
Handbook of Soy Oil Processing and Utilization

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Chapter 2

COMPOSITION OF SOYBEAN OIL

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INTRODUCTION

The soybean has the following approximate composition (Krober and Cartter, 1962):

Protein	40%
Lipid	20%
Cellulose and hemicellulose	17%
Sugars	7%
Crude fiber	5%
Ash (dry weight basis)	6%

When soybeans are crushed and extracted to remove the oil, the residual meal is a valuable feed with enhanced protein content (relative to the whole bean) for poultry, hog, and some beef production.

The relative values for the meal and oil per bushel (60 lb) of soybeans are (prices as of November 1978):

Crude soybean oil	10.7 lb X 0.2568 dollars/lb	= \$2.748
Soybean meal	47.5 lb X 0.09815 dollars/lb	= 4.662
		<u>\$7.410</u>

Although 17.8 weight percent of a bushel of soybeans is converted to oil and 79.2 weight percent is converted to meal, the respective dollar value percentages are 37.1% and 62.9%, since the oil commands a higher price per pound.

Soybeans are crushed and dehulled to extract the oil (see Chapter 4, Recovery of Oil from Soybeans). The crude oil thus extracted needs further treatment to convert it to a bland, stable, and nutritious product that is used in the manufacture of shortening, margarine, and salad and cooking oils. The

TABLE 1
Average Compositions for Crude and Refined Soybean Oil

	Crude oil	Refined oil
Triglycerides, %	95-97	>99
Phosphatides, ^{a,b} %	1.5-2.5	0.003-0.045 ^c
Unsaponifiable matter, %	1.6	0.3
Plant sterols, %	0.33	0.13
Tocopherols, ^e %	0.15-0.21	0.11-0.18
Hydrocarbons (Squalene), ^f %	0.014	0.01
Free fatty acids, %	0.3-0.7	<0.05
Trace metals ^a		
Iron, ppm	1-3	0.1-0.3
Copper, ppm	0.03-0.05	0.02-0.06

^aEvans et al., 1974

^bList et al., 1978.

^cCorresponding to 1-15 ppm of phosphorus.

^dWeihrauch and Gardner, 1978.

^eBauernfeind, 1977.

^fGutfinger and Letan, 1974a.

refining process may include degumming, neutralization (alkali refining), bleaching, and deodorization, and is necessary to remove phosphatides and free fatty acids, both of which affect stability adversely.

Typical compositions of crude and refined soybean oils are given in Table 1. The refining process does not affect fatty acid composition of the glyceride but removes most of the free fatty acids and pigmentation and lowers the contents of some of the lesser constituents such as the tocopherols (by 31-47%), the sterols (by 25-32%), and squalene (by 15-37%) (Gutfinger and Letan, 1974a).

In addition to the lesser constituents already mentioned, there are in the crude oil very small quantities of a number of other materials including waxes, pigments, and minerals. Waxes originate from seed coats and are the esters of long chain fatty alcohols and acids. One of the more prevalent pigments is β -carotene, which is responsible for the yellow color of soybean oil and is the most important of the provitamins A. When present in stronger concentration, β -carotene is also responsible for the red color of such vegetable oils as palm oil. The chromophore groups of β -carotene are destroyed by hydrogenation and by high temperature deodorization. Chlorophyll is also present and is responsible for the greenish cast of the oil after hydrogenation has removed the yellow color due to β -carotene. Ordinarily, chlorophyll is adequately removed during the refining process, unless immature or freeze-damaged beans were used for extraction. Minerals present in trace amounts include phosphorus, sodium, iron, and copper.

