FOOD FATS AND OILS

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PREFACE

This publication has been prepared to provide useful information to the public regarding the nutritive and functional values of fats in the diet, the composition of fats and answers to the most frequently asked questions about fats and oils. It is intended for use by consumers, nutritionists, dieticians, physicians, food technologists, food industry representatives, students, teachers, and others having an interest in dietary fats and oils. A glossary is also provided.

Table of Contents

Food Fats and Oils

I. IMPORTANCE OF FATS AND OILS

Fats and oils are recognized as essential nutrients in both human and animal diets. Nutritionally, they are concentrated sources of energy (9 Kcal/gram); provide essential fatty acids which are the building blocks for the hormones needed to regulate bodily systems; and are a carrier for the oil soluble vitamins A, D, E, and K. They also enhance the foods we eat by providing texture and mouth feel, imparting flavor, and may contribute to the feeling of satiety after eating. Fats and oils are also important functionally in the preparation of many food products. They act as tenderizing agents, facilitate aeration, carry flavors and colors, and provide a heating medium for food preparation. Fats and oils are present naturally in many foods, such as meats, dairy products, poultry, fish, nuts, and in prepared foods, such as baked goods, margarines, dressings and sauces. To understand the nutritional and functional importance of fats and oils, it is necessary to understand their chemical composition.

II. WHAT IS A FAT OR OIL?

Fats and oils are constructed of building blocks called “triglycerides” (also known as triacylglycerides) resulting from the combination of one unit of glycerol and three units of fatty acids. They are insoluble in water but soluble in most organic solvents. They have lower densities than water, and may have consistencies at ambient temperature of solid, semi-solid, or clear liquid. When they are solid-appearing at a normal room temperature, they are referred to as “fats,” and when they are liquid at that temperature, they are called “oils.” For simplification purposes, the terms “fat” and “oils” are used interchangeably in the remainder of this publication.

Fats and oils are classified as “lipids” which is a category that embraces a broad variety of chemical substances. In addition to triglycerides, it also includes mono- and diglycerides, phosphatides, cerebrosides, sterols, terpenes, fatty alcohols, fatty acids, fat-soluble vitamins, and other substances.

The fats and oils most frequently used in North America for food preparation and as ingredients include soybean, canola, palm, cottonseed, olive, coconut, peanut, lard, beef tallow, butterfat, sunflower, corn, palm kernel, and safflower. More detailed information on the use of some of these oils in specific products is provided in Section IX.

III. CHEMICAL COMPOSITION OF FATS

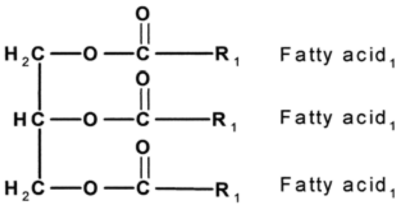
The main components of edible fats and oils are triglycerides. The minor components include mono- and diglycerides, free fatty acids, phosphatides, sterols, fat-soluble vitamins, tocopherols, pigments, waxes, and fatty alcohols. The free fatty acid content of crude oil varies widely based on the source. Other than the free fatty acids, crude vegetable oils contain approximately two percent of these minor components. Animal fats contain smaller amounts.

A. The Major Component – Triglycerides

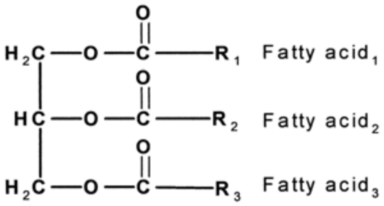
A triglyceride consists of three fatty acids attached to one glycerol molecule. If all three fatty acids are identical, it is a simple triglyceride. The more common forms, however, are the “mixed” triglycerides in which two or three kinds of fatty acids are present in the molecule. Illustrations of typical simple and mixed triglyceride molecular structures are shown below.

Figure 1

Diagrams of simple and mixed triglycerides



Simple Triglyceride



Mixed Triglyceride

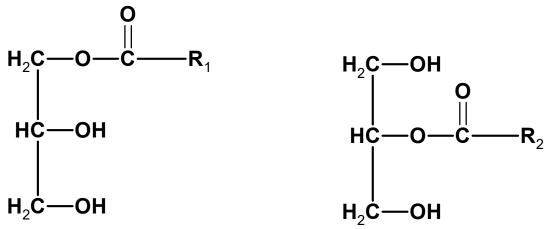
The fatty acids in a triglyceride define the properties and characteristics of the molecule and are discussed in greater detail in Chapter IV.

B. The Minor Components

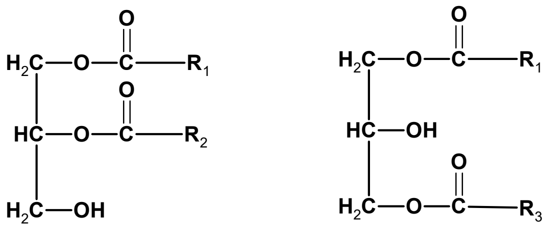
1. Mono- and Diglycerides. Mono- and diglycerides are mono- and diesters of fatty acids and glycerol. They are used frequently in foods as emulsifiers. They are prepared commercially by the reaction of glycerol and triglycerides or by the esterification of glycerol and fatty acids. Mono- and diglycerides are formed in the intestinal tract as a result of the normal digestion of triglycerides. They occur naturally in very minor amounts in both animal fats and vegetable oils. Oil composed mainly of diglycerides has also been used as a replacement for oil composed of triglycerides. Illustrations of mono- and diglyceride molecular structures are provided below:

Figure 2

Diagrams of mono- and diglycerides.



1 (α) - Monoglyceride 2 (β) - Monoglyceride



1, 2 (α, β) - Diglyceride 1, 3 (α, α') - Diglyceride

2. Free Fatty Acids. As the name suggests, free fatty acids are the unattached fatty acids present in a fat. Some unrefined oils may contain as much as several percent free fatty acids. The levels of free fatty acids are reduced in the refining process. (See Section VI.) Fully refined fats and oils usually have a free fatty acid content of less than 0.1%.

3. Phosphatides. Phosphatides, also known as phospholipids, consist of an alcohol (usually glycerol) combined with fatty acids, and a phosphate ester. The majority of the phosphatides are removed from oil during the degumming and refining operations. Phosphatides are an important source of natural emulsifiers marketed as lecithin.

4. Sterols. Sterols are found in both animal fats and vegetable oils, but there are substantial biological differences. Cholesterol is the primary animal fat sterol and is found in vegetable oils in only trace amounts. Vegetable oil sterols and plant sterols are collectively called "phytosterols." Stigmasterol and sitosterol are the best-known vegetable oil sterols. Sitosterol has been shown to reduce both serum and LDL cholesterol when incorporated into margarines, margarine spreads, salad dressings and various other food products to provide a convenient mode of delivery for consumers who choose to leverage phytosterols as a component of their personal plan to manage serum cholesterol levels. The type and amount of vegetable oil sterols vary with the source of the oil.

5. Tocopherols and Tocotrienols. Tocopherols and tocotrienols are important minor constituents of most vegetable fats. They serve as antioxidants to retard rancidity and as sources of the essential nutrient vitamin E. The common types of tocopherols and tocotrienols are alpha (α), beta (β), gamma (γ), and delta (δ). They vary in antioxidation and vitamin E activity. Among tocopherols, alpha-tocopherol has the highest vitamin E activity and the lowest antioxidant activity. Delta tocopherol has the highest antioxidant activity. Tocopherols which occur naturally in most vegetable oils are partially removed during processing. Corn and soybean oils contain the highest levels. Tocopherols are not present in appreciable amounts in animal fats. Tocotrienols are mainly present in palm oil, but can also be found in rice bran and wheat germ oils.

6. Pigments. Carotenoids are yellow to deep red color materials that occur naturally in fats and oils. They consist mainly of carotenes such as lycopene, and xanthophylls such as lutein. Palm oil contains the highest concentration of carotene. Chlorophyll is the green coloring matter of plants which plays an essential role in photosynthesis. Canola oil contains the highest levels of chlorophyll among common vegetable oils. At times, the naturally occurring level of chlorophyll in oils may cause the oils to have a green tinge. Gossypol is a pigment found only in cottonseed oil. The levels of most of these color bodies are reduced during the normal processing of oils to give them acceptable color, flavor, and stability.

7. Fatty Alcohols. Long chain alcohols are of little importance in most edible fats. A small amount esterified with fatty acids is present in waxes found in some vegetable oils. Larger quantities are found in some marine oils.

Table I provides a comparison of some of the non-triglyceride components of various crude oils.

