Protein and Oil Patterns in U.S. and World Soybean Markets

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The Japan Oilseed Processors Association provided yearly data showing the average protein and oil content of imported soybeans from the U.S. (No. 2 Yellow and IOM grades), Brazil, Argentina, and the People's Republic of China. Throughout the years 1972–1988, U.S. No. 2 soybeans contained about 1–1.5% less oil than Brazilian soybeans. Recently, the protein content of U.S. soybeans has also fallen behind that of Brazil. U.S. IOM soybeans, a designation based on seed size, contained about 1.5% more protein and about 0.5% less oil than U.S. No. 2 soybeans. Surveys of U.S. soybeans in the years 1986, 1987, and 1988 showed consistent state and regional differences in protein and oil content. Soybeans from northern and western soybean-growing states (North Dakota, South Dakota, Minnesota, Iowa, Wisconsin) contained 1.5–2% less protein and 0.2–0.5% more oil than soybeans from southern states (Texas, Arkansas, Louisiana, Mississippi, Tennessee, Kentucky, Alabama, Georgia, South Carolina, North Carolina). State and regional differences in composition represented differences of up to 25 cents per bushel in Estimated Processed Value for one set of soybean meal and oil prices.

KEY WORDS: Composition, oil, protein, soybeans.

In the past 3–5 years, there has been a change in the attitude of the grain market toward quality. In essence, the change is one of realizing that customer (user) needs will play an increasing role in purchasing decisions. This is logical in view of expanding competitive supply. Availability is no longer a paramount concern. The stimulus for action has been an industry report, Commitment to Quality (1). This report defined four new, consumer-oriented objectives for U.S. Grain Standards, one of which is the inclusion of specialized quality factors of relevance to end users. The United States Department of Agriculture, Federal Grain Inspection Service, added soybean protein and oil content to the U.S. Soybean Standards in September, 1989.

Protein and oil contents determine the amount and quality of end products, soybean meal and soybean oil, that can be produced from a bushel of raw soybeans. At least two mathematical models have been developed to aid in the understanding of protein and oil values (2,3). The Updaw model is statistical and incorporates fixed assumptions about processing-plant variables, whereas the Brumm–Hurburgh model is a mass-balance of the solvent-extraction process. With the Brumm–Hurburgh model, and product prices of $250/ton for 44% protein meal and $0.23/lb for soybean oil, Iowa soybeans have a range in Estimated Processed Value (EPV) of nearly $1.00 per bushel. EPV is the sum of revenue from meal, oil and mill run (hulls). The importance of protein and oil content to processors was confirmed in interviews conducted by the Office of Technology Assessment, to support its study of the U.S. grain market (4).

A related physical issue is also important to processors. Soybeans below 34% protein (at 13% moisture, 19% oil) must be partly dehulled to make low-protein 44% meal. Some plants have no dehulling equipment; in those that do, merchandizing excess hulls separately is an expensive complication. Processors expect to add hulls to 44% meal because production of high-protein 47–49% meal already requires dehulling.

Geographic patterns will be important to both buyers and sellers faced with price differentials based on protein and oil content. At least five geographic levels of protein and oil patterns have been identified by recent studies and data compilations — international, domestic, regional, state, and local (5–10).

Consistent differences among exporting nations are an important source of supplier competition. Import buyers generally receive grain in 20,000 to 100,000-ton ship lots. The comingling necessary to produce these large lots obscures all variations except average country-to-country differences.

South America (Brazil in particular) is the major competitor for U.S. soybeans. South American production has steadily increased over the past 20 years. There has been a long-term perception that U.S. soybeans are inferior in oil content to Brazilian soybeans. The USDA reported that several shipments of U.S. soybeans as received in Japan contained 0.6% less oil and 0.5% more protein than Brazilian soybeans (5). However, more complete data are needed to update and substantiate these findings.

