecting the growth and performance of animals (21).

VARIATIONS IN SOYBEAN MEAL QUALITY

Dudley (22) evaluated quality of SBM samples originating from the United States, China, Korea, India, and South America. When the crude protein value met the trading specification, the true metabolizable energy (TME) was sometimes much lower then expected. Animal growth and performance would be reduced if diet consisted of SBM with lower TME.

Several researchers have studied the impact of weather conditions on soybean composition. Table 2 is a qualitative presentation of soybean quality changes to be expected from weather and agronomic factors. In the past Nicholas (23) found that exported U.S. soybeans were lower in oil and higher in protein content compared to Brazilian beans, but now U.S. soybeans are lower in both oil and protein (24). Past studies have shown that geographical locations within the U.S. affect the compositional quality of soybeans. Hurburgh et al, (25), surveyed soybean production in 1983-84 from Iowa, Minnesota, and Ohio. The study found high protein content in the beans from Ohio and high oil content in beans from Minnesota and Iowa. Breene et al, (26), reported the protein content of the soybean decreased from South to North (r= -0.77 with latitude). Based on these geographical considerations, soybeans from northern regions have received a lower price than southern and central soybeans (27).

Table 2:
Soybean component response to weather and non-agronomic variables [a]

Variable	Impact on	
	Protein	Oil
High temperatures	Unclear	Unclear
Early season drought	-	+
Late season drought	+	-
Additional soil nitrogen	+	-
Increased fertility (P, S)	+	+
Late planting	+	-
Insect defoliation	-	-
Insect depodding	+	Unclear
Inoculation with Rhizobia (N-fixing bacteria)	+	-

[a] After Westgate et al. (28), + = increase; - = decrease

Table 3, generated from the 1986 - 1996 Iowa State University survey of U.S. soybean quality, demonstrates the variation in U.S. soybeans, with the associated impact on processing (29). These variations in quality cannot be corrected without giving incentive to producers to 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% 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 add that the amino acid profile is really the key to the SBM protein value. An American Soybean Association (ASA) funded survey of the West European Feed manufacturers found that their preference for buying SBM from a specific supplier was dependent on the product quality and the consistency of quality above all other factors (20).

The nutritional value of soybean meal could be improved by increasing amounts of the sulfur-containing amino acids, methionine and cystine. Soy protein is often supplemented with other protein sources, or with synthetic amino acids, when soy meal is used as the primary source of protein for humans and for monogastric animals. Glycinin (11S) and β-conglycinin (7S) are the two main classes of multi subunit seed storage proteins and account for ~70%, of' total soybean seed protein (30). Glycinin is a well balanced protein with 3.0 to 4.5% of its amino acid residues consisting of cysteine and methionine (31, 32), but β-conglycinin is very deficient in S-amino acids. Only 1%, of its amino acid residues contain S (33, 34), with one of its three subunits, the β-subunit, having no S-amino acids at all (35).

In hydroponic nutrition studies in which 'Harper' soybean was grown on various compositions of N during seed filling, Paek et al. (36) showed that total protein concentration of seed could be increased 4.5 to 5.0%, from 369 to 420 g kg^{-1} in one experimental run and from 410 to 455 g kg^{-1} in the second, by substitution of NH_3-N for NO_3, in the growth medium. Storage proteins were increased by ~ 4% in both runs, but the increase in storage protein was entirely because of an increase in β-conglycinin, in particular of the S-devoid β-subunit of β-conglycinin. Thus, protein quality declined with increases in protein concentration. Paek et al. (36) concluded that breeding efforts to improve soybean seed protein should not focus entirely on protein concentration. Potentially, soy protein quality could decline as lines with greater protein concentration are developed.

SOYBEAN TO SOYBEAN MEAL

Soybean meal is priced at either 44% (with hulls) or 48% (dehulled) protein content, with no premium for exceeding specifications. Soybean oil revenue is dependent only on volume extraction, but usually any gain in oil percentage (of whole soybean) is accompanied by a loss in protein percentage. Smith, (37) discussed the positive relationship between soybean yield and oil content; while the relationship between the protein and oil and between protein and grain yield was negative. Therefore, pricing to increase oil alone could be a net loss, because as soon as the high oil soybean became low enough in protein, the basic contract for protein could not be guaranteed. 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 point of sale and price adjusted accordingly (38).

Protein analysis is the first step in describing meal quality. Animal geneticists and plant breeders know that protein digestibility - concentrations of amino acids and compounds that are 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 acid and other low-level compounds needs to follow.

As stated earlier, soybeans and soybean products are traded commodities in the world market. For the soybean processors in the United States, the benefit lies in the price difference between the cost of the raw soybeans and the market price of the finished products per unit of the raw beans. However, United States continues to loose the world market share for all soy commodities. An option to increase the domestic consumption of SBM would be to increase the export of meat. However, meat is more expensive and will require a relatively affluent buyer. Increasing the export of SBM involves more than meat exports. The U.S. share of world SBM trade fell in the late 70's against the South American market (29). To reverse this trend and increase the value of domestically utilized meal, a comprehensive nutritional understanding of SBM quality from various origins (global and domestic) must be made.

THESIS ORGANIZATION

The contents consists of four chapters; General introduction, paper I, "Soybean meal quality in the U.S. and world market," paper II, "Relationship of soybean meal (SBM) quality and soybean quality," and general conclusions. The general introduction is intended to provide information about soybean meal, how it is made, and some of the quality issues that impact the nutritional value of the SBM. Some basic information about the market value of the SBM and the need to understand the relationship between soybean and soybean meal quality are discussed. The general introduction is followed by two papers in the format of manuscripts for submission to the journal of American Oil Chemists' Society. The thesis is finalized with conclusions, a list of references for the general introduction and an appendix.

Table 3: State by state variation in soybean quality and process yields, 1986-1996

Region	State	N	Soybeans		Products			Variability of components as measured by average standard deviation	
			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
		6596	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	49.7	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	USA							1.38	0.84
	Within Region							1.38	0.84
	Within State							1.30	0.76

Soybean quality basis 13% moisture, Process yields and quality basis 12% moisture (29)

CHAPTER II

QUALITY OF SOYBEAN MEAL IN THE U.S. AND WORLD MARKET

A paper to be submitted to *J. Am. Oil Chem. Soc.*

By

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Running title: Soybean meal quality in U.S. and world markets.

ABSTRACT

A survey project funded by the United Soybean Board created database of soybean meal (SBM) samples in 1996, 1997, and 1999. American Soybean Association representatives in 27 countries collected SBM samples at the port of trade. The SBM were compared by points of meal origin and across number of years within an origin. Consistency in SBM protein content was evident for the meals originating in the U.S. The samples from Argentina were lowest in protein. The protein content of the SBM and its' KOH solubility values were positively correlated ($r = 0.996$). Based on KOH values, SBM samples from Argentina and India were overcooked. SBM samples from India were consistently higher in fiber than all other SBM samples tested. The SBM protein and oil content were negatively correlated ($r^2 = -0.903$). Total sulfur containing amino acids (TSAA) in the U.S. SBM considerably improved over the three surveyed years 1.22 % in 1996 to 1.44 % in 1999. The relative percentage of lysine in protein was higher in SBM from the U.S. and EU. The relative percentage of TSAA in SBM from Argentina, Brazil, China, and India showed significant decline in value from meals collected in 1999 compared to the meals from 1997, SBM from the U.S. over the surveyed years was highest in compositional and protein quality.

KEY WORDS: Soybean meal, quality, U.S., world, KOH, amino acid

INTRODUCTION

Soybean meal (SBM) and soybean oil (SBO) are the two principal products from soybean processing. Solvent extraction using hexane is the most common method for soybean oil extraction in the USA. The oil extraction efficiency using the solvent extraction method is higher than with mechanical expellers (1). The process produces soybean oil and low fat white-flakes, which after toasting, become SBM. SBM is a widely traded high protein animal feed concentrate. In the U.S., soybean meals are traded on the basis of specifications set by the National Oil Processors Association (NOPA) (2). Solvent extracted meals can be separated into two categories based on their protein concentrations, standard (44%) and dehulled (48%) (2). Other specifications included in the NOPA trading rules are moisture, crude oil, and fiber (Table 1).

The world use of SBM was 125 million metric tons in 2001 (3). However, the U.S. share of the world markets has been decreasing against South America (Figure 1) (3). An American Soybean Association funded survey of the Western European feed manufacturers found that their preference for buying SBM from a specific supplier was dependent on the product quality and consistency of quality above all other factors (4).

The homogeneity of soybean and SBM is attractive quality for feed. However, factors such as origin and growing condition affect the protein quality and digestibility (5). Feed formulators and animal nutritionists often find the NOPA specification values incomplete for formulating feed rations. The quality of SBM protein (amino acid profile) is important to meet the limiting amino acid requirements of certain livestock (sulfur containing amino acids for poultry, lysine for swine, and tryptophane in both poultry and swine). Dudley (6) reported poultry growth variation and performance from different SBM sources even though they all met minimum specification for protein. This study and others reported that growth rates of chickens and pigs were positively correlated with the protein solubility, tested by the KOH method (7, 8, 9).

Comparisons of meals from different origins have showed significant differences in nutrient composition and general protein quality (10, 11). Dudley-Cash (6) and Kang and Swick in 1995 (12) compared SBM from the U.S., China, Korea, India, and Brazil. The true metabolizable energy (TME) in meals from China and India was lower than the Hi pro meals from the U.S. The low TME in the Indian and Chinese meals negatively affected broiler feed efficiency. A similar trial reported by Swick and Srinongkote (13) was done using meals from the U.S., India, and Brazil. Pigs fed U.S. SBM grew faster than the pigs fed Indian meal. U.S. soybean growers asked if a more comprehensive analysis could be done to support international marketing efforts. The objectives of this study were to compare soybean meal from various worldwide origins and identify relationships among soybean meal quality factors.

Protein solubility (14) and urease activity (15) are tests that determine processing conditions used for SBM. Protein solubility by KOH method was a good indicator of under processed meal. Other studies have found that a pH increase of up to 0.50 for the urease test was a good indicator for optimum processing (16, 17 18). In commercially produced SBM, Dale and Whittle, (19) stated that the KOH value should be between 80 and 85%. Meals with KOH values less than 80% were over processed and more than 85% were under processed. The urease test is a standard method to determine inadequate toasting of SBM by industry. Dale et al. (20) reported that a SBM sample of 0.00 Urease value can be either optimally processed or over cooked.

MATERIALS AND METHODS

Soybean Meal Quality Database: American Soybean Association representatives in 27 countries collected (1996 – 1999) SBM samples at plants or export locations. U.S. samples were obtained from feed mills, elevators, and processors. All 791 samples (500 - 1000g) were shipped to the Grain Quality Laboratory at Iowa State University in Tyvek bags. Samples from solvent extraction processes were requested but the sampling methods were not generally provided.

Compositional Analyses: Samples were identified with the date of collection, country of origin, the country of collection and the method of oil extraction. Samples with incomplete information were not used in this study. Only data from solvent extraction were used. The samples were mixed and scanned using a near-infrared (Foss-Tecator Infratec, Foss North America, Eden Prairie, Minn.) transmission instrument calibrated at Iowa State University for moisture, protein, oil and fiber. Samples were then divided using a rotary grain divider (Gamet Rotary Divider, Gamet MFG. CO., Minn., MN) into four sub-samples. Two sub-samples were sent to the Woodson-Tenent, Laboratories Inc., Des Moines, Iowa. One Woodson-Tenent sub-sample was analyzed for moisture, protein, oil, fiber and urease content by AOCS official methods (15) Ba 4e-93 (revised 1995), Ba 3-38 (revised 1993), Ba 6-84 (revised 1995), Ba 2a-38 (revised 1993), and Ba 9-39 (revised 1993), respectively. The other was analyzed for protein solubility by the KOH method (14). The protein solubility test by KOH also required protein determination by the kjeldahl method. The protein values from this method were compared against predicted protein values by NIR and the combustion method. The third sub-sample was sent to the University of Missouri-Columbia for quantitative determination (w/w %) of 23 amino acids (AOAC, 982.30E (a,b,c) (21). The last sub-sample was retained at the GQL under refrigeration at 4 °C.

Statistical Analysis: All analytical results except KOH and urease were expressed at 12% moisture basis; KOH and urease are relative values. Survey data were sorted by the country of origin, points of collection, and year of collection. SBM originating from all countries in Asia except China and India were pooled into one category, labeled as "Asia". The pooling of the data was necessary because few samples were collected from individual Asian countries in each year. Sample means, standard deviations, and minimum and maximum values were determined by individual years and by country of origin. Treatment means (origin and years) were evaluated by least significant difference (LSD, $P < 0.05$). Relationships among the SBM constituents were determined by correlation.

RESULTS AND DISCUSSION

Proximate Analysis: Table 2 is a comparison among samples of SBM from various countries of origin. Samples from EU and U.S. had the highest level of protein and the lowest level of fiber. SBM samples from India were not significantly different in protein content from Brazilian samples. However, Indian meals had the highest amount of fiber and the lowest oil. Meals from Argentina, China and the pooled data representing other Asian (Asia) countries contained the lowest levels of protein. Chinese meals were statistically similar to the meals from India in fiber content. The highest protein solubility in SBM samples originated from EU, U.S. and China. The lowest protein solubility values were reported in meals from India and Argentina. This data supports earlier studies of SBM in world markets (6, 10, 11).

Although the contract specifications were not known, the average protein contents were all above 44%. Figure 2 shows the three year data for protein content and solubility by point of meal origin. Consistency in SBM protein content was best for the meals from the U.S. The SBM samples from Asia had a sharp decline in the protein content of their meals between 1997 and 1999, and the samples from Argentina and Asia were consistently lowest. The samples from the Europe (EU) and U.S. were highest in protein content. Only a weak relationship existed between the protein content of SBM samples and their KOH solubility values (r = 0.258, Table 3).

Solubility values of the meals from Argentina and India were not within the 80 – 85% range given by the Dale and Whittle (14) study for optimum processing and were likely overcooked (Figure 2). SBM from Brazil had a KOH value of 80%, leaving little room for quality deterioration during shipping and storage. U.S., EU and Chinese meals were within the acceptable KOH range (80 – 85%), with the best overall quality consistency in U.S. samples.

The urease test has been a standard method to determine inadequate toasting. A negative correlation between protein solubility (KOH) and the urease value was expected, since overcook will result in lower KOH value and higher urease activity. However, of the 141 samples tested for urease 76% of the result was 0.03 resulting in a weak correlation (r = 0.047, Table 3) All samples were in the acceptable range for urease.