TABLE I [*]

Typical Non-Triglyceride Components of Crude Fats and Oils

Fat or Oil	Phosphatides (%)	Sterols (ppm)	Cholesterol (ppm)	Tocopherols (ppm)	Tocotrienols (ppm)
Soybean	2.2 ± 1.0	2965 ± 1125	26 ± 7	1293 ± 300	86 ± 86
Canola	2.0 ± 1.0	8050 ± 3230	53 ± 27	692 ± 85	—
Corn	1.25 ± 0.25	15,050 ± 7100	57 ± 38	1477 ± 183	355 ± 355
Cottonseed	0.8 ± 0.1	4560 ± 1870	68 ± 40	865 ± 35	30 ± 30
Sunflower	0.7 ± 0.2	3495 ± 1055	26 ± 18	738 ± 82	270 ± 270
Safflower	0.5 ± 0.1	2373 ± 278	7 ± 7	460 ± 230	15 ± 15
Peanut	0.35 ± 0.05	1878 ± 978	54 ± 54	482 ± 345	256 ± 216
Olive	<0.1	100	<0.5	110 ± 40	89 ± 89
Palm	0.075 ± 0.025	2250 ± 250	16 ± 3	240 ± 60	560 ± 140
Tallow	<0.07	1100 ± 300	1100 ± 300	—	—
Lard	<0.05	1150 ± 50	3500 ± 500	—	—
Coconut	<0.07	805 ± 335	15 ± 9	6 ± 3	49 ± 22
Palm kernel	<0.07	1100 ± 310	25 ± 15	3 ±	30 ± 30

*O'Brien, R.D. Characterization of Fats and Oils, in *Fats and Oils: Formulating and Processing for Applications*, second edition. CRC Press, Boca Raton, p.8, 2004.

IV. FATTY ACIDS

A. General

Triglycerides are comprised predominantly of fatty acids present in the form of esters of glycerol. One hundred grams of fat or oil will yield approximately 95 grams of fatty acids. Both the physical and chemical characteristics of fats are influenced greatly by the kinds and proportions of the component fatty acids and the way in which these are positioned on the glycerol molecule. The predominant fatty acids are saturated and unsaturated carbon chains with an even number of carbon atoms and a single carboxyl group as illustrated in the general structural formula for a saturated fatty acid given below:

CH3-(CH2) x—COOH

Saturated carbon chain carboxyl group

Edible oils also contain minor amounts of branched chain and cyclic acids. Also straight chain acids with an odd number of carbon atoms are typically found in animal fats.

B. Classification of Fatty Acids

Fatty acids occurring in edible fats and oils are classified according to their degree of saturation.

1. Saturated Fatty Acids. Those containing only single carbon-to-carbon bonds are termed “saturated” and are the least reactive chemically.

The saturated fatty acids of practical interest are listed in Table II by carbon chain length and common name. The principal fat sources of the naturally occurring saturated fatty acids are also included in the table.

TABLE II
Saturated Fatty Acids

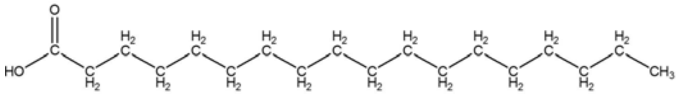
Systematic Name	Common Name	No. of Carbon Atoms*	Melting Point °C	Typical Fat Source
Butanoic	Butyric	4	-7.9	Butterfat
Hexanoic	Caproic	6	-3.4	Butterfat
Octanoic	Caprylic	8	16.7	Coconut oil
Decanoic	Capric	10	31.6	Coconut oil
Dodecanoic	Lauric	12	44.2	Coconut oil
Tetradecanoic	Myristic	14	54.4	Butterfat, coconut oil
Hexadecanoic	Palmitic	16	62.9	Most fats and oils
Heptadecanoic	Margaric	17	60.0	Animal fats
Octadecanoic	Stearic	18	69.6	Most fats and oils
Eicosanoic	Arachidic	20	75.4	Peanut oil
Docosanoic	Behenic	22	80.0	Peanut oil

*A number of saturated odd and even chain acids are present in trace quantities in many fats and oils.

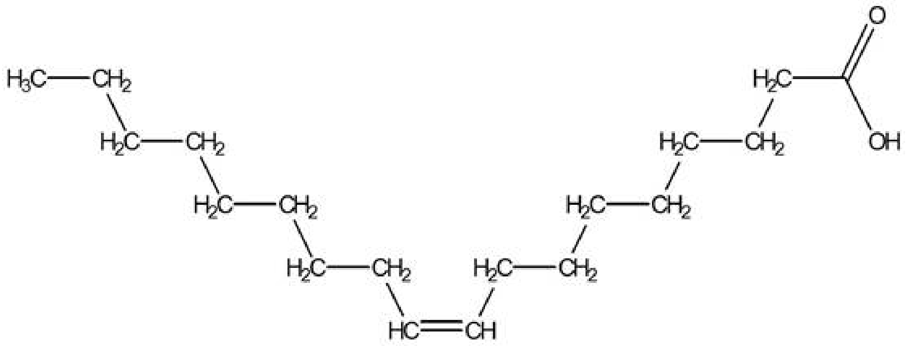
The melting point of saturated fatty acids increases with chain length. Decanoic and longer chain fatty acids are solids at normal room temperatures.

2. Unsaturated Fatty Acids. Fatty acids containing one or more carbon-to-carbon double bonds are termed “unsaturated.” Some unsaturated fatty acids in food fats and oils are shown in Table III. Oleic acid (cis-9-octadecenoic acid) is the fatty acid that occurs most frequently in nature.

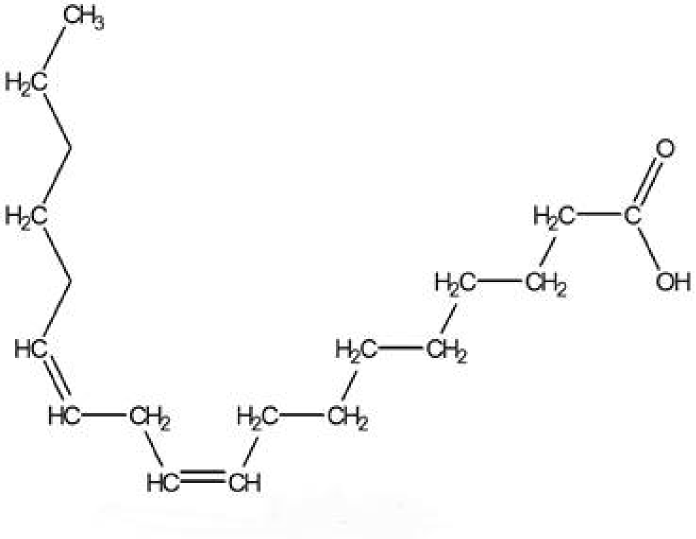
Saturated and unsaturated linkages are illustrated below:



Saturated Bond



Monounsaturated Bond

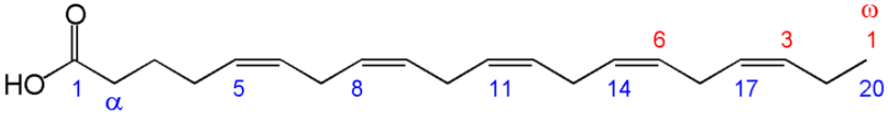


Polyunsaturated Bond

When the fatty acid contains one double bond it is called “monounsaturated.” If it contains more than one double bond, it is called “polyunsaturated.” In the International Union of Pure and Applied Chemistry (IUPAC) system of nomenclature, the carbons in a fatty acid chain are numbered consecutively from the end of the chain, the carbon of the carboxyl group being considered as number 1. By convention, a specific bond in a chain is identified by the lower number of the two carbons that it joins. In oleic acid (cis-9-octadecenoic acid), for example, the double bond is between the ninth and tenth carbon atoms.

Another system of nomenclature in use for unsaturated fatty acids is the “omega” or “n minus” classification. This system is often used by biochemists to designate sites of enzyme reactivity or specificity. The terms “omega” or “n minus” refer to the position of the double bond of the fatty acid closest to the methyl end of the molecule. Thus, oleic acid, which has its double bond 9 carbons from the methyl end, is considered an omega-9 (or an n-9) fatty acid. Similarly, linoleic acid, common in vegetable oils, is an omega-6 (n-6) fatty acid because its second double bond is 6 carbons from the methyl end of the molecule (i.e., between carbons 12 and 13 from the carboxyl end). Eicosapentaenoic acid (EPA), found in many fish and algal oils, is an omega-3 (n-3) fatty acid. Alpha-linolenic acid (ALA), found in certain vegetable oils, is also an omega-3 (n-3) fatty acid.