The glyceride structure, fatty acids, tocopherols, ster-

TABLE 2
The Fatty Acids of Soybean Oil and Partially Hydrogenated Soybean Oil

Common name	Fatty acid		Formula
	Systematic name	Symbolic notation	
Saturated			
Lauric	Dodecanoic	12:0	$\text{CH}_3(\text{CH}_2)_{10}\text{COOH}$
Myristic	Tetradecanoic	14:0	$\text{CH}_3(\text{CH}_2)_{12}\text{COOH}$
Palmitic	Hexadecanoic	16:0	$\text{CH}_3(\text{CH}_2)_{14}\text{COOH}$
Stearic	Octadecanoic	18:0	$\text{CH}_3(\text{CH}_2)_{16}\text{COOH}$
Arachidic	Eicosanoic	20:0	$\text{CH}_3(\text{CH}_2)_{18}\text{COOH}$
Behenic	Docosanoic	22:0	$\text{CH}_3(\text{CH}_2)_{20}\text{COOH}$
Monounsaturated			
Palmitoleic	cis-9-Hexadecenoic	9c-16:1	$\begin{array}{c} \text{H} \\ \diagup \\ \text{C}=\text{C} \\ \diagdown \\ \text{H} \end{array} \text{CH}_3(\text{CH}_2)_5(\text{CH}_2)_7\text{COOH}$
Oleic	cis-9-Octadecenoic	9c-18:1	$\begin{array}{c} \text{H} \\ \diagup \\ \text{C}=\text{C} \\ \diagdown \\ \text{H} \end{array} \text{CH}_3(\text{CH}_2)_7(\text{CH}_2)_7\text{COOH}$
Elaidic	trans-9-Octadecenoic	9t-18:1	$\begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{C} \\ \diagup \\ \text{H} \end{array} \text{CH}_3(\text{CH}_2)_7(\text{CH}_2)_7\text{COOH}$
Positional isomers	trans-x-Octadecenoic (where x = 2 to 16)	xt-18:1	$\begin{array}{c} \text{H} \\ \diagdown \\ \text{C}=\text{C} \\ \diagup \\ \text{H} \end{array} \text{CH}_3(\text{CH}_2)_m(\text{CH}_2)_n\text{COOH}$ $m + n = 14$

TABLE 2--Continued

Common name	Fatty acid Systematic name	Symbolic notation	Formula
--	<u>cis</u> -9-Eicosenoic (or <u>cis</u> -11-eicosenoic)	9 \underline{c} -20:1	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3(\text{CH}_2)_9 & & (\text{CH}_2)_7\text{COOH} \end{array}$
Diunsaturated			
Linoleic	<u>cis</u> -9, <u>cis</u> -12-Octadecadienoic	9 \underline{c} ,12 \underline{c} -18:2	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3(\text{CH}_2)_3 & & (\text{CH}_2)_2\text{COOH} \end{array}$
Conjugated diene	<u>trans</u> -9(10), <u>trans</u> -11(12)-Octadecadienoic	9(10) \underline{c} ,11(12) \underline{c} -18:2 m = 2 or 3 usually n = 7 or 8 usually m + n = 10	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3(\text{CH}_2)_m & & (\text{CH}_2)_n\text{COOH} \end{array}$
Non-conjugatable diene, e.g.	<u>cis</u> -9, <u>trans</u> -13-Octadecadienoic	9 \underline{c} ,13 \underline{t} -18:2	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3(\text{CH}_2)_3 & & (\text{CH}_2)_2\text{COOH} \end{array}$
Triunsaturated			
Linolenic	<u>cis</u> -9, <u>cis</u> -12, <u>cis</u> -15-Octadecatrienoic	9 \underline{c} ,12 \underline{c} ,15 \underline{c} -18:3 also 18:3 n.l. 3	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3 & & (\text{CH}_2)_3\text{COOH} \end{array}$
Tetraunsaturated			
Arachidonic	<u>cis</u> -5, <u>cis</u> -8, <u>cis</u> -11, <u>cis</u> -14-Eicosatetraenoic	5 \underline{c} ,8 \underline{c} ,11 \underline{c} ,14 \underline{c} -20:4	$\begin{array}{c} \text{H} & & \text{H} \\ & \diagdown & / \\ & \text{C}=\text{C} \\ & / & \diagdown \\ \text{CH}_3(\text{CH}_2)_3 & & (\text{CH}_2)_3\text{COOH} \end{array}$

TABLE 3
Fatty Acid Composition of Soybean Oil

Component acid	Fatty acid composition, wt. %	
	Range ^a	Average ^b
Saturated		
Lauric	---	0.1
Myristic	<0.5	0.2
Palmitic	7-12	10.7
Stearic	2-5.5	3.9
Arachidic	<1.0	0.2
Behenic	<0.5	---
Total	10-19	15.0
Unsaturated		
Palmitoleic	<0.5	0.3
Oleic	20-50	22.8
Linoleic	35-60	50.8
Linolenic	2-13	6.8
Eicosenoic	<1.0	---
Total	---	80.7

^a O'Connor and Herb, 1970.