Figure 3 shows a three year trend in oil and fiber content. SBM samples from the U.S. were consistently lower in fiber over the three years of the survey compared to the samples from other countries. There was variability in fiber content of the SBM from Argentina and Brazil. SBM samples from India were consistently the highest in fiber. Indian SBM samples contained the lowest oil, while the pooled samples from Asia had the highest oil content. NOPA specification includes a minimum requirement for oil (0.5%) and has no maximum limit. All samples were above the minimum NOPA specification and published value (22). There was a negative relationship between protein and oil (r = -0.296, Table 3).

Amino Acids: Figure 4 shows lysine, sum of methionine and cystine expressed as total sulfur containing amino acids (TSAA) and tryptophane. The lysine content in meals was consistently higher for samples from the U.S. and EU. The lowest lysine samples were from China. These patterns were statistically significant as shown by the overall data in Table 2. Published data (22) reported the lysine content in a 44% and 48% solvent extracted SBM to be 2.9 % and 2.96% respectively at 12% moisture. Average lysine content of all SBM samples in the survey except samples from EU and US were below the published result. Since methionine is converted through to cystine (23, 24) by animals, the TSAA in SBM is a better representation of sulfur containing amino acids. TSAA in the U.S. SBM improved from 1.22 % in 1996 to 1.44 % in 1999. Other reporting countries did not show TSAA improvement similar to the U.S. except SBM samples from Brazil. Average TSAA values from Brazil were below the U.S. averages. Published data (22) reported the TSAA content in a 44% and 48% solvent extracted SBM to be 1.32 % and 1.39 % respectively. The average TSAA value of SBM samples from EU and US were above the 48% (Hi-Pro) value while the over all average of the samples from Argentina were below the 44% (Low-Pro) (Table 2). Tryptophan is used in the synthesis of tissue protein, with any excess converted to niacin

(23). The highest tryptophan content reported in the surveyed samples (1999 U.S. and EU) was 0.71 % w/w which was above the published value of 0.60 (22). However, the variability (std. dev.) within each reporting year was very large (Figure 4).

Figure 5 shows lysine, TSAA, and tryptophan, within each sampling year as a percent of crude protein (CP). Park et al., (26) suggested that the amino acid content as a percent of CP is unchanged by oil removal, and is a useful measure of SBM protein quality. Assuming that meal is blended to a market target protein level, the relative amino acid level will distinguish higher and lower value meals. An example is the comparison of three year trend of SBM protein in Figure 2 with the relative lysine trend in Figure 5. The Chinese samples collected in 1999 had much higher protein content than the previous sampling years (Figure 2), but a much lower relative lysine percent than the previous sampling years (Figure 5). The CP of the SBM was positively correlated to lysine ($r = 0.269$) and negatively correlated to the relative lysine ($r = -0.385$) meaning that as the protein in SBM increased the lysine content will not rise proportionally. Samples from Argentina, Brazil, China and India all showed a decline in their relative TSAA values (Figure 5). From the weight / weight TSAA value shown in Figure 4, the decline was not apparent. Figure 6 shows the trend in some of the essential amino acids relative to their SBM protein. The amino acid relative percentages did not increase or decrease with the increase or decrease of SBM protein.

Three methods were used in determining the protein content of the SBM. Near infrared (NIR) method (predictive), the Dumas combustion method (measured) and the Kjeldahl method (measured). Figure 7 compares these methods. Results from the NIR and the Dumas combustion methods were nearly identical and their SD of the means from three years of sampling for each method was 1.15 and 1.35 respectively. The average difference between the results was 0.36 % (Dumas being higher), regardless of the source of the samples. The Kjeldahl method produced lower protein values (SD of means from one year of sampling = 1.67). The average protein value difference between the Kjeldahl and the NIR method was 0.10 % (NIR being higher) and the protein value difference between Dumas and Kjeldahl was 0.45 % (Dumas being higher). Jung et al. (27) reported the Dumas combustion method gave 0.91% higher protein value over Kjeldahl (R^2 = 0.997) in various soy products.

Soybean meal from different countries and continents varied in proximate composition as well as amino acid profile. Soybean meals from the U.S. were highest in compositional quality, amino acid profile, and protein solubility. SBM samples from Argentina, Brazil and India were of lower quality. Relative amino acid percentages (of the meal protein) showed that increases in amino acids were not proportional to increases in protein content.

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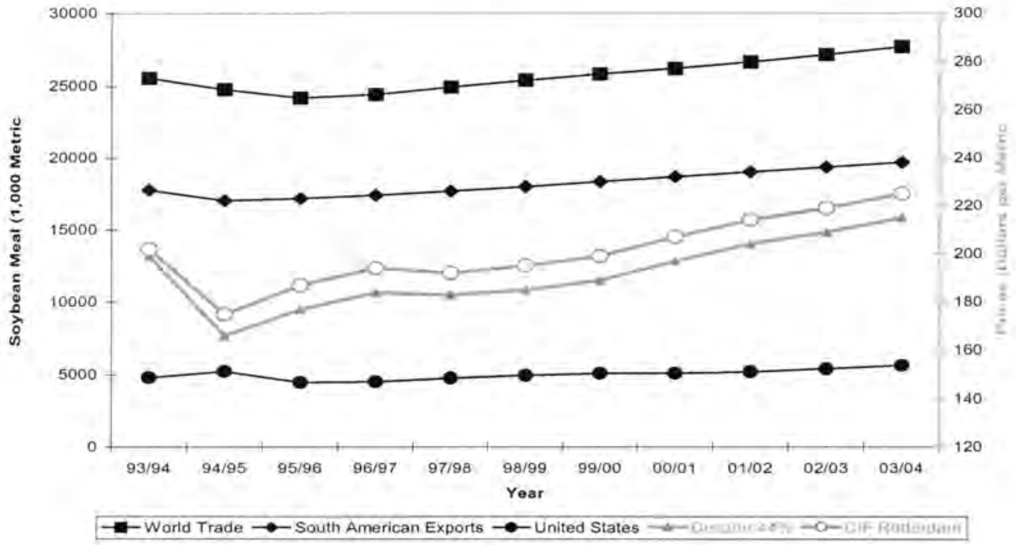
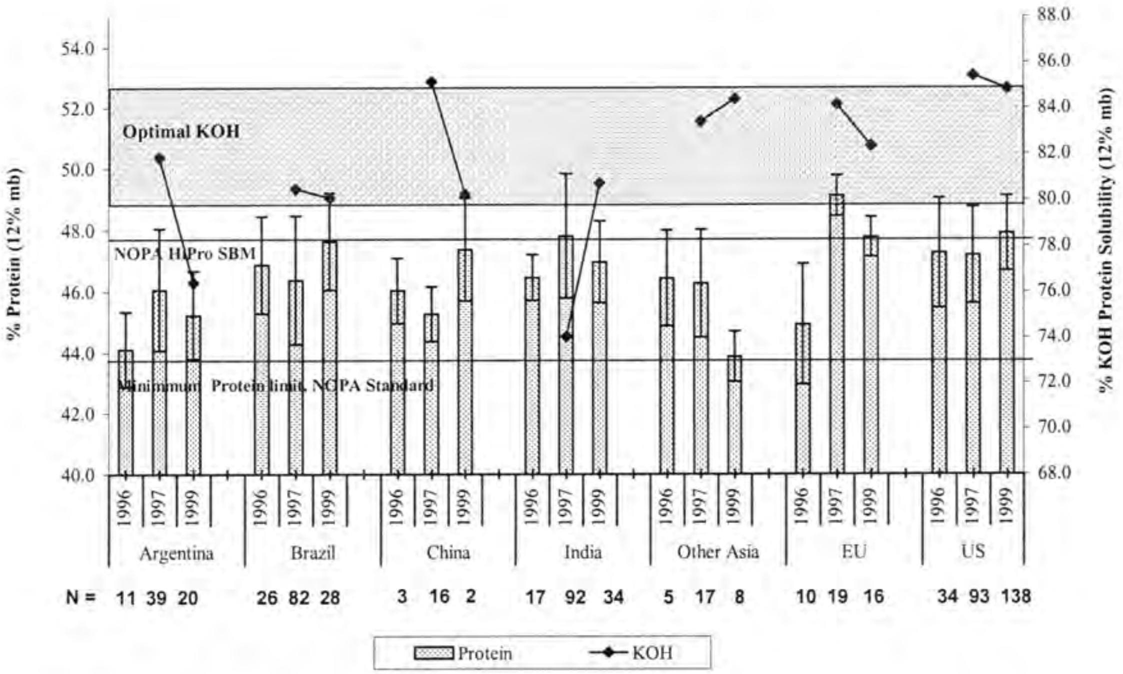
Figure 1: World soybean meal trade and price



Data are @ 12% moisture basis.

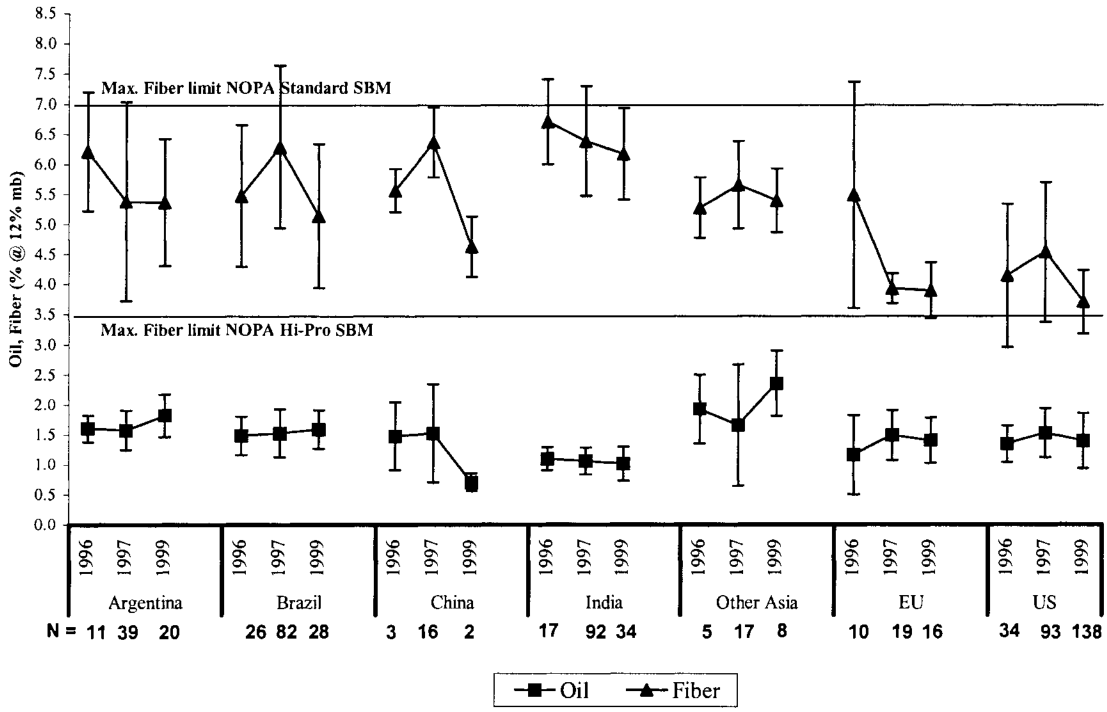
Source: USDA (3)

Figure 2: Protein and KOH solubility in SBM by points of meal origin



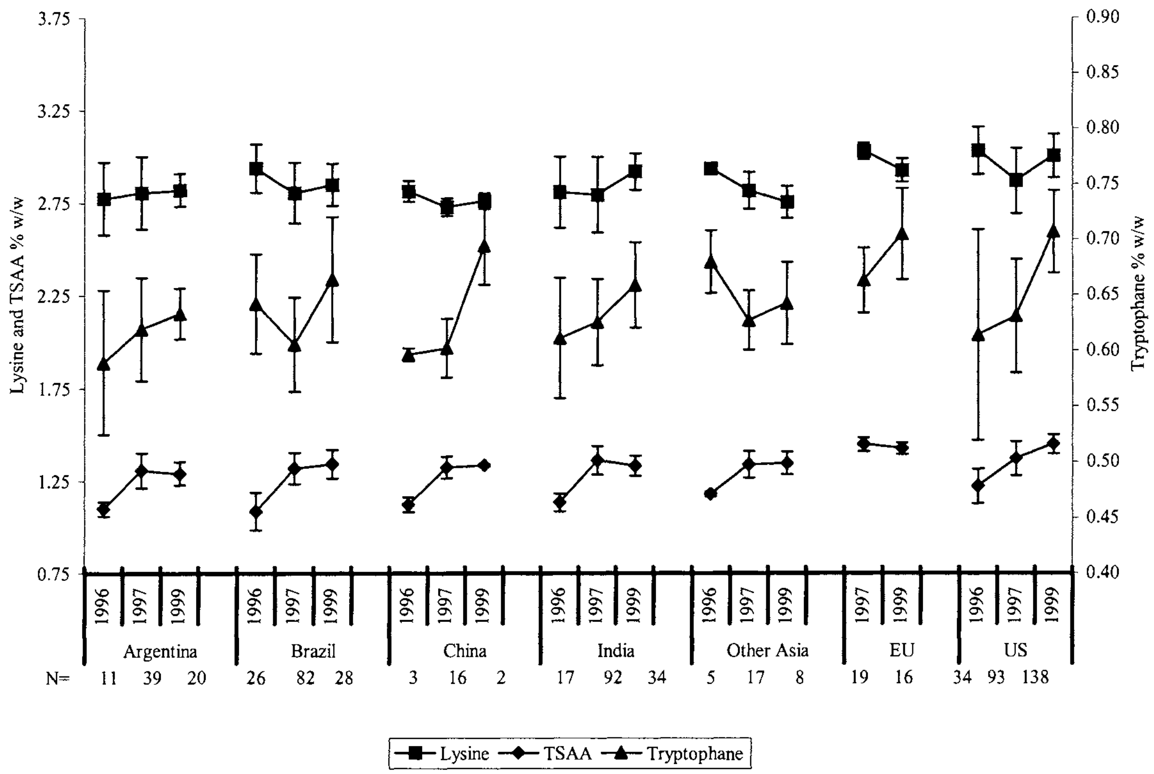
Data are @ 12% moisture basis. Error bars represent SD

