Technical

Postharvest Handling of Soybeans: Effects on Oil Quality[1]

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ABSTRACT

Effects of postharvest handling (such as storage and transportation) of soybeans on the quality of extracted oil were evaluated. Identity-preserved export shipments of soybeans were sampled at origin points and at destination ports. Samples of new crop beans were also acquired from domestic elevators. Lots were separated to yield three fractions each: original, whole beans, and split beans. Crude oil extracted from each fraction was characterized for free fatty acid content, iron content, peroxide value, phosphatide, nonhydratable phosphatide, color, chromatographic refining loss, and fatty acid composition. Oil extracted from split beans had free fatty acid and iron contents significantly greater than those of oil from whole beans. These two deleterious qualities of crude oils were found to increase during shipment. Degumming studies showed an increase in the nonhydratable phosphatide content of extracted oil due to shipment.

INTRODUCTION

Soybeans are the world's single most important source of edible oil and vegetable proteins. Successful techniques for the postharvest delivery of these vital food components to the consumer are necessary to the maintenance and improvement of both the domestic and the world food supplies. Studies are underway to measure the total amounts of physical and quality losses in shipping and handling whole soybeans from country elevators to both domestic and overseas destinations (1). Splits and foreign material are two soybean grade variables that showed in-transit deterioration.

Quality of oil extracted from soybeans damaged by unfavorable harvest conditions, early frosts, and storage has been characterized as being deteriorated by analyses of iron, free fatty acid, and nonhydratable phosphatide content (2). The effects of handling of soybeans in export shipment on the quality of extracted oil is the subject of the present report.

This study is part of a cooperative effort by regional laboratories of the Science and Education Administration, U.S. Department of Agriculture.

EXPERIMENTAL PROCEDURES

Sample Acquisition and Preparation

Identity-preserved shipments of soybeans from Toledo, OH, to Rotterdam, Holland, and from New Orleans, LA, to Tilbury, England, were sampled by representatives of the Transportation and Packaging Laboratory, Agricultural Research, Science and Education Administration, U.S. Department of Agriculture, and the U.S. Department of Agriculture, Agricultural Marketing Services (AMS) using standard techniques (3). Samples were identified and graded by AMS and, following a preliminary evaluation of soybean quality by the Seed Research Laboratory, Beltsville Agricultural Research Center, AR/SEA, USDA, were shipped to the Northern Regional Research Center, Peoria, IL.

Toledo-Rotterdam Shipping and Sampling

In the Toledo to Rotterdam shipment, 11,250 tons of U.S. No. 2 soybeans were loaded into three holds of the ocean vessel Nanfri at Toledo in August 1975. Approximately 2 weeks after loading, the vessel arrived in Rotterdam. The soybeans were unloaded with pneumatic "suckers" into barges for delivery to European processors. Samples were collected at two points in the marketing channel. (a) Probe samples were collected from the holds of the vessel in Toledo. Each hold was loaded intermittently in 3.5 m (11.5 ft) layers, which permitted sampling prior to adding the next layer. Each layer was subdivided into four quadrants in each hold, with one composite sample obtained from five probes in each quadrant. (b) At Rotterdam, probe samples were similarly taken from each 3.5 m (11.5 ft) layer of the Nanfri during unloading. Samples taken at each layer were combined without regard to the hold sampled. Four samples were thus obtained at the origin and destination points. After determinations of splits and moisture content, the samples were combined to

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TABLE I

Soybean Quality Characteristics of Export Shipments of Soybeans[a]

Location	Oil (%)	Protein (%)	Splits (%)	Moisture (%)
Toledo-Rotterdam				
Toledo	19.4 ± 0.6[b]	39.0 ± 1.0[b]	10.6 ± 0.6[b]	10.0 ± 0.5[b]
Rotterdam	19.5 ± 0.6	38.8 ± 1.1	10.0 ± 0.6	8.5 ± 0.5
New Orleans-Tilbury				
New Orleans (barge-train)	19.8 ± 0.5	39.1 ± 1.0	10.4 ± 0.6	10.8 ± 0.5
New Orleans (vessel)	19.3 ± 0.5	39.3 ± 1.0	10.2 ± 0.6	10.8 ± 0.5
Tilbury	19.4 ± 0.5	38.2 ± 1.1	10.8 ± 0.6	10.8 ± 0.5

[a]All values are the average of triplicate analyses.

[b]Standard deviations.