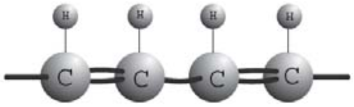
EPA



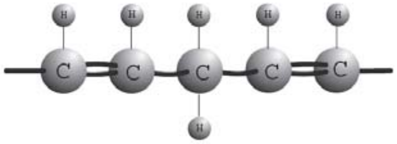
When two fatty acids are identical except for the position of the double bond, they are referred to as positional isomers. Fatty acid isomers are discussed at greater length in subparagraph C of this section.

Because of the presence of double bonds, unsaturated fatty acids are more reactive chemically than are saturated fatty acids. This reactivity increases as the number of double bonds increases.

Although double bonds normally occur in a non-conjugated position, they can occur in a conjugated position (alternating with a single bond) as illustrated below:



Conjugated



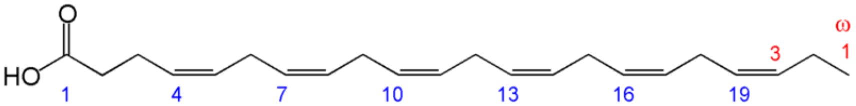
Non-conjugated

With the bonds in a conjugated position, there is a further increase in certain types of chemical reactivity. For example, fats are much more subject to oxidation and polymerization when bonds are in the conjugated position.

3. Polyunsaturated Fatty Acids. Of the poly-unsaturated fatty acids, linoleic, linolenic, arachidonic, eicosapentaenoic, and docosahexaenoic acids containing respectively two, three, four, five, and six double bonds are of most interest."

Vegetable oils are the principal sources of linoleic and linolenic acids. Arachidonic acid is found in small amounts in lard, which also contains about 10% of linoleic acid. Fish and algae based oils contain large quantities of a variety of longer chain fatty acids having three or more double bonds including eicosapentaenoic (EPA) and docosahexaenoic acids (DHA).

DHA



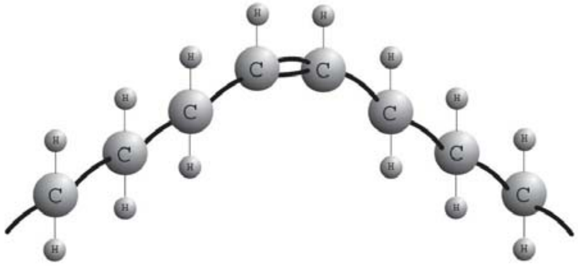
C. Isomerism of Unsaturated Fatty Acids

Isomers are two or more substances composed of the same elements combined in the same proportions but differing in molecular structure. The two important types of isomerism among fatty acids are (1) geometric and (2) positional.

1. *Geometric Isomerism*. Unsaturated fatty acids can exist in either the *cis* or *trans* form depending on the configuration of the hydrogen atoms attached to the carbon atoms joined by the double bonds. If the hydrogen atoms are on the same side of the carbon chain, the arrangement is called *cis*. If the hydrogen atoms are on opposite sides of the carbon chain, the arrangement is called *trans*, as shown by the following diagrams. Conversion of *cis* isomers to corresponding *trans* isomers result in an increase in melting points as shown in Table III.

A comparison of *cis* and *trans* molecular arrangements.

CIS



TRANS

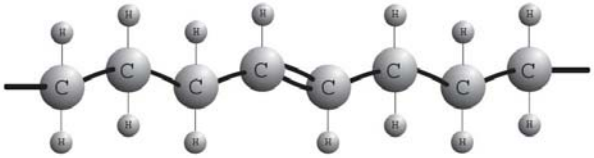


TABLE III
Some Unsaturated Fatty Acids in Food Fats and Oils

Systematic Name	Common Name	No. of Double Bonds	No. of Carbon Atoms	Melting Point °C	Typical Fat Source
9-Decenoic	Caproleic	1	10	-	Butterfat
9-Dodecenoic	Lauroleic	1	12	-	Butterfat
9-Tetradecenoic	Myristoleic	1	14	-4.5	Butterfat
9-Hexadecenoic	Palmitoleic	1	16	-	Some fish oils, beef fat
9-Octadecenoic	Oleic	1	18	16.3	Most fats and oils
9-Octadecenoic*	Elaidic	1	18	43.7	Partially hydrogenated oils
11-Octadecenoic*	Vaccenic	1	18	44	Butterfat
9,12-Octadecadienoic	Linoleic	2	18	-6.5	Most vegetable oils
9,12,15-Octadecatrienoic	Linolenic	3	18	-12.8	Soybean oil, canola oil
9-Eicosenoic	Gadoleic	1	20	-	Some fish oils
5,8,11,14-Eicosatetraenoic	Arachidonic	4	20	-49.5	Lard
5,8,11,14,17-Eicosapentaenoic	-	5	20	-53.5	Some fish and algal oils
13-Docosenoic	Erucic	1	22	33.4	Rapeseed oil
4,7,10,13,16,19-Docosahexaenoic	-	6	22	-	Some fish and algal oils

*All double bonds are in the *cis* configuration except for elaidic acid and vaccenic acid which are *trans*.

Elaidic and oleic acids are geometric isomers; in the former, the double bond is in the *tran*s configuration and in the latter, in the *cis* configuration. Generally speaking, *cis* isomers are those naturally occurring in food fats and oils. *Trans* isomers occur naturally in ruminant animals such as cows, sheep and goats and also result from the partial hydrogenation, and to a limited extent, the deodorization of fats and oils.

2. Positional Isomerism. In this case, the location of the double bond differs among the isomers. Vaccenic acid, which is a minor acid in tallow and butterfat, is *trans*-11-octadecenoic acid and is both a positional and geometric isomer of oleic acid.

The position of the double bonds affects the melting point of the fatty acid to a limited extent. Shifts in the location of double bonds in the fatty acid chains as well as *cis-trans* isomerization may occur during hydrogenation.

The number of positional and geometric isomers increases with the number of double bonds. For example, with two double bonds, the following four geometric isomers are possible: *cis-cis, cis-trans, trans-cis, and trans-trans. Trans-trans* dienes, however, are present in only trace amounts in partially hydrogenated fats and thus are insignificant in the human food supply.

V. FACTORS AFFECTING PHYSICAL CHARACTERISTICS OF FATS AND OILS

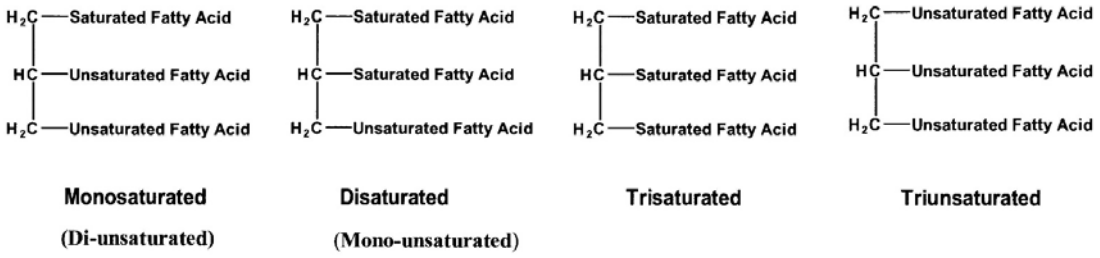
The physical characteristics of a fat or oil are dependent upon the degree of unsaturation, the length of the carbon chains, the isomeric forms of the fatty acids, molecular configuration, and processing variables.

A. Degree of Unsaturation of Fats and Oils

Food fats and oils are made up of triglyceride molecules which may contain both saturated and unsaturated fatty acids. The fatty acids that combine to make up triglycerides will vary; therefore, triglycerides can contain all saturated fatty acids, all unsaturated fatty acids or a mixture of both saturated and unsaturated fatty acids. Depending on the type of fatty acids combined in the molecule, triglycerides can be classified as mono- or di-, -saturated (alternatively mono- or di- unsaturated), tri-saturated and tri-unsaturated as illustrated in Figure 3.

Figure 3

Diagrams of Mono-, Di-, Trisaturated and Triunsaturated Triglycerides



Generally speaking, fats that are liquid at room temperature tend to be more unsaturated than those that appear to be solid, but there are exceptions.

For example, coconut oil has a high level of saturates, but many are of low molecular weight, hence this oil melts at or near room temperature. Thus, the physical state of the fat does not necessarily indicate the amount of unsaturation

The degree of unsaturation of a fat, i.e., the number of double bonds present, normally is expressed in terms of the iodine value (IV) of the fat. IV is the number of grams of iodine which will react with the double bonds in 100 grams of fat and may be calculated from the fatty acid composition. The typical IV for soybean oil is 123-139, for cottonseed oil 98-110, and for butterfat it is 25-42.