^b Brignoli et al., 1976.

ols, and hydrocarbons of soybean oil are discussed in greater detail in the following paragraphs. The phosphatides (soybean lecithins) are discussed in Chapter 6 (Oil Degumming and Soybean Lecithin). Fedeli and Jacini (1971) have reviewed the lipid composition of soybean and other vegetable oils in some detail.

SOYBEAN FATTY ACIDS

FATTY ACID TYPES AND COMPOSITION

Soybean oil triglycerides contains both saturated and unsaturated fatty acids of the types indicated in Table 2. The only processing step that has any effect on the types of fatty acids present is partial hydrogenation, which results in the formation of small amounts of geometrical and positional isomers of the unsaturated acids originally present. In the geometrical isomers, the cis bonds originally present have been converted in part to the trans form. In the positional isomers, the original cis-9 double bonds as in oleic acid have been converted in part to a mainly trans double bond at other positions in the chain.

The fatty acid average composition and range of composition are given in Table 3. The composition of crude soybean oil varies over a rather wide range, particularly for the type of unsaturated fatty acid, depending upon variety and climatic conditions. The degree of hydrogenation in partially hydrogenated soybean oils also has a major impact on the composition.

TABLE 4
Composition of Margarines from Partially Hydrogenated Soybean Oil^a

Fatty acid	Type of margarine		
	Stick or brick	Soft tub	Tub
Weight percent			
Saturated			
16:0	9.0	8.4	6.3
18:0	6.8	4.4	3.3
Unsaturated			
18:1	39.0	36.2	27.2
18:2	19.1	25.9	19.4
18:3	1.9	1.1	0.8
Total saturated	16.0	13.0	9.6
Total monounsaturated	39.0	36.2	27.2
Total polyunsaturated	21.0	27.0	20.2
cis-Methylene interrupted polyunsaturated	17.5	25.5	---
Ratio, polyunsaturated/saturated (P/S)	1.3	2.1	2.1

^a Weihrauch et al., 1977.

Soybean oil is noteworthy for its high content of linoleic acid, a polyunsaturated fatty acid that is essential for proper nutrition.

Soybean oil also has 2-13%, with an average of about 7%, of linolenic acid in its fatty acid make-up. Climate and variety have marked effects on the linolenic acid content. Linolenic acid is an unessential polyunsaturated fatty acid and is much more susceptible to autoxidation than oleic or linoleic acids. Because of this relatively high linolenic acid content, soybean oil is not as stable to autoxidation as desired, and off-flavors and odors develop more easily than in oils that contain no linolenic acid (Evans et al., 1965).

The linolenic acid content can be lowered by partial hydrogenation as is done in processing soybean oil for many food uses.

EFFECT OF PARTIAL HYDROGENATION

During partial hydrogenation, the linolenic and linoleic acid contents are lowered, while the monoene content is increased. There may be also an increase of saturated fatty acid content if the catalyst has poor selectivity (see Chapter 9, Hydrogenation Practices).

Besides saturation of the double bond, there are at least two other reactions that occur during partial hydrogenation--positional and geometrical isomerization. These reactions usually occur concurrently. Advances in analytical methodology in recent years now permit determination of these fatty acid isomers (Johnston et al., 1978).

