Variability of Linolenic and Linoleic Acids in Soybean Oil[1]

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THE LITERATURE contains only a limited number of references to the linolenic and linoleic acid content of soybean oil. An extensive investigation of these acids in several soybean varieties was reported by Scholfield and Bull (11). They used the thiocyanogen method, A.O.C.S. official method Cd 2–38 (2), and obtained results which, in view of later work, appear to be low for linolenic and high for linoleic. Alderks (1) reported that, in oil from 13 varieties of soybeans, linolenic acid varied from 6.16% to 8.45% and linoleic from 49.26% to 58.62%. Dutton *et al.* (5) and Sreenivasan and Brown (14) have reported linolenic acid values of about the same magnitude as Alderks (1) in single samples. Dutton *et al.* (5) also found linoleic acid contents similar to those of Alderks, but Sreenivasan and Brown (14) found only about 30% linoleic acid. An average of 2.3% linolenic acid reported by Mattil (8) appears to be too low. Simmons and Quackenbush (12) have reported on the linolenic and linoleic acid content of oil from immature soybean seeds of various ages.

A recent modification (4) of the equipment specified in the A.O.C.S. tentative spectrophotometric method, Cd 7–48 (2), has made possible production-line testing of samples of soybean oil for linolenic and linoleic acid content. The new method was used in the present study a) to obtain data on the variability in linolenic and linoleic acids in oil of soybean varieties which are currently of importance and in new experimental lines, some of which will be of commercial importance in the future, and b) to show that the observed variability was related to temperature conditions during the growing season.

Experimental

Soybean seed from the 1955 Uniform Test Groups II, III, and IV (9) of the U. S. Regional Soybean Laboratory was used in this study. These test groups include locations in east-west geographical areas, each about 100 to 150 miles north to south as shown by the map of Figure 1. Practically all soybean areas of Illinois, Indiana, Iowa, Missouri, and Ohio are included in these three groups. About three-fourths of the total U. S. soybean production is in these states. Test varieties and locations in the present study therefore represent the heaviest soybean production areas.

Seed samples from these test groups were combined into composite samples, representing each location and each variety. Oil was extracted by the A.O.C.S. official method (2), and linolenic and linoleic acid contents were determined by the method of Collins and Sedgwick (4).

A study of temperature effects on these components was made, utilizing U. S. Weather Bureau data (15). The period 45 to 11 days before maturity was selected for the temperature study since it has been shown that the principal effect of temperature on oil occurs during this time (6). The period was divided into periods 45 to 31 and 30 to 11 days before maturity, which were considered separately. This provided a comparison of temperature effects in the early and late portions of seed development. Coefficients of correlation between the temperatures during these periods and the fatty acids at maturity were determined by standard statistical techniques (13).

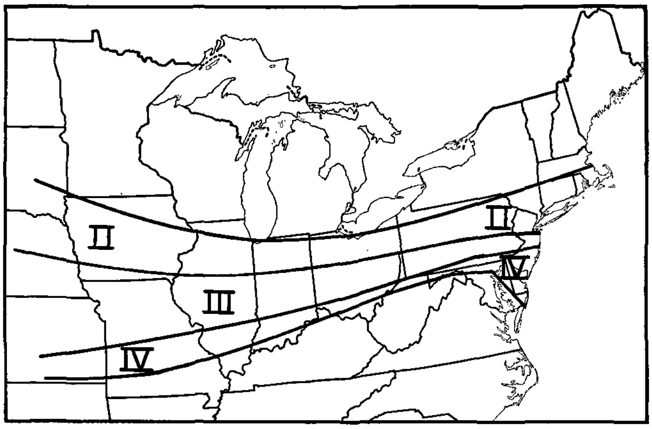

FIG. 1. Approximate areas of Maturity Group Zones II, III, and IV as used in uniform tests of the U. S. Regional Soybean Laboratory.

Results

The linolenic and linoleic acid values in composite samples for the locations and varieties of Group II are presented in Tables I and II. Among the location composites linolenic varied from 5.9% to 8.3%. Among the variety composites it varied from 5.4% to 8.0%. Location composites varied from 45.3% to 50.4% in linoleic acid and variety composites from 43.9% to 51.6%. The magnitude and range of values shown in Table II are similar to those reported by Alderks (1). Two of the varieties of Table II were also included in Alderks' study. They are Lincoln, for which he found 7.7% linolenic and 55.8% linoleic, and Richland, for which he found 7.2% linolenic and 49.7% linoleic. By comparison, our values for Lincoln are 7.3% and 50.0%, and for Richland, 5.4% and 44.2%.

Variabilities of linolenic and linoleic acid similar to those shown in Tables I and II were observed in composites of Groups III and IV. Possibly somewhat greater variability would have been observed if individual rather than composite samples had been analyzed. However individual samples from various sources have been analyzed in studying the effects of different environmental factors, and the levels of these acids have been generally within the range shown in Tables I and II. It is therefore concluded that the data of Tables I and II are representative of the variability to be expected in these fatty acids during a single season.

The coefficients of correlation between linolenic and linoleic acid contents and the temperatures during development of the seeds are presented for all three

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TABLE I

Linolenic and Linoleic Acid Percentages in Soybean Oil from Location Composites

Locations	Linolenic %	Linoleic %
Group II		
Ames, Iowa	6.0	46.0
Bluffton, Ind.	7.0	46.7
Columbus, Ohio	7.2	48.1
Dwight, Ill.	6.1	45.3
Englishtown, N. J.	7.1	50.0
Greenfield, Ind.	6.8	45.8
Hoytville, O.	7.1	46.6
Independence, Iowa	6.2	46.9
Kanawha, Iowa	6.2	46.7
Kirksville, Mo.	6.4	46.4
Lafayette, Ind.	6.4	47.0
Lincoln, Neb.	5.9	46.5
Madison, Wis.	7.0	47.9
Marcus, Iowa	6.3	47.2
Mt. Healthy, O.	6.1	46.8
Newark, Del.	6.3	50.1
Shabbona, Ill.	7.2	48.4
State College, Pa.	8.3	50.4
Urbana, Ill.	6.7	47.1
Walkerton, Ind.	6.9	48.5
Waseca, Minn.	7.0	49.3
Wooster, O.	7.4	47.9
Group II Means	6.7	47.5
Group III Means[a]	6.7	48.1
Group IV Means[b]	6.6	49.7

[a] Composites of 10 varieties.
[b] Composites of 14 varieties.

TABLE II

Linolenic and Linoleic Acid Percentages in Soybean Oil from Variety Composites

Varieties	Linolenic %	Linoleic %
Group II		
Adams	6.6	51.6
Blackhawk	6.0	43.9
Harosoy	6.5	46.2
Hawkeye	5.9	45.8
Lincoln	7.3	50.0
Richland	5.4	44.2
AO–8618	6.3	48.0
AX29–163–1–2	6.7	48.8
C1056	6.9	49.8
C1128	6.4	46.1
H13116	6.7	47.6
H13501	7.3	50.6
H14025	6.9	49.3
H14521	7.5	49.7
H15548	8.0	49.6
L9–5139	7.2	49.4
Group II Means	6.7	48.2
Group III Means[a]	6.7	48.8
Group IV Means[b]	6.6	49.0

[a] Composites of 21 locations in 10 states.
[b] Composites of 13 locations in 6 states.

groups in Table III. Both acids are negatively correlated with temperature since lower percentages of these acids were produced with high temperatures during seed development. Correlations of both acids were much greater with maximum than with minimum temperatures. Linolenic was more closely associated with temperature than was linoleic. Temperatures during the period 30 to 11 days before maturity are a little more closely associated with the acids than are temperatures during the earlier period, but differences between the two periods are too small to attach more importance to temperatures during one than during the other.

Other environmental factors may also affect the levels of these acids. The effects of photoperiod, light intensity and quality, certain phases of mineral nutrition, and soil type have been studied. Details of that work are being published elsewhere (7). While some of these factors may affect linolenic and linoleic acid, they appear to be of minor importance in comparison with maximum temperature. As can be seen from Table III, minimum temperature is much less important than maximum.

Very little information comparing linolenic and linoleic acids in currently important soybean varieties is available. Four of the varieties studied by Alderks (1), Lincoln, S–100, Ogden, and Roanoke are presently on recommended lists in one or more states (3). Of the six named varieties in Table II, all except Richland are on recommended lists. Four additional recommended varieties were included among the lines studied in Groups III and IV, the means of which are presented in Table II. Although information for variety comparisons is limited, it will be noted that the second lowest linolenic acid value among varieties in Table II is that of Hawkeye. This variety occupies about 25% of all soybean acreage, and about twice as much as any other single variety. The only variety in Table II with lower linolenic acid was Richland, a variety of little commercial importance.

TABLE III

Coefficients of Correlation Between Fatty Acids in Soybean Oil of Location Composite Samples and Temperature[a]

	Maximums A[b]	Maximums B[b]	Minimums A	Minimums B
Group II				
Linolenic	–.640	–.859	–.431	–.630
Linoleic	–.438	–.766	–.060	–.287
Group III				
Linolenic	–.696	–.694	–.235	–.318
Linoleic	–.436	–.536	–.020	–.013
Group IV				
Linolenic	–.814	–.844	–.381	–.379
Linoleic	–.608	–.738	–.204	–.160

Values Required for Various Probabilities

	0.05	0.01	0.001
Group II	±.423	±.537	±.652
Group III	±.433	±.549	±.665
Group IV	±.553	±.684	±.801

[a] Samples were composites of 16 varieties at 22 Group II locations; 10 varieties at 21 Group III locations; and 14 varieties at 13 Group IV locations.
[b] A refers to temperatures during period 45 to 31 days before maturity; B to period 30 to 11 days before maturity.

Linolenic and linoleic acids are positively correlated with each other in soybean oil. For the Group II, III, and IV locations the coefficients of correlation of the two acids are .611, .714, and .735. For the three sets of varieties the coefficients are .775, .818, and .759. This is in agreement with Scholfield and Bull (11). In view of this positive correlation it will be difficult to obtain simultaneously a significant increase in linoleic and decrease in linolenic acid in soybean oil by either breeding or cultural practices. In contrast Powers (10) reported that in flax oil an increase in linolenic was accompanied by a decrease in linoleic.

Summary

Soybean oil from all locations and varieties of Uniform Test Groups II, III, and IV have been analyzed for linolenic and linoleic acid by an improved spectrophotometric method. Location composites in Group II varied from 5.9% to 8.3% in linolenic acid and from 45.3% to 50.4% in linoleic. Variety composites varied from 5.4% to 8.0% in linolenic and from 43.9% to 51.6% in linoleic.

The location variability was shown to be closely associated with maximum temperature during seed development. Temperature appears to be the most important environmental factor affecting these acids, especially linolenic.

The percentages of the two acids are positively correlated with each other.

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The Effect of Builders on the Sorption of Sodium Myristyl Sulphate on Cotton and on Carbon

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THE BENEFICIAL EFFECT of builders on the detergent efficiency of soaps and synthetic detergents is well known, but as yet no completely sastisfactory theory of builder action has been proposed. It is believed that the sorption of detergent ions by both soil and fabric plays an important part in the mechanism of detergency although the precise relationship between sorption and detergency has not been established (4,11). The present work was undertaken in the hope that some further clarification might be obtained of the mechanism of builder action and/or of the role of sorption in the detergent process.

Data have already been presented relating to the sorption of various soaps and synthetic detergents on carbon black (7, 8, 13) and on textile fibers (12, 14). While builders in general were not included in this work, it was shown that the addition of sodium sulphate to solutions of synthetic detergents led to an increase in the sorption of the detergent in all cases (8, 12). The sorption of synthetic detergents on various textile fibers was also found to be influenced by the pH of the solution; the sorption of anionic detergents was greater in acid than in alkaline media (3, 12).

Meader and Fries (4) noted that the addition of salts to a solution of sodium alkybenzene sulphonate increased the sorption of the latter on cotton. Sodium sulphate was more effective than tetrasodium pyrophosphate.

Boyd and Bernstein (1), on the other hand, have recently reported that the addition of builders, including sodium sulphate, sodium carbonate, and various phosphates, to solutions of sodium dodecylbenzene sulphonate decreased the sorption of the latter on cotton and on various synthetic soils. Their data however do not refer to equilbrium sorption but rather to the amount of sorbed material remaining after a specified rinsing procedure.

Schneider (10) has studied the heats of immersion of a carbonaceous soil in built detergent solutions and has concluded that builders increase the rate of sorption of the detergent. Those builders which have a high anionic charge were most effective.

Materials and Methods

Sodium myristyl sulphate was prepared by the method of Dreger *et al.* (2) and was recrystallized several times from absolute alcohol. The melting point was 182–3°C., and the infrared spectrum was free of bands in the hydroxyl region.

The builders used are listed in Table I. The phosphate builders were obtained from Electric Reduction Sales Company Ltd., Buckingham, Quebec, and the silicate from National Silicates Ltd., Toronto, Ontario.

TABLE I

Builders Used

Compound	Abbreviation	Anionic charge	pH of 1% solution	Analysis
Sodium metasilicate	S M	—2	12.3	Na_2O–29.4%; SiO_2–29.2%
Trisodium phosphate	T S P	—3	12.1	18.6% as P_2O_5
Tetrasodium pyrophosphate	T S P P	—4	10.3	53.2% as P_2O_5
Sodium tripolyphosphate	S T P P	—5	9.8	57.5% as P_2O_5
Sodium hexametaphosphate	S H M P	—6	7.6	64.2% as P_2O_5
Sodium carbonate, anhydrous	Na_2CO_3	—2	10.6	Reagent grade[a]
Sodium sulphate, anhydrous	Na_2SO_4	—2	6.7	Reagent grade[a]

[a] Conforms to A.C.S. specification.

The carbon black was uncompressed Standard Micronex, supplied by the Binney and Smith Company, New York. The cotton was a fully-bleached nainsook fabric supplied by Tootal and Broadhurst Lee Co., Manchester, England, and was prepared as described previously (14).

The sorption of sodium myristyl sulphate on cotton was determined at 50 ± 2°C. by the method described previously (12) except that the weight of cotton used for each determination was increased to 10 g. and the volume of solution was decreased to 100 ml. The initial solutions contained 0.1% of sodium myristyl sulphate and 0–0.2% of the various builders.

The sorption on carbon was determined at 50 ± 2° C. as in previous work (8) except that the volume of solution used was 100 ml. instead of 150 ml. In the first trials a concentration of 0.1% sodium myristyl sulphate was used, but difficulty was encountered in filtering the equilibrium solution. It had been noted previously (8) that suspensions of carbon black in detergent solutions at concentrations below the critical micelle concentration filtered readily, but

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