B. Length of Carbon Chains in Fatty Acids

The melting properties of triglycerides are related to those of their fatty acids. As the chain length of a saturated fatty acid increases, the melting point also increases (Table II). Thus, a short chain saturated fatty acid such as butyric acid has a lower melting point than saturated fatty acids with longer chains. This explains why coconut oil, which contains almost 90% saturated fatty acids but with a high proportion of relatively short chain low melting fatty acids, is a clear liquid at 80°F while lard, which contains only about 42% saturates, most with longer chains, is semi-solid at 80ºF.

C. Isomeric Forms of Fatty Acids

For a given fatty acid chain length, saturated fatty acids will have higher melting points than those that are unsaturated. The melting points of unsaturated fatty acids are profoundly affected by the position and conformation of double bonds. For example, the monounsaturated fatty acid oleic acid and its geometric isomer elaidic acid have different melting points (Table III). Oleic acid is liquid at temperatures considerably below room temperature, whereas elaidic acid is solid even at temperatures above room temperature.

D. Molecular Configuration of Triglycerides

The molecular configuration of triglycerides can also affect the properties of fats. Melting points vary in sharpness depending on the number of different chemical entities present. Simple triglycerides have sharp melting points while triglyceride mixtures like lard and most vegetable shortenings have broad melting ranges.

In cocoa butter, palmitic (P), stearic (S), and oleic (O) acids are combined in two predominant triglyceride forms (POS and SOS), giving cocoa butter its sharp melting point just slightly below body temperature. This melting pattern partially accounts for the pleasant eating quality of chocolate.

A mixture of several triglycerides has a lower melting point than would be predicted for the mixture based on the melting points of the individual components and will have a broader melting range than any of its components. Monoglycerides and diglycerides have higher melting points than triglycerides with a similar fatty acid composition.

E. Polymorphism of Fats

Solidified fats often exhibit polymorphism, i.e., they can exist in several different crystalline forms, depending on the manner in which the molecules orient themselves in the solid state. The crystal form of the fat has a marked effect on the melting point and the performance of the fat in the various applications in which it is utilized. The crystal forms of fats can transform from lower melting to successively higher melting modifications. The order of this transformation is:

Alpha → Beta Prime → Beta

The rate and extent of transformation are governed by the molecular composition and configuration of the fat, crystallization conditions, and the temperature and duration of storage. In general, fats containing diverse assortments of molecules with varying fatty acids or fatty acids locations tend to remain indefinitely in lower melting crystal forms (i.e. Beta Prime), whereas fats containing a relatively limited assortment of these types of molecules transform readily to higher melting crystal forms (i.e. Beta). Mechanical and thermal agitation during processing and storage at elevated temperatures tends to accelerate the rate of crystal transformation. Table IV lists the crystal form, in their most stable condition of many of the fats and oils used in today’s products.

Table IV
Crystal Form

Beta	Beta Prime
Canola*	Cottonseed*
Lard	Palm
Soybean*	Milk Fat
Sunflower*	Rapeseed*
Peanut*	Tallow
Corn*	
Cocoa Butter	

*Hydrogenated

Additional processing steps such as interesterification and fractionation can be used to further enhance and develop these crystal forms.

Manufacturers use this knowledge of crystal formation to create many of the shortening products used today. Beta crystals tend to be large course grainy crystal and are desired in products such as frying and liquid shortenings. They are also ideal for creating pie crusts. Beta-prime crystals are small, fine crystals that create a smooth creamy shortening or margarine. Most solid shortenings use Beta-prime crystals because they aerate and cream well and are ideal for most baking and frosting applications.

VI. PROCESSING

A. General

Food fats and oils are derived from plant seeds, fruits and nuts (generally referred to as oilseeds) and animal sources. Animal fats are generally heat rendered from animal tissues to separate them from protein and other naturally occurring materials. Rendering may be accomplished with either dry heat or steam. Rendering and processing of meat fats is conducted in USDA inspected plants. Vegetable oils are obtained by the extraction or the expression of the oil from the oilseed source. Historically, cold or hot expression methods were used. These methods have largely been replaced with solvent extraction or pre-press/solvent extraction method which gives a better oil yield. In this process the oil is extracted from the oilseed by hexane (a light petroleum fraction) and the hexane is then separated from the oil, recovered, and reused. Because of its high volatility, hexane does not remain in the finished oil after processing.

The fats and oils obtained directly from rendering or from the extraction of the oilseeds are termed “crude” fats and oils. Crude fats and oils contain varying but relatively small amounts of naturally occurring non-glyceride materials that are removed through a series of processing steps. For example, crude soybean oil may contain small amounts of protein, free fatty acids, and phosphatides which must be removed through subsequent processing to produce the desired shortening and oil products. Similarly, meat fats may contain some free fatty acids, water, and protein which must be removed.

It should be pointed out, however, that not all of the nonglyceride materials are undesirable elements. Tocopherols, for example, perform the important function of protecting the oils from oxidation and provide vitamin E. Processing is carried out in such a way as to control retention of these substances.

B. Degumming

Crude oils having relatively high levels of phosphatides (e.g., soybean oil) may be degummed prior to refining to remove the majority of those phospholipid compounds. The process generally involves treating the crude oil with a limited amount of water to hydrate the phosphatides and make them separable by centrifugation. Soybean oil is the most common oil to be degummed; the phospholipids are often recovered and further processed to yield a variety of lecithin products.

A relatively new process in the United States is enzymatic degumming. An enzyme, phospholipase, converts phospholipids, present in crude oil, into lysophospholipids that can be removed by centrifugation. Crude oil, pre-treated with a combination of sodium hydroxide and citric acid, is mixed with water and enzymes (phospholipase) by a high shear mixer, creating a very stable emulsion. The emulsion allows the enzyme to react with the phospholipids, transforming them into water-soluble lysophospholipids. This emulsion is broken by centrifugation, separating the gums and phospholipids from the oil. This process generates a better oil yield than traditional degumming/refining. Enzymatic degumming is currently not widely commercialized.

C. Refining/Neutralization

There are two general types of refining alkali refining and physical refining. Alkali refining (i.e. treatment of the fat or oil with an alkali solution) is the most widespread method and is performed to reduce the free fatty acid content and to remove other impurities such as phosphatides, proteinaceous, and mucilaginous substances. This process results in a large reduction of free fatty acids through their conversion into high specific gravity soaps. Most phosphatides and mucilaginous substances are soluble in the oil only in an anhydrous form and upon hydration with the caustic or other refining solution are readily separated. After alkali refining, the fat or oil is water-washed to remove residual soap.

Oils low in phosphatide content (palm and coconut) may be physically refined (i.e. steam stripped) to remove free fatty acids. In physical refining, free fatty acids in crude or degummed oil are removed by evaporation rather than being neutralized and removed as soap in an alkaline refining process.

D. Bleaching

The term “bleaching” refers to the process for removing color producing substances and for further purifying the fat or oil. Normally, bleaching is accomplished after the oil has been refined.

The usual method of bleaching is by adsorption of the color producing substances on an adsorbent material. Acid-activated bleaching earth or clay, sometimes called bentonite, is the adsorbent material that has been used most extensively. This substance consists primarily of hydrated aluminum silicate. Anhydrous silica gel and activated carbon also are used as bleaching adsorbents to a limited extent.

E. Deodorization

Deodorization is a vacuum steam distillation process for the purpose of removing trace constituents that give rise to undesirable flavors, colors and odors in fats and oils. Normally this process is accomplished after refining and bleaching.

The deodorization of fats and oils is simply a removal of the relatively volatile components from the fat or oil using steam. This is feasible because of the great differences in volatility between the substances that give flavors, colors and odors to fats and oils and the triglycerides. Deodorization is carried out under vacuum to facilitate the removal of the volatile substances, to avoid undue hydrolysis of the fat, and to make the most efficient use of the steam. In the case of vegetable oils, sufficient tocopherols remain in the finished oils after deodorization to provide stability.

Deodorization does not have any significant effect upon the fatty acid composition of most fats or oils. Depending upon the degree of unsaturation of the oil being deodorized, small amounts of *trans* fatty acids may be formed by isomerization.