When carried out to a greater extent, partial hydrogenation also serves the purpose of altering the physical prop-

TABLE 5
Average Composition of Margarines from Partially Hydrogenated
Mixtures of Vegetable Oils^a

Fatty acid	Type of margarine		
	Stick or brick	Soft tub	Light blends
Total saturated, wt %	15.8	15.0	10.3
Total monounsaturated, wt %	37.4	31.2	28.4
Total polyunsaturated, wt %	22.7	30.1	18.2
Total <u>cis</u> -methylene interrupted polyunsaturated, wt %	17.3	28.1	---
Total <u>trans</u> content, wt %	21.7	14.2	---
Range of <u>trans</u> content, wt %	10-29	11-21	---
Ratio, polyunsaturated/saturated (P/S)	1.4	2.0	1.8

^a Weihrauch et al., 1977.

erties of the oil, i.e., raising the titer so that the oil is converted to semi-solid or solid more suitable for margarines and shortenings. The hardened oil is the result of greater amounts of the higher melting stearate and elaidate components.

Representative compositions of margarines from partially hydrogenated soybean oil are given in Table 4. Frequently, margarines are made up of mixtures of soybean and other vegetable oils or animal fats, and compositions for these mixtures have also been given (Table 5) (Weihrauch et al., 1977). More detailed analyses have been given by Carpenter and Slover (1973) and by Smith et al. (1978) (Table 6). Consumer-available margarines have been discussed from the consumer viewpoint (Anonymous, 1979).

The composition of consumer-available liquid vegetable oils, including soybean oil, has been given by Carpenter et al. (1976) (Table 7).

EFFECTS OF BREEDING AND TEMPERATURE

Attempts to breed out linolenic acid have been unsuccessful for a number of complicating reasons. Out of the 4000 items in the germ plasm collection at the University of Illinois, no genotype produces an oil with less than about 3.5% linolenic acid, and an ideal germ plasm for routine breeding is not available (Howell, 1972). Other species in the genus contain even higher amounts of linolenic acid than does Glycine max (L.) Merrill (Hymowitz et al., 1970).

Temperature during seed development has a major impact on linolenic acid content and therefore confuses genetic effects (Collins and Howell, 1957). Specific varieties grown near the northern range of their area of adaptation have 1-2% more linolenic acid and 3-6% more linoleic than those grown at the southern range (Collins and Sedgwick, 1959). The average

TABLE 6
Detailed Analysis of Representative Margarines

Fatty acid	Type of margarine			Unidentified ^b
	Hard cube ^a	Whipped cube ^a	Soft tub ^a	
Weight percent				
12:0	---	---	---	0.2
14:0	<0.1	<0.1	0.1	0.1
<u>t</u> 14:1	---	---	---	0.1
16:0	9.6	9.2	9.2	12.5
<u>t</u> 16:1	---	---	---	<0.1
<u>c</u> 16:1	---	---	---	0.2
18:0	5.5	5.7	5.6	7.5
<u>t</u> 18:1 } <u>c</u> 18:1 }	67.6	62.6	55.8	{ 20.9 32.2
<u>tt</u> 18:2 } <u>ct</u> 18:2 } <u>cc</u> 18:2 }	11.0	15.3	24.2	{ --- 2.3 22.6
X ₁ ^c	1.6	1.2	0.8	---
X ₂ ^c	2.6	3.3	1.6	---
18:3 ω 6 } 18:3 ω 3 }	0.7	1.1	1.3	{ 0.2 1.4
20:0	0.4	0.3	0.3	0.3
20:2	0.3	0.3	0.3	---
22:0	0.5	0.5	0.5	---

^aCarpenter and Slover, 1973.

^bSmith et al., 1978.

^cTentatively identified as isomers of 18:2.

linolenic acid content and iodine values for several varieties under different climatic conditions are given in Table 8.

Under field conditions at different locations, Lincoln soybeans showed a range of 7.70% to 8.98% of linolenic acid, and Chippewa soybeans a range of 7.75% to 9.62% (Collins and Sedgwick, 1959). Lincoln soybeans grown under controlled temperatures at one location produced 10.5% linolenic acid at 70°F, 8.2% at 77°F, and 6.8% at 85°F (Collins and Howell, 1957).