Figure 3: Oil and fiber content of SBM by points of meal origin



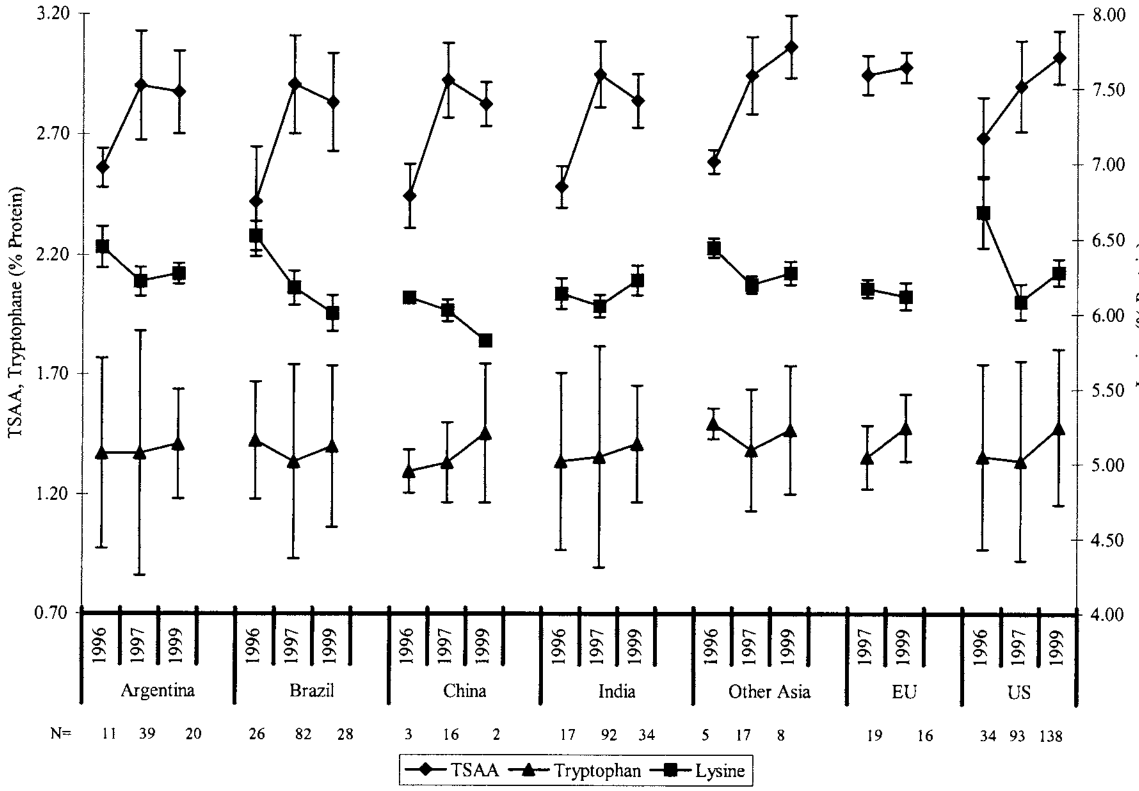
Data are @ 12% moisture basis. Error bars represent SD

Figure 4: Lysine, total sulfur amino acid and tryptophan contents of SBM by points of meal origin



Data are @ 12% moisture basis. Error bars represent SD

Figure 5: Total sulfur amino acids, tryptophane and lysine content expressed as percent of SBM protein by points of meal origin



Error bars represent SD

Figure 6: Soybean meal amino acids as a percent of crude protein (1996 – 1999)

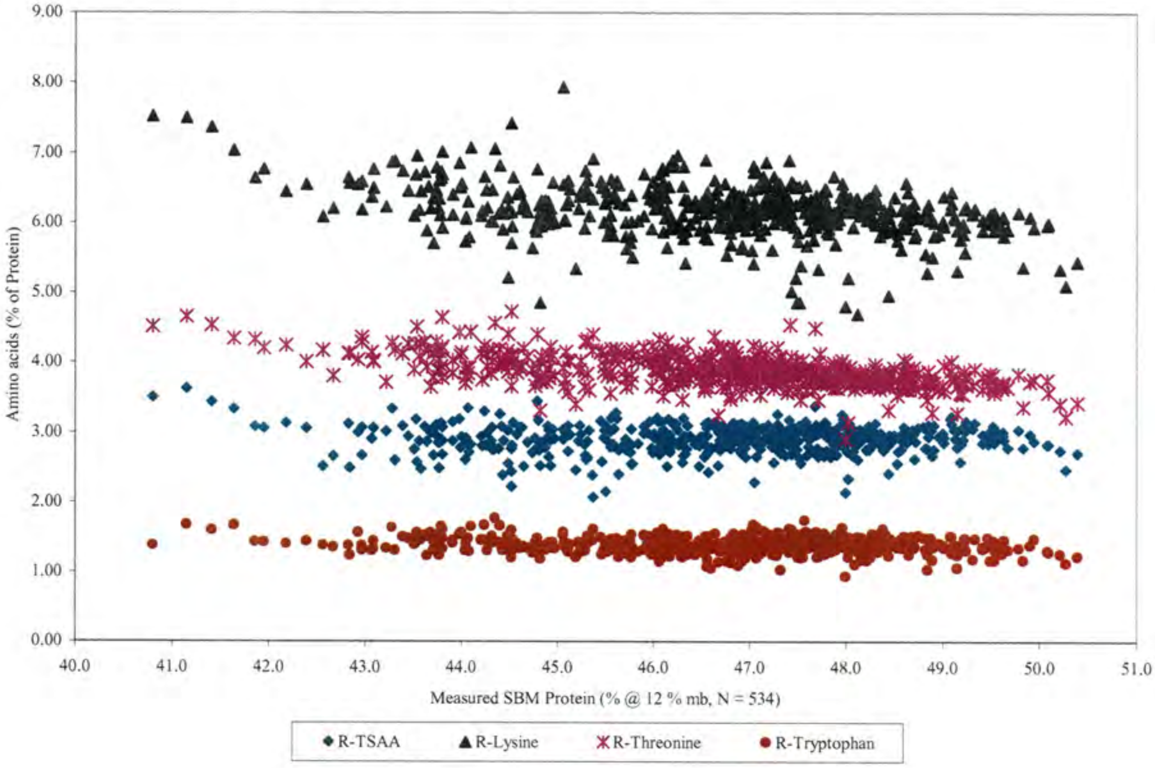
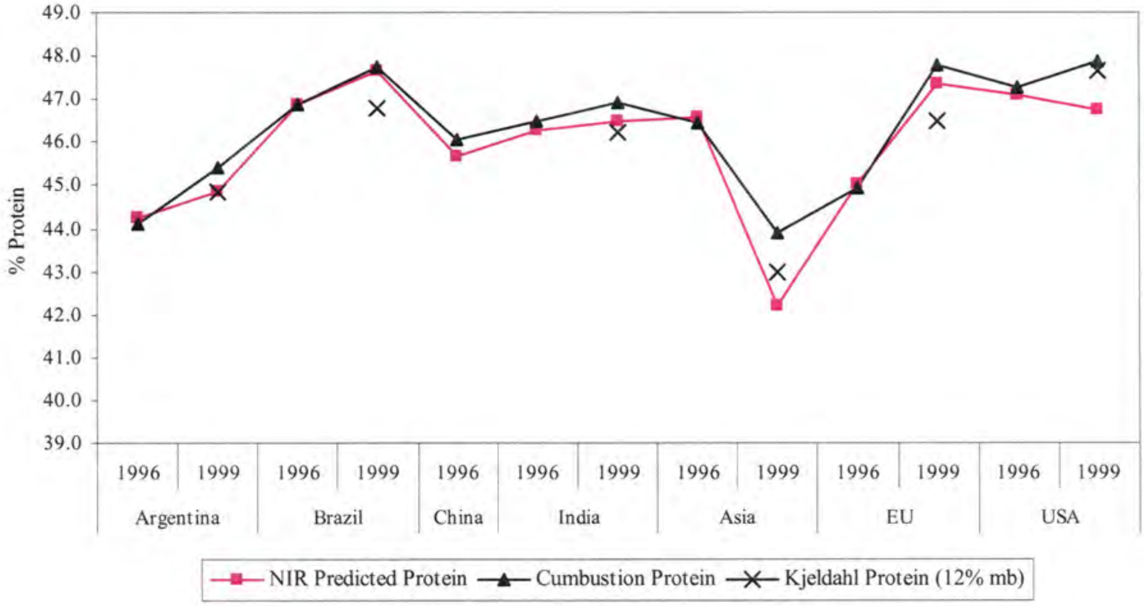


Figure 7: Predictive (NIR) and measured (combustion and kjeldahl) methods to determining SBM protein



Data are @ 12% moisture basis.

TABLE 1

Specifications for solvent extracted and dehulled soybean meal (SBM) (%)

	Min./Max.	Solvent extracted SBM	Dehulled SBM
Moisture	Max.	12.0	12.0
Protein	Min.	44.0	47.5 – 49.0
Oil	Min.	0.5	0.5
Crude Fiber	Max.	7.0	3.3 – 3.5
Anticacking agent	Max.	0.5	0.5

Source: NOPA (2)

TABLE 2

Summary of Soybean Meal quality by points of Meal Origin (1996-1999)[a]

Charactaeristic	Published Values (22)	EU		US		India		Brazil		Other Asia		China		Argentina	
N		35		265		143		136		30		21		70	
Crude Protein (%)	44.00/47.50	47.72	A	47.58	A	47.46	AB	46.74	B	45.66	C	45.59	C	45.53	C
Oil (%)	0.5/1.00	1.38	C	1.43	C	1.05	D	1.53	BC	1.89	A	1.44	C	1.65	B
Fiber (%)	7.00/3.00	4.26	DE	4.05	E	6.37	A	5.88	BC	5.52	C	6.09	AB	5.51	C
Protein Solubility %[b]		83.34	AB	85.01	A	76.32	C	80.37	B	83.72	AB	84.60	A	79.90	BC
Urease Δ pH		0.04	BC	0.04	BC	0.06	AB	0.04	BC	0.03	C	0.08	A	0.03	C
Essential Amino Acids (% w/w)															
Cystine	0.67	0.76	A	0.74	B	0.68	CD	0.69	C	0.69	C	0.69	CD	0.67	D
Methionine	0.65	0.67	A	0.67	A	0.65	B	0.62	CD	0.63	C	0.61	D	0.62	CD
Lysine	2.90/2.96	2.98	A	2.95	A	2.85	B	2.83	B	2.80	BC	2.74	C	2.81	B
Tryptophan	0.60	0.68	A	0.67	A	0.64	B	0.63	BC	0.64	B	0.61	C	0.62	BC
Arginine	3.40	3.56	A	3.43	B	3.42	B	3.41	B	3.26	C	3.31	C	3.31	C
Histadine	1.10	1.29	A	1.27	A	1.27	A	1.23	BC	1.21	C	1.27	A	1.24	B
Isoleucine	2.50	2.14	A	2.08	B	2.10	AB	2.06	B	1.99	C	1.93	D	2.00	C
Leucine	3.40	3.71	A	3.61	BC	3.66	AB	3.57	C	3.48	D	3.44	D	3.48	D
Phenylalanine	2.20	2.48	A	2.36	C	2.42	B	2.39	BC	2.27	DE	2.24	E	2.31	D
Threonine	1.70	1.84	A	1.82	AB	1.85	A	1.79	BC	1.77	CD	1.74	D	1.77	CD
Valine	2.40	2.29	A	2.23	BC	2.26	AB	2.20	C	2.12	D	2.12	D	2.18	C
TSAA	1.32/1.39	1.43		1.40		1.33		1.31		1.32		1.30		1.29	
Total Essential Amino Acids		17.31		16.80		16.98		16.65		16.10		16.04		16.28	
Total Nonessential Amino Acids		24.31		23.92		24.37		23.73		23.19		22.80		23.03	
Total Amino Acids		46.82	A	45.82	BC	46.26	AB	45.23	C	44.15	D	43.54	D	44.15	D

a: All values are expressed on 12% moisture basis and Means in the same row with the same letter are not significantly different ($P<0.05$).

b: Protein Solubility in potassium hydroxide (KOH-method).

TABLE 3
Correlation of soybean meal constituents

	N	Protein [1]	Oil	Fiber	KOH [2]	Urease	Lys	Thr	Try	Total AA[3]	TSAA	R-TSAA[4]	R Lys[4]	R-Thr[4]	R-Try[4]
Protein [1]	700	1.000													
Oil	700	-0.296	1.000												
Fiber	700	**-0.529**	-0.076	1.000											
KOH	305	0.258	0.029	-0.385	1.000										
Urease	141	-0.034	-0.113	0.090	0.047	1.000									
Lys	534	0.269	-0.079	-0.360	0.208	-0.021	1.000								
Thr	534	0.126	-0.141	-0.067	0.053	0.045	**0.617**	1.000							
Try	534	0.322	-0.060	-0.432	0.202	0.036	**0.547**	0.410	1.000						
Total AA	534	0.284	-0.164	-0.190	0.110	0.027	**0.757**	**0.839**	**0.578**	1.000					
TSAA	534	**0.501**	-0.096	-0.455	0.213	0.048	**0.537**	0.368	**0.510**	**0.613**	1.000				
R TSAA	534	-0.010	0.058	-0.145	0.071	0.073	0.457	0.342	0.394	**0.535**	**0.860**	1.000			
R Lys	534	-0.385	0.110	0.070	0.049	-0.001	**0.784**	**0.501**	0.317	**0.541**	0.194	0.447	1.000		
R Thr	534	**-0.549**	0.073	0.366	-0.122	0.060	0.345	**0.758**	0.134	**0.517**	-0.020	0.294	**0.685**	1.000	
R-Try	534	-0.117	0.089	-0.160	0.098	0.052	0.456	0.375	**0.902**	0.479	0.309	0.422	**0.513**	0.393	1.000
Kjeldahl [4]	169	**0.925**	-0.286	**-0.495**	-	-	0.154	0.120	0.231	0.170	0.436	-0.091	-0.410	**-0.584**	-0.18

1. Protein by Dumas combustion method
2. KOH = Protein solubility in a solution of 0.2% potassium hydroxide
3. Sum of 23 amino acids
4. Protein by kjeldahl method
5. Relative ratio of amino acid to SBM protein

CHAPTER III

RELATIONSHIP OF SOYBEAN MEAL QUALITY AND SOYBEAN QUALITY

A paper to be submitted to *J. Am. Oil Chem. Soc.*

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Running title: Soybean and soybean meal quality.

ABSTRACT

Data on the U.S. soybean quality were summarized by geographical regions and matched with soybean meal samples from 55 soybean processing plants. Both soybean and soybean meal protein followed the soybean protein regional trend (higher in southwestern regions and lower for northwestern regions). However, the ratio of essential amino acids to soybean meal protein did not change within and across region. This validated the earlier findings from whole soybeans; that soybean meal from the low protein regions may have equal protein quality to that of soybean meal produced in high protein regions.