Processors have stated that northern U.S. soybeans are "inferior" to central and southern soybeans. Several recent studies have focused on the regionality issue. In a 1983–84 survey of Iowa soybeans, which also included one Ohio and several Minnesota locations, Hurburgh *et al.* (6) reported the data given in Table 1. Breene *et al.* (7) obtained data from two processing firms. One firm, with plants scattered from North to South, showed a −0.77 correlation of protein with North latitude. Another firm reported data for four states in a 1983–1986, as summarized in Table 2. Breene *et al.* (7) concluded that patterns may exist but that a more rigorous sampling of the U.S. soybean crop was necessary.

The Uniform Soybean Tests (UST) are an annual, publicly sponsored comparison of soybean varieties. A limited number of varieties are grown at sites in every major soybean-producing state. Green and Williams (8) analyzed 1957–1986 data from the UST. The overall U.S. mean protein content as computed by the mean of all entries remained nearly constant in this period. Soybeans from southern states increased in protein, while Corn Belt soybeans fell about 1.0% in relative to the national average. Soybeans from Kansas, Nebraska, the Dakotas, and Minnesota were consistently about 1%

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TABLE 1

Data on 1983 and 1984 Iowa, Minnesota, and Ohio Soybeans [after Hurburgh *et al.* (6)]

State	Number of locations	Number of Samples	Protein (%)[a]	+	Oil (%)[a]	=	Sum (%)[a]
IA	9	486	33.7		19.6		53.3
MN	10	75	34.0		19.7		53.7
OH	1	52	36.3		18.3		54.6

[a]Basis 13.0% moisture.

TABLE 2

Protein and Oil Data from One Processing Firm with Plants in Iowa, Illinois, Indiana, and Minnesota, 1983–1986 [after Breene *et al.* (7)]

State	Number of samples	Protein (%)[a]	+	Oil (%)[a]	=	Sum[a]
IA	2963	35.1		18.9		54.0
IL	1640	35.9		19.2		55.1
IN	1674	36.6		18.5		55.1
MN	698	34.7		18.5		53.2

[a]Basis 13% moisture.

TABLE 3

Protein and Oil Content of Soybeans Delivered in 1985–1987 to Two Iowa Elevators Located 25 Miles Apart [after Hurburgh and Brumm (9)]

Elevator	Number of Samples (1985, 1986, 1987)	Protein (%)[a]	+	Oil (%)[a]	=	Sum (%)[a]
1	38, 13, 47	35.0		19.0		54.0
8	41, 39, 35	34.2		19.4		53.6

[a]Basis 13.0% moisture.

lower in protein and 0.2–0.5% higher in oil than the national average.

Large processing firms will attempt to isolate localized areas (such as individual counties or country-elevator trade areas) of higher-valued soybeans as a competitive advantage. There is logic for this practice. Protein and oil in soybeans delivered to 12 Iowa country elevators located within a 75-mile-diameter circle showed consistent patterns that persisted across three growing seasons (9). Table 3 was taken from this study. The two elevators were about 25 miles apart in north-central Iowa. Patterns like these will be brought into the open by protein and oil testing at market locations.

Factors other than geographic location will influence protein and oil content. Several reports have listed standard deviations of 1.0 and 0.5% for protein and oil in randomly selected lots delivered to an individual elevator (6,7,9). Thus, the country elevator will encounter a range (±2 standard deviations) of about 4% protein and 2% oil.

Much of the random variation can be traced to genetics. Although soybean breeders have not had an incentive to include protein and oil as variety development criteria, variation does exist in the current mix of varieties. Several states are including protein and oil information in public-domain evaluations of soybean varieties. A summary listing of the Iowa Soybean Yield Test protein and oil data for 1988 is given in Table 4 (11).

There was about the same range of composition in variety test reports from Arkansas, Iowa, Minnesota, and North Dakota (10). Therefore, regional differences caused by environment may not be erased by genetic selection, particularly if breeders in all regions receive the same economic signals to change composition.