Both linolenic and linoleic acid contents are affected by temperature during seed development in an inverse relationship (Howell and Collins, 1957). Changes in other environmental factors including photoperiod, light intensity and quality, nutrition (N, P, K, and S), or addition of manure or plant

TABLE 7
Composition of Consumer-Available Soybean Oils^a

Fatty acid	Brand			
	Crisco ^b	Giant ^b	Hollywood ^c	Kraft ^b
	Wt % of total fatty acid methyl esters			
14:0	<0.1	<0.1	<0.1	<0.1
16:0	8.9	10.1	10.6	10.0
18:0	3.9	4.8	4.1	5.0
18:1	47.2	40.8	24.7	45.8
Unknown	0.1	0.1	---	0.1
18:2	36.7	40.8	52.6	36.6
Unknown	0.2	0.2	---	0.4
18:3	2.7	2.7	7.6	2.0
20:0	0.3	0.3	0.3	---
20:1	<0.1	<0.1	---	---
22:0	0.2	0.2	0.2	0.2
P/S ratio	3.0	2.8	4.0	2.6

^a Carpenter et al., 1976.

^b Specially processed (partially hydrogenated) soybean oil.

^c Cold pressed.

TABLE 8
Effect of Location on Linolenic Acid Contents and Iodine Value of Soybeans^a

Uniform test group	Linolenic acid content, wt %		Iodine value	
	1956	1957	1956	1957
I	8.58	8.76	131.9	132.7
III	7.87	8.14	132.0	131.9
IV	8.14	8.06	132.8	132.2
VII	7.24	8.02	133.1	136.9

^a Collins and Sedgwick, 1959.

The groups represent different climatic conditions ranging from the northernmost (group I) to the southernmost (group VII) locations in the United States. Each group consisted of three to six different varieties.

residues had little effect on linolenic and linoleic contents.

The effects of temperature and location have also been observed in Germany with several soybean varieties (Schuster, 1971; Schuster and Marquard, 1972).

Other characteristics are also controlled by temperature during seed development. For example, oil content varies directly with temperature as shown by the following average values for Chief, Illini, and Lincoln varieties (Howell and Cartter, 1958):

Temperature, °F	Oil Content, %
70	19.5
77	20.8
85	23.2

However, differences were not significant in acetone insolubles content of the oil, nor protein and non-protein nitrogen

TABLE 9
Compositional Changes in Soybeans During Seed Development^a

Days after flowering ^b	Oil content, % dry	Oil composition, %			Linolenic acid, mg/seed
		Oleic	Linoleic	Linolenate	
24	3.5	7.5	35.0	30.0	0.009
26	7.9	11.3	39.1	25.4	0.102
32	15.5	24.0	46.2	12.1	0.581
39	19.5	26.3	51.0	9.2	1.159
46	20.1	25.8	52.7	7.7	1.594
72	23.6	26.4	54.1	5.8	2.552

^a Rubel et al., 1972.

^b Harosoy 63 soybeans.

content, and yield of soybeans.

Another problem in breeding for low linolenic acid is the maternal effect. Both oil content and composition are determined by the maternal genotype (Brim et al., 1968). However, even though the pollen parent has little effect on oleic and linoleic acids, in certain crosses it does influence linolenic acid content. Further, some indications have been obtained that lipoxygenase activity as well as fatty acid composition are genetically controlled (Chapman et al., 1976). Lipoxygenase activity may be a major factor in soy protein flavor problems (Sessa and Rackis, 1977).

Compositions of the soybean and the oil change markedly during seed development and maturation, but the actual amounts of the individual fatty acids do not decrease at any time (Table 9) (Rubel et al., 1972). For example, while the percent linolenic acid decreases, the absolute amount of this acid increases because both dry seed weight and oil content are also increasing. The final composition of soybean oil is apparently achieved through differential rates of synthesis of the various fatty acids. Both oil and fatty acid synthesis must be rigidly controlled, because during the last 25 days of development, when percent oil and fatty acids maintain their relative proportion, these components continue to increase in absolute amounts.

The linolenic acid content of soybean seed is not closely related to the chlorophyll content as had been suggested at one time (Fehr et al., 1971). Foliar application of boron and manganese has no effect on oil content or composition (Boswell and Worthington, 1971).