F. Fractionation (Including Winterization)

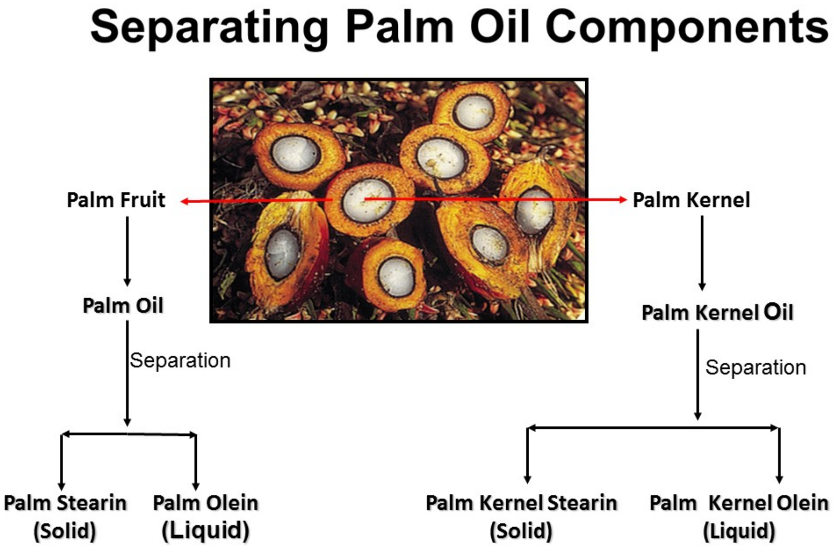
Fractionation is the process of separating the triglycerides in fats and oils by difference in melt points, solubility or volatility. It is most commonly used to separate fats that are solid at room temperature but is also used to separate triglycerides found in liquid oils.

Fats that are solid at room temperature usually contain a mixture of many individual triglycerides, all of which have different melting points. These components can be separated from one another by the fractionation process.

The result of fractionation is the production of two components, called fractions that typically differ significantly from each other in their physical properties. The fractions can be fractionated again (“double” fractionation) to produce additional fractions, which will have unique physical properties. The process was originally developed to fractionate animal fats such as beef tallow.

There are two types of fractionation techniques: dry and wet. Dry fractionation refers to a process that does not use a solvent to assist in the separation of the fat components. The fat is first melted, and then cooled slowly to generate large, high melting point fat crystals. The slurry of crystals suspended in liquid oil is transferred to a high pressure filter press where the liquid (olein) fraction is squeezed out and the hard (stearin) fat is retained on the filter. This process is widely applied to palm oil and palm kernel oil to generate several unique products from a single natural source, without the need for chemical processing. Fractions produced in this way can be blended together or mixed with liquid vegetable oils to make a wide variety of functional products for many food applications.

FIGURE 4



In the case of wet fractionation, the fat is first dissolved in a solvent, then cooled slowly and separated in a high pressure filter press. The resulting specialty fractions can be used in value added applications such as confectionery or as a substitute for cocoa butter. Traditionally, fractionation using solvents resulted in fractions of greater purity compared to dry fractionation. However, the use of solvent fractionation is declining due to improvements in dry fractionation filter press technology that can generate fractions of similar quality.

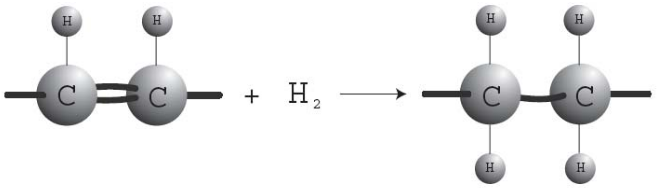
Winterization is another form of fractionation. In this case the starting oil is usually a liquid at room temperature that contains a small amount of dissolved solid fat. At lower temperatures solid fat crystals can form in the oil, giving it an undesirable cloudy appearance. The winterization process cools the oil and the crystals that form are removed by filtration. Cottonseed, and to a diminishing degree partially hydrogenated oils are sometimes winterized.

A similar process called de-waxing is applied to some oils to remove waxes and other high melting point components. Oils that are typically dewaxed include canola, sunflower, rice bran oil and corn. Dewaxing is generally conducted on oils to improve physical appearance (e.g. to make them clear for retail bottling) not for functionality.

G. Hydrogenation

Hydrogenation is the process by which hydrogen is added to points of unsaturation in the fatty acids. Hydrogenation was developed as a result of the need to (1) convert liquid oils to the semi-solid form for greater utility in certain food uses and (2) increase the oxidative and thermal stability of the fat or oil.

In the process of hydrogenation, hydrogen gas reacts with oil at elevated temperature and pressure in the presence of a catalyst. The catalyst most widely used is nickel which is removed from the fat after the hydrogenation processing is completed. Under these conditions, the gaseous hydrogen reacts with the double bonds of the unsaturated fatty acids as illustrated below:



The hydrogenation process is easily controlled and can be stopped at any desired point. As hydrogenation progresses, there is generally a gradual increase in the melting point of the fat or oil. If the hydrogenation of cottonseed or soybean oil, for example, is stopped after only a small amount of hydrogenation has taken place, the oils remain liquid. These partially hydrogenated oils can be used to produce institutional cooking oils, liquid shortenings and liquid margarines.

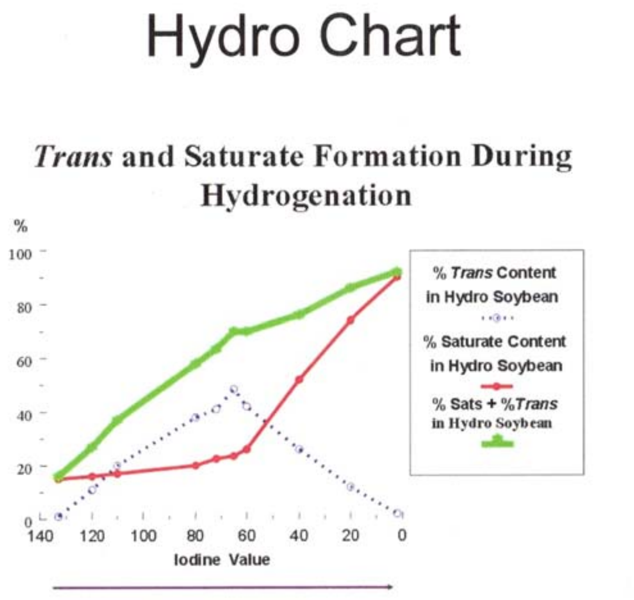
Further hydrogenation can produce soft but solid appearing fats which still contain appreciable amounts of unsaturated fatty acids and are used in solid shortenings and margarines. When oils are more fully hydrogenated, many of the carbon to carbon double bonds are converted to single bonds increasing the level of saturation. If oil is hydrogenated completely, the carbon to carbon double bonds are practically eliminated.

The hydrogenation conditions can be varied by the manufacturer to meet certain physical and chemical characteristics desired in the finished product. This is achieved through selection of the proper temperature, pressure, time, catalyst, and starting oils. Both positional and geometric (*trans*) isomers are formed to some extent during hydrogenation, the amounts depending on the conditions employed.

See Figure 5 for characterization of *trans* isomer formation as related to increase in saturated fat during hydrogenation.

Biological hydrogenation of polyunsaturated fatty acids occurs in some animal organisms, particularly in ruminants. This accounts for the presence of some *trans* isomers that occur in the tissues and milk of ruminants.

Figure 5*



* Source of Chart: Cargill Dressings, Sauces and Oils

H. Interesterification

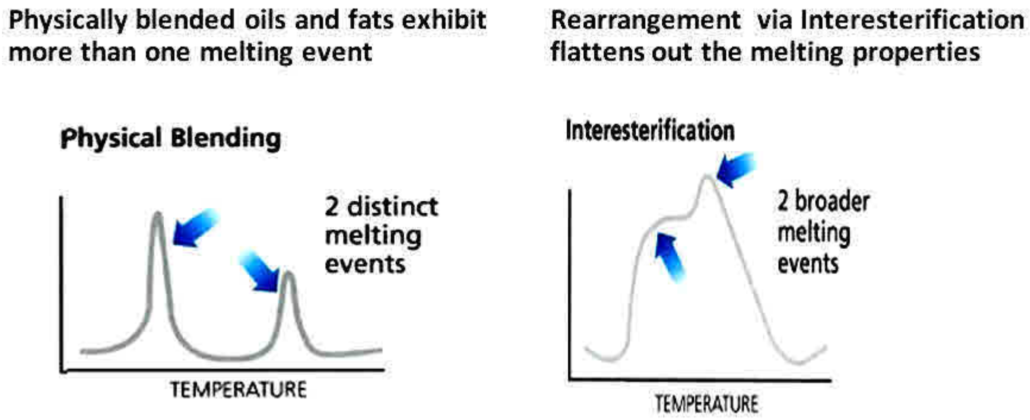
Another process used by oil processors is interesterification which causes a redistribution of the fatty acids on the glycerol fragment of the molecule. This rearrangement process does not change the composition of the fatty acids from the starting materials. Interesterification may be accomplished by chemical or enzymatic processes.

