The Unsaturated Fatty Acids of Hydrogenated Shortening and Other Edible Fats

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Hydrogenation of fatty oils serves the double purpose of increasing resistance to rancidity and of increasing the proportion of solid fat. The increased resistance to rancidity depends largely upon the selective hydrogenation of linoleic acid to oleic acid, or, more generally, the selective conversion of the more highly unsaturated fatty acids to those of molecular structure containing one double bond. This situation partly accounts for the widespread but mistaken impression that hydrogenated shortening contains no glycerides derived from fatty acids more unsaturated than oleic.

TABLE 1
Lard

Sample No.	Brand	Iodine Value	Thiocyanogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of		
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd
1-M	1	58.0	48.3	11.2	44.9	43.9	11.7	43.6	44.7
2-M	2	64.7	54.3	12.0	51.0	37.0	12.6	49.7	37.7
3-M	3	68.9	57.4	13.3	53.3	33.4	13.9	51.9	34.2
4-M	1	57.0	47.7	10.7	44.6	44.7	11.2	43.5	45.3
5-M	4	66.4	55.3	12.8	51.4	35.8	13.4	50.0	36.6
6-M	5	66.5	55.4	12.8	51.5	35.7	13.4	50.1	3(.5
38	5	66.9	56.8	11.7	54.3	34.0	12.2	53.1	34.7
23	6	63.0	53.2	11.3	50.4	38.3	11.8	49.3	38.9
24	7	67.3	56.5	12.5	53.1	34.4	13.0	51.8	35.2
55	7	63.1	54.1	10.4	52.4	37.2	10.8	51.4	37.8
103	7	61.7	52.7	10.4	50.8	38.8	10.8	49.7	39.5
135	7	65.1	55.1	11.5	52.4	36.1	12.1	51.2	36.7
25	8	68.1	56.2	13.7	51.5	34.8	14.4	49.9	35.7
26	9	65.0	54.5	12.1	51.1	36.8	12.7	49.8	37.5
39	10	72.8	61.2	13.4	57.6	29.0	14.0	56.2	29.8
102	10	66.5	56.6	11.4	54.3	34.3	11.9	53.1	35.0
56	11	67.1	56.4	12.3	53.3	34.4	12.9	51.8	35.3
75	11	60.6	52.4	9.5	51.4	39.1	9.8	50.5	39.7
105	11	67.8	56.5	13.0	52.5	34.5	13.7	51.1	35.2
134	11	64.0	53.9	11.7	50.9	37.4	12.2	49.7	38.1
57	12	58.4	48.6	11.3	45.1	43.6	11.9	43.9	44.2
101	13	66.4	55.4	12.7	51.6	35.7	13.3	50.2	36.5
104	14	64.7	53.9	12.5	50.1	37.4	13.1	48.7	38.2
119	15	66.9	56.7	11.8	54.0	34.2	12.3	52.8	34.9
120	16	64.3	53.7	12.2	50.1	37.7	12.8	48.8	38.4
132	17	57.7	52.1	6.5	54.0	39.5	6.6	53.6	39.8
133	18	65.0	55.7	10.7	53.9	35.4	11.2	52.9	35.9

In semitechnical literature hydrogenated fats have been criticized for edible use for alleged lack of the nutritive value attaching to the so-called essential fatty acids having more than one double bond in the molecular formula. Such statements, although they are regularly unaccompanied by actual evidence, are beginning to appear in the scientific literature, as evidenced by the first reference at the end of the present paper (1). Recently a prominent biochemist went so far as to include the same criticism in testimony given in a legal proceeding, and incidentally he testified that certain brands of shortening were deficient in linoleic acid due to hydrogenation, calling by name the brands identified herein as No. 4 in Table 4 and No. 17 in Table 5 (2). By analysis we find these brands to contain about 17% and 35% glyceride derived from linoleic acid, respectively! With view to avoiding misunderstandings of this kind, the present paper attempts to supply systematic information on the distribution of the unsaturated fatty acids in hydrogenated shortenings and in other types of edible fat of practical importance in this country.

The distinctive value of linoleic acid, and of the other unsaturated fatty acids commonly classed as essential for the rat, has not yet been clearly established in the study of human nutrition. The present paper is concerned only with composition, with no implications as to biological values. Some writers on scientific subjects are currently assuming that linoleic acid is essential for human nutrition, and our effort to improve their information as to composition of certain fats implies neither support nor contradiction of their opinion as to biochemical values.