TABLE 4

Protein and Oil Data from the 1988 Iowa Soybean Yield Tests [Iowa State University (11)]

District	Number of varieties	Protein (%)[a]		Oil (%)[a]	
		High	Low	High	Low
North	264	37.2	32.3	20.8	18.6
Central	288	36.4	31.8	21.2	18.6
South	242	37.6	33.4	20.6	18.2
LSD[b], percentage points		1.2		0.7	

[a]Basis 13.0% moisture.
[b]Least significant difference between varieties, at the 0.05 probability level. Average of all districts.

Improvements in all regions would improve the U.S. competitive position in world markets and would reduce the number of situations in which the processor was operationally handicapped by not being able to produce meal of a specified protein content.

Development of near-infrared reflectance (NIR) technology has been crucial to evaluating large numbers of samples. The accuracy of NIR is well documented (6,9,12,13). Recently, Hurburgh and Brumm (9) reported a successful test operation of an NIR unit at an Iowa country elevator. Federal Grain Inspection Service (FGIS) provides NIR-based protein and oil analysis.

The preceding information points to the need for comprehensive study of protein and oil patterns in both world and domestic markets.

MATERIALS AND METHODS

Data on soybeans in world markets were provided by the Japan Oilseed Processors Association (JOPA). JOPA inspectors monitored the quality of shipments received in Japan. Data were provided for the 1972–1988 marketing years. Origins included were the U.S., Brazil, Argentina, the People's Republic of China (PRC), and U.S.-IOM. IOM is a special type of U.S. soybeans purchased for food. IOM stands for Indiana-Ohio-Michigan, but the criterion for meeting IOM specifications is seed size. IOM beans have fewer than 2000 seeds per pound.

The national survey was done with the cooperation of the American Soybean Association. Its purpose was to obtain state and regional estimates of soybean quality as quickly after harvest as possible.

Tyvek sample return envelopes were sent in August to growers in the 573 U.S. counties that produce more than 1 million bushels of soybeans, according to 1985 production data. These counties contributed about 80% of total U.S. production. In 1986, four growers per county received envelopes. In 1987 and 1988, sampling intensity was related to the previous year's county production:

$$n = 4 + 2(INT(P - 1.0)) \quad [1]$$

where n = number of bags mailed per county, P = county soybean production in million bushels, INT = integer function that truncates P to the lowest whole number. This formula yielded a frequency of 0.5 million bushels per sample envelope mailed. Growers were asked to fill the bags (400–600 g), identify the soybean variety and return them to Iowa State.

Protein and oil percentages were obtained with a Dickey-john Instalab 800 10-filter near-infrared reflectance (NIR) analyzer (Dickey-john Corp., Auburn, IL). Samples were cleaned over a 3.2-mm (8/64-inch) round-hold screen before analysis. A Magic Mill III+ (Magic Mill, Inc., Salt Lake City, UT) home flour mill was used to grind 30 to 50-g subsamples, in preparation for NIR analysis. Subsamples were obtained with a Boerner sample divider. Details of the calibration for this unit were reported by Hurburgh *et al.* (6). The NIR unit measured moisture of the ground grain, which was then used to convert protein and oil to 13% moisture basis. The stability and precision of the instrument were determined by Brumm and Hurburgh (3). The coefficient of variation (CV) among replicate measurements, including sampling errors, was 1.7% and 1.8% for protein and oil content, respectively.