TABLE II

Toledo-Rotterdam Shipment: Soybean Oil Quality Evaluation[a]

Fraction	Fe (ppm)	FFA (%)	PV (meq/kg)
Toledo			
Original	1.4 ± 0.4[b]	0.43 ± 0.3[b]	1.6 ± 0.3[b]
Wholes	0.8 ± 0.5	0.27 ± 0.3	0.6 ± 0.3
Splits	4.9 ± 0.5	1.16 ± 0.6	13.6 ± 1.0
Rotterdam			
Original	0.8 ± 0.3	0.34 ± 0.3	1.2 ± 0.4
Wholes	3.9 ± 1.0	0.69 ± 0.5	56.4 ± 3.0
Splits	2.7 ± 0.8	1.24 ± 0.2	85.7 ± 4.0

[a]All values are the average of triplicate analyses.
[b]Standard deviation.

give one composite sample at each point.

New Orleans-Tilbury Shipping and Sampling

In the New Orleans to Tilbury shipment, 15,000 tons of soybeans were shipped to New Orleans by 20 barges and a unit train of 45 cars. Ten samples of 2 kg each were taken from each barge and nine samples from the entire 45 car train. When the beans were loaded into four holds of the vessel, Pacific WASA, 29 samples of 2 kg each were taken. All sampling was accomplished by mechanical sampler. Approximately 6 weeks after the vessel was loaded in New Orleans, the soybeans arrived in the Tilbury port. Probe samples (29 at 2 kg each) were taken from the soybeans during unloading, which was accomplished using pneumatic suckers into barges. The multiple samples were combined to give a single composite sample at each point, a total of three samples characteristic of the shipment.

Local Elevator Sampling

Samples were acquired from three country elevators in Central Illinois (Farmer City, Edwards, and Trivoli).

A portion of each composite sample was retained as the original fraction, while the rest was subdivided into whole bean and split bean fractions using a Eureka spiral gravity extraction tower. One kilogram of each fraction was cleaned, cracked, decorticated, and flaked in laboratory simulations of standard commercial procedures (4). Oil was hexane-extracted in laboratory scale, all-glass batch equipment, and solvent was vacuum stripped on a rotary evaporator.

Analysis of Crude Oil

The recovered crude oil was analyzed in accordance with AOCS official methods (5) for the following determinations: free fatty acids (FFA), iron (Fe), peroxide value (PV), chromatographic refining loss, phosphorus (P), and color (Lovibond). Fatty acid composition was determined by the method previously described (6). The crude oil was degummed in laboratory simulations of standard U.S. batch degumming techniques (7). Small scale procedures were optimized by performing several degummings using varying amounts of water while holding other conditions constant (300 g oil, 60 C, 15 min, stirred at 400 rpm, centrifuged at 2000 rpm, 15 min). The nonhydratable phosphatide content was estimated by determination of the residual phosphorus in degummed oils. Triplicate analyses were performed for most determinations.

RESULTS AND DISCUSSION

Determinations of splits content and moisture content on the layer samples obtained from the Toledo-Rotterdam shipment showed identical results regardless of the layer sampled.

As shown in Table I, soybean quality characteristics were generally unaffected by shipment. A Significant decrease in the moisutre content of soybeans was noted in the Toledo-Rotterdam shipment. There was no explanation for this observation, but there is no indication that the decrease in moisture had any effect on the quality of the extracted soybean oil. Analysis of the extracted crude oils showed that the fatty acid composition, color, and chromatographic refining loss were identical for all fractions, origin and destination.

Results of critical oil quality determinations (Fe, FFA, PV, and P) for the crude oils are presented in Tables II, III, and IV. The results presented in Table II for analysis of whole and split bean fractions of the Toledo-Rotterdam shipment were affected, to some extent, by contamination during processing of the extracted oils. However, the values for Fe, FFA, and PV for original fractions indicate there was no variation due to shipment. During the New Orleans-Tilbury shipment (Table III), these factors, Fe, FFA, and PV, indicated quality deterioration of the oil from original and splits fractions. Differences between observations may be reflective of the longer in-transit time of the New Orleans-Tilbury shipment. The same quality factors (Fe, FFA, PV) determined for whole bean fractions indicated no deterioration during shipment. Analysis of the oil extracted from whole and split bean fractions of soybeans obtained

TABLE III

New Orleans-Tilbury Shipment: Soybean Oil Quality Evaluation[a]