Chemical interesterification is a process by which fatty acids are randomly distributed across the glycerol backbone of the triglyceride. This process is carried out by blending the desired oils, drying them, and adding a catalyst such as sodium methoxide. When the reaction is complete, the catalyst is neutralized and the rearranged product is washed, bleached, and deodorized to give a final oil product with different characteristics than the original oil blends.

Enzymatic interesterification is another means by which oils and fats can be interesterified. This process uses immobilized lipases to rearrange the fatty acids on the glycerol backbone of the triglyceride. These immobilized lipases can target fatty acids at specific positions on the glycerol backbone, therefore, the rearrangement of fatty acids during enzymatic interesterification is less random than with chemical interesterification. After interesterification, the oil is deodorized to make finished oil products. Enzymatic interesterification has gained popularity over the last decade due to the flexibility of the process and reduced capital process input.

The predominant commercial application for interesterification in the US is the production of specialty fats such as shortenings, table spreads, confectionary fats (see also Section VIII D.) and nutritional lipids. These processes permit further tailoring of triglyceride properties to achieve the required melting curves.

Figure 6*



* Source of Chart: Bunge Oils

I. Esterification

Fatty acids are usually present in nature in the form of esters and are consumed as such. Triglycerides, the predominant constituents of fats and oils, are examples of esters. When consumed and digested, fats are hydrolyzed initially to diglycerides and monoglycerides which are also esters. Carried to completion, these esters are hydrolyzed to glycerol and fatty acids. In the reverse process, esterification, an alcohol such as glycerol is reacted with an acid such as a fatty acid to form an ester such as mono-, di-, and triglycerides. In an alternative esterification process, called alcoholysis, an alcohol such as glycerol is reacted with fat or oil to produce esters such as mono- and diglycerides. Using the foregoing esterification processes, edible acids, fats, and oils can be reacted with edible alcohols to produce useful food ingredients that include many of the emulsifiers listed in Section K.

J. Additives and Processing Aids

Manufacturers may add low levels of approved food additives to fats and oils to protect their quality in processing, storage, handling, and shipping of finished products. This insures quality maintenance from time of production to time of consumption. When their addition provides a technical effect in the end-use product, the material added is considered a direct food additive. Such usage must comply with FDA and USDA regulations governing levels, and product labeling. Typical examples of industry practice are listed in Table V.

When additives are included to achieve a technical effect during processing, shipping, or storage and followed by removal or reduction to an insignificant level, the material added is considered to be a processing aid. Typical examples of processing aids and provided effects are listed in Table VI. Use of processing aids also must comply with federal regulations which specify good manufacturing practices and acceptable residual levels.

TABLE V
Some Direct Food Additives Used in Fats and Oils

Additive	***Effect Provided***
Butylated hydroxyanisole (BHA) Butylated hydroxytoluene (BHT) Tertiary butylhydroquinone (TBHQ) Propyl Gallate (PG)	Antioxidant, retards oxidative rancidity
Carotene (pro-vitamin A) Annatto	Color additive, enhances color of finished foods
Dimethylpolysiloxane (Methyl Silicone)	Inhibits oxidation tendency and foaming of fats and oils during frying
Vegetable oil tocopherols Rosemary Extracts	Antioxidant, retards oxidative rancidity
Lecithin	Water scavenger to prevent lipolytic rancidity, emulsifier
Citric acid Phosphoric acid	Metal chelating agents, inhibit metal-catalyzed oxidative breakdown
Polyglycerol esters	Crystallization modifier and inhibitor

TABLE VI
Some Processing Aids Used in Manufacturing Edible Fats and Oils

Aid	***Effect***	***Mode of Removal***
Sodium hydroxide	Refining aid	Water wash, Acid neutralization
Carbon/clay (diatomaceous earth)	Bleaching aid	Filtration
Nickel	Hydrogenation catalyst	Filtration
Sodium methoxide	Chemical interesterification catalyst	Water wash, acid neutralization,
Phosphoric acid Citric acid	Refining aid, metal chelators	Neutralization with base, bleaching, water washing
Acetone Hexane Isopropanol	Extraction solvent, fractionation media	Solvent stripping and deodorization
Nitrogen	Inert gas to prevent oxidation.	
Silica hydrogel	Adsorbent	Filtration
Enzymes	Degumming, interesterification, structured triglycerides	Filtration and immobilization

K. Emulsifiers

Many foods are processed and/or consumed as emulsions, which are dispersions of immiscible liquids such as water and oil, e.g., milk, mayonnaise, ice cream, icings, and sauces. Emulsifiers, either present naturally in one or more of the ingredients or added separately, provide emulsion stability. If emulsions lack stability, separation of the oil and water phases can occur. Some emulsifiers also provide valuable functional attributes in addition to emulsification, including aeration, starch and protein complexing, hydration, crystal modification, solubilization, and dispersion. Typical examples of emulsifiers and the characteristics they impart to food are listed in Table VII.

L. Blending

Blending of oils and fats is a common approach to produce a wide array of edible products such as baking and frying shortenings, margarine oils, specialty products and even salad and cooking oils. The basestock used for blending may be composed of liquid oils and/or modified oils produced through hydrogenation, fractionation, interesterification, or trait enhanced vegetable oils.[1] These basestock oils and fats can be blended in multiple combinations to satisfy various needs related to cost, nutrition, functionality and oil availability. Blends are often formulated for use in liquid applications such as for frying or spray oils; and in semi solid applications such as baking shortenings.

Liquid blending can entail combining two or more oils to target a flavor or nutritional profile in a frying application. For the application where an improved oxidative stability is desired, commodity vegetable oils such as canola or soybean oil can be blended with oils that contain low levels of linolenic acid or linoleic acid (e.g. corn oil and cottonseed oil). Another approach for increasing the oxidative stability is to blend less stable oils such as canola or soybean with one of the significantly more stable trait enhanced vegetable oils.

Blending is also used to achieve a certain solid fat content in shortenings and to create a nutritional profile in food products. Typically, palm oil or palm stearin is blended with the liquid vegetable oils, including trait enhanced oils, to target varying baking or frying applications. Shortening blends incorporating liquid oils mixed with interesterified hard stocks (solid fats) can also yield a desired functional shortening for use in baking applications. These interesterified hard stocks can be produced from palm / palm kernel oil blends or soybean/fully

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[1] Trait enhanced vegetable oils produced from oilseeds that have been modified through breeding or biotechnology to have a higher content of more stable fatty acids such as oleic acid or a lower content of less stable linolenic and linoleic acids.

hydrogenated oil blends. A different approach to shortenings is to mix liquid oils with fully hydrogenated vegetable oil targeting a specific functional shortening.

TABLE VII

Emulsifiers and Their Functional Characteristics in Processed Foods

Emulsifier	***Characteristic***	***Processed Food***
Mono-diglycerides	Emulsification of water in oil Anti-staling or softening Prevention of oil separation	Margarine Bread and rolls Peanut butter
Lecithin	Viscosity control and wetting Anti-spattering and anti-sticking	Chocolate Margarine
Lactylated mono-diglycerides	Aeration Gloss enhancement	Batters (cake) Confectionery coating
Polyglycerol esters	Crystallization promoter Aeration Emulsification	Sugar syrup Icings and cake batters
Sucrose fatty acid esters	Emulsification	Bakery products
Sodium steroyl lactylate (SSL) Calcium steroyl lactylate (CSL)	Aeration, dough conditioner, stabilizer	Bread and rolls
Sorbitan Esters	Crystallization modifier	Creams, water in oil emulsions
Propylene glycol esters	Emulsification	Margarine, Baking, Ice Cream

CHAPTER VII – UNDER CONSTRUCTION

VIII. REACTIONS OF FATS AND OILS

A. Hydrolysis of Fats

Like other esters, glycerides can be hydrolyzed readily. Partial hydrolysis of triglycerides will yield mono- and diglycerides and free fatty acids. When hydrolysis is carried to completion with water in the presence of an acid catalyst, the mono-, di-, and triglycerides will hydrolyze to yield glycerol and free fatty acids. With aqueous sodium hydroxide, glycerol and the sodium salts of the component fatty acids (soaps) are obtained. This process is also called saponification. In the digestive tracts of humans and animals and in bacteria, fats are hydrolyzed by enzymes (lipases). Lipolytic enzymes are present in some edible oil sources (i.e., palm fruit, coconut). Any residues of these lipolytic enzymes (present in some crude fats and oils) are deactivated by the elevated temperatures normally used in oil processing.

B. Oxidation of Fats

1. Autoxidation. Of particular interest in the food arena is the process of oxidation induced by air at room temperature referred to as “autoxidation”. Ordinarily, this is a slow process which occurs only to a limited degree. However, factors such as the presence of light can increase the rate of oxidation. In autoxidation, oxygen reacts with unsaturated fatty acids at the double bond site. Initially, peroxides are formed which may break down into secondary oxidation products (hydrocarbons, ketones, aldehydes, and smaller amounts of epoxides and alcohols). Metals, such as copper or iron, present at low levels in fats and oils can also promote autoxidation. Fats and oils are normally treated with chelating agents such as citric acid to complex these trace metals (thus inactivating their prooxidant effect).

The result of the autoxidation of fats and oils is the development of objectionable flavors and odors characteristic of the condition known as “oxidative rancidity”. Some fats resist this change to a remarkable extent while others are more susceptible depending on certain factors, such as the degree of unsaturation.

When rancidity has progressed significantly, it becomes readily apparent from the flavor and odor of the oil. Expert tasters are able to detect the development of rancidity in its early stages. The peroxide value determination, if used judiciously, is oftentimes helpful in measuring the degree to which oxidative rancidity in the fat has progressed.

It is common practice in the industry to protect fats and oils from oxidation to preserve their acceptable flavor and to maximize shelf life. For instance, manufacturers avoid air contact by routinely blanketing oils with nitrogen during processing, storage and transportation; and may use chelating agents or antioxidants to further deter autooxidation.

2. Oxidation at Higher Temperatures. Although the rate of oxidation is greatly accelerated at higher temperatures, oxidative reactions which occur at higher temperatures may not follow precisely the same routes and mechanisms as the reactions at room temperature. Thus, differences in the stability of fats and oils often become more apparent when the fats are used for frying or slow baking. The stability of a fat or oil may be predicted to some degree by determining the oxidative stability index (OSI).

The more unsaturated the fat or oil, the greater will be its susceptibility to oxidative rancidity. Predominantly unsaturated oils (i.e., soybean, cottonseed, or corn) are less stable than predominantly saturated oils (i.e., coconut oil, palm oil). Dimethylsilicone is usually added to institutional frying fats and oils to reduce oxidation tendency and foaming at elevated temperatures. Historically, partial hydrogenation has often been employed in the processing of liquid vegetable oil to increase the stability and functionality of the oil. The trend of utilizing partial hydrogenation has been declining during the last decade due to developments in oils/fat processes and trans fat legislation.

C. Polymerization of Fats

All commonly used fats and particularly those high in polyunsaturated fatty acids tend to form larger molecules (known broadly as polymers) when heated under extreme conditions of temperature and time. Under normal processing and cooking conditions, polymers are formed. Although the polymerization process is not completely understood, it is believed that polymers in fats and oils arise by formation of either carbon-to-carbon bonds or oxygen bridges between molecules. When an appreciable amount of polymer is present, there is a marked increase in viscosity.

D. Reactions during Heating and Cooking

Glycerides are subject to chemical reactions (oxidation, hydrolysis, and polymerization) which can occur particularly during deep fat frying. The extent of these reactions, which may be reflected by a decrease in iodine value of the fat and an increase in free fatty acids, depends on the frying conditions (principally the temperature, aeration, moisture, and duration). The composition of a frying medium also may be affected by the kind of food being fried. For example, when frying foods such as chicken, some fat from the food will be rendered and blend with the frying medium while some of the frying medium will be absorbed by the food. In this manner the fatty acid composition of the frying medium will change as frying progresses. Since absorption of frying medium into the food may be extensive, it is often necessary to replenish the fryer with fresh frying medium. Obviously, this replacement with fresh medium tends to dilute overall compositional changes of the fat that would have taken place during prolonged frying.

Frying conditions do not saturate the unsaturated fatty acids, although the ratio of saturated to unsaturated fatty acids will change due to degradation and polymerization of the unsaturated fatty acids. The frying operation also results in an increase in the level of "polar compounds" (mono- and diglycerides, free fatty acids, and other polar transformation products) formed during frying/heating of foodstuffs in the oil.

It is the usual practice to discard the frying medium when (1) prolonged frying causes excessive foaming of the hot oil, (2) the medium tends to smoke excessively, usually from prolonged frying with low turnover, or (3) an undesirable flavor or dark color develops. Any or all of these qualities associated with the frying medium can decrease the quality of the fried food.

The "smoke", "flash", and "fire points" of a fatty material are standard measures of its thermal stability when heated in contact with air. The "smoke point" is the temperature at which smoke is first detected in a laboratory apparatus protected from drafts and provided with special illumination. The temperature at which the fat smokes freely is usually somewhat higher. The "flash point" is the temperature at which the volatile products are evolved at such a rate that they are capable of being ignited but not capable of supporting combustion. The "fire point" is the temperature at which the volatile products will support continued combustion. For typical non-lauric oils with a free fatty acid content of about 0.05%, the "smoke", "flash", and "fire" points are around 420°F, 620°F, and 670°F respectively. The typical smoke, flash and fire points of commercially available oils and fats used for food purposes in the U.S. are given in Table VIII. The degree of unsaturation of an oil has little, if any, effect on its smoke, flash, or fire points. Oils containing fatty acids of low molecular weight such as coconut oil, however, have lower smoke, flash, and fire points than other animal or vegetable fats of comparable free fatty acid content. Oils subjected to extended use will have increased free fatty acid contents resulting in a lowering of the smoke, flash, and fire points. Accordingly, used oil freshened with new oil will show increased smoke, flash, and fire points. For additional details see *Bailey's Industrial Oil and Fat Products*[2]

It is important to note that all oils will burn if overheated. This is why most household fat and oil products for cooking carry a warning statement on their labels about potential fire hazards. Accordingly, careful attention must be given to all frying operations. *When heating fat, do not leave the pan unattended.* The continuous generation of smoke from a frying pan or deep fryer is a good indication that the fat is being overheated and could ignite if high heating continues. *If smoke is observed during a frying operation, the heat should be reduced.* If, however, the contents of the frying pan ignite, extinguish the fire by covering the pan immediately with a lid or by spraying it only with an appropriate fire extinguisher. Do not attempt to remove a burning pan of oil from the stove. Allow the covered frying container to cool. Under no circumstances should burning fat be dumped into a kitchen sink or sprayed with water.

Furthermore, if a consumer wishes to save the fat or oil after cooking, the *hot* fat or oil should *never* be poured back into its original container. Most containers for cooking oils are *not* designed to withstand the high temperatures reached by the oil during cooking. Pouring hot oil into such containers could result in breakage or melting of the container and possible burns to the user.

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[2] Hui, Y.H., ed. Bailey's Industrial Oil and Fat Products, vol. 2, *Edible Oil and Fat Products: Oils and Oilseeds*, 5th ed., New York, John Wiley & Sons, Inc., p. 214, 1996.

TABLE VIII

Typical Smoke, Flash, and Fire Points of Commercially Available Edible Fats and Oils in the U.S.*

OIL TYPE	Smoke Point		Flash Point		Fire Point	
	(C°)	(F°)	(C°)	(F°)	(C°)	(F°)
Palm Olein (IV-57)	230	446	324	615	352	666
Palm Hard Fraction (IV-35)	230	446	326	619	352	666
Palm	254	489	324	615	354	669
Coconut Oil	196	385	295	563	330	626
Canola	236	457	326	619	350	662
Hi Oleic Canola Oil	240	464	340	644	360	680
Corn Ol	235	455	325	617	354	670
Soya Oil	240	464	330	626	360	680
Low Linolenic Soya	237	458	331	628	362	684
Hydrogenated Soya Oil (IV 70)	230	446	330	626	360	680
Cottonseed Oil	232	450	319	606	360	680
Peanut Oil	230	446	334	633	360	680
Mid Oleic Sunflower Oil	211	412	319	607	359	678
HI Oleic Sunflower	244	471	319	606	360	680
Lard	240	464	330	626	360	680
Tallow	230	446	330	626	360	680
Rice Bran Oil	229	444	324	615	368	695
Rice Bran (High Oryzanol)	222	432	316	601	361	682

*The values in this table represent typical smoke, flash and fire points for commercially available edible fats and oils. The values are based on a single test for each fat and oil source, thus they do not represent a statistically valid mean or indicate the range of values attributable to each of the source oils. Smoke, flash and fire points may vary within a source oil due to such factors as processing techniques and/or seasonal variations. In addition, there can be analyst subjectivity when using this test procedure (i.e. AOCS Cc 9a-48 method, Cleveland Open Cup). Therefore, to the extent practicable, ISEO recommends that individual companies conduct independent testing that accounts for such variability within source fats and oils unique to their business practices. Further, to the extent any company chooses to rely upon the accompanying data, ISEO strongly urges the employment of a prudent margin of safety below the ISEO test based smoke, flash, and fire points. Commercial samples were tested after deodorization and had a free fatty acid content of 0.05% or less.

IX. PRODUCTS PREPARED FROM FATS AND OILS

A. General

A wide variety of products based on edible fats and oils is available to consumers. Shortenings, salad and cooking oils, butter, margarines and tablespreads, mayonnaise, spoonable and pourable salad dressings, and confections are some of the widely available products that are based entirely on fats and oils or contain fat or oil as a principal ingredient. Many of these products also are sold in commercial quantities to food processors, snack food manufacturers, bakeries, restaurants, and institutions.

For statistical reporting purposes, dietary fats are categorized as either “added” or “naturally occurring.” The former are those that are added either (1) at the table: butter and margarine for example or (2) during preparation of a food: shortening or oil added to a cake or cake mix for example, whether added to the mix during in home preparation or at the cake mix plant by the food processor. They account for more than half of dietary fat, the majority of which is derived from vegetable sources (soybean, canola, cottonseed, corn, palm, etc.).

Naturally occurring fats and oils, on the other hand, are found in whole foods like nutmeats, dairy products (other than butter) and meats. Beef, pork, poultry and fish consumption is the source of most naturally occurring dietary fat. Consumption statistics can be found at the Economic Research Service U.S. Department of Agriculture website http://www.ers.usda.gov/Data/foodconsumption. The typical fatty acid composition of the principal vegetable oils and animal fats used for food purposes in the U.S. is given in Table IX.

TABLE IX

Typical Fatty Acid Composition of the Principal Vegetable and Animal Fats and Oils in the U.S.*

(% of total fatty acids)

	BUTYRIC	CAPROIC	CAPRYLIC	CAPRIC	LAURIC	MYRISTIC	PENTADECANOIC	PALMITIC	MARGARIC	STEARIC	ARACHIDIC	BEHENIC	LIGNOCERIC	MYRISTOLEIC	PALMITOLEIC	OLEIC	MARGAROLEIC	GADOLEIC	LINOLEIC	LINOLENIC
	SATURATED													MONO-UNSATURATED					POLY-UNSATURATED	
Oil or Fat	4:0	6:0	8:0	10:0	12:0	14:0	15:0	16:0	17:0	18:0	20:0	22:0	24:0	14:1	16:1	18:1	17:1	20:1	18:2	18:3
Beef tallow						3	1	24	2	19				1	4	43	1		3	1
Butterfat	4	2	1	3	3	11	2	27	1	12					2	29			2	1
Canola								4		2						62			22	10
Cocoa butter								26		34	1					34			3	
Coconut		1	8	6	47	18		9		3						6			2	
Corn								11		2						28			58	1
Cottonseed						1		22		3					1	19			54	1
Flaxseed								5		4						20			17	53
High oleic canola								4		2						75			17	2
High oleic safflower								7		2						78			13	
High oleic sunflower								4		5						79			11	
Lard						2		26		14					3	44		1	10	
Mid oleic sunflower								4		5						65			26	
Olive								13		3	1				1	71			10	1
Palm kernel			3	4	48	16		8		3						15			2	
Palm						1		45		4						40			10	
Palm Olein (IV 56)						1		40		4						42			11	
Palm Stearin																				
Peanut								11		2	1	3	2			48		2	32	
Rice Bran																				
Safflower								7		2						13			78	
Soybean								11		4						24			54	7
Sunflower								7		5						19			68	1

[1] Fatty acid composition data determined by gas-liquid chromatography and provided by member companies of the Institute of Shortening and Edible Oils. Fatty acids (designated as number of carbon atoms: number of double bonds) occurring in trace amounts are excluded.
Component fatty acids may not add to 100% due to rounding.

In recent years, a number of trait-enhanced vegetable oils have been commercialized. Their fatty acid compositions have been modified via either traditional selective hybridization or gene insertion techniques. These oils generally tend to be lower in polyunsaturates (e.g. linoleic and linolenic acid) and, depending upon the particular modification, higher in mono-unsaturates (e.g., oleic acid). Trait enhanced oils are designed to deliver two primary objectives: (1) improved nutritional profile and (2) improved oxidative and flavor stability thereby precluding the need for partial hydrogenation. Genetically modified oils of the future will likely have customized fatty acid compositions and triglyceride profiles to meet specific applications.

The ingredient statement of FDA-regulated packaged food products lists the source oils (along with all other ingredients) that are or may be present in the product. All ingredients are listed in descending order of predominance. If a fat or oil is the predominant ingredient of a food product (e.g., salad and cooking oil, shortening, or margarine), the actual source oil(s) used must be shown on the product label. However, for foods in which a fat or oil is not the predominant ingredient (e.g., baked products or snack foods) and for which a manufacturer may wish to substitute one oil for another depending on commodity prices and availability, the manufacturer is permitted to list the alternative oils that may be present.

B. Salad and Cooking Oils

Salad and cooking oils are prepared from vegetable oils that are refined, bleached, deodorized, and sometimes dewaxed or lightly hydrogenated and winterized. Soybean and corn oil are the principal oils sold in this form, although cottonseed, peanut, safflower, sunflower, canola and olive oil also are used. Advanced plant breeding technology, much of which includes biotechnology applications, has resulted in a wide variety of new oils that may be used as salad and cooking oils. These newer oils include high oleic varieties of canola, safflower, soybean and sunflower oils, and mid oleic sunflower oil. Many of these oils are now regularly used for commercial frying or are incorporated into blended fry shortenings.

C. Shortenings (Baking and Frying Fats)

Shortenings are fats used in the preparation of many foods. In the past, lard and other animal fats were the principal edible fats used in shortenings in this country, but during the last third of the nineteenth century they were largely replaced by cottonseed oil, a by-product of the cotton industry. Many types of vegetable oils including soybean, cottonseed, corn, sunflower, and palm can be used in shortening products.

Traditionally, partially hydrogenated oils have been used in the formulation of shortenings and generally two or more stocks have been used to deliver the required performance characteristics including storage stability, creamy consistency over a wide temperature range and the ability to incorporate and hold air. More recently, developments in the fats and oil industry enable shortenings without using partially hydrogenated oils. Higher stability liquid oils and oil blends have grown in use in commercial frying. In addition, shortenings produced using interesterification and fractionation techniques are gaining expanded use in bakery and other food applications. Lard and other animal fats and mixtures of animal and vegetable fats also are used in shortenings.

Fats tenderize (shorten the texture of) baked goods by preventing cohesion of gluten strands during mixing, hence the term shortening. All-purpose shortenings are used primarily for cookies but are also common ingredients in cakes, breads, and icings and are also used for frying applications. The quality of cakes and icings is highly dependent upon aeration; therefore, a variety of very specialized shortenings has been developed over the years to satisfy that demand. High ratio shortenings (containing mono and diglycerides), designed primarily for cakes, began to appear in the ‘30s. Fluid cake shortenings were commercialized in the ‘60s and offer many advantages including pumpability, ease of handling and the option of bulk delivery and storage.

Frying shortenings are specially formulated to stand up to the extreme conditions presented during deep fat frying. To preserve the eating quality of products fried therein, the melting range is carefully controlled. The antifoaming agent, methyl silicone, is added to many frying fats. Fluid products, both clear and opaque, are also available. Fluidity makes for ease in handling and filtration – important criteria when (1) product is handled in container formats (jugs, pails etc. are simply emptied into the fryer) and (2) operator involvement is required for filtration (shortening can be filtered at cooler temperatures).

D. Cocoa Butter and Butterfat Alternatives (Hard Butters)

Cocoa butter is generally characterized by a steep melting profile thereby delivering quick and complete flavor release. The term hard butter describes a collection of specialty fats that are designed to either replace or extend cocoa butter (cocoa butter alternatives) and/or butterfat. They are used primarily in confectionery (coatings, centers, drops) and vegetable dairy applications (coffee whiteners, non-dairy toppings, sour dressings). Cocoa butter alternatives are divided into 3 classifications; cocoa butter substitutes (CBS), cocoa butter replacers (CBR), cocoa butter equivalents (CBE).

Cocoa butter substitutes (CBS) are sourced from lauric fats such as palm kernel and /or coconut oils. These fats may be fractionated, hydrogenated and /or interesterified. CBS products