Data were grouped by region (groups of states) and by state. As more data become available through annual repetition, identification of district (groups of counties) and county patterns may also be possible. Means and standard deviations were calculated. Because each state and region had different numbers of samples, the analysis of variance was based on an average number of samples per state. This overstated the significance of states with very few samples returned (three or less) and understated the significance of states with many returned. An alternative would have been to do paired t-tests on every combination of state, year, and region. The former was chosen because single-value estimates of standard deviation and least significant difference are useful in predicting future variability. Breene *et al.* (7) did not attempt to statistically differentiate among states. The regional groupings were: Western Corn Belt (WCB), Iowa, Kansas, Minnesota, Missouri, Nebraska, North Dakota, South Dakota; Eastern Corn Belt (ECB), Illinois, Indiana, Michigan, Ohio, Wisconsin; Midsouth (MDS), Arkansas, Kentucky, Louisiana, Mississippi, Oklahoma, Tennessee, Texas; Southeast (SE), Alabama, Florida, Georgia, North Carolina, South Carolina; and Least significant differences (LSD) ($P = 0.05$) and standard deviations were calculated by year, region, state, year × region, and year × state.

The economic impact of protein and oil variations was determined by application of the Brumm–Hurburgh model on a sample-by-sample basis. EPV was calculated by using $250 per ton for 44% protein meal and $0.23 per pound for soybean oil. The same statistics were calculated for EPV as for protein and oil.

Within a survey year, regional and national means were weighted by number of samples returned. This was justified because the mailing frequency was intended to approximate production concentration. Across years, means were the average of the three years' results without regard for numbers of samples.

RESULTS AND DISCUSSION

World market data. Figure 1 shows the data provided by the Japan Oilseed Processors Association. The entire imports from the respective nations were included in the

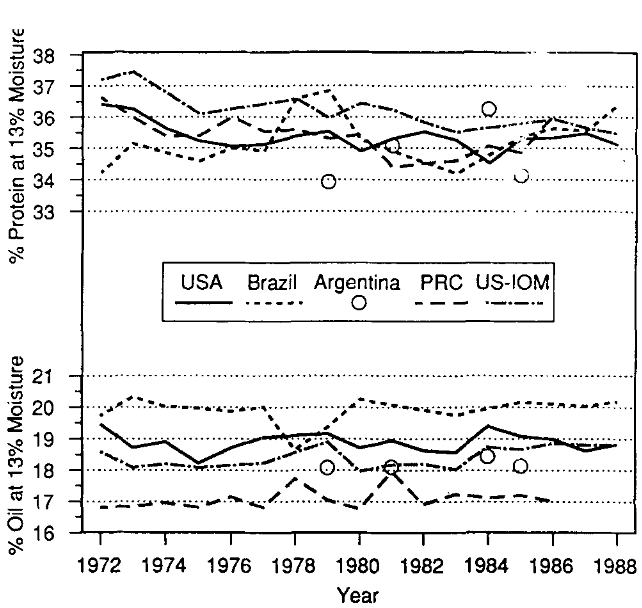

FIG. 1. Protein and oil data for soybeans as received in Japan, by country of origin and year of receipt.

JOPA summary. Individual-lot data were not provided, so statistical analysis could not be done.

U.S. No. 2 soybeans are inferior in oil content to those of our major competitor, Brazil. Recently, the U.S. protein content has also been below that of Brazil. The U.S.-IOM soybeans generally were higher in protein content, but they, too, have declined in recent years. The U.S. share of Japanese imports has fallen from 95% in 1984 to 75% in 1988.

The economic importance of this information is demonstrated by Figure 2, generated from the Brumm-Hurburgh model and one set of meal and oil prices. This set favors meal over oil, so the differences between Brazil and the U.S. are somewhat less than they would be in an oil-driven market. Brazilian beans have a consistent, and increasing, economic advantage over U.S. beans on the basis of protein and oil content. U.S. advantages — logistics, credit terms, availability — must be used to offset the quality disadvantage.