INTRODUCTION

Soybean yield and acreage planted has been increasing for the last 15 years. These increases have had little effect on the average protein and oil content of the soybean (Table 1). The U.S. soybean breeders have continued to improve yield, which is the primary factor determining producer income, and have been successful in preventing a loss of quality. This was the primary request of many international customers when the American Soybean Association (ASA) initiated an annual soybean quality survey and supported a continuing research emphasis on composition (1). Yet, the United States share of the world market for all soy commodities has been declining; soybean share, down 50%, soybean oil share, down 66%, and the SBM share down 70% between 1977 and 2001 (2).

Protein and oil content determine the amount and quality of end products - soybean meal (SBM) and soybean oil from a 60 lbs bushel (27.24 kg) of soybeans (3). In 1989, the U.S. Federal Grain Inspection Service added soybean protein and oil content to the U.S. Soybean Standards (4). However, modern high-performance nutrition focuses more on the soybean meals' amino acid composition than on their crude protein composition. In livestock diets, the concentrations of limiting amino acids such as lysine (swine), methionine + cystine (poultry), and tryptophan (both poultry and swine) are important factors. Including amino acid data in assessment of soybean value may magnify the variability of feed value among lots at all protein levels. If an amino acid rises (or falls) with increasing (or decreasing) protein, then the amino acid change could add or subtract from the value gain from protein, depending on whether the ratio of amino acid to protein increased or decreased. If the protein content is low but the amino acid of interest is high, then the low protein soybeans can still be used to achieve the feed formulation.

At present, the SBM protein quality determination includes the protein solubility test by the KOH (5) method and the urease activity test (6) which measure SBM processing conditions. The urease test is a standard method to determine inadequate toasting of SBM by industry. Dale et al. (7) reported that a SBM sample of 0.00 Urease value can be either optimally processed or over cooked. Protein Solubility by KOH method (5) was a good indicator of over processed meal. Other studies have found that a pH increase of 0.50 for the Urease test was a good indicator for the optimum processing of SBM (8, 9, 10). Dale et al. (7) reported that there was variability in the protein solubility results which could be used to measure processing status among samples collected from different processing facilities. In commercially produced SBM, Dale and Whittle (11) stated that the KOH value should be between 80 and 85%. Meals with KOH values less than 80% were over processed and more than 85% were under processed.

In the United States, soybeans from northern and western regions trade at lesser prices than southern and central beans because of well-documented compositional differences (12, 13). Figure 1, generated from 17-year survey of U.S. soybeans, demonstrates the variation in U.S. soybean quality by region, with meal protein estimated by the soybean processing model SPROC (3).

Soybean meal is one of the two major products of soybean oil extraction. Approximately 95% of oil extraction plants utilize the solvent extraction process the other 5% through the mechanical extrusion (14). The market standard soybean meal protein content is 44% for standard meal and 48% for dehulled meal (15). This raises a quality issue for SBM producers, because producers located in northern regions where the beans are lower in protein have difficulty meeting the protein standards compared to their southern counterparts. However, no incentives are given to soybean growers in the northern states to produce higher protein bean.

Soybean meal is a major source of essential amino acids in livestock feed. According to the United States Department of Agriculture (USDA) and United Soybean Board (USB) 2000, 38.2 million metric tons (MMT) of SBM were produced in the U.S. and 30.4 MMT were used by the livestock industry. It seems obvious then that essential amino acids should be considered when evaluating SBM quality.

The general feed mixing assumption is that amino acid percentages follow the crude protein content and that therefore meal of a given protein content is consistent in amino acid levels. Hurburgh (16) reported that soybeans with high protein did not have increased sulfur containing amino acids (particularly methionine and cystine). Lysine increased at a slower relative rate with increasing protein. This meant that lower protein soybeans may produce meal that is higher in value for certain uses even though it may have lower total protein content than meal from high protein soybeans. Figure 2, from the Iowa State database, shows trends in selected essential amino acids relative to soybean protein (16). Obviously the increase in soybean protein had little effect on the cystine and methionine contents.

Paek et al., (17) found that changing the nitrogen fertilizer source from NH_3-N to NO_3 increased the seed protein by 4% in hydroponiclly grown soybeans. However, only the non-sulfur containing storage protein (beta-form) increased, and overall protein quality was reduced. Measurements of soybean meal quality across geographical regions in the U.S. and an evaluation of the relationship between soybean meal qualities to the quality of soybean grown in those regions are needed. The objective of this study were to summarize meal quality data from a geographically based survey of U.S. processing plants and to relate actual soybean meal quality to inbound soybean quality, estimated from the annual soybean quality survey

MATERIALS & METHODS

Soybean Meal Quality Survey: A national survey of SBM quality was done in 1998 – 1999, supported by the United Soybean Board (USB). The first year the study investigated soybean and SBM nutritional value for swine from 10 soybean processing plants located in 3 soybean production regions. Iowa State University was not part of this study. The 1999 study expanded that investigation to include 70 soybean processing plants representing all soybean growing regions in the United States.

The goal was to represent all the U.S. SBM production as shown in Table 2. Seventy processing plants were chosen to represent the ten soybean maturity zones, as shown in Figure 3(18). These plants were assigned a number 1-70. A list was generated which included the plant location (state and county), and the surrounding counties within the state and into the neighboring states that typically sent soybeans to that processing plant. Since a state could fall into more than one soybean maturity zone, decision was made to regroup plants in the same regional divisions that were used for the soybean harvest survey (Table 3). This was collected in approximate proportion to state production of soybean. Of the 70 processing plants surveyed, 55 responded. Samples were collected at the Fraizer Barn &Associate, Memphis TN office and forwarded to Iowa State for analysis.

The plants were requested to obtain two samples at three times during their fall 1999 processing season (last half of October, first half of November, and last half of November), which should have resulted in 420 total samples. They were also requested to sample once in the morning and once in the evening of the day or subsequent morning. Of the 420 samples requested: we received 104 samples, one sample per plant in the first two periods from 55 plants. Two allotments of samples were received from the FB&A (the beginning of the '99 harvest and the middle of the '99 harvest), the third would have completed the sampling of an entire harvest year, but the third sample was not received except from plant #66 in Ohio which sent 3 samples. There was no way to determine the sampling procedure or the exact sampling time for any sample. The timing of the allotments received at Iowa State, created above assumption. This illustrates a difficulty of voluntary survey programs, especially if the result does not generate economic value to the participants.

Soybean Quality Survey: A survey of soybean quality that included the 29 soybean producing states was conducted in 1999. This was the 1999 operation of the on going annual quality survey done with the cooperation of the United Soybean Board and the American

Soybean Association since 1986 (19). The purpose of the survey was to obtain state and regional estimates of soybean quality (protein and oil content) immediately after harvest. For the 1999 survey, approximately 4000 bar-coded tyvek sample return envelopes were mailed to producers in August, who in return provided samples of soybeans for analysis. The procedure for this survey was as described by Hurburgh, et al. (1). In 1999, 1059 samples were returned. Data were organized by state and by region (groups of states) (Table 3).

Survey results were placed in a spreadsheet that included state code, county code and farmer code followed by composition; moisture, fat, and protein on a 13% moisture basis. A soybean processing computational model (SPROC, 2.42,) (3) was applied to the composition data to predict SBM yield, protein content and other processing values on a sample by sample basis.

Compositional Analysis of soybean meal: The samples were mixed and tested with the same Infratec NIR (Foss-Tecator Infratec, Foss North America, Eden Prairie, Minn.) transmission instrument, using soybean meal calliberation for moisture, protein, oil and fiber. Samples were then split into two sub-samples. One was sent to the Woodson-Tenent, Laboratories Inc., Des Moines Iowa, where it was analyzed for moisture, protein, oil, and fiber content by the AOCS Official Methods 1998, Ba 4e-93 (revised 1995), Ba 3-38 (revised 1993), Ba 6-84 (revised 1995), and Ba 2a-38 (revised 1993) respectively (20). Protein solubility was measured using the KOH method (6). The other sub-sample was sent to the University of Missouri-Columbia where it was used for quantitative determination (w/w %) of 23 amino acids (AOAC, 982.30E (a,b,c)) (21). All results were adjusted to 12 % moisture basis. The amino acid results were also expressed as a percent of the crude protein (relative

% AA). Park and Hurburgh, (22) suggested that amino acid as a percent of its crude protein is unchanged by oil removal, and therefore is a useful measure of SBM protein quality. Assuming the meal is blended to a market target protein level, the relative amino acid levels will distinguish higher and lower value meals.

Merging of the soybean and the soybean meal surveys: Data from both surveys were sorted by state and county codes. The results of the SBM samples were matched to soybean data from the counties that likely sent soybeans to that processing plant. This was made possible because of the list generated by the Fraizer Barns & Associates which included the plant location (state and county), and the surrounding counties within the state and into the neighboring states that typically sent soybeans to that processing plant. So, if a county sent their soybeans to more than one SBM processing plant, then that county had soybean data assigned to both plants. Soybean and SBM data that could not be related to each other were not used. There were 3 plants that sent SBM samples that could not be related to any county from the SB survey and there were 10 plants that were related to some counties from the soybean survey that did not submit SBM samples. This resulted in 52 plants that sent SBM samples and were related to one or more counties from the soybean survey.

Statistical Analysis: Compositional results were corrected to a 13% moisture basis (soybean) and 12% moisture basis (SBM). Results were sorted by SBM processing plant, state, county, and soybean growing region. Compositional results were averaged by processing plant and by locations (regions). Means, standard deviations, minimum and maximum values were calculated by state, region. Differences among compositional and quality means for plants and regions were tested for significance by least significant difference (LSD) formed from paired t-tests ($P = 0.05$).

RESULTS AND DISCUSSION

Soybean Quality Survey: The results of the 1999 soybean survey are shown in Table 3. One thousand fifty nine soybean samples were collected from 29 states, a 29% response rate. The geographical effect of increasing protein concentration from northwest to southeast was present. Over all this was a below average quality soybean crop, as shown also in Table 1. Protein was the lowest and oil second lowest in the survey history. Of the 1,059 soybean samples collected by the annual survey, 871 samples matched the counties that likely sent their soybeans to the 70 processing plants selected for the soybean meal survey.

Soybean Meal Quality Survey: A total of 104 samples were collected in two batches, covering 55 of the 70 plants. Seven plants (13%) only sent one sample; plant # 66 from Ohio sent three samples. Since no details except plant numbers were provided, duplicates were treated as replications. Averages were assumed to represent the plant's product quality for the 1999 crop year.

Predicted (by the SPROC simulation) and measured (by the survey) SBM, were sorted by processing plant, state, and region as shown in Table 4. More than half of the SBM (67 %) were in the 48% protein (above 47.5 %) classification specified by the National Oil Processors Association (NOPA) to be called "Hi Pro" (Figure 4). All the samples were above 44% protein. The majority of the lower protein SBM samples originated from WCB crushing plants Figure 4. The overall average for SBM protein in the survey was similar to the published estimate for SBM protein (23). Since product and trade specifications were not known for these samples, it was not possible to know whether the plants were targeting 44% or 48% SBM. However, only one plant (#44, Minnesota) produced SBM with protein content below 46 %, while all others were producing SBM with 46 % and higher protein.

The highest fiber content was 4.87%. This suggests that the plants were aiming to maximize protein content while allowing as much fiber as possible within the high-pro trading specification. Figure 5 shows that the residual oil content in all SBM samples was above the 0.5% assumed in the SPROC mathematical model setup. The overall average for the SBM residual oil was also 28% higher than the published value of 1.00%. The highest oil content of 4.40% was in samples from one plant in Arkansas that also received soybeans from Mississippi. Of the SBM samples, 31% (representing 31% of the crushing plants) passed the crude fiber specification for Hi Pro SBM (3.3 – 3.5 %), 13% were below the requirement and 56% were above the maximum fiber specification for Hi Pro. No SBM samples that met the Hi Pro fiber specification, met the Hi Pro protein specification of > 47.5%. Part of the explanation could be the high residual oil content in majority of the samples (range from 0.65 to 1.00 %).

Dale and Whittle (11) recommended an optimum protein solubility value of 80 - 85 % in SBM. Meals with KOH value less than 80% are over processed and meals with KOH value greater than 85% are under processed. By the Dale and Whittle specifications, 46% of the SBM processing plants were under processing SBM. However, regional averages show that all regions except ECB were within the 80 – 85% KOH value. The majority of the crushing plants (69%) in ECB regions were under processing their SBM. On the other hand, plant #3 in Arkansas was severely overcooking their SBM (KOH = 65.53%) as shown in Table 4.

The SBM samples were compared to the amino acid averages from previously published data (23) Table 4. The overall averages for lysine, TSAA (total sulfur containing amino acid), and their relative percentages of protein were similar to the published averages.

Correlations among the soybean and SBM constituents are shown in Table 5. The important correlations are the relationship among the soybean protein and oil to the predicted and measured SBM protein, oil and amino acids. As expected, predicted SBM values for protein and fiber were strongly correlated to the soybean protein (r = 0.948, 0.801 respectively), since the soybean constituents were used to predict them. The measured SBM protein was also positively correlated to soybean protein (r = 0.553) and predicted SBM protein (r = 0.644), however, the measured SBM protein was also positively correlated to the predicted SBM fiber (r = 0.710) but a positive correlation could only mean that SPROC could not predict the SBM fiber accurately.

Heat treatment of oilseeds during the oil extraction process can reduce the amount of available lysine. Barneveld et al. (24) showed that there was a relationship between lysine content and the true ileal digestible lysine ($R^2 = 0.9997$) and that these results can be a good indicator of available lysine and heat damage. In our samples the protein solubility of the SBM measured by the KOH method was positively correlated to lysine (r = 0.578) and the relative % lysine (r = 0.536). The SBM crude protein was positively correlated to TSAA (r = 0.692), lysine (r = 0.542), threonine (r = 0.801) and the total-AA (sum of 23 amino acid, r = 0.859).

Comparing Soybean to Soybean Meal Quality: The quality data from the 1999 SBM survey was merged with the quality data from the 1999 soybean survey by points of SBM origination. Compositional attributes among processing plants, protein concentration in soybean and SBM, and the ratio of SBM amino acids to SBM protein were compared by soybean processing plants, states and regions.

Figure 6 shows the SPROC model predictions of SBM protein. Values greater than zero meant that the model was over predicting protein and below zero meant the model was under predicting the protein content. Some of the probable cause of the over and under prediction could be the model assumptions. The model assumes that: 1) during SB preparation 10% of the hulls will be removed during the dehulling process, 2) after the oil extraction, 0.5% residual oil will remain in the flakes, 3) all meal formulation will be done at 12% moisture, and 4. the fiber content of the soybean will be 4.4 % at 13 % moisture base. Changes in points 1, 2, and 4 will affect the accuracy of this model. For example, higher residual oil and or fiber content will lower the protein value.