BREEDING FOR LOW LINOLENIC ACID CONTENT

Although attempts to reduce linolenic acid are complicated by the factors described in the foregoing paragraphs, some recent results are encouraging.

Preliminary evidence suggests that breeding for high oleic acid may be an effective although indirect method for lowering linolenic acid as indicated below (Wilson et al., 1976):

Soybean Line	Oil Composition, Mole %	
	Oleic	Linolenic
N70-3436	40.1	5.1
N70-3432	38.1	5.5
N70-3001	34.7	6.0
Dare	18.1	8.1

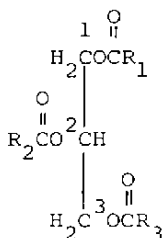
The saturated fatty acid content did not change, although the oleic acid content was about doubled compared to the Dare soybean.

X-Ray irradiation of soybean seeds from low-linolenic lines has produced seeds that contained significantly lower linolenic content (Hammond et al., 1972). Some of the progeny from irradiated seeds contained 2% lower linolenic acid than the untreated control plants. Ethyl methylsulfonate is also being used to induce mutations in these research studies at Iowa State University (Hammond and Fehr, 1975).

TRIGLYCERIDE STRUCTURE

Because of the high unsaturated fatty acid content of soybean oil, nearly all of the glyceride molecules contain at least two unsaturated fatty acids, and di- and tri-saturated glycerides are essentially absent.

The fatty acids are not randomly distributed in a single glyceride molecule, and the glyceride is biosynthesized with a definite configuration. Each hydroxyl group of glycerol is unique and has been assigned a stereospecifically numbered (sn) position as in the following general structure:



The distributions of fatty acids in some commercial soybean oil products are given in Table 10 (Carpenter et al., 1976). These analyses, determined by a combination of en-

TABLE 10
Positional Distribution of the
Fatty Acids in Commercial^a
Soybean Oil Products

Soybean Oil Products			
Brand	Fatty acid	Position	
		sn-2	sn-1,3
Mole percent			
Crisco	16:0	0	14
	18:0	1	6
	18:1	51	45
	18:2	46	32
	18:3	2	3
Giant	16:0	1	16
	18:0	0	7
	18:1	44	39
	18:2	52	35
	18:3	2	3
Hollywood	16:0	0	17
	18:0	0	6
	18:1	25	24
	18:2	69	45
	18:3	6	8
Kraft	16:0	0	16
	18:0	1	7
	18:1	52	43
	18:2	46	31
	18:3	1	3

^a Carpenter et al., 1976.

zyme hydrolysis with thin-layer chromatography (TLC) and gas-liquid chromatography (GLC), confirmed the compositions calculated from the fatty acid composition by Evans' rules (Evans et al., 1969) as well as the glyceride composition determined by countercurrent distribution along with lipase hydrolysis (Evans et al., 1966). A typical distribution for the soybean oil triglyceride structures has been given as follows (S = saturated, U = unsaturated fatty acid) (List et al., 1977):

SSS	0.07
SUS	5.2
USS	0.4
USU	0.7
UUS	35.0
UUU	58.4
Total	99.8

Three simple rules can be used to calculate the glyceride composition provided an accurate fatty acid analysis is available (Evans et al., 1969): (1) Palmitic, stearic, and $>C_{18}$ fatty acids are exclusively assigned to positions 1 and 3; (2) oleic and linoleic acids are treated alike and distributed randomly and equally in all three positions; any excess of these acids are added to the 2-position; and (3) all remaining

positions are filled by linoleic acid.

Fatemi and Hammond (1977) in more recent work have shown that there is little palmitic or stearic acid in the sn-2 position, confirming Evans' first rule. However, the sn-1 position was shown to be consistently richer in palmitic, stearic, and linolenic acids, while the sn-3 position was enriched in oleic acid and the sn-2 position with linoleic. A soybean variety was found having a deviant distribution that is probably genetically controlled.

Knowledge of glyceride structure along with possible variation in the structure by genetic control become very important if glyceride oxidative stability is affected by the structure, as suggested for soybean oil (Raghuveer and Hammond, 1967).