Domestic market data. A summary of the 1986, 1987, and 1988 U.S. soybean surveys is given in Figure 3. The pattern of lower protein and higher oil in the north and west was consistent across the three years. Figure 4 presents the economic importance of the three-

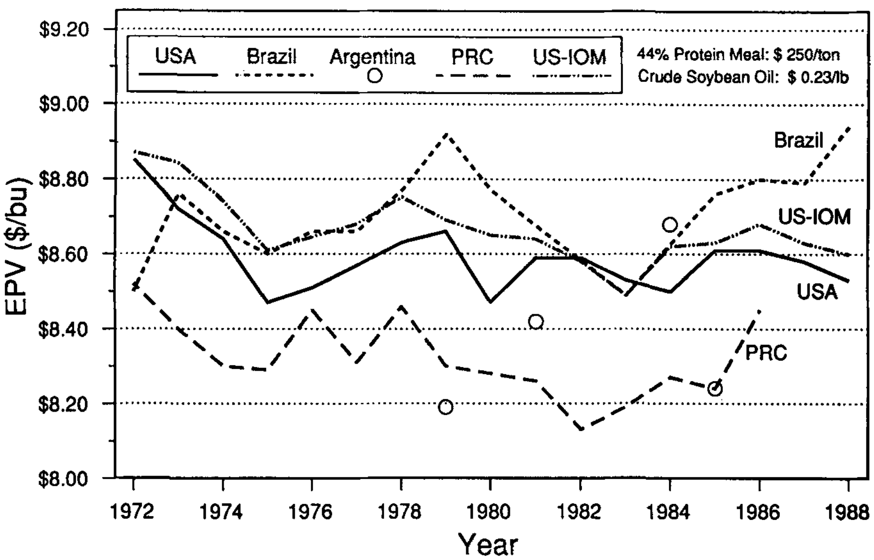

FIG. 2. Estimated Processed Value of soybeans imported by Japan, by country of origin.

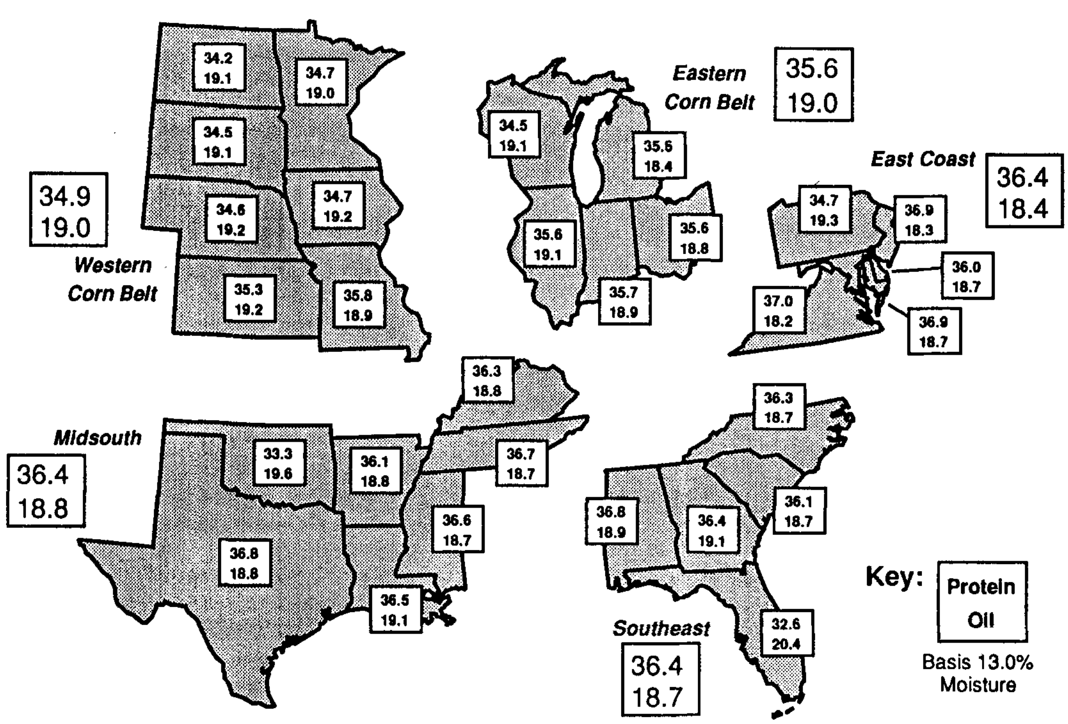

FIG. 3. Protein and oil content of U.S. soybeans, 1986–1988 crops.