Distinctions Among Shortenings Containing Hydrogenated Fat

Two types of shortening containing hydrogenated fat can be clearly distinguished, corresponding to the prevailing types introduced commercially in the early days of the hydrogenation industry. At the one extreme, vegetable oil, hydrogenated almost to saturation, has been widely used in mixture with about six times its own weight of unhydrogenated oil, the molten mixture being chilled and agitated so as to

TABLE 2
Butter Fat

Sample No.	Brand	Iodine Value	Thiocyanogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of		
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd
16	1	34.5	31.4	3.6	32.9	63.5	3.6	32.7	63.7
67	1	33.0	30.0	3.5	31.4	65.1	3.5	31.2	65.3
17	2	32.5	29.3	3.7	30.3	66.0	3.8	30.1	66.1
27	3	34.3	31.4	3.3	33.1	63.6	3.4	33.0	63.6
28	4	31.0	28.2	3.2	29.5	67.3	3.3	29.3	67.4
29	5	32.2	28.9	3.8	29.5	66.7	3.9	29.5	66.6
30	6	31.2	28.4	3.2	29.8	67.0	3.3	29.6	67.1
31	7	31.1	27.8	3.8	28.3	67.9	3.9	28.2	67.9
44	7	32.5	29.2	3.8	30.1	66.1	3.9	29.8	66.3
61	7	32.0	29.5	2.9	31.4	65.7	2.9	31.3	65.8
100-M	7	36.2	33.2	3.5	34.9	61.6	3.5	34.9	61.6
102-M	7	33.3	30.7	3.0	32.7	64.3	3.0	32.5	64.5
32	8	33.5	31.3	2.5	33.8	63.7	2.5	33.8	63.7
46	8	32.1	29.3	3.2	30.8	66.0	3.3	30.6	66.1
41	9	34.2	31.2	3.5	32.8	63.7	3.5	32.6	63.9
42	10	33.2	30.6	3.0	32.5	64.5	3.0	32.4	64.6
90	10	31.1	28.8	2.7	30.8	66.5	2.7	30.7	66.6
43	11	32.2	29.4	3.2	30.9	65.9	3.3	30.8	65.9
45	12	32.9	30.0	3.3	31.5	65.2	3.4	31.3	65.3
62	13	31.3	28.4	3.3	29.6	67.1	3.4	29.4	67.2
63	14	31.6	28.0	4.2	28.4	67.4	4.3	28.0	67.7
64	15	30.8	27.4	3.9	27.9	68.2	4.0	27.6	68.4
65	16	32.2	29.0	3.7	30.0	66.3	3.8	29.7	66.5
66	17	32.8	30.0	3.2	31.6	65.2	3.3	31.5	65.2
82	18	30.1	27.3	3.2	28.5	68.3	3.3	28.3	68.4
83	19	33.2	30.3	3.3	31.8	64.9	3.4	31.7	64.9
84	20	32.7	30.2	2.9	32.2	64.9	2.9	32.1	65.0
85	21	34.5	31.3	3.7	32.7	63.6	3.8	32.4	63.8
86	22	31.1	29.9	1.4	33.4	65.2	1.3	33.5	65.2
87	23	32.4	29.9	2.9	31.8	65.3	2.9	31.7	65.4
88	24	31.1	28.3	3.2	29.6	67.2	3.3	29.5	67.2
89	25	31.9	29.5	2.8	31.5	65.7	2.8	31.4	65.8
114	26	33.9	31.2	3.1	33.1	63.8	3.1	33.0	63.9
115	27	39.2	36.2	3.5	38.6	57.9	3.5	38.5	58.0
116	28	39.7	35.5	4.8	36.4	58.8	5.0	36.0	59.0
117	29	32.4	29.3	3.6	30.4	66.0	3.6	30.2	66.2
118	30	31.8	28.7	3.6	29.8	66.6	3.6	29.5	66.9
101-M	31	32.1	29.0	3.6	30.1	66.4	3.6	29.9	66.5
103-M	32	32.1	29.8	2.7	32.0	65.3	2.6	31.9	65.5
104-M	33	38.2	34.5	4.3	35.8	59.9	4.4	35.5	60.1
105-M	34	31.9	29.1	3.2	30.6	66.2	3.3	30.4	66.3

form a partially solidified, plastic mass. This kind of mixture was at one time commonly called "compound," a name which now seems to be going rapidly out of use without being replaced by an exact equivalent. At the other extreme, it has been common practice to subject cottonseed oil and other unsaturated vegetable oils to selective hydrogenation until the iodine value is about 75, for example, and the term "hydrogenated shortening" generally refers to such a product in plasticized form, with or without the addition of relatively small quantities of more highly hydrogenated fat.