UNSAPONIFIABLE MATTER

INTRODUCTION

Itoh et al. (1973a) reported the following composition of soybean unsaponifiabiles obtained by direct extraction of saponified oil:

Hydrocarbons	15%
Triterpene alcohols	14%
4-Methylsterols	11%
Sterols	60%

Gutfinger and Letan (1974b) report the following average composition of crude soybean oil:

Unsaponifiable	1.6%
Squalene	135 µg/g
Sterols	3,650 µg/g
Tocopherols	1,240 µg/g

Unsaponifiabiles constituted about 23% of a shell drain condensate sample obtained from a commercial deodorizer (see Chapter 11, Deodorization) (Hoffman et al., 1964). This value undoubtedly varies considerably depending upon the deodorizer unit used and upon operating conditions. The unsaponifiabiles had the following approximate composition:

Phytosterols	70%
Tocopherols	15%
Hydrocarbons	15%

Chromatographic separation of the unsaponifiabiles ob-

TABLE 11
Sterol Content of Soybean Oil^a

Sterol	Soybean oil		
	Crude	Refined	Refined and hydrogenated
	mg/100 g of oil		
β -Sitosterol	183	123	76
Campesterol	68	47	26
Stigmasterol	64	47	30
Δ^5 -Avenasterol	5	1	ND
Δ^7 -Stigmasterol	5	1	ND
Δ^7 -Avenasterol	2	<0.5	ND
Cholesterol	ND ^b	ND	ND
Total	327	221	132

^a Weihrauch and Gardner, 1978.

^b ND = not detected.

tained by direct extraction produced three main fractions: 15-30% of a non-polar (hydrocarbon) fraction, about 50% of a fraction of intermediate polarity, and 35-45% of a polar fraction containing the sterols (Hoffman et al., 1962). The hydrocarbons contained 50% of squalene with the remainder consisting of C₂₉-C₃₅ paraffins.

THE PHYTOSTEROLS

The majority of vegetable oils contain 100-500 mg of sterols per 100 g of oil, with soybean oil containing an average of 327 mg per 100 g (Weihrauch and Gardner, 1978) (Table 11). The refining process reduces this amount by 32%, and hydrogenation by another 27%. The plant sterols present include β -sitosterol, campesterol, stigmasterol, and others in lesser amounts (Fig. 1). Soybean oil in common with corn, cottonseed, peanut, and sunflower oils contains no cholesterol. Other oils such as coconut, palm, palm kernel, and sesame seed oils may contain up to 6 mg of cholesterol per 100 g of oil.

In addition to the phytosterols already named, there occur in soybean oil in small amounts a number of 4-methylsterol and triterpene alcohol compounds that also occur in the majority of vegetable oils (Itoh et al., 1973b).

THE TOCOPHEROLS

Although present in somewhat smaller quantities than the sterols, the tocopherols in soybean oil perform a more valu-

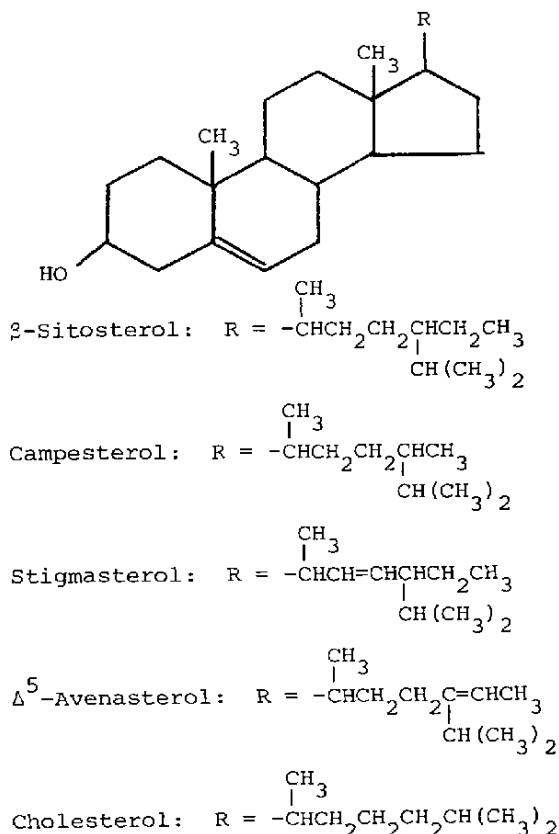
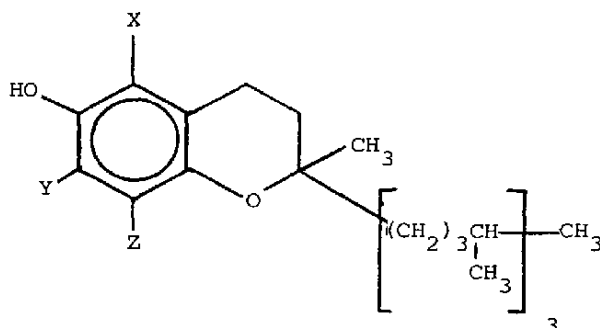