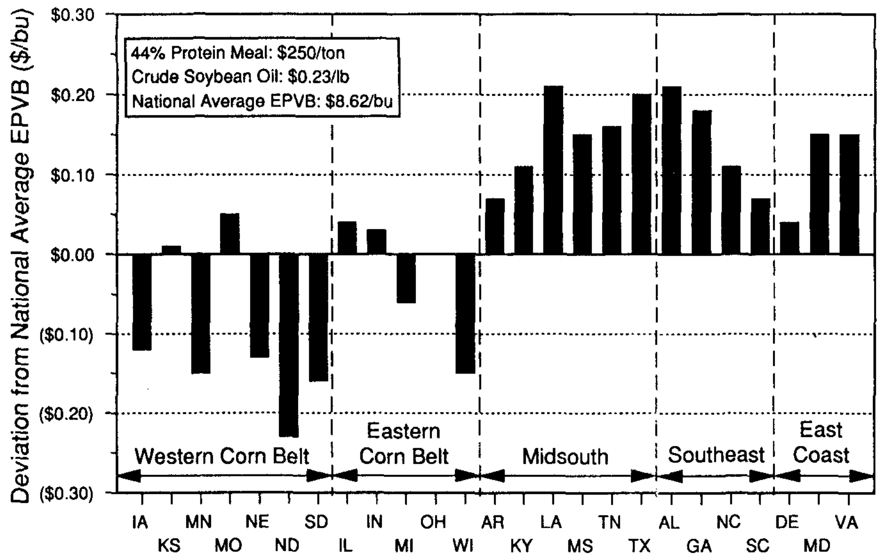

FIG. 4. Differences in Estimated Processed Value per Bushel for 1986–1988 soybeans.

TABLE 5

Standard Deviations for the Soybean Composition Survey, 1986–1988

	Standard deviation, %[a]		
Classification	Protein	Oil	EPV ($/bu)[b]
Within a year	1.50	0.75	0.20
Within a region[c]	1.35	0.70	0.18
Within a state[d]	1.15	0.60	0.15

[a]Basis 13.0% moisture.
[b]Meal valued at $250/ton, oil at $0.23/lb.
[c]Across years.
[d]Across years and regions.

year state-to-state differences by use of the Brumm-Hurburgh model and one set of meal and oil prices. The national mean EPV was subtracted from individual state EPVs to obtain the data presented.

Although advantages for certain areas are evident, protein and oil pricing will not automatically mean a loss in net revenue for some growers. To the extent that these patterns are already known by processors, the protein and oil differences probably are included in the base price offered in a given area. Protein and oil pricing will provide incentive for improvement. Incentive is not offered if anticipated protein and oil content is built into base prices.

Statistics (standard deviations) for the survey are shown in Table 5. LSDs were less than 0.2% for states, regions, and years. Relatively small differences at the year and regional levels were significant because of the large number of samples involved. The variability within a state was approximately 25% larger than that reported by Hurburgh and Brumm (9) for a local elevator trade area. However, the greatest potential for capturing the value of current protein and oil variations exists at the local-elevator level.

Table 6 gives the state-by-state data by year. There were changes in protein and oil content among years. Typically, the Western Corn Belt data were more variable between years. This indicates a greater sensitivity to or changes in weather conditions in these areas. However, the general trend of lower protein, higher oil in the North and West persisted over the three years surveyed.

Over the period, national average protein declined by about 0.6% but oil increased by 0.7%. With the example set of meal and oil prices, this trend would produce very little net change in EPV. However, protein is approaching the level at which the processor must dehull to make 44% meal. Therefore, further reductions in protein content would have very negative effects on EPV.

The Japanese reported slightly lower protein and oil percentages than the national averages in this survey. This could be caused by measurement method differences or by informal sorting by U.S. processors, leaving the less valuable beans for export. Most processors do attempt to identify regions of favorable composition, so export beans probably are of lesser protein and oil content than U.S. averages.

The national average sample return rate increased from 20% in 1986 (403/2020) and 1987 (789/3950) to 38% in 1988 (1506/3972). The 1988 mailing list contained the names of all growers who returned samples in 1986 or 1987. State soybean associations also sent reminder letters to growers in their respective states. Table 7 shows that a reasonably consistent ratio of samples to production was obtained, particularly in the two years after the production-weighting formula (eq. [1]) was used to allocate samples to states. As a check, the regional and national averages by year were calculated by using production-weighting by state, instead of sample-number weighting. There was never more than 0.1% difference in either protein or oil between the two methods of calculating averages.

TABLE 6

Soybean Quality Survey Data 1986–1988 [a]

		Number of samples			Protein (%)			Oil (%)		
Region	State	1986	1987	1988	1986	1987	1988	1986	1987	1988
Western	IA	52	86	277	35.3	34.3	34.5	18.4	19.4	19.6
Corn	KS	2	9	37	35.1	35.6	35.1	19.2	19.1	19.3
Belt	MN	41	70	141	35.5	34.0	34.4	18.0	19.3	19.7
(WCB)	MO	29	73	113	35.6	36.0	35.8	18.9	18.9	19.0
	NE	19	36	91	35.0	34.7	35.1	18.9	19.1	19.7
	ND	2	7	19	35.3	33.4	34.0	17.7	19.5	19.9
	SD	13	18	22	35.4	33.9	34.4	18.2	19.3	19.6
Averages (WCB)		158	299	701	35.4	34.7	34.6	18.4	19.2	19.5
Eastern	IL	61	163	391	35.5	35.8	35.5	18.6	19.3	19.3
Corn	IN	58	105	121	35.8	36.0	35.3	18.6	19.1	19.0
Belt	MI	7	14	24	35.5	36.2	35.1	18.1	18.6	18.6
(ECB)	OH	34	80	105	35.5	35.8	35.3	18.7	19.3	19.4
	WI	3	2	5	34.6	34.7	34.3	18.7	19.3	19.4
Averages (WCB)		163	364	646	35.6	35.9	35.4	18.6	19.2	19.1
Midsouth	AR	6	31	76	36.7	35.6	35.8	18.6	18.8	19.0
(MDS)	KY	9	12	17	36.3	36.2	36.3	18.8	18.9	18.6
	LA	8	15	25	36.5	36.8	36.2	19.4	18.8	19.1
	MS	19	20	30	37.1	36.9	35.9	18.4	18.6	19.0
	OK	2	1	1	34.5	32.2	33.3	19.2	20.2	19.4
	TN	7	3	9	36.8	36.9	36.3	18.7	18.6	18.7
	TX	1	1	3	38.7	35.3	36.3	18.1	19.4	18.9
Averages (MDS)		52	83	161	36.8	36.3	35.9	18.7	18.8	18.9
Southeast	AL	2	8	10	37.7	36.1	36.6	19.0	18.8	19.0
(SE)	FL	0	0	1	—	—	32.7	—	—	20.4
	GA	1	6	9	37.3	36.1	35.2	19.3	19.0	19.4
	NC	7	14	12	36.9	35.8	35.9	18.7	18.4	19.0
	SC	8	4	4	37.3	35.2	35.9	18.4	18.9	18.7
Averages (SE)		18	32	36	37.2	35.9	35.8	18.6	18.7	19.1
East	DE	1	1	7	35.9	36.4	35.7	18.6	18.5	18.8
Coast	MD	6	4	5	37.7	36.6	36.4	17.9	18.5	18.5
(EC)	NJ	3	1	1	35.5	35.7	35.5	18.8	18.8	18.5
	PA	0	1	1	—	34.2	35.2	18.0	19.1	19.6
	VA	2	4	6	38.0	36.4	35.7	18.2	18.2	18.6
Averages (EC)		12	11	20	37.1	36.2	35.8	18.2	18.5	18.7

[a]Protein and oil percentages basis 13.0% moisture.

TABLE 7

Sampling Frequency Analysis for the 1986, 1987, and 1988 National Soybean Quality Surveys

		Mailing frequency, million bu/samples[a]			Return frequency, million bu/samples		
Region	State	1986	1987	1988	1986	1987	1988
Western Corn Belt (WCB)	Iowa	1.3	0.6	0.5	7.0	4.0	1.2
	Kansas	5.4	0.8	0.9	29.9	7.5	1.8
	Minnesota	1.0	0.6	0.6	4.2	2.6	1.3
	Missouri	1.2	0.5	0.4	6.1	2.1	1.4
	Nebraska	1.0	0.5	0.4	5.1	2.2	0.9
	North Dakota	1.0	0.6	0.5	8.3	2.3	0.8
	South Dakota	0.7	0.6	0.5	3.7	2.5	2.0
Average (WCB)		1.2	0.6	0.5	5.9	3.0	1.3
Eastern Corn Belt (ECB)	Illinois	1.2	0.4	0.4	6.0	2.0	0.8
	Indiana	0.7	0.5	0.6	2.8	1.6	1.4
	Michigan	0.7	0.6	0.6	4.3	2.7	1.6
	Ohio	0.9	0.5	0.4	4.4	1.8	1.4
	Wisconsin	1.3	1.5	1.1	3.8	6.1	2.4
Average (ECB)		1.0	0.5	0.4	4.4	1.9	1.1
Midsouth (MDS)	Arkansas	1.2	0.3	0.3	11.6	2.2	0.9
	Kentucky	0.7	0.3	0.3	4.2	2.0	1.4
	Louisiana	0.6	0.4	0.5	4.8	2.5	1.6
	Mississippi	0.6	0.4	0.4	2.3	2.4	1.6
	Oklahoma	0.7	0.7	0.6	2.4	5.7	5.8
	Tennessee	1.0	0.3	0.4	5.4	9.6	3.1
	Texas	0.4	0.3	0.3	1.5	3.9	3.9
Average (MDS)		0.7	0.3	0.2	7.2	1.0	0.8
Southeast (SE)	Alabama	0.9	0.2	0.2	7.2	1.0	0.8
	Florida	0.5	0.3	0.3	—[b]	—[b]	2.3
	Georgia	0.9	0.3	0.4	15.3	2.6	1.7
	North Carolina	1.1	0.5	0.7	5.5	2.3	2.7
	South Carolina	0.4	0.3	0.3	1.5	3.9	3.9
Average (SE)		0.8	0.3	0.4	4.8	2.3	2.1
East Coast (EC)	Delaware	0.8	0.3	0.2	6.0	4.2	0.7
	Maryland	0.5	0.4	0.3	1.8	2.3	1.8
	New Jersey	0.4	0.4	0.3	1.1	3.1	3.1
	Pennsylvania	—[c]	0.7	1.4	—[b]	5.6	5.6
	Virginia	1.8	0.4	0.6	7.4	2.7	2.2
Average (EC)		0.9	0.4	0.4	3.4	3.0	1.8
Averages for U.S.		1.00	0.47	0.46	4.98	2.41	1.22

[a]1986, four bags per county producing over 1 million bu; 1987 and 1988, 1 bag/0.5 million bu.
[b]None returned.
[c]None sent.

This survey is being continued on an annual basis but we have already demonstrated that geographic protein and oil patterns exist in both world and domestic soybean markets. The differences among nations, and among geographic areas within the U.S. are large enough to be economically significant. Protein and oil pricing in the U.S. soybean market could provide growers with the incentives to correct proven deficiencies.

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