Table III shows a comparison between the fatty acids found in the lecithin and those of the soybean glycerides as reported in the literature (14).

TABLE III

Fatty Acids of Soybean Lecithin and Soybean Glycerides

Fatty Acid	Lecithin	Glycerides
Palmitic	15.77	6.8-14.3
Stearic	6.30	2.4- 5.5
Arachidic	0.0	0.3- 0.9
Oleic	12.98	25.9-33.7
Linoleic	62.92	50.7-58.8
Linolenic	2.02	2.1- 6.5

The glycerides were much lower in saturated acids than was the sample of lecithin analyzed. However, since the lecithin contains more linoleic and less oleic acid than do the glycerides, the iodine numbers of the acids from the two sources were approximately equal.

Summary

Lecithin was prepared from crude soybean phosphatides by the Pangborn modification of the cadmium chloride method. Results of analysis indicated that this preparation was 97 per cent lecithin and 3 per cent cephalin. Its fatty acid composition was as follows: palmitic—15.77 per cent; stearic—6.30 per cent; oleic—12.98 per cent; linoleic—62.92 per cent; linolenic—2.02 per cent.

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Relation Between the Fatty Acid Composition and the Iodine Number of Soybean Oil

C. R. SCHOLFIELD [1] and W. C. BULL [1]
U. S. Regional Soybean Industrial Products Laboratory [2]

It has been shown by Dollear, Krauczunas, and Markley (1) that there is a high degree of constancy in the ratio of total saturated acids to total unsaturated acids in different soybean oils, but that the proportions of individual unsaturated acids vary, with corresponding variations in iodine number. This conclusion is based on the analysis of seven samples of soybean oil ranging in iodine number from 102.9 to 151.4. The present investigation was undertaken to determine the fatty acid composition of a large number of samples of soybean oil, in which the iodine numbers were distributed over a wide range of values, and to determine the relation between the iodine number and the percentage of each of the fatty acids by the use of statistical methods. This has been done, and from the relations determined it is possible to estimate the fatty acid composition of a soybean oil from a determination of its iodine number. Such an estimation may be of value in technical work on soybean oil and as a guide in breeding experiments with soybeans.

Ninety-five samples of soybeans with oils having a range in iodine values from 99.6 to 147.6 were chosen from those produced by the Bureau of Plant Industry, Soils, and Agricultural Engineering and previously analyzed in this laboratory (2). The beans were grown in 1936 to 1940 inclusive, and since harvesting had been stored at a temperature of 70° F. and a relative humidity of 18 percent.

[1] Northern Regional Research Laboratory, Peoria, Illinois.
[2] The Chemical and Engineering Sections of the Soybean Industrial Products Laboratory, Urbana, Illinois, were merged with the Northern Regional Research Laboratory, Peoria, Illinois, July 1, 1942.

Acid numbers were run on all samples as an indication of the preservation of the oil. The results, which were mostly low, indicated excellent preservation.

The samples were ground and, without drying the samples, the oil was extracted with petroleum ether in a percolator. The solvent was removed on a steam bath under an air jet, experience having shown that the use of an air jet in removal of the solvent has a negligible effect on the composition of crude soybean oil.

The acid number and unsaponifiable matter were determined on one portion of the oil (3-gm. sample), and the mixed fatty acids were prepared from another portion by the methods of the A.O.C.S. (3). The thiocyanogen numbers of the mixed acids were also determined by the methods of the A. O. C. S., using approximately 0.2 normal thiocyanogen solution (3). The iodine numbers of the oil and of the mixed acids were determined using Wijs solution with a 30-minute reaction time (3). The saturated acids were determined by the low-temperature crystallization method of Earle and Milner (4).

From these data the percentage of each of the unsaturated acids was calculated assuming that oleic, linoleic, and linolenic were the only unsaturated acids present. The empirical values for the thiocyanogen numbers of linoleic and linolenic acid as determined by Kass and coworkers (5) were used instead of the theoretical values formerly used. The analytical data are given in Table 1.

The linear equations best expressing the relations between the percentages of individual fatty acids in

TABLE 1

Analysis of Soybean Oils

Sample number	Variety	Analysis of oil			Analysis of mixed fatty acids					
		Iodine number (Wijs)	Acid number	Unsaponifiable matter	Iodine number (Wijs)	Thiocyanogen number	Saturated acids	Oleic acid	Linoleic acid	Linolenic acid
				Percent			*Percent*	*Percent*	*Percent*	*Percent*
1	Dunfield	99.6	16.39	0.98	105.4	78.7	15.2	53.5	30.6	0.7
2	Dunfield B	101.0	2.10	0.80	105.2	80.4	13.3	57.6	28.2	0.9
3	T117	104.2	1.88	0.81	108.2	78.4	15.5	49.5	34.8	0.3
4	Mukden	104.9	1.44	0.82	111.2	78.3	16.4	45.0	37.7	0.9
5	Manchu	109.5	1.96	0.81	117.3	80.8	15.4	42.2	39.5	2.9
6	Illini	111.4	1.18	0.86	125.2	80.9	15.1	33.1	50.0	1.8
7	Dunfield B	116.6	0.37	0.79	123.9	79.8	15.8	32.4	50.6	1.1
8	Dunfield A	116.8	0.34	0.69	123.5	82.4	14.2	38.0	44.6	3.1
9	Mandarin	116.9	0.63	0.80	124.3	83.1	15.2	37.6	41.8	5.4
10	Mandarin	117.0	2.43	0.85	122.1	82.2	15.9	38.3	40.6	5.1
11	Dunfield B	117.1	0.52	0.68	127.8	81.7	16.3	30.3	49.0	4.3
12	Dunfield B	117.2	0.29	0.67	122.8	82.2	13.9	38.8	44.8	2.6
13	Dunfield B	117.9	0.17	0.58	127.1	82.0	15.7	32.1	48.1	4.1
14	Mukden	118.2	0.35	0.67	125.0	80.2	17.4	30.7	48.2	3.7
15	Dunfield B	118.6	0.18	0.52	126.7	81.6	14.8	32.6	50.4	2.3
16	Dunfield B	118.8	0.63	0.59	128.2	83.8	14.5	34.4	45.9	5.2
17	Dunfield B	119.5	0.60	0.60	127.9	82.9	13.8	33.8	49.5	2.9
18	Dunfield B	119.8	0.35	0.64	126.4	81.2	14.7	32.4	51.3	1.6
19	Mukden	119.8	0.32	0.69	125.2	80.3	17.7	30.4	47.6	4.2
20	Dunfield B	120.0	0.29	0.69	128.0	82.7	15.2	32.5	47.9	4.4
21	Mukden	120.7	0.27	0.67	126.7	81.1	16.9	30.4	48.4	4.2
22	Dunfield B	121.9	0.65	0.70	130.5	82.9	14.8	30.0	51.3	3.9
23	Dunfield B	122.0	0.52	0.74	130.1	83.4	13.4	32.3	51.4	2.9
24	Dunfield B	122.2	0.23	0.54	128.7	81.8	14.2	30.8	53.2	1.6
25	Mukden	123.7	0.32	0.79	130.0	80.5	15.8	26.2	56.3	1.5
26	Mukden	123.7	0.31	0.67	130.5	81.5	16.4	26.7	53.1	3.8
27	Mukden	124.1	0.18	0.78	130.3	81.2	16.0	26.8	54.3	2.8
28	Dunfield B	124.4	0.19	0.57	129.4	82.6	13.9	31.4	52.3	2.4
29	Peking	124.4	5.39	1.26	135.4	85.2	15.4	27.4	49.6	7.7
30	Dunfield B	124.5	0.21	0.67	131.1	81.6	14.8	27.2	56.2	1.9
31	Dunfield B	124.8	0.24	0.60	131.5	83.9	14.2	30.8	50.4	4.5
32	Dunfield B	125.2	0.16	0.64	130.9	82.7	15.0	29.1	52.0	3.9
33	Dunfield B	125.4	0.22	0.70	131.7	83.4	14.7	29.4	51.4	4.4
34	Dunfield B	125.4	0.35	0.71	130.8	82.6	14.7	29.3	52.7	3.3
35	Illini	125.7	0.20	0.69	130.8	83.8	14.1	31.6	50.0	4.4
36	Dunfield B	125.9	0.26	0.66	132.2	84.1	14.8	29.8	49.7	5.5
37	Dunfield B	126.2	0.28	0.74	131.0	81.3	14.8	26.9	57.0	1.4
38	Illini	127.3	0.55	0.67	131.3	83.9	14.9	30.6	49.2	5.5
39	Mukden	127.3	0.42	0.76	131.8	82.7	16.9	26.7	50.1	6.2
40	Dunfield B	127.4	0.18	0.59	130.8	84.9	12.2	34.6	49.6	3.7
41	Dunfield B	128.0	0.32	0.79	136.4	83.2	15.3	23.0	57.3	4.4
42	Illini	128.1	0.96	0.80	134.0	81.8	15.4	23.6	58.3	2.6
43	Illini	128.1	0.18	0.67	135.1	86.2	14.6	29.8	47.4	8.3
44	Dunfield B	128.1	0.20	0.82	133.6	82.8	15.1	25.9	55.2	3.8
45	Illini	128.2	0.23	0.72	133.4	84.7	14.5	29.6	49.9	6.0
46	Dunfield B	128.2	0.15	0.59	134.6	83.0	14.6	25.4	56.7	3.4
47	Illini	128.7	0.23	0.87	133.5	84.5	15.4	28.5	49.3	6.9
48	Illini	129.0	0.23	0.90	134.0	83.0	14.5	26.1	56.0	3.2
49	Illini	129.1	0.19	0.82	135.9	84.1	14.6	25.5	54.9	4.9
50	Illini	129.2	0.18	0.64	137.4	82.3	14.8	20.7	62.3	2.2
51	Illini	129.3	0.31	0.72	134.1	83.6	15.8	26.0	52.1	5.9
52	Illini	129.5	0.18	0.76	135.7	82.8	14.4	23.9	59.1	2.7
53	Illini	129.9	0.21	0.64	135.6	84.8	14.6	27.0	52.4	6.1
54	Illini	130.5	0.76	0.79	136.5	82.7	14.5	22.6	60.2	2.6
55	Peking	130.5	0.39	0.86	136.8	83.5	13.6	24.2	59.6	2.6
56	Illini	130.6	0.19	0.66	135.8	85.3	13.6	28.2	52.7	5.5
57	Illini	130.9	0.83	0.82	136.4	82.9	14.8	22.8	59.1	3.3
58	Illini	131.2	0.23	0.83	135.6	84.1	15.0	25.6	53.8	5.5
59	Illini	131.2	0.92	0.81	140.7	86.4	14.2	23.5	54.7	7.4
60	Illini	131.7	0.32	0.84	137.4	83.9	15.1	23.0	56.8	5.1
61	Illini	131.8	0.19	0.68	137.0	85.1	14.1	26.1	54.1	5.7
62	Illini	132.2	0.27	0.69	137.7	84.2	15.5	23.0	55.5	6.0
63	Manchu	132.3	0.39	0.84	138.6	84.5	13.8	23.5	58.6	4.2
64	Illini	132.6	0.18	0.76	137.8	83.9	14.6	23.0	58.1	4.4
65	Scioto	133.4	0.28	0.80	139.8	83.5	14.4	20.0	62.3	3.3
66	Peking	133.9	0.22	1.02	139.7	85.9	15.0	23.6	53.6	7.6
67	Peking	134.1	0.84	1.03	139.4	83.9	14.4	21.1	60.5	3.9
68	Peking	134.6	0.14	0.98	140.8	84.7	13.8	21.1	60.9	4.3
69	Manchu	134.7	0.39	0.72	140.4	85.3	13.6	22.6	58.7	5.0
70	Peking	134.7	0.46	0.94	142.0	86.4	14.5	21.8	56.0	7.7
71	Illini	134.8	0.39	1.10	140.6	84.3	15.1	19.8	59.7	5.3
72	Illini	134.8	0.29	0.64	140.5	86.8	13.9	24.7	53.7	7.7
73	Peking	135.2	0.18	1.04	141.0	84.6	14.8	20.0	59.8	5.4
74	Scioto	135.4	0.26	0.94	141.6	85.2	14.1	20.8	59.8	5.3
75	Scioto	135.8	0.30	0.68	141.3	84.8	14.3	20.3	60.4	5.0
76	Scioto	136.2	0.26	0.78	142.0	85.4	13.9	20.7	60.1	5.4
77	Peking	136.2	0.19	0.99	141.7	86.0	14.6	21.5	56.7	7.4
78	Peking	136.6	0.88	1.06	144.7	86.1	14.4	18.2	60.6	6.8
79	Peking	137.0	0.20	0.98	143.0	85.7	14.4	19.6	59.6	6.4
80	Peking	137.0	0.27	0.98	143.0	85.2	14.6	18.8	60.9	5.9
81	Peking	137.5	0.74	1.10	144.4	86.6	13.8	19.8	59.6	6.8
82	Peking	137.6	0.27	1.00	143.2	86.1	13.8	20.4	59.6	6.1
83	Peking	137.6	0.12	0.92	143.4	86.2	14.5	19.8	58.4	7.2
84	Peking	138.1	0.18	1.01	143.4	87.2	13.8	21.9	56.5	7.8
85	Peking	138.3	0.25	0.91	145.2	88.0	14.2	20.8	55.7	9.4
86	Peking	138.4	0.24	0.98	144.8	86.2	14.2	18.3	60.7	6.7
87	Peking	138.8	0.32	1.41	144.2	87.4	13.3	21.5	57.7	7.4
88	Peking	139.0	0.20	0.98	144.8	87.8	14.5	20.6	55.2	9.6
89	Peking	139.3	0.24	1.02	145.6	86.4	14.4	17.5	60.9	7.2
90	Peking	139.6	0.22	1.01	145.0	86.8	12.6	20.3	61.7	5.5
91	O3654A	139.6	0.24	0.65	145.3	85.6	13.8	17.1	64.0	5.2
92	Peking	140.2	0.17	0.86	146.0	87.7	14.2	19.3	57.6	8.8
93	Peking	140.7	0.21	1.03	147.1	87.0	13.7	17.2	62.1	7.0
94	Peking	143.2	0.25	0.94	148.8	88.2	12.6	17.9	62.3	7.3
95	Wild Bean	147.6	0.74	2.68	154.6	89.0	14.3	10.9	64.8	10.1

the mixed fatty acids and the iodine numbers of the mixed fatty acids were determined. The equations were calculated by the method of least squares (6). This means that, in applying the equations, minimum values will be obtained for the sum of the squares of the differences between the experimentally-determined values for the fatty acids and the values calculated from the equations. The standard errors of estimate were also calculated as a measure of the agreement of the equations with the experimental values. According to theory, 68 percent of the experimental values will differ from the calculated values by less than the standard error of estimate; 95 percent will differ from the calculated values by less than twice the standard error of estimate, and 99.73 percent will differ from the calculated values by less than three times the standard error of estimate.

The equations obtained are as follows:

Per cent saturated acids = 20.7 — 0.045 iodine number of mixed fatty acids.
Standard error of estimate = 0.9.
Percent oleic acid = 138.1 — 0.827 iodine number of mixed fatty acids.
Standard error of estimate = 2.1.
Percent linoleic acid = —39.9 + 0.696 iodine number of mixed fatty acids.
Standard error of estimate = 2.9.
Percent linolenic acid = —19.0 + 0.177 iodine number of mixed fatty acids.
Standard error of estimate = 1.5.

Similar equations were determined for the relations between the percentages of each fatty acid in the mixed fatty acids and the iodine number of the oil. These equations are as follows:

Percent saturated acids = 20.5 — 0.045 iodine number of oil.
Standard error of estimate = 0.9.
Percent oleic acid = 128.3 — 0.792 iodine number of oil.
Standard error of estimate = 2.5.
Percent linoleic acid = —31.9 + 0.669 iodine number of oil.
Standard error of estimate = 3.2.
Percent linolenic acid = —17.0 + 0.170 iodine number of oil.
Standard error of estimate = 1.5.

The equations for the relations between the percentages of individual fatty acids in the mixed fatty acids and the iodine number of the oil are illustrated in Figure 1.

Since the proportions of the individual fatty acids calculated as glycerides in the oils are almost identical with those of the individual fatty acids in the mixed fatty acids, the relations given above also represent the variation in the composition of the oils.

The percentages of the unsaponifiable matter in the oil samples are included in the analytical data. However, the accuracy of values for unsaponifiable matter is rather uncertain since the values obtained are affected by such factors as kind of solvent used, sample size, and method of extraction. Also, in any attempt to correct to an unsaponifiable-free basis, an assumption concerning the iodine number and thiocyanogen number of the unsaponifiable matter would be involved. Because of these facts and because the correction would be small in any case, compared with

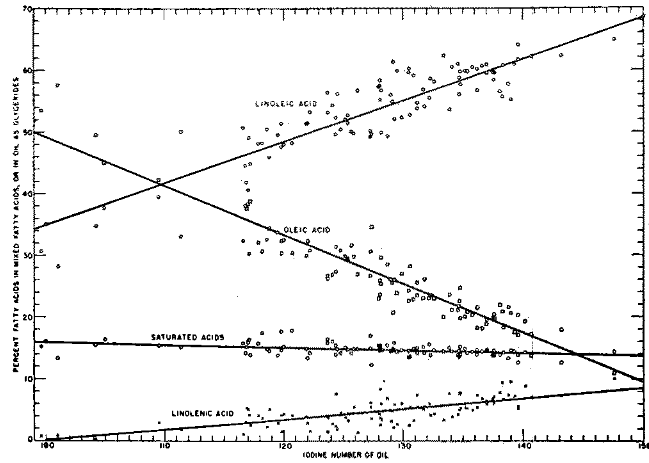

FIG. Relation of the percentages of saturated, oleic, linoleic, and linolenic acids present in mixed fatty acids to the iodine number of soybean oil.

the standard error of estimate, it was thought that a calculation of the percentage of fatty acids to an unsaponifiable-free basis would not be justified.

It may be observed in the table that higher values for unsaponifiable matter appear to be associated with higher iodine numbers. However, most of the high unsaponifiable values are found in samples of oil from the Peking variety and from the Wild Bean These are rather small beans, and their oil would be expected to be high in unsaponifiable matter since much of the unsaponifiable matter is found in the seed coat which constitutes a higher proportion of components in small beans.

It was found that over the entire range of iodine numbers the percentages of total saturated and individual unsaturated fatty acids in soybean oil extracted in the manner described vary in a regular manner, within reasonable limits, according to the iodine numbers. Similar relations were observed whether the variables considered were the percentages of individual fatty acids and iodine numbers of the mixed acids, or the percentages of individual fatty acids in the mixed acids and iodine numbers of the oils. The proportions of individual fatty acids in the mixed fatty acids also represent the proportions of individual fatty acids as glycerides in the oil. The principal variation in fatty acid composition is the large decrease in oleic acid and the large increase in linoleic acid with increasing iodine number. Linolenic acid increases slightly with increasing iodine number, while the proportion of saturated acids is relatively constant for the entire range of iodine numbers.

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