Figure 7 plots the predicted and measured SBM protein concentrations, and the measured soybean protein concentration, group by U.S. growing regions. As usual, the protein declined from northern to southern regions. The calculated values for SBM protein were also significantly lower for the meals produced in the Corn Belt (Eastern CB & Western CB) regions than for the Midsouth (MDS), Southeast (SE) and East Cost (EC). Based on the measured value from the survey, the SBM protein concentrations were not significantly different across the U.S. regions except in the meals originating from WCB area, which were lower in protein. The SE and EC regions were skewing the data, however. These regions are soybean deficit – there is greater processing capacity than soybean production. Thus, soybeans are imported from the other regions. Without using the six plants from the EC and SE regions, the correlation of calculated to measured protein decreased (r = 0.629).

There was no significant regional difference in relative lysine and TSAA content of SBM protein (Figure 8). The relative lysine values for plants located in WCB states were equal to or better than southern states. This was independent support of the previous prediction based on soybean samples (16) that soybeans from historically low protein areas could produce better amino acid profiles in their SBM than the soybean meals from high protein areas. Cystine and methionine are important limiting amino acids for poultry. Figure 8 also shows the relative ratio of total sulfur containing amino acid (TSAA) to SBM protein across the U.S. regions. The relative TSAA levels in SBM were not significantly different across the U.S. regions. Again, low protein regions did not have poor protein quality meal.

Tryptophane and threonine are the other limiting amino acids for the livestock. Threonine was positively correlated to the meal protein (r = 0.801), lysine (r = 0.552), Total-AA (r = 0.835), and TSAA (r = 0.716). The relative threonine content was negatively correlated to the non-protein nitrogen (r = -0.536) and positively correlated to methionine (r = 0.547). There were no significant differences in relative tryptophane or threonine content in SBM across the U.S. regions.

Figure 9 shows the relationship of relative lysine and TSAA in meal to the soybean protein across all soybean growing regions in the United Sates. Clearly, increases in soybean protein concentration had no significant effect on the relative concentration of these amino acids in the SBM made from those soybeans.

The quality of soybean meal on the basis of crude protein and fiber followed the regional trend predicted by soybean protein. The quality of soybean meal protein on the basis of amino acids did not track the protein trend. The relative amino acid concentrations in SBM samples collected from historically low soybean protein zones were not significantly different from relative amino acid levels in samples from historically high soybean protein zones.

ACKNOWLEDGMENT

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Figure 1: Summary of surveyed soybean and predicted soybean meal protein (1986 – 2000)

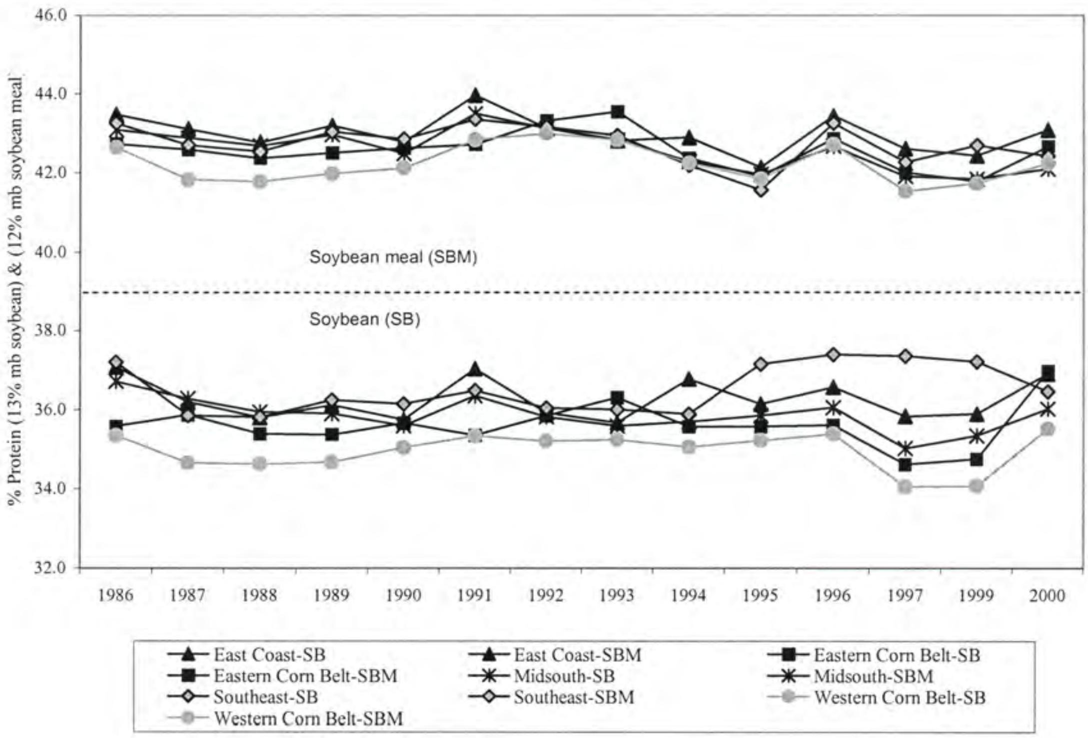
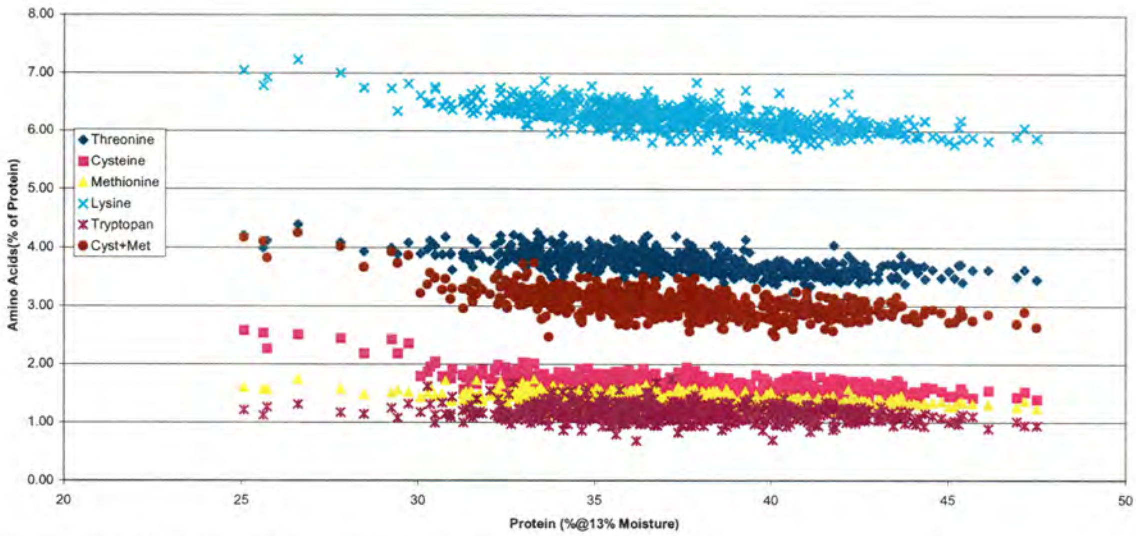
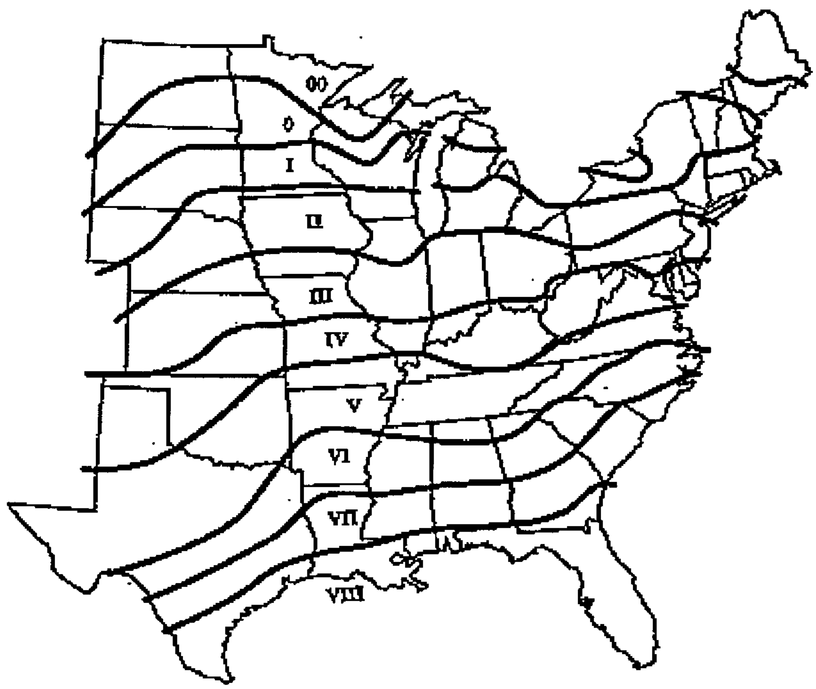


Figure 2: Soybean amino acids as a percent of crude protein



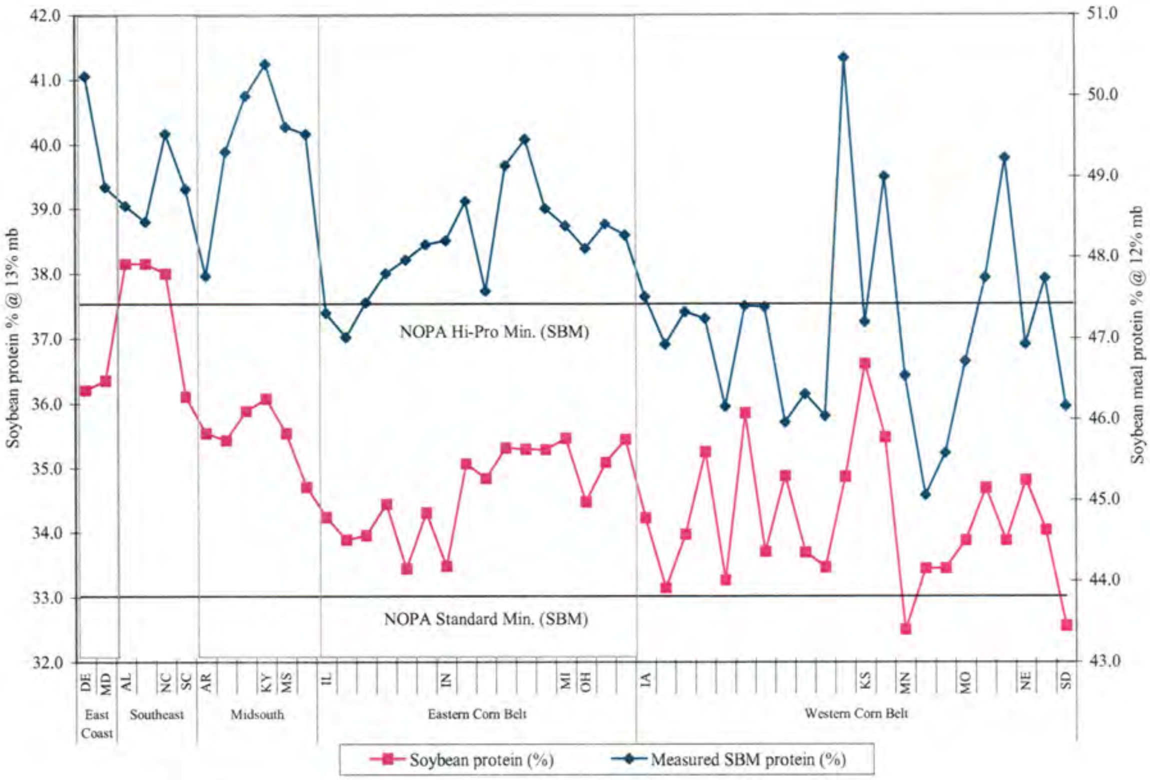
Source: Iowa State University, Soybean Quality Database 3/06/2003, n = 787

Figure 3: Soybean maturity zones



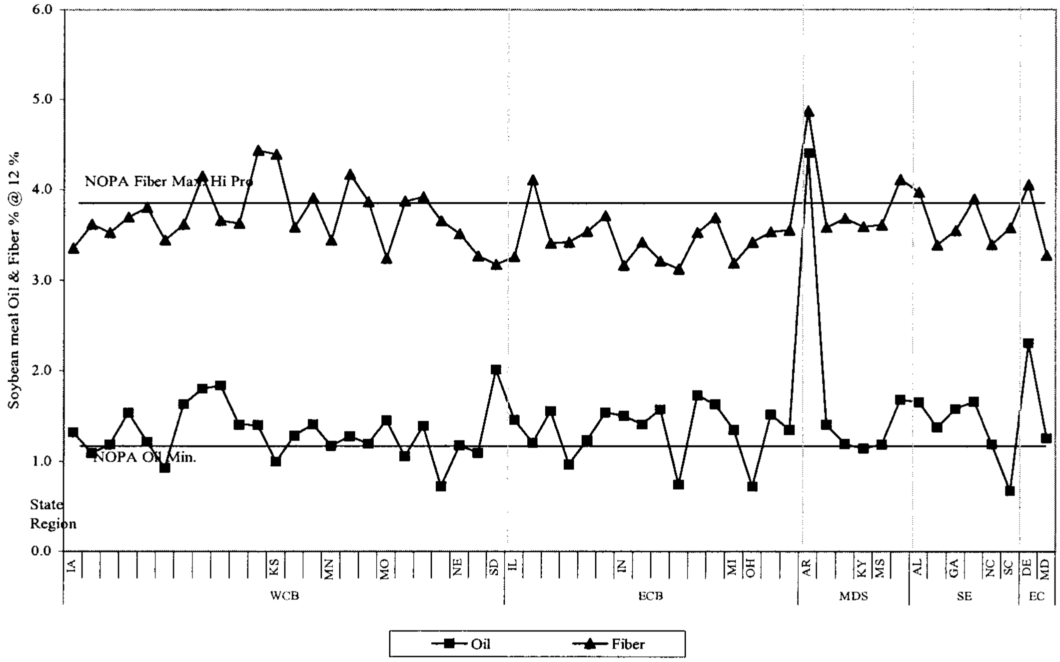
The 10 maturity groups correspond to horizontal bands across the United States. The soybean varieties that are best adapted to Iowa conditions are from groups I through III. Source (18)

Figure 4: Protein content in soybean and soybean meal by processing plant, 1999 USA



