TECHNICAL

Quality of Soybeans in Export

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Soybean quality is of concern to processors throughout the world, as deterioration during storage, handling and shipment can result in crude oil which is difficult to process and has high refining losses. Little information is available comparing the relative quality of soybeans in export shipment based on crop year and origin. Shipments of soybeans originating from the United States, Brazil, Paraguay, and Argentina were sampled in Europe and Asia during a four-year period. Soybean samples were graded, protein and oil contents determined, and oil quality characteristics assessed by laboratory procedures. Results of these analyses present, for the first time, direct comparisons of the quality of soybeans exported from the principal producing countries. The data suggests that United States (U.S.) farmers and exporters must continue their efforts to improve the physical characteristics of soybeans in export shipment; the emphasis of breeding and genetic engineering research should be to increase the protein content of soybeans grown in the U.S.; and that the high quality of crude oil recovered from U.S. soybeans should prove an advantage to the processor using soybeans imported from the United States.

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Soybean quality is a concern to processors throughout the world, because deterioration during storage, handling and shipment can result in crude oil which is difficult to process and has high refining losses (1–3). Although European and Asian soybean processors have previously expressed these concerns (4), particular dissatisfaction with United States (U.S.) soybean quality developed in 1984 and 1985 (5). The 1984 U.S. soybean crop reportedly yielded oil with free fatty acid (FFA) content of 1.2–1.6%. As a result, a number of European processors turned to South American soybeans. Soy oil processors, margarine formulators, and cooking oil bottlers switched to other oils.

Several years earlier, identity-preserved shipments of U.S. soybeans were sampled at origin ports and at export destinations (6–9). Foreign material and splits increased as the soybeans were moved from U.S. ports to overseas buyers due to handling and mechanical damage (6,7). Degumming studies showed significant increases in the nonhydratable phospholipid (NHP) content of the oil extracted from the destination beans relative to that from the origin beans. Refining loss increased with the increase in NHP (8,9). Water treatment of crude oil followed by centrifugation is the principal degumming process used in the U.S. (10). Normally, this simple water treatment effectively removes the phospholipids to below 0.3% (11). European processors, using imported U.S. soybeans were reportedly unable to lower the content of phospholipids to below 0.3% by the simple water degumming process (12). Analysis of oil extracted from whole soybeans and splits fractionated from the same lot of soybeans showed an apparent relationship between splits and free fatty acid (FFA) contents, indicating that oil deteriorates as the frequency of splits increases (13). This study was designed to assess the quality of soybeans as received at destination ports in Europe and Asia.

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EXPERIMENTAL PROCEDURES

Sampling procedures. Destination samples 5–2 kg samples/vessel) were taken from one hold of vessels unloading soybean at the importing elevator. Shipments were sampled, during a 42-mon period at five European ports (Rotterdam and Amsterdam, the Netherlands; Ghent, Belgium; Hamburg, West Germany; and Lisbon, Portugal) and during a 20-mon period at three Asian ports (Tokyo, Japan; Inchon, Korea; and Kaohsiung, Taiwan). For the samples from European ports, employees of the European Marketing Research Center, ARS/USDA, Rotterdam, the Netherlands, trained in sampling and inspection procedures, operated the samplers and verified the integrity of every sample. For the samples from Japan, Korea and Taiwan, sampling was accomplished by survey companies in the port country as specified under contract with the Horticultural Crops Research Laboratory, Postharvest Quality and Genetics Research Unit, ARS/USDA, Fresno, California.

Each sample was divided into two 1,000-g portions using a Seedburo's (Europe) or Gamet (Asia) divider, was packed in plastic bags, then was placed into jute bags and finally boxed for shipment. Half of each sample was forwarded to the Vegetable Oil Research Unit (VOR), Northern Regional Research Center, Peoria, Illinois, and the second half was shipped to the Board of Appeals and Review (BAR), FGIS/USDA, Kansas City, Missouri.

Equipment. At most ports a mechanical diverter sampler capable of continuous or intermittent sampling was used to obtain samples. At Ghent, Belgium, a mechanical sampler was employed that removed samples from the right center of the belt parallel to the flow of beans. At Hamburg, West Germany, samples were taken with a trier (probe) from a weighing bunker on a random basis, both in terms of location and time. At Amsterdam, an Ellis Cup was used to obtain samples. All samples were taken half-hourly during unloading.