Fraction	Fe (ppm)	FFA (%)	PV (meq/kg)	Phosphorus (ppm)	
				Crude	Degummed
New Orleans (barge-train)					
Original	0.4 ± 0.04[b]	0.7 ± 0.3[b]	0.9 ± 0.0[b]	442 ± 11.4[b]	37 ± 1.1[b]
Wholes	0.7 ± 0.4	1.0 ± 0.3	1.2 ± 0.1		
Splits	1.2 ± 0.5	1.1 ± 0.6	2.2 ± 1.0		
New Orleans (vessel)					
Original	0.5 ± 0.4	1.1 ± 0.5	0.7 ± 0.1	500 ± 10.0	40 ± 1.1
Wholes	0.5 ± 0.2	0.7 ± 0.5	1.3 ± 0.5		
Splits	1.9 ± 0.4	1.4 ± 0.0	1.7 ± 0.9		
Tilbury					
Original	2.5 ± 0.9	1.7 ± 0.3	2.8 ± 1.0	359 ± 11.0	183 ± 63.9
Wholes	0.4 ± 0.1	0.9 ± 0.7	1.8 ± 0.7		
Splits	2.5 ± 0.2	1.7 ± 0.2	1.9 ± 1.0		

[a]All values are the average of triplicate analyses.
[b]Standard deviation.

TABLE IV

Soybeans from Local Elevators: Oil Quality Evaluation[a]

Sample	Iron (ppm)	FFA (%)	Peroxide value
Trivoli, Illinois			
Wholes	0.4 ± 0.2[b]	0.6 ± 0.3[b]	0.3 ± 0.3[b]
Splits	1.1 ± 0.6	1.0 ± 0.4	2.8 ± 0.6
Edwards, Illinois			
Wholes	0.3 ± 0.1	0.6 ± 0.2	1.0 ± 0.2
Splits	1.4 ± 0.3	1.9 ± 0.9	3.2 ± 0.9
Farmer City, Illinois			
Wholes	0.9 ± 0.1	0.7 ± 0.2	1.5 ± 0.4
Splits	2.8 ± 0.4	1.2 ± 0.2	3.6 ± 0.9

[a]All values are the average of triplicate analyses.

[b]Standard deviation.

TABLE V

Laboratory Scale Degumming of Crude Soybean Oil[a]

Run	% H_2O	Degummed oil P (ppm)
1[b]	2.0	36.4
2[b]	2.0	37.2
3	3.0	36.8
4	3.0	38.1
5	4.0	38.7
6	4.0	40.0

[a]Starting oil: P = 660 ppm.

[b]Conditions used in the present study.

from local elevators (Table IV) showed significant differences in the results for Fe, FFA, and PV, confirming the findings with the exported beans. Split beans appear to contribute a disproportionate deleterious influence on the quality of oil. Enzymatic processes are initiated when the bean is split (8). Hydrolysis of triglycerides gives an increase in the free fatty acid content of the oil. The free fatty acids form iron soaps, and these, in addition to particulate iron from split surfaces, account for increases in iron content of the oil (9). Iron has been shown to be an active catalyst for oxidation of soybean oil (10). Free fatty acids are directly related to refining losses during processing of the oil.

The phosphorous content of the crude oil from the exported beans sampled at the origins was normal. Removal during degumming followed domestic commercial experience (11), that is ≅90% removal of the phosphatides. Oil from destination beans showed deterioration as indicated by analysis of phosphorus in the crude oil and residual phosphorus in the degummed oil (Table III). Robertson et al. (12) showed that phospholipids are progressively broken down during damage. They suggested that the formation of nonhydratable phosphatides is the first stage in the rapid deterioration of phospholipids in damaged soybeans. Hvolby (13) and Braae (14) have discussed the nature of these nonhydratables and alternative treatments of crude oil to facilitate their removal. Since our degumming techniques were small scale simulations of commercial degumming, we tested the method on a crude oil known to be free of nonhydratable phosphatides. Results of several degummings using varying amounts of water, as shown in Table V, indicate that adequate degumming is achieved. Increasing the amount of water used above 2% did not lower the residual phosphorus content of the oil. Although nonhydratable phosphatides are seldom encountered by domestic oil processors, except with oil from field- or storage-damaged beans, foreign processors have long contended that they could not achieve adequate phosphatide removal by water hydration. Most find it necessary to use phosphoric acid to obtain a more satisfactory removal of phosphatides. The evidence presented here indicates that phosphatides deteriorate during shipment and explains the poor phospholipid removal experienced by foreign processors.

The results of these investigations should be helpful in developing revisions to U.S. standards for soybeans.

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