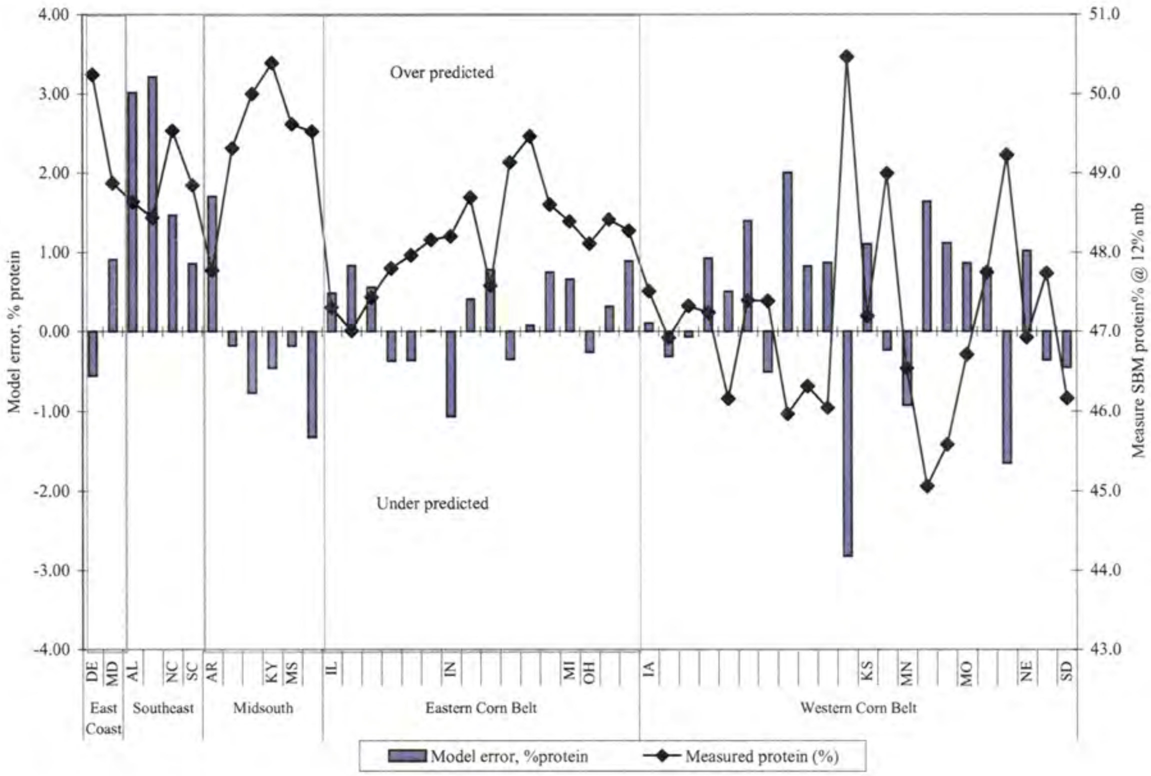
Note: each point on the graph represents average value from a processing plant

Figure 5: Oil and fiber content in soybean meal by processing plants



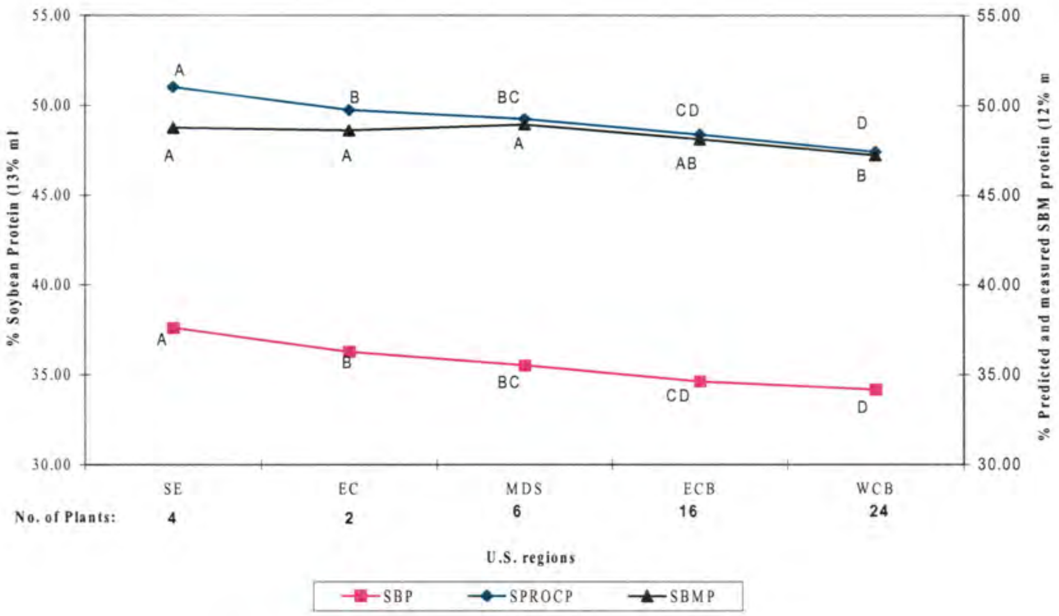
Note: each point on the graph represents average value from a processing plant

Figure 6: Protein content in soybean meal (SBM) and the difference between predicted and measured soybean meal protein



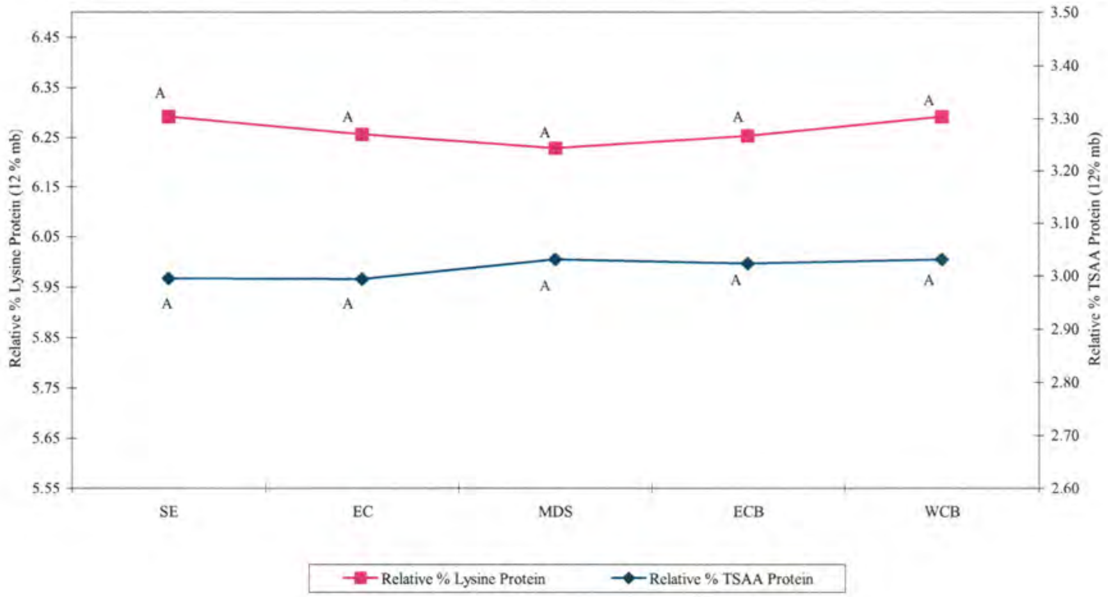
Note: each point on the graph represents average value from a processing plant

Figure 7: Protein content in soybean (SBP), soybean meal predicted (SPROCP) and measured (SBMP) across U.S. soybean growing regions



Note: Points of a graph with the same letter are no significantly different at P 0.05

Figure 8: Relative lysine and total sulfur containing amino acids (TSAA) content in soybean meal protein across U.S. soybean growing regions



Note: Points of a graph with the same letter are no significantly different at P 0.05

Figure 9: Relationship of the relative lysine and TSAA content in soybean meal protein to soybean protein

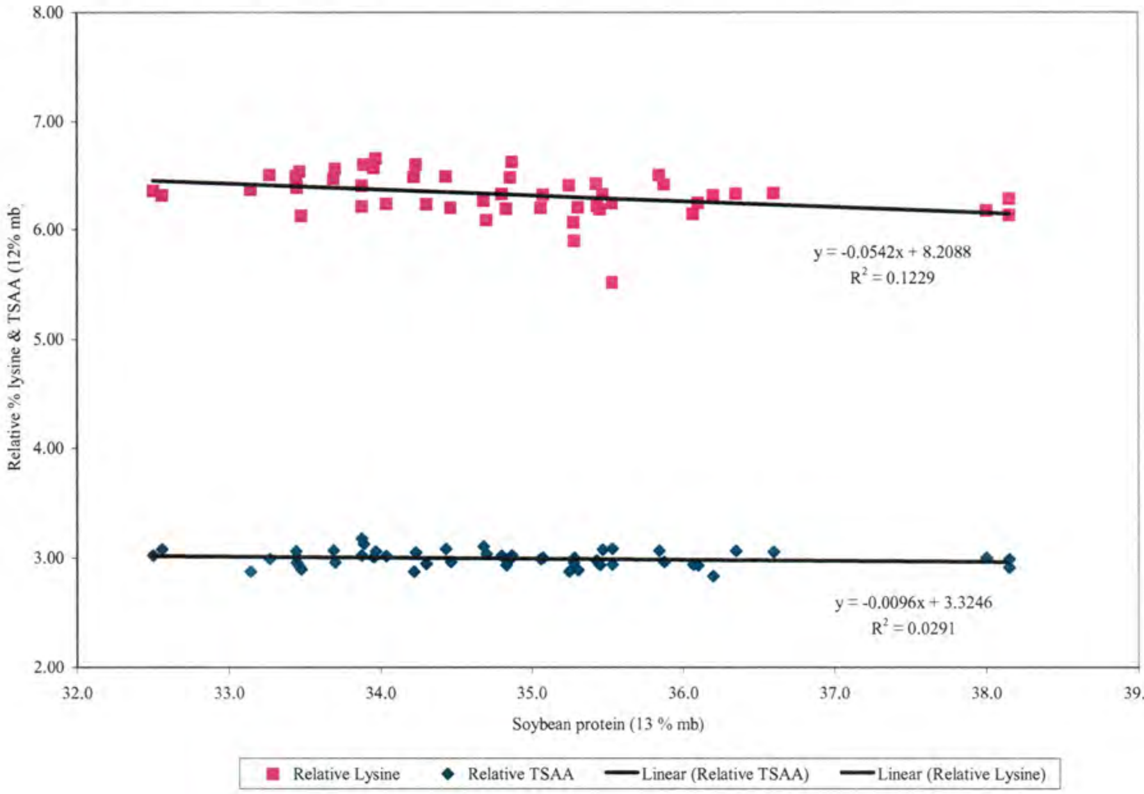


TABLE 1
Summary of yield and quality data for U.S. soybeans

Year	Yield (bu/acr.)	Protein (%)*	Oil (%)*	Sum (%)	Harvested (000 acres)	Production (000 bu)
1986	33.3	35.76	18.54	54.3	58,312	1,942,558
1987	33.9	35.46	19.11	54.57	57,172	1,937,722
1988	27	35.13	19.27	54.4	57,373	1,548,841
1989	32.3	35.18	18.73	53.91	59,538	1,923,666
1990	34.1	35.4	19.18	54.58	56,512	1,925,947
1991	34.2	35.48	18.66	54.14	58,011	1,986,539
1992	37.6	35.56	17.27	52.83	58,233	2,190,354
1993	32.6	35.73	18.03	53.76	57,307	1,869,718
1994	41.4	35.39	18.2	53.59	60,809	2,514,869
1995	35.3	35.45	18.19	53.64	61,544	2,174,254
1996	37.6	35.57	17.9	53.47	63,349	2,380,274
1997	38.9	34.55	18.47	53.02	69,110	2,688,750
1998	38.9	36.13	19.14	55.27	70,441	2,741,014
1999	36.6	34.55	18.61	53.16	72,446	2,653,758
2000	38.1	36.22	18.65	54.87	72,408	2,757,810
2001	39.6	34.98	18.97	53.95	72,975	2,890,682
2002	37.8	35.46	19.34	54.80	72,160	2,729,709
Averages	35.8	35.40	18.60	53.97	63,394	2,285,674
Std. Dev.	3.5	0.45	0.56	0.68	6,519	409,196

Sources: (25, 26)

* Protein and Oil content 13% moisture basis

TABLE 2
U.S. Soybean processing plants

Region	State	Number of Plants
Western Corn Belt	IA	13
	KS	3
	MN	3
	MO	4
	ND	2
	NE	3
	SD	1
Eastern Corn Belt	IL	9
	IN	6
	MI	1
	OH	5
Midsouth	AR	3
	KY	1
	LA	1
	MS	3
Southeast	AL	2
	GA	2
	NC	3
	SC	2
East Coast	DE	1
	MD	1
	VA	1
Total		70

TABLE 3
United soybean board 1999 soybean quality survey data

Region	State	N	Protein Average (%)	Protein SD	Oil Average (%)	Oil SD
Western Corn Belt (WCB)	Iowa	209	34.39	1.64	18.41	0.95
	Kansas	24	33.60	1.72	18.33	1.23
	Minnesota	109	33.61	1.55	18.35	0.84
	Missouri	53	34.18	2.08	19.04	1.05
	Nebraska	65	34.59	1.53	18.13	1.01
	North Dakota	8	33.48	1.40	17.78	1.09
	South Dakota	40	32.92	1.59	18.50	0.94
Averages	Western Corn Belt	508	34.06	1.72	18.42	0.99
Ranges			(25.3-40.0)		(15.0 - 23.9)	
Eastern Corn Belt (ECB)	Illinois	180	34.14	1.69	19.01	1.13
	Indiana	88	34.83	1.67	18.81	0.93
	Michigan	34	35.91	1.54	18.39	0.96
	Ohio	78	35.45	2.02	18.53	0.89
	Wisconsin	20	35.14	1.96	18.38	0.94
Averages	Eastern Corn Belt	400	34.75	1.85	18.79	1.05
Ranges			(28.3 – 40.3)		(15.9 - 22.4)	
Midsouth (MDS)	Arkansas	38	35.37	1.63	18.90	1.02
	Kentucky	14	35.49	2.27	18.50	1.22
	Louisiana	9	37.13	1.55	19.13	1.46
	Mississippi	22	35.15	2.27	19.03	1.57
	Oklahoma	5	34.24	1.29	18.56	0.91
	Tennessee	17	34.96	1.48	19.02	1.14
	Texas	3	34.17	1.86	19.03	1.15
Averages	Midsouth	108	35.34	1.90	18.90	1.22
Ranges			(30.1 - 40.4)		(15.2 - 21.4)	
Southeast (SE)	Alabama	7	38.13	1.74	18.17	1.31
	Florida	0	—	—	—	—
	Georgia	2	37.15	3.18	18.80	1.27
	North Carolina	8	36.86	0.84	17.81	0.65
	South Carolina	3	36.00	0.82	19.37	0.76
Averages	Southeast	20	37.21	1.55	18.27	1.07
Ranges			(34.9 – 40.9)		(16.6 - 20.2)	
East Coast (EC)	Delaware	2	36.15	1.20	19.10	0.99
	Maryland	6	36.37	1.52	18.63	0.31
	New Jersey	5	36.56	1.44	18.66	0.52
	Pennsylvania	6	35.52	2.21	18.65	0.88
	Virginia	4	34.70	1.20	18.83	0.42
Averages	East Coast	23	35.88	1.66	18.72	0.58
Ranges			(32.1 – 38.5)		(17.5 – 19.9)	
USA	Averages	1059	34.55	1.88	18.61	1.05
	Ranges		(25.3-40.9)		(15.0-23.9)	