Sample evaluations—grade. The portion of the samples shipped to BAR were given an official grade determination, in accordance with official procedures (14). Specific factors considered in this evaluation were test weight (TW), moisture content (M), total damaged kernels (DKT), foreign material (FM) and splits (SPL).

Protein and oil content (15). Approximately 7 g of soybeans were placed in a beaker and dried in a forced air oven for 3 hr at 130°C. The soybeans were transferred to a 50-g bottle, sealed, allowed to cool for 1 hr, then ground in a Varco model Mx-228 electric dry-food grinder. The ground meal was returned to the 50-g bottle. The meal was analyzed by near-infrared reflectance spectroscopy (NIR) in a Neotec model 51A grain-quality analyzer (NIRSystems Inc., Silver Spring, MD). The analyzer had previously been calibrated with 40 soybean samples having a protein range of 33 to 50% and an oil range of 12 to 24%. Protein and oil content are reported on a dry basis.

Oil quality factors. Soybean samples (250 g) were cleaned, cracked, decorticated, and flaked, using laboratory-scale equipment simulating commercial processing procedures (16). The moisture content was adjusted to between 9 and 10% before processing. The flakes were hexane-extracted in laboratory-scale all-glass batch equipment, and solvent-free oil was recovered by vacuum stripping with a rotary evaporator. Oil was analyzed in accordance with AOCS official methods (17) for free fatty acid (FFA), Ca 5a-40; phosphorus (P), Cd 8-53; and color, Cc 13b-45. TOTOX was calculated as two times the peroxide value, Ca 9f-57, plus the anisidine value (18).

Data handling. Data were averaged and considered for comparison purposes only when five or more shipments were sampled.

RESULTS AND DISCUSSION

The number of shipments and total samples obtained during each sampling year from each origin country are shown in Table 1. The number of shipments from origins was uneven due to availability at destination ports. Data were averaged and considered for comparison purposes only when five or more shipments were sampled.

Summary analyses, i.e., average value and standard deviations, of all samples from all shipments by crop year and origin are presented in Table 2. The standard deviation (STD) indicates that the average value is a valid measure of the factor. Variations in grade or oil quality factors did not correlate with specific sampling methods or port of sampling.

Grade factors. There is no difference in TW or M of U.S. soybeans for the four crop years studied (Fig. 1). TW for South American soybeans is consistently lower than that for U.S. soybeans. M was constant regardless of origin or crop year. U.S. soybeans sampled during the crop years 1986–88 showed lower levels of DKT and SPL than during the 1985 crop year. This indicates favorable preharvest conditions and improved post-harvest handling of the beans. The content of FM in U.S. soybeans has been of continuing concern to both the U.S. farmer and the foreign processor. Our data indicates that U.S. soybeans' FM content met origin contract specifications (2.0% for Grade #2) at destination only in 1986 and the level of FM is generally higher than that of soybeans from other origins.

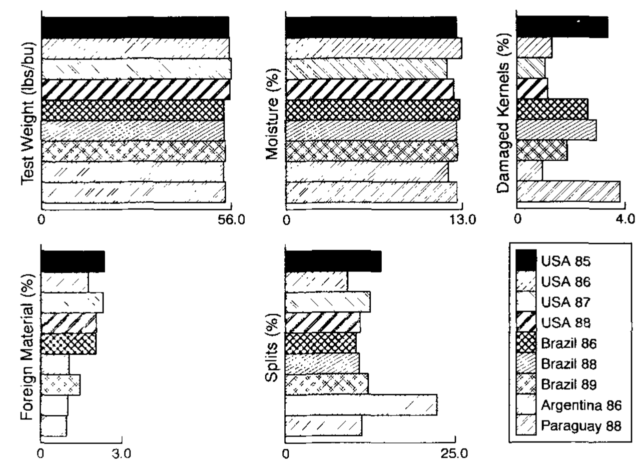

FIG. 1. Comparison of grade factors.

During the last 2 yr of sampling, Brazilian soybeans were consistently higher in DKT than U.S. soybeans, while there was little difference in SPL. On the other hand, soybean shipments originating from Brazil showed lower levels of FM than shipments originating from the U.S. in each crop year for which comparative samples were obtained. It was noted that all the samples of Brazilian soybeans contained red dust to such an extent that the samples were classified as Sample Grade by the U.S. Standards for Soybeans, i.e., containing more than four pieces of unknown foreign substance. Crop year comparisons show that samples representative of the 1989 Brazilian crop year were lower in FM, but higher in SPL content than in 1986 and 1988.