The term "hydrogenated shortening" is accordingly used in the present paper to include those shortenings which appear from their labels to consist wholly of hydrogenated shortening. Those which from their labels appear to contain rather than to consist wholly of hydrogenated fat are grouped in Table 5, without attempt to give them a class name. It does not seem to us advisable to attempt a more exact classification in view of the fact that many shortenings at the present time are known to be intermediate between the two distinctive types mentioned in the preceding paragraph. It should be noted that any deductions which we would draw from the analytical results herein reported are consistent with the classification deduced from the labels.

For comparison with the hydrogenated shortenings and the other shortenings containing hydrogenated fat, we have included in our study a considerable number of samples of lard, of butter, of margarine, and of mixed animal and vegetable shortenings. From known practice in the margarine industry and from our analytical results we must assume that hydrogenated vegetable oil very similar to commercial hydrogenated shortening is the principal type of fat used in margarine, but we have not attempted to classify the margarine samples with respect to type of fats used.

Collection of Samples

Samplers, having no knowledge of our intended use for the materials purchased, were instructed to visit a chain store and an independent grocery in each of seven cities, and to obtain the following samples:

Each available brand or distinctive grade of lard.
Each available brand or distinctive grade of butter.
Each available brand of margarine.
Each brand of other shortening or cooking fat.