Basis 13% moisture
Source: (27)

TABLE 4

Quality of soybean and soybean meal

				Soybean		Soybean Meal Composition					Amino Acid (w/w %)			
Region	**#**	**State**	**N**	**Protein**	**Oil**	**N**	**Δ a**	**Oil**	**Fiber**	**KOH**	**Lysine**	**TSAA[b]**	**Relative Lys.**	**Relative TSAA**
	9	IA	29	34.22	18.57	2	0.35	1.32	3.35	86.20	2.98	1.36	6.31	2.87
	10		26	33.14	18.91	2	-0.31	1.09	3.62	85.41	2.94	1.37	6.26	2.92
	11		19	33.97	18.37	2	-0.30	1.19	3.52	87.52	3.04	1.43	6.40	3.00
	12		24	35.25	17.78	2	0.65	1.54	3.70	83.01	2.99	1.36	6.30	2.87
	13		17	33.69	18.38			.	.	.	.	.	.	.
	14		33	33.27	18.80	2	0.46	1.21	3.80	83.90	2.93	1.39	6.34	3.02
	15		14	35.84	17.58	2	1.08	0.93	3.44	88.78	2.98	1.43	6.24	3.00
	16		5	33.70	18.68	2	-0.09	1.63	3.62	85.13	3.01	1.42	6.40	3.02
	17		14	35.84	17.58	1	1.96	1.80	4.52	85.69	2.88	1.41	6.16	3.00
	18		35	34.87	18.27	2	1.02	1.94	3.63	84.18	3.01	1.39	6.41	2.96
	19		17	33.69	18.38	2	0.45	1.47	3.63	84.78	2.96	1.41	6.33	3.03
	20		11	33.46	18.72	2	0.77	1.43	4.13	85.90	2.98	1.38	6.46	2.99
	21		7	34.86	17.77	1	-2.82	0.85	3.17	86.22	3.27	1.51	6.48	2.99
	37	KS	1	36.60	16.70	1	1.10	1.00	4.39	84.87	2.99	1.44	6.33	3.05
WCB	38		.	.	.	2		1.28	3.58	85.97	2.99	1.50	6.31	3.16
	39		3	35.47	17.67	2	1.22	1.41	3.91	83.86	3.03	1.49	6.36	3.13
	44	MN	16	32.50	18.80	2	-0.93	1.17	3.44	87.05	2.93	1.45	6.29	3.10
	45		29	33.44	18.16	2	1.07	1.28	4.17	82.63	2.89	1.36	6.33	2.99
	46		29	33.44	18.16	2	0.63	1.20	3.87	81.99	2.90	1.40	6.29	3.04
	47	MO	8	32.84	19.19	2	-1.30	1.45	3.24	88.60	2.94	1.49	6.16	3.13
	48		4	33.88	18.90	2	-1.33	1.05	3.87	80.50	2.98	1.46	6.09	2.98
	49		15	34.68	19.03	2	0.43	1.39	3.92	85.19	2.96	1.50	6.16	3.12
	50		4	33.88	18.90	2	-0.98	0.73	3.66	83.25	2.95	1.52	6.08	3.14
	57	ND	6	33.62	17.97			.	.	.	.	.	.	.
	58		9	34.22	17.79			.	.	.	.	.	.	.
	59	NE	28	34.80	17.84	2	0.90	1.18	3.51	85.54	2.94	1.44	6.25	3.06
	60		25	34.04	18.33	2	0.03	1.10	3.26	84.60	2.97	1.44	6.28	3.04
	61		6	34.78	18.77			.	.	.	.	.	.	.
	69	SD	12	32.56	18.47	2	-0.42	2.01	3.17	84.83	2.92	1.43	6.33	3.10
Average	**Western Corn Belt**		446	34.16	**18.30**	47	**0.11**	**1.30**	**3.68**	**85.02**	**2.97**	**1.43**	6.29	**3.03**
Ranges				**(32.50 - 36.60)**	**(16.70 - 19.19)**			**(0.73 - 2.01)**	**(3.17 - 4.52)**	**(80.50 - 88.78)**	**(2.88 - 3.27)**	**(1.36 - 1.52)**	**(6.08 - 6.48)**	**(2.87 - 3.16)**
	22	IL	44	34.23	18.86	2	0.24	1.46	3.26	84.12	3.04	1.45	6.40	3.04
	23		9	33.89	19.32	2	0.49	1.21	4.11	85.72	3.06	1.47	6.46	3.11
	24		26	33.95	19.35	2	0.57	1.56	3.41	87.26	3.06	1.44	6.46	3.04
	25		13	34.43	17.84	2	0.21	0.97	3.42	85.32	2.97	1.44	6.30	3.04
	26		15	33.44	19.91	2	-0.03	1.24	3.54	82.02	3.04	1.48	6.38	3.11
	27		52	34.24	18.78	.	.	.	.		.	.	.	.
	28		3	34.30	19.07	2	0.37	1.54	3.71	89.43	2.99	1.46	6.26	3.06
	29		32	34.09	19.28	.	.	.	.	.	.	.	.	.
	30		25	34.67	18.82	.	.	.	.	.	.	.	.	.
	31	IN	19	33.47	19.08	1	-1.06	1.50	3.16	84.91	2.99	1.44	6.20	2.98
ECB	32		7	35.06	19.17	2	0.13	1.41	3.42	86.65	3.00	1.49	6.13	3.03
	33		13	34.83	18.78	2	0.61	1.57	3.21	87.61	2.95	1.44	6.18	3.02
	34		19	35.31	18.46	2	-0.55	0.74	3.12	81.71	3.01	1.43	6.10	2.89
	35		5	35.28	19.76	2	0.61	1.73	3.52	88.29	2.95	1.49	6.03	3.06
	36		4	35.28	19.23	2	0.45	1.62	3.69	86.74	2.96	1.46	6.04	2.98
	43	MI	2	35.45	18.65	2	1.20	1.35	3.19	87.88	2.99	1.42	6.24	2.98
	62	OH	11	35.56	18.29	.	.	.	.	.	.	.	.	.
	63		11	34.46	18.41	2	-0.55	0.73	3.41	85.57	3.01	1.48	6.23	3.05
	64		20	36.02	18.23	.	.	.	.	.	.	.	.	.
	65		15	35.07	18.69	2	0.47	1.51	3.53	88.89	3.04	1.43	6.30	2.97
	66		9	35.43	18.56	3	0.75	1.34	3.55	87.49	3.02	1.46	6.25	3.02
Average	**Eastern Corn Belt**		354	34.69	**18.88**	32	**0.28**	**1.34**	**3.45**	**86.23**	**3.01**	**1.46**	**6.25**	**3.02**
Ranges				**(33.44 - 36.02)**	**(17.84 - 19.91)**			**(0.73 - 1.73)**	**(3.12 - 4.11)**	**(81.71 - 89.43)**	**(2.95 - 3.06)**	**(1.42 - 1.49)**	**(6.03 - 6.46)**	**(2.89 - 3.11)**
	3	AR	18	35.53	19.18	1	1.71	4.40	4.87	65.53	2.64	1.40	5.52	2.94
	4		19	35.43	19.22	2	0.43	1.40	3.58	87.97	3.08	1.47	6.33	3.01
	5		4	35.88	18.60	2	0.44	1.19	3.68	83.33	3.05	1.46	6.24	2.99
MDS	40	KY	3	36.07	18.07	2	-0.23	1.14	3.59	85.75	3.07	1.53	6.12	3.04
	41	LA	.	.	.	.	.	.	.	.	.	.	.	.
	51	MS	3	35.53	18.47			.	.	.	.	.	.	.
	52		3	35.53	18.47	2	0.09	1.19	3.61	90.21	3.09	1.54	6.25	3.13
	53		2	34.70	18.80	2	-0.67	1.68	4.11	88.98	3.02	1.51	6.18	3.08
Average	**Midsouth**		52	**35.52**	**18.69**	11	**0.32**	**1.83**	**3.90**	**83.63**	**2.99**	**1.48**	**6.11**	**3.03**
Ranges				**(34.70 - 36.07)**	**(18.07 - 19.22)**			**(1.14 - 4.40)**	**(3.58 - 4.87)**	**(65.53 - 90.21)**	**(2.64 - 3.09)**	**(1.40 - 1.54)**	**(5.52 - 6.33)**	**(2.94 - 3.13)**
	1	AL	2	38.15	17.00	2	2.98	1.65	3.97	83.72	3.03	1.47	6.22	3.02
	2		2	38.15	17.00	1	3.21	1.37	3.38	85.54	3.04	1.41	6.29	2.91
	7	GA	.	.	.	2		1.58	3.55	81.75	3.04	1.44	6.38	3.03
	8		.	.	.	2		1.66	3.90	80.33	3.04	1.42	6.38	2.99
SE	54	NC	1	38.00	18.10	2	1.92	1.19	3.39	85.87	3.06	1.52	6.24	3.09
	55		.	.	.			.	.	.	.	.	.	.
	56		.	.	.			.	.	.	.	.	.	.
	67	SC	.	.	.			.	.	.	.	.	.	.
	68		1	36.10	18.30	1	0.86	0.68	3.57	83.98	3.05	1.43	6.25	2.93
Average	**Southeast**		6	**37.60**	**17.60**	10	**2.60**	**1.35**	**3.62**	**83.53**	**3.04**	**1.45**	**6.29**	**2.99**
Ranges				**(36.10 - 38.15)**	**(17.00 - 18.30)**			**(0.68 - 1.66)**	**(3.38 - 3.97)**	**(80.33 - 85.87)**	**(3.03 - 3.06)**	**(1.41 - 1.52)**	**(6.22 - 6.38)**	**(2.91 - 3.09)**
	6	DE	7	36.20	18.77	2	1.55	2.30	4.05	82.41	2.99	1.40	6.22	2.90
EC	42	MD	6	36.35	18.60	2	0.68	1.26	3.27	86.44	3.09	1.52	6.29	3.09
	70	VA	.	.	.	.	.	.	.	.	.	.	.	.
Average	**East Coast**		13	**36.28**	**18.69**	4	**1.12**	**1.78**	**3.66**	**84.43**	**3.04**	**1.46**	**6.26**	**2.99**
Ranges				**(36.20 - 36.35)**	**(18.60 - 18.77)**			**(1.26 - 2.30)**	**(3.27 - 4.05)**	**(82.41 - 86.44)**	**(2.99 - 3.09)**	**(1.40 - 1.52)**	**(6.22 - 6.29)**	**(2.90 - 3.09)**
Overall Average			871	34.78	18.51	104	0.38	1.39	3.63	85.04	3.00	1.45	6.26	3.02
Published Averages*								1.00	3.00		2.96	1.39	6.23	2.93

Samples represented = 871; Samples not associated with a plant = 188

Western Corn Belt (W Midsouth (MDS); Eastern Corn Belt (EC Southeast (SE); East Coast (EC)

Soybean @ 13% moisture basis; Soybean Meal @ 12% moisture basis

* = Source Feedstuff (21)

TABLE 5

Correlation among Soybean and soybean meal constituents

	Soybean Protein(%)	Soybean Oil(%)	Predicted SBM Protein(%)	Predicted SBM Fiber(%)	Measured SBM Protein(%)	Measured SBM Oil(%)	Measured SBM Fiber(%)	SBM Protein Solubility (KOH)%	Threonine	Cystine	Methionine	Lysine	Tryptophan	Total AA	TSAA	Threonine (% Protein)	Cystine (%Protein)	Methionine (% Protein)
Soybean Oil(%)	**-0.519**	1.000																
Predicted SBM Protein(%)	**0.948**	-0.271	1.000															
Predicted SBM Fiber(%)	**0.801**	-0.127	**0.824**	1.000														
Measured SBM Protein(%)	**0.553**	0.048	**0.644**	**0.710**	1.000													
Measured SBM Oil(%)	0.072	0.218	0.142	0.105	-0.155	1.000												
Measured SBM Fiber(%)	0.132	-0.122	0.100	0.077	-0.256	0.488	1.000											
SBM Protein Solubility (% KOH)	-0.022	-0.013	-0.027	0.102	0.131	**-0.578**	-0.492	1.000										
Threonine	0.424	0.141	0.499	**0.527**	**0.801**	-0.295	-0.377	0.170	1.000									
Cystine	0.186	0.160	0.270	0.336	**0.588**	-0.156	-0.078	0.303	**0.575**	1.000								
Methionine	0.262	0.147	0.351	0.381	**0.726**	-0.320	-0.365	0.233	**0.806**	**0.692**	1.000							
Lysine	0.258	-0.138	0.238	0.290	0.542	**-0.598**	-0.484	**0.578**	**0.552**	0.321	**0.563**	1.000						
Total-AA	0.430	0.034	0.486	**0.573**	**0.859**	-0.301	-0.334	0.186	**0.835**	**0.501**	**0.779**	0.759	0.403	1.000				
TSAA	0.232	0.167	0.325	0.382	**0.692**	-0.236	-0.201	0.299	**0.716**	**0.956**	**0.874**	0.446	0.092	**0.656**	1.000			
Threonine (% Protein)	-0.239	0.141	-0.269	-0.330	-0.367	-0.211	-0.176	0.054	0.263	-0.053	0.083	-0.012	0.073	-0.085	-0.002	1.000		
Cystine (% Protein)	-0.148	0.163	-0.107	-0.068	0.047	-0.089	0.074	0.283	0.168	**0.836**	0.364	0.028	-0.232	0.037	**0.711**	0.185	1.000	
Methionine (% Protein)	-0.271	0.156	-0.248	-0.282	-0.122	-0.280	-0.227	0.184	0.225	0.312	**0.593**	0.179	-0.063	0.120	0.452	**0.547**	0.472	1.000
Lysine (% Protein)	-0.219	-0.197	-0.325	-0.327	-0.309	**-0.538**	-0.311	**0.536**	-0.114	-0.179	-0.031	0.632	-0.128	0.067	-0.133	0.325	-0.011	0.317
Tryptophane (% Protein)	-0.132	0.184	-0.130	-0.188	-0.185	0.136	0.078	-0.362	-0.017	-0.318	-0.151	-0.122	**0.864**	-0.040	-0.275	0.273	-0.269	-0.003
TSAA (% Protein)	-0.218	0.184	-0.178	-0.162	-0.012	-0.177	-0.033	0.285	0.214	**0.752**	**0.507**	0.092	-0.199	0.075	**0.713**	0.354	**0.938**	**0.748**

GENERAL CONCLUSIONS

Soybean meal from different countries and continents varied in their proximate composition as well as their amino acid profile. This reflected on the average quality portrayed by the soybean meal compositions. Soybean meals from the U.S. over the three surveyed years have lead the global soybean meal in compositional quality and amino acid profile. Soybean meal processing quality was best determined by protein solubility. SBM samples from Argentina, Brazil and India were of lower quality. Relative lysine percentages (of the meal protein) showed that the rise in lysine in the meal was not proportional to the rise in meal protein.