The Argentina soybeans showed the lowest levels of DKT and FM, but the highest level of SPL. Only the 1986 Argentina crop year was sampled and therefore, we were unable to confirm this observation in subsequent years. The high level of splits may be attributable to a particular variety of soybean grown in Argentina or excessively abusive handling and transportation procedures. We were unable to determine the actual factors contributing to this observation.

Soybeans originating from Paraguay were sampled only during 1988. These soybeans showed the highest

TABLE 1

Soybeans Sampled in Export[a]

Crop year/ origin	Shipments	Samples total	Period
1985 Crop year			
U.S.	8	33	Feb.–Aug. 86
1986–1987 Crop Year			
U.S.	12	60	Oct. 86–Apr. 87
Brazilian	7	32	May–Oct. 86
Argentina	5	21	Jul.–Sep. 86
1987–1988 Crop year			
U.S.	30	150	Nov. 87–Mar. 88
Paraguay	9	45	May–Oct. 88
Brazil	9	45	Apr.–Sep. 88
Argentina	2	10	Jul.–Aug. 88
1988-1989 Crop year			
U.S.	27	135	Jan.–Jun. 89
Brazil	6	30	Jun.–Aug. 89
Argentina	1	5	July 89

[a]Ports: Rotterdam, Amsterdam, Gent, Hamburg, Lisbon, Tokyo, Inchon, Kaohsiung (4–5 samples/shipment).

TABLE 2

Summary of Analyses of All Shipments Sampled 1985–1989*

	TW[a]	M[b]	DKT[c]	FM[d]	SPL[e]	Protein	Oil	FFA[f]	Phos[g]	TOTOX
					USA 85					
Avg[h]	55.20	12.54	3.35	2.36	14.03	41.25	20.83	1.13	1032.97	0.35
Std[i]	0.73	0.27	1.00	1.21	2.56	0.68	0.40	0.13	148.86	0.33
					USA 86					
Avg	55.41	12.96	1.28	1.73	9.13	39.74	19.61	0.73	1006.64	4.71
Std	0.81	0.78	0.83	0.85	4.04	0.65	0.73	0.23	73.70	2.39
					USA 87					
Avg	55.89	11.86	1.05	2.29	12.50	39.29	20.71	0.70	1096.48	3.56
Std	0.62	0.69	0.43	1.24	4.34	1.03	0.86	0.12	116.13	1.37
					USA 88					
Avg	55.52	12.36	1.14	2.05	10.99	39.56	21.08	0.67	1107.13	2.98
Std	0.77	0.55	0.45	0.91	3.30	1.13	0.57	0.14	94.31	1.06
					Brazil 86					
Avg	53.65	12.78	2.58	2.05	10.45	40.83	21.59	0.97	834.47	5.40
Std	0.85	0.57	1.88	3.46	1.59	0.82	0.58	0.22	92.86	3.89
					Argentina 86					
Avg	55.64	11.94	0.95	0.99	22.34	41.30	19.75	0.51	991.57	2.64
Std	0.93	0.13	0.39	0.69	3.03	0.88	0.53	0.10	93.64	1.70
					Brazil 88					
Avg	53.97	12.62	2.94	1.05	10.90	40.46	22.09	1.13	858.38	4.49
Std	0.70	0.58	1.71	0.65	2.98	1.05	0.67	0.21	82.66	1.51
					Paraguay 88					
Avg	54.16	12.60	3.78	0.96	11.30	39.71	21.97	1.11	877.26	3.62
Std	0.60	0.51	1.64	0.51	2.23	2.00	1.12	0.19	83.00	0.76
					Brazil 89					
Avg	54.88	12.65	1.87	1.44	12.19	40.13	22.22	0.96	911.60	2.88
Std	0.74	0.32	0.90	0.64	2.70	0.77	1.10	0.22	72.83	0.51

*Includes all samples from all shipments by crop year and origin.
[a]TW = test weight.
[b]M = moisture %.
[c]DKT = damaged kernels total %.
[d]FM = foreign material %.
[e]SPL = splits %.
[f]FFA = free fatty acids %.
[g]Phos = Phosphorus ppm.
[h]Avg = average of all samples.
[i]Std = standard deviation.

level of DKT, but the lowest level of FM of the shipments sampled.