TABLE 3

Margarine Fat

Sample No.	Brand	Iodine Value	Thiocyanogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of			Insoluble Bromides
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd	
50-M	1	73.5	62.3	12.9	59.4	27.7	13.5	58.1	28.4	
19	1	78.7	66.5	14.1	63.1	22.8	14.7	61.6	23.7	
36	1	71.8	63.0	10.2	63.0	26.8	10.5	62.1	27.4	
48	1	69.3	62.7	7.6	65.2	27.2	7.8	64.7	27,5	
73	1	73.3	63.6	11.2	62.6	26.2	11.6	61.6	26.8	
98	1	71.7	63.1	9.9	63.3	26.8	10.2	62.5	27.2	
130	1	75.3	66.9	9.7	68.0	22.3	10.0	67.2	22.8	
51-M	2	69.6	61.6	9.2	62.3	28.5	9.5	61.6	28.9	
129	2	69.7	64.6	5.9	69.1	25.0	5.9	69.0	25.1	
52-M	3	45.1	41.7	3.9	44.5	51.6	3.9	44.4	51.7	
53-M	4	76.9	64.1	14.8	59.6	25.6	15.5	58.0	26.5	Neg.
54-M	5	83.6	63.3	23.4	50.0	26.6	24.8	46.9	28.3	Neg.
21	5	86.4	67.8	21.5	57.2	21.3	22.7	54.5	22.8	Neg.
51	5	83.4	66.4	19.6	57.4	23.0	20.7	55.0	24.3	Neg.
91	5	84.6	67.2	20.1	57.9	22.0	21.2	55.4	23.4	Neg.
123	5	82.5	65.9	19.2	57.3	23.5	20.2	55.0	24.8	Neg.
55-M	6	38.6	35.7	3.3	38.1	58.6	3.3	38.0	58.7	
126-M	6	73.0	71.9	1.3	82.3	16.4	0.8	83.0	16.2	
56-M	7	66.3	53.6	14.7	47.5	37.8	15.4	45.8	38.8	Pos.
93	7	86.3	74.3	13.8	72.4	13.8	14.4	71.1	14.5	
57-M	8	81.1	71.1	11.5	71.0	17.5	11.9	70.0	18.1	
123-B	8	81.4	71.8	11.1	72.3	16.6	11.4	71.4	17.2	
125	8	82.1	74.4	8.9	77.5	13.6	9.0	77.0	14.0	
58-M	9	72.2	62.9	10.7	62.3	27.0	11.1	61.3	27.6	
35	9	72.7	64.8	9.1	66.1	24.8	9.4	65.4	25.2	
47	9	74.6	65.7	10.3	66.0	23.7	10.6	65.2	24.2	
68	9	71.6	63.9	8.9	65.3	25.8	9.1	64.7	26.2	
97	9	73.7	66.4	8.4	68.7	22.9	8.6	68.1	23.3	
122	9	72.7	64.8	9.1	66.1	24.8	9.4	65.4	25.2	
131	9	72.0	65.7	7.3	69.0	23.7	7.4	68.7	23.9	
59-M	10	31.5	29.2	2.7	31.3	66.0	2.6	31.2	66.2	
18	11	82.7	65.3	20.1	55.7	24.2	21.2	53.2	25.6	Neg.
50	11	85.4	73.1	14.2	70.7	15.1	14.8	69.3	15.9	
72	11	74.3	62.6	13.5	59.2	27.3	14.1	57.7	28.2	
95	11	83.5	66.9	19.2	58.5	22.3	20.2	56.2	23.6	Neg.
127	11	73.7	70.6	3.6	78.4	18.0	3.3	78.7	19.0	
20	12	68.4	60.1	9.6	60.2	30.2	9.9	59.4	30.7	
22	12	27.2	24.6	3.0	25.6	71.4	3.1	25.4	71.6	
33	13	75.8	72.8	3.5	81.1	15.4	3.2	81.5	15.3	
34	14	75.5	72.7	3.2	81.2	15.6	2.9	81.6	15.5	
37	15	72.0	70.0	2.3	79.0	18.7	2.0	79.5	18.5	
128	15	65.7	64.1	1.8	72.6	25.6	1.5	73.1	25.4	
49	16	53.5	46.9	7.6	46.8	45.6	7.9	46.2	45.9	
52	17	84.2	77.2	8.1	81.6	10.3	8.1	81.2	10.7	
53	18	85.0	67.5	20.2	58.1	21.7	21.4	55.7	22.9	Neg.
96	18	78.2	63.9	16.5	57.6	25.9	17.3	55.7	27.0	Neg.
124	18	75.1	62.2	14.9	57.3	27.8	15.6	55.6	28.8	Neg.
54	....	81.5	73.9	8.8	77.0	14.2	8.9	76.5	14.6	
69	19	25.9	23.3	3.0	24.1	72.9	3.1	23.9	73.0	
74	19	26.9	24.1	3.2	24.8	72.0	3.3	24.5	72.2	
70	20	26.5	20.7	6.7	17.3	76.0	7.1	16.5	76.4	
71	21	56.2	47.6	9.9	45.3	44.8	10.4	44.3	45.3	
92	22	78.2	65.3	14.9	60.9	24.2	15.6	59.3	25.1	Neg.
94	23	83.7	69.8	16.0	65.0	19.0	16.8	63.2	20.0	Neg.
99	24	78.5	66.3	14.1	62.9	23.0	14.7	61.4	23.9	
100	25	84.5	66.2	21.1	55.7	23.2	22.3	53.0	24.7	Neg.
121	26	78.8	65.3	15.6	60.2	24.2	16.3	58.5	25.2	Neg.

Samplers were instructed not to purchase a second sample of the same brand from the same city, but samples were not excluded in the few cases where the second sample was sent to us by mistake. The cities covered were: Chicago, Cincinnati, Dallas, Kansas City, Long Beach, Calif., Macon, Ga., and Quincy, Mass. These retail samples were supplemented by samples of whatever shortenings happened to be available at Ivorydale and which included chiefly the important brands of vegetable shortening commonly sold in this country to restaurants and bakers. We believe that this plan could not fail to give samples representative of considerably more than 90% of the shortening consisting of or containing hydrogenated fat, and that the other samples can be accepted as fairly representative of their respective types.

Preparation of Samples for Analysis

All analyses on lards and other dry shortenings were made on samples as received. Butter and margarines were melted, the fat layer filtered and analyses were performed on the dry oil thus obtained. In the few in which moisture still appeared to be present the melted fat was dried with anhydrous Na_2SO_4 and refiltered before analysis.

Methods of Analysis

Iodine value determinations were made by the Official Wijs Method prescribed by the Committee on Analysis of Commercial Fats and Oils of the American Chemical Society and American Oil Chemists' Society (3).

Thiocyanogen value analyses were made by the Official Thiocyanogen Method prescribed by the Fat Analysis Committee (4).