The quality of soybean meal on the basis of crude protein and fiber does follow the regional trend predicted by soybean protein. The quality of soybean meal protein on the basis of amino acids may not always track protein trend. The relative lysine and threonine concentrations in SBM samples collected from historically low soybean protein zones were not significantly different from relative lysine and threonine concentrations in samples from historically high soybean protein zones.

Recommendations for Further Study

1. The U.S. SBM survey should be done with fewer processing plants and with better control over the sampling procedure.
2. A more robust mathematical model such as SPROC model which was used in the second part of this study will further improve the predictability of SBM composition for the periphery samples.

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APPENDIX

The Standards of identity governing U.S. Soybean and SBM

UNITED STATES STANDARDS FOR SOYBEANS (Revised Effective May 1, 1988)

USDA sets the standard by which grains are evaluated. (The following sections are reprinted from the Official United States Standards for Grain*)

Section C

Subpart A - General Provisions Terms Defined

8: Grains for which standards are established:

Grain refers to barley, corn, flaxseed, mixed grain, oats, rye, sorghum, soybeans, s, sunflower seeds, triticale and wheat. Standards for these food grains, feed grains, and oilseeds are established under the' United States Grain Standards Act.

 # 810.102 Definition of other terms

(d) Test weight per bushel. The weight per Winchester bushel (2,150.42 cubic inches) as determined using an approved device according to procedures prescribed in FGIS instructions. Test weight per bushel in the standards for corn, mixed grain, oats, sorghum and soybeans, is determined on the original sample. Test weight per bushel in the standards for barley, flaxseed, rye, sunflower seed, triticale and wheat is determined after mechanically cleaning the original sample. Test weight per bushel is recorded in whole and tenth pounds to the nearest tenth pound for wheat, rye, and triticale.

Special grade designations are shown as prescribed in #810.106 . Multiple special grade designations will be listed in alphabetical order. In the case of treated wheat, the official certificate shall show whether the wheat has been scoured, limed, washed, sulphured or otherwise treated.

SUBPART I - UNITED STATES STANDARDS FOR SOYBEANS

Terms Defined

#810.1601 Definition of soybeans:

Grain that consists of 50 percent or more of whole or broken soybeans (Glycine max (L)Merr.) that will not pass through an 8/64 round hole sieve and not more than 10.0 percent of other grains for which standards have been established under the United States Grain Standards Act.

#810.1602 Definition of other terms

(c) Stones. Concreted earthy or mineral matter and other substances of similar hardness that do not disintegrate in water.

(f) Sieve, 8/64 round hole sieve. A metal sieve 0.032 inch thick perforated with round holes 0.125 inch in diameter.

a) Classes: There are two classes for soybeans: Yellow soybeans and Mixed soybeans.

(1) Yellow soybeans: Soybeans that have yellow or green seed coats and which in cross section are yellow or have a yellow tinge, and may include not more than 10% of soybeans of other colors.

(2) Mixed soybeans: Soybeans that do not meet the requirements of the class of Yellow Soybeans.

b) Damaged kernels. Soybeans and pieces of soybeans that are badly ground-damaged, badly weather-damaged, diseased, frost-damaged, germ-damaged, heat damaged, insect-bored, mould-damaged, sprout-damaged, stinkbug stung or otherwise materially damaged. Stinkbug-stung kernels are considered damaged kernels at the rate of one fourth of the actual percentage of the stung kernels.

c) Foreign material. All matter that passes through an 8/64 round/hole sieve and all matter other than soybeans remaining in the sieved sample after sieving according to procedures prescribed in FGIS instructions.

d) Heat damaged kernels. Soybeans and pieces of soybeans that are materially discolored and damaged by heat.

e) Purple, mottled or stained. Soybeans that are discolored by the growth of fungus; or by dirt; or by a dirt-like substance(s) including non-toxic inoculants; or by other nontoxic substances.

f) Sieve, 8/64 round hole sieve. A metal sieve 0.032 inch thick perforated with round holes 0.125 inch in diameter.

g) Soybeans of other colours. Soybeans that have green, black, brown or bicoloured seed coats. Soybeans that have green seed coats will also be green in cross section. Bicoloured soybeans will have seed coats of two colours, one of which is brown or black, and the brown or black colour covers 50% of the seed coat. The hilum of the soybean is not considered a part of the seed coat for this determination.

h) Splits. Soybeans with more than 1/4 of the bean removed and that are not damaged.

Principles governing the application of standards

#810.1063 Basis of determination.

Each determination of class, heat damaged kernels, damaged kernels, splits and soybeans of other colours is made on the basis of the grain when free from foreign material. Other determinations not specifically provided for under the general provisions are made on the basis of the grain as a whole.

Grades and Grade Requirements

#810.1604 Grades and grade requirements for soybeans:

Grade	Minimum test	Maximum Limits of:				
	Weight per Bushel (pounds)	Damaged Kernels		Foreign	Splits %	Soybean
		Heat Damaged %	Total %	Material %		Of other Colors %
U.S. No.1	56.0	0.2	2.0	1.0	10.0	1.0
U.S. No.2	54.0	0.5	3.0	2.0	20.0	2.0
U.S. No.3 1/	52.0	1.0	5.0	3.0	30.0	5.0
U.S. No.4 2/	49.0	3.0	8.0	5.0	40.0	10.0
U.S. Sample grade						

U.S. Sample Grade is soybeans that:

(a) Do not meet the requirements for U.S. Nos. 1,2,3 or 4, or;

(b) Contain 8 or more stones which have an average weight in excess of 0.2% of the sample weight, 2 or more pieces of glass, 3 or more Crotalaria seeds, 2 or more castor beans, 4 or more particles of an unknown substance(s), 10 or more rodent pellets, bird droppings or equivalent quantity of other abnormal filth per 1,000 grams of soybeans; or

(c) Have a musty, sour or commercially objectionable foreign odor (except garlic odor);or

(d) Are heating or otherwise of distinctly low quality.

1/ Soybeans that are purple mottled or stained are graded not higher than U.S. No. 3

2/ Soybeans that are materially weathered are graded not higher than U.S. No.4.

UNITED STATES STANDARDS FOR SOYBEANS MEAL (Revised May 1, 1988)

NOPA and AAFCO provides guidelines for the quality of SBM, but for different venues. Meaning that NOPA represents the oilseed processors and therefore will lean towards the best interest of the SBM producers.

(The following sections are reprinted from NOPA's Yearbook and Trading Rules).

Section 2: Standard Definitions:

A. Soybean Cake or Soybean Chips is the product after the extraction of part of the oil by pressure or solvents from soybeans. A name description of the process of manufacture, such as expeller, hydraulic, or solvent extracted shall be used in the brand name. It shall be designated and sold according to its protein content.

B. Soybean Meal is ground soybean cake, ground soybean chips, or ground soybean flakes. A name descriptive of the process of manufacture, such as expeller, hydraulic, or solvent extracted shall be used in the brand name. It shall be designated and sold according to in protein content.

C. (1) Soybean Mill Feed is the by-product resulting from the manufacture of soybean flour or grits and is composed of soybean hulls and the offal from the tail of the mill. A typical analysis is 13% crude protein and 32% crude fiber, and 13% moisture.

C (2) Soybean Mill Run is the product resulting from the manufacture of dehulled soybean meal and is composed of soybean hulls and such bean meats that adhere to the hull in normal milling operations. A typical analysis is I 1 % crude protein and 35% crude fiber, and 13% moisture.

C (3) Soybean Extracted Soybean Flakes is the product obtained after extracting part of the oil from soybeans by the use of hexane or homologous hydrocarbon solvents. It shall be designated and sold according to its protein content.

Section 3. Standards Specifications:

A. Soybean Flakes and 44% Protein Soybean Meal are produced by cracking, heating and flaking soybeans and reducing the oil content of the conditioned product by the use of hexane or homologous hydrocarbon solvents. The extracted flakes are cooked and marketed as such or ground into meal. Standard specifications are as follows:

Protein	Minimum 44.0 %
Fat	Minimum 0.5 %
Fiber	Maximum 7.0 %
Moisture	Maximum 12.0 %

B. Soybean Flakes and High Protein or Solvent Extracted Soybean Meal are produced by cracking, heating and flaking dehulled soybeans and reducing the oil content of the conditioned flakes by the use of hexane or homologous hydrocarbon solvents. The extracted flakes are cooked and marketed as such or ground into meal. Standard specifications are as follows:

Protein	Minimum 47.5 % - 49.0%
Fat	Minimum 0.5 %
Fiber	Maximum 3.3 % - 3.5 %
Moisture	Maximum 12.0 %

(* As determined by Buyer and Seller at time of sale.)

C. Any of the above meal products (listed in Section 3 above) may contain a non-nutritive inert, non-toxic conditioning agent to reduce caking and improve flow-ability, in an amount not to be exceeded that is necessary to accomplish its intended effect and in no case to exceed 0.5% or 10 lbs. per ton by weight of the total meal product. The name of the conditioning agent must be shown as an added ingredient.

In trade even a little edge translates into monetary gain for one of the party involved in the transaction. Thus the rules are more specific to include SBM compositional analyses and declaration of the type of additive used as an anticaking agent.

AAFCO repersents among other, the feed industries. Therefore they are more concerned about having the SBM manufacturer disclose the method used in producing the SBM (solvent extraction or extruder expelled). The rules regarding SBM compositional specification are much laxed (7% max. crude fiber content).

(The following section is reprinted from the AAFCO Official Publication 1990.)*

ASSOCIATION OF AMERICAN FEED CONTROL OFFICIALS INC. (AAFCO)

84. SOYBEAN PRODUCTS

a. OFFICIAL

84.1 Ground Soybeans is obtained by grinding whole soybeans without cooking or removing any of the oil. (Adopted 1933). IFN 5-04 -596 soybean seeds, ground.

84.3 Soybeans Hulls consist primarily of the outer covering of the soybean (Adopted 1948). IFN-1-04-560 Soybean seed coats (hulls).

84.4 Soybean Feed, Solvent Extracted, is the product remaining after the partial removal of protein and nitrogen free extract from dehulled solvent extracted soybean flakes. (Adopted 1948, Amended 1960, 1964). IFN 5-04-613 Soybean seeds low protein low carbohydrates meal solvent extracted.

84.7 Soybean Meal, Dehulled, Solvent Extracted is obtained by grinding the flakes remaining after removal of most of the oil from dehulled soybeans by a solvent extraction process. It must contain not more than 3.3% crude fiber. It may contain an inert non-toxic conditioning agent either nutritive or non-nutritive or any combination thereof, to reduce caking and improve flow-ability in an amount not to exceed that necessary to accomplish its intended effect and in no case to exceed 0.5% . The name of the conditioning agent must be shown as an added ingredient. When listed as an ingredient in a manufactured feed, it may be identified as "dehulled Soybean Meal". (Proposed 1978, Adopted 1980). IFN 5-04-612 Soybean seeds without hulls meal solvent extracted.

84.8 Soybean Mill Feed is composed of soybean hulls and the offal from the tail of the mill which results from the manufacture of soy grits or flour. It must contain not less than 13% crude protein and not more than 32% crude fiber. (Proposed 1960, Adopted 1961, Amended 1964). IFN 4-04-594 Soybean Flour by-product.

84.09 Soybean Mill Run is composed of soybean hulls and such bean meats that adhere to the hulls which results from . normal milling operations in the production of dehulled soybean meal. It must contain not less than 11 % crude protein and not more than 35% crude fiber. (Proposed 1960, Adopted 1961, Amended 1964). IFN 4-04-595 Soybean mill run.

84.13 Kibbled Soybean Meals is the product obtained by cooking ground solvent extracted soybean meal, under pressure and extruding from an expeller or other mechanical pressure device. It must be designated and sold according to its protein content and shall contain not more than 7% crude fiber.(Proposed 1969. Adopted 1971). IFN 5-09-343 Soybean seed kibbled solvent extracted.

84.15 Ground Extruded Whole Soybeans is the meal product resulting from extrusion by friction heat and/or steam, whole soybeans without removing any of the component parts. It must be sold according to its crude protein, fat and fiber content. (Proposed 1974, Adopted 1975). IFN 5-14-005 Soybean seeds extruded ground.

84.60 Soybean Meal Mechanical Extracted, is the product obtained by grinding the cake or chips which remain after removal of most of the oil from soybeans by a mechanical extraction process. It must contain not more than 7% crude fiber. It may contain an inert, non-toxic conditioning agent either nutritive or non-nutritive or any combination thereof, to reduce caking and improve flow-ability in an amount not to exceed that necessary to accomplish its intended effect and in no-case exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient. The words "Mechanical Extracted" are not required when listing as an ingredient in a manufactured feed. (Proposed 1978, Adopted 1980). IFN 5-04-600 Soybean seeds meal mechanical extracted.

84.61 Soybean Meal, Solvent Extracted, is the product obtained by grinding the flakes which remain after removal of most of the oil from soybeans by a solvent extraction process. It must contain not more than 7% crude fiber. It may contain and inert non-toxic conditioning agent either nutritive or non-nutritive and any combination thereof, to reduce caking and improve flow-ability in an amount not to exceed that necessary to accomplish its intended effect and in no case exceed 0.5%. The name of the conditioning agent must be shown as an added ingredient. The words "Solvent

Following are some basic differences NOPA and AAFCO specify:

NOPA: SBM compositional standards to meet maximum and minimum are specified.

AAFCO: Only crude fiber limit is specified. But the discloser of the type of method used to produce the SBM must be mentioned in the label.