Fig. 1. Some phytosterols of soybean oil.

able function, because they have antioxidant properties and protect the oil against oxidation. There are at least seven types of tocopherol, and four of them are given in Figure 2. α -Tocopherol has the greatest activity as Vitamin E, but δ -tocopherol is a more effective antioxidant. The α -, γ -, and δ -tocopherols are present in refined as well as crude soybean oil. Some representative values are given in Table 12. γ -Tocopherol is present in the largest amounts. β -Tocopherol is present in smaller quantities--less than 3% of the total tocopherols (Mordret and Laurent, 1978).

Eighty percent of the tocopherols originally present in soybean oil were retained after 10 hr of simulated deep-fat frying (Yuki and Ishikawa, 1976).

No more tocopherol is lost than in alkali-refined oil, when a phosphoric-acid treatment, bleaching, and deodorization



α -Tocopherol, $X = Y = Z = \text{CH}_3$

β -Tocopherol, $X = Z = \text{CH}_3$; $Y = \text{H}$

γ -Tocopherol, $Y = Z = \text{CH}_3$; $X = \text{H}$

δ -Tocopherol, $X = Y = \text{H}$; $Z = \text{CH}_3$

Fig. 2. Structures for the various tocopherols.

are used in place of the alkali treatment (Mag, 1973).

THE HYDROCARBONS

According to Evans et al. (1964), the hydrocarbon fraction of unsaponifiabiles has the following composition:

<u>n-Alkanes</u>		4%
Nonacosane	27%	
Triacontane	8%	
Untriacontane	65%	
<u>Alkenes</u>		>50%
Squalene	50%	
Branched chain		~45%
Alkanes (C_{30} - C_{35})		

Squalene is the major component of the hydrocarbon fraction and is the biosynthetic precursor of sterols.

CONCLUSION

Soybean oil has a high content of linoleic acid, an essential polyunsaturated fatty acid. As an inexpensive coproduct of soybean meal, the oil is a useful starting material for many edible products such as margarine, shortening, and salad and cooking oils. The presence of 7-8% of linolenic acid contributes to less oxidative stability than that of more

TABLE 12
Representative Tocopherol Content of Various
Soybean Oil Products

Soybean oil product	Tocopherol, mg/100 g			
	α -	γ -	δ -	Total
Crude ^a	9-12	74-102	24-30	113-145
Refined ^a	6-9	45-50	19-22	73-77
Crisco ^b	14	102	37	153
Giant ^b	10	80	22	112
Hollywood ^b	9	68	23	100
Kraft ^b	5	42	11	58

^a Gutfinger and Letan, 1974a.

^b Carpenter et al., 1976.

saturated fats, but the linolenic acid content is lowered to a considerable extent by selective hydrogenation during processing of the oil into food products. Attempts are being made to breed the linolenic acid out directly by genetic transformations and indirectly by breeding for high-oleic lines.

In addition to the desired high concentration of polyunsaturated fatty acids, soybean oil has several minor constituents that are valuable commercial products. These minor constituents, which include lecithin, phytosterols, and tocopherols, are made available as a result of the high volume of soybean oil processed.

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