Of all the grade factors, DKT, FM and SPL were found to be the most variable between samples on the basis both of origin and crop year. While FM is a critical economic factor (the purchaser is paying for non-soybean material) and may play a role in storability of soybeans, if FM is removed during the bean cleaning process it may not have a direct impact on end-use quality. It has generally been theorized that DKT and SPL content are more closely related to end-use quality, as these are indicators of pre- and post-harvest damage and the loss of seedcoat integrity.

Quality factors. The end-use value of soybean is currently determined by its protein and oil content (19). Small differences between crop year or origin are generally cited as indicating a superiority of one over the other. During the last two years of this study, the average protein content of U.S. soybeans was 0.5 to 1.3% lower and the average oil content 1.4% lower than those determined for Brazilian and Paraguayan soybeans (Fig. 2). However, this comparison does not consider the oil quality factors which also impact on the end-use value.

Free fatty acid (FFA) is a measure of enzymatic hydrolysis of the triglycerides of the oil and is indicative of damage to the seed (2). The trading rules of the National Oilseed Processors Association (NOPA) (20) limit the FFA in crude degummed soybean oil to a maximum of 0.75%. Excess FFA contributes to increased neutral oil loss during processing.

Crude oil from U.S. soybeans showed FFA contents below the NOPA maximum the last three crop years. The FFA content of oil from Brazilian soybeans was about 1.0% for each of the crop years evaluated. This finding suggests that while Brazilian soybeans have a higher oil content, processors would experience higher refining losses during processing than with oil from U.S. soybeans. There are indications of a rough correlation between DKT and FFA in comparing the grade and quality factors.

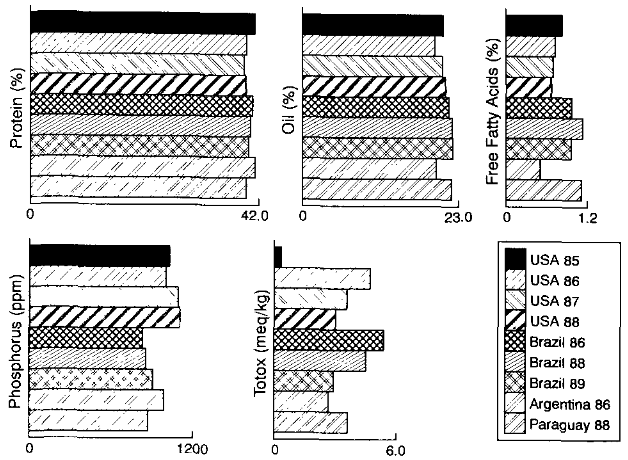

FIG. 2. Comparison of yield data and oil quality factors.

Phosphatides also contribute to neutral oil losses during soybean oil processing. Enzymatic action in the seed causes the formation of "nonhydratable phosphatides" (NHP) which are difficult to remove and increase processing losses. Previous research (2) indicates that crude soybean oil having a phosphorus content of less than 400 ppm is damaged and will have an elevated NHP content. The phosphatide content is related to the phosphorus content of the oil (% P × 30 = % equivalent phospholipid) (21). Phosphorus contents of oils from like origins did not vary by crop year. The U.S. soybean showed oil phosphorus contents consistently higher than those beans from other origins for all crop years.

The TOTOX value indicates the degree of oil deterioration due to the action of lipoxygenase on the polyunsaturated fatty acids of the oil (18). Products of oxidation present in crude oils are thought to have a negative impact on the flavor and stability of finished edible oils (22). High quality crude soybean oils generally have a TOTOX value $<$ 3.0 meq/kg. TOTOX values, which exceeded 3.0 meq/kg for both U.S. and Brazilian soybeans in the early years of the study, were below 3.0 meq/kg for soybeans of both origins sampled during 1989. The DKT was at low levels for these samples and there may be a relationship between damaged kernels and oxidative deterioration of the oil in the bean.

A fourth quality factor originally considered in this study was oil color. Measured by Lovibond, the crude oil "shall not have a predominantly green color" (20). None of the samples evaluated in this study had a green color regardless of origin or crop year.

The results presented here suggest that U.S. farmers and exporters must continue their efforts to improve the physical characteristics of soybeans in export shipment. The emphasis of breeding and genetic engineering research should be to increase the protein content of soybeans grown in the U.S. The high quality of crude oil recovered from U.S. soybeans should prove an advantage to the processor using soybeans imported from the United States.

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