The Insoluble Bromides Test (qualitative) was performed as described in the Wizoff Method translated by Dean (5). The sensitivity of the test is such that 25% unhydrogenated soybean or 5% linseed oil may be detected in a hydrogenated shortening.

Calculation of Composition

Composition, in terms of apparent percentages of glycerides of linoleic, oleic and saturated acids, was calculated by use of the formulas given in the Official Thiocyanogen Method, based upon Kaufmann's as-

TABLE 4

Hydrogenated Shortening

Sample No.	Brand	Iodine Value	Thiocyanogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of			Insoluble Bromides
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd	
12	1	67.3	56.2	12.8	52.4	34.8	13.4	51.0	35.6	
13	1	67.2	58.5	10.0	57.9	32.1	10.4	57.0	32.6	
15	2	72.6	60.6	13.8	56.5	29.7	14.5	55.0	30.5	
150-M	3	70.5	59.5	12.7	56.4	30.9	13.3	55.0	31.7	
170	3	65.7	61.0	5.4	65.4	29.2	5.4	65.3	29.3	
171	3	69.1	60.1	10.4	59.4	30.2	10.8	58.4	30.8	
172	3	70.3	60.6	11.2	59.2	29.6	11.6	58.1	30.3	
173	3	65.8	60.8	5.8	64.8	29.4	5.8	64.7	29.5	
174	3	67.6	60.0	8.8	60.9	30.3	9.0	60.2	30.8	
175	3	67.5	59.3	9.5	59.4	31.0	9.8	58.6	31.6	
151-M	4	71.3	56.8	16.7	49.2	34.1	17.6	47.1	35.3	Neg.
164	4	73.8	61.3	14.4	56.7	28.9	15.1	55.1	29.8	Neg.
165	4	71.0	57.8	15.2	51.8	33.0	16.0	50.1	33.9	Neg.
166	4	71.9	58.3	15.7	51.9	32.4	16.5	50.1	33.4	Neg.
167	4	76.2	59.9	18.8	50.7	30.5	19.9	48.4	31.7	Neg.
168	4	75.0	60.5	16.7	53.5	29.8	17.6	51.5	30.9	Neg.
169	4	74.0	58.1	18.3	49.0	32.7	19.4	46.8	33.8	Neg.
152-M	5	70.4	60.8	11.1	59.5	29.4	11.5	58.5	30.0	
140	6	62.6	55.6	8.1	56.5	35.4	8.3	55.9	35.8	
141	7	64.9	54.8	11.7	51.9	36.4	12.2	50.7	37.1	
146	8	69.1	59.0	11.7	56.8	31.5	12.1	55.7	32.2	
187	8	72.6	58.4	16.4	51.4	32.2	17.3	49.4	33.3	Neg.
188	8	67.7	54.5	15.2	48.0	36.8	16.0	46.2	37.8	Neg.
142	9	65.5	58.1	8.5	58.9	32.6	8.8	58.3	32.9	
143	9	64.6	58.5	7.0	60.9	32.1	7.2	60.5	32.3	
153	9	65.7	59.1	7.6	61.0	31.4	7.8	60.5	31.7	
154	9	65.2	57.8	8.5	58.6	32.9	8.8	57.9	33.3	
155	9	63.7	56.4	8.4	57.1	34.5	8.7	56.4	34.9	
161	9	70.7	61.1	11.1	59.8	29.1	11.5	58.8	29.3	
144	10	66.5	55.2	13.0	51.0	36.0	13.7	49.6	36.7	
145	10	63.4	58.2	6.0	61.6	32.4	6.0	61.3	32.7	
158	10	64.0	57.6	7.4	59.5	33.1	7.5	59.0	33.5	
159	10	63.3	58.0	6.1	61.2	32.7	6.2	61.0	32.8	
147	11	73.6	62.0	13.4	58.6	28.0	14.0	57.2	28.8	
148	12	80.1	62.6	20.2	52.4	27.4	21.3	49.9	28.8	Neg.
149	12	70.1	56.5	15.7	49.9	34.4	16.5	48.0	35.5	Neg.
150	12	77.5	58.1	22.4	45.0	32.6	23.7	42.1	34.2	Neg.
156	13	73.1	64.6	9.8	65.2	25.0	10.1	64.4	25.5	
157	13	71.2	60.6	12.2	58.1	29.7	12.8	56.9	30.3	
151	14	67.4	60.9	7.5	63.2	29.3	7.6	62.8	29.6	
152	15	77.0	63.0	16.2	56.9	26.9	17.0	55.1	27.9	Neg.
177	16	73.6	60.2	15.5	54.4	30.1	16.3	52.6	31.1	Neg.
178	16	70.9	61.1	11.3	59.6	29.1	11.8	58.5	29.7	
179	16	69.8	58.5	13.0	54.9	32.1	13.6	53.5	32.9	
180	16	56.8	54.3	2.9	60.2	36.9	2.7	60.4	36.9	
181	17	73.7	61.8	13.7	58.0	28.3	14.4	56.5	29.1	
182	17	72.4	59.4	15.0	53.9	31.1	15.8	52.2	32.0	Neg.
183	17	67.3	52.2	17.4	43.1	39.5	18.4	40.9	40.7	Neg.
184	18	65.4	57.1	9.6	56.7	33.7	9.9	55.9	34.2	
185	19	68.6	58.2	12.0	55.5	32.5	12.5	54.3	33.2	
186	19	74.0	61.2	14.8	56.2	29.0	15.5	54.6	29.9	Neg.
190	20	78.3	61.5	19.4	51,9	28.7	20.5	49.6	29.9	Neg.
194	21	68.3	52.7	18.0	43.1	38.9	19.0	40.8	40.2	Neg.
199	22	70.4	59.3	12.8	56.0	31.2	13.4	54.7	31.9	
200	23	65.4	56.4	10.4	55.1	34.5	10.8	54.1	35.1	
160	24	71.2	59.6	13.4	55.8	30.8	14.0	54.3	31.7	
14	25	71.7	58.8	14.9	53.3	31.8	15.6	51.6	32.8	Neg.
197	26	76.5	61.7	17.1	54.5	28.4	18.0	52.5	29.5	Neg.
201	27	77.7	62.4	17.7	54.7	27.6	18.6	52.6	28.8	Neg.
189	28	74.1	59.8	16.5	52.9	30.6	17.4	50.9	31.7	Neg.

TABLE 5

Shortening Containing Some Hydrogenated Fat

Sample No.	Brand	Iodine Value	Thiocy-anogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of			Insoluble Bromides
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd	
1	1	68.9	50.2	21.6	36.6	41.8	22.9	33.7	43.4	Neg.
2	1	71.9	54.4	20.2	42.9	36.9	21.4	40.3	38.3	Neg.
60	1	74.8	61.2	15.7	55.3	29.0	16.5	53.5	30.0	Neg.
3	2	85.8	58.0	32.1	35.1	32.8	34.2	30.6	35.2	Neg.
110	2	81.8	61.0	24.0	46.7	29.3	25.5	43.6	30.9	Neg.
4	3	76.2	57.3	21.8	44.6	33.6	23.1	41.8	35.1	Neg.
5	3	77.8	59.6	21.0	48.1	30.9	22.2	45.4	32.4	Neg.
137	3	77.9	62.4	17.9	54.5	27.6	18.9	52.4	28.7	Neg.
7	4	74.9	57.8	19.7	47.3	32.0	20.9	44.8	34.3	Neg.
8	5	83.4	79.3	4.7	87.4	7.9	4.5	87.6	7.9	
9	6	73.6	68.3	6.1	73.2	20.7	6.1	73.1	20.8	
10	7	78.3	66.2	14.0	62.9	23.1	14.6	61.4	24.0	
163	7	78.7	64.6	16.3	58.7	25.0	17.1	56.8	26.1	Neg.
153	8	85.6	62.2	27.0	45.1	27.9	28.7	41.5	29.8	Neg.
79	8	73.9	53.5	23.5	38.5	38.0	25.0	35.3	39.7	Neg.
198	8	71.3	50.3	24.2	34.0	41.8	25.8	30.7	43.5	Neg.
58		79.9	60.7	22.2	48.2	29.6	23.5	45.4	31.1	Neg.
76	9	66.8	54.0	14.8	47.9	37.3	15.5	46.1	38.4	Neg.
108	9	76.7	63.6	15.1	58.7	26.2	15.9	57.0	27.1	Neg.
138	9	79.8	53.6	30.2	31.8	38.0	32.3	27.6	40.1	Neg.
77	10	71.7	64.1	8.8	65.7	25.5	9.0	65.0	26.0	
80	11	70.0	53.3	19.3	42.5	38.2	20.4	40.1	39.5	Neg.
81	12	67.7	54.7	15.0	48.5	36.5	15.8	46.7	37.5	Neg.
196	13	78.8	52.1	30.8	29.5	39.7	32.9	25.1	42.0	Neg.
107	14	93.0	68.9	27.8	52.1	20.1	29.5	48.4	22.1	Neg.
195	14	91.7	58.9	37.9	30.3	31.8	40.4	24.9	34.7	Pos.
162	15	75.7	57.1	21.5	44.7	33.8	22.8	42.0	35.2	Neg.
109	16	70.6	52.0	21.5	38.8	39.7	22.8	36.0	41.2	Neg.
191	17	87.4	57.6	34.4	32.3	33.3	36.7	27.4	35.9	Neg.
192	17	86.9	57.7	33.7	33.1	33.2	36.0	28.4	35.6	Neg.
193	17	92.4	59.3	38.2	30.4	31.4	40.8	25.0	34.2	Pos.

sumption that one mol of thiocyanogen reacts with exactly one equivalent of either oleate or linoleate. These percentages are shown in the columns under "Official Method."

Riemenschneider, Swift and Sando (6) have reviewed the literature and have presented their own evidence on the actual iodine and thiocyanogen values of methyl esters of oleic and linoleic acids. By substituting their recommended thiocyanogen values for the theoretical values, the following formulas for triglycerides were derived:

$$\% \text{ Linoleic glycerides} = 1.247 \text{ I.V.} - 1.254 \text{ T.V.}$$

$$\% \text{ Oleic glycerides} = 2.525 \text{ T.V.} - 1.350 \text{ I.V.}$$

$$\% \text{ Saturated glycerides} = 100.0 - (\% \text{ O.G.} + \% \text{ L.G.})$$

Composition calculated by use of these formulas is shown in the columns under "Special Calculation."

It should be borne in mind that these calculated compositions are predicated on the absence of fatty acids more unsaturated than linoleic. Whenever the test for insoluble bromides is positive, this condition is unfulfilled and the calculations lack strict validity, being offered only as an approximation which indicates the order of magnitude of the proportion of fatty acid more unsaturated than oleic. The error is not a large one and required no consideration as long as cottonseed oil was practically the only edible oil subjected to hydrogenation in this country. The presence of linolenic acid in soybean oil, now widely used in manufacture of shortening, made it seem desirable in the present study to subject to the insoluble bromide test all samples with an indicated content of linoleic acid above 15%. Whenever a positive test is reported, it is a warning that some linolenic acid is present and the estimated percentage of linoleic acid is slightly too high.

Discussion of Analytical Data

The analytical results are shown in Tables 1-6. Only one value (6.5%) for linoleic acid in lard lies outside the range 9.5 to 13.7% by the official method. Naturally this range is more narrow than shown in the values accumulating in the literature over the years. Butter fat shows the expected low range of values for linoleic acid, with a maximum of 4.8% by the official method. Margarine shows a much wider range of values, very low values being an indication of the possible use of coconut oil and the highest values suggesting some use of unhydrogenated domestic oils.

The proportion of glyceride derived from linoleic acid appears to be higher in hydrogenated shorten-

TABLE 6

Mixed Animal and Vegetable Shortening

Sample No.	Brand	Iodine Value	Thiocy-anogen Value	Official Method Per Cent Glycerides of			Special Calc. Per Cent Glycerides of			Insoluble Bromides
				Linoleic	Oleic	Sat'd	Linoleic	Oleic	Sat'd	
6	1	81.7	59.0	26.2	42.2	31.6	27.9	38.7	33.4	Neg.
11	2	66.7	57.7	10.4	56.6	33.0	10.8	55.6	33.6	
40	3	70.7	54.6	18.6	44.7	36.7	19.7	42.4	37.9	Pos.
59	3	80.2	59.7	23.7	45.6	30.7	25.1	42.4	32.5	Pos.
113	3	76.2	55.8	23.5	41.1	35.4	25.0	38.0	37.0	Pos.
139	3	78.4	55.8	26.1	38.6	35.3	27.8	35.0	37.2	Neg.
78	4	75.1	60.8	16.5	54.0	29.5	17.4	52.1	30.5	Neg.
106	5	76.9	56.4	23.7	41.7	34.6	25.1	38.6	36.3	Pos.
111	6	81.1	62.9	21.0	51.9	27.1	22.2	49.3	28.5	Neg.
136	6	67.2	55.5	13.5	50.9	35.6	14.2	49.4	36.4	
112	7	72.9	52.8	23.2	38.0	38.8	24.7	34.9	40.4	Neg.

TABLE 7

Per Cent Linoleic in Edible Fats

	Lard	Butter	Margarine	Hydrogenated (100%)	Hydrogenated (<100%)	Mixed Animal and Vegetable
No. of samples	27	41	57	60	31	11
High	13.7	4.8	23.4	22.4	38.2	26.2
Low	6.5	1.4	1.3	2.9	4.7	10.4
Median	11.8	3.3	9.9	12.8	21.5	23.2
Average	11.7	3.3	10.9	12.6	22.0	20.6

ings as a class than in butter, margarine, or lard, and higher still in shortenings of the groups which are made by blending hydrogenated fat or animal fat with unhydrogenated oils. The results are better summarized in Table 7 than in the concluding statement below.

Summary

Analysis of 227 samples of edible fats collected from widely scattered cities of the United States shows that the average percentage of glyceride derived from linoleic acid increases in the order: butter fat, margarine, lard, hydrogenated shortening, and blended shortening containing some hydrogenated fat or animal fat as stiffening agent.

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Some Observations On the Effect of Moisture On the Quantitative Extraction of Lipids From Soybeans

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The fact that the amount of water present at the time of extraction has a definite effect on the amount and composition of the extract obtained from oil-seed materials by solvent extraction is well known. Milner,[2] writing as Chairman of the Soybean Analysis Committee of the American Oil Chemists Society, has given data showing that a variation of as little as one percent of moisture in certain ranges produces a difference as large as one-half of one percent in the total lipids or crude fat extracted when calculated to a moisture-free basis. Also, he indicated that the phosphorus in the higher yield of lipids may be ten times that in the lower yield. There can be no doubt that the materials removed by solvent extraction at various moisture levels are not all of the same composition. The total lipids in soybeans include, besides triglycerides of fatty acids, phosphatides, sterols, waxes, and less common substances. Soybeans and soybean oil are sources of commercial phosphatides. The variations in the phosphorus content of the lipid extract would indicate that more of the phosphatides are extracted at a high-moisture content than at a low-moisture content in the analytical sample. However, there is still no complete explanation of the variations obtained in quantitative extraction results when the moisture content of the sample has been varied over fairly wide limits. The present report does not attempt to explain these phenomena, but rather presents some further observations on the variations in quantity of lipids extracted due to moisture in samples that have had special treatment. The data obtained are presented in order that they may be of use to others doing work on methods of determining lipids in soybeans and other oil seeds and their meal products.

The soybeans used in all of the following series of samples were of the Illini variety and were from the 1938 crop. The original lot of beans was subsampled with a Boerner sampler to obtain uniform samples for the different phases of the work. In all cases the extraction solvent was a petroleum ether (Skellysolve F) and extractions were run for four hours using Butt extraction tubes. The standard quantitative oil-determination method used in this laboratory is a four-hour extraction of a 2-gram sample in a Butt extractor, the sample being removed after two hours and reground in a mortar before being replaced for the last two hours of extraction. The results are discussed on the basis of the percent of lipids in the moisture-free sample.

The samples were conditioned to various moisture contents either by being replaced for a suitable period in an atmosphere of 100 percent relative humidity at room temperature, or by drying over phosphorus pentoxide in vacuum at room temperature. The samples were ground fine enough in a Wiley mill to pass through a sieve having circular holes one millimeter in diameter before conditioning to shorten the time required.

As a standard, a series of samples having various moisture contents was prepared in which the oil was determined by the regular analytical procedure, in-

[1] The Chemical and Engineering Sections of the U. S. Regional Soybean Industrial Products Laboratory, Urbana, Illinois, were merged with the Northern Regional Research Laboratory, Peoria, Illinois, July 1, 1942. The Soybean Industrial Products Laboratory was a cooperative organization participated in by the Bureaus of Agricultural Chemistry and Engineering and Plant Industry of the Agricultural Research Administration, U. S. Department of Agriculture, and the Agricultural Experiment Stations of Illinois, Indiana, Iowa, Kansas, Michigan, Minnesota, Missouri, Nebraska, North Dakota, Ohio, South Dakota and Wisconsin.

[2] Milner, R. T., *et al.* Oil and Soap, *16*, pp. 129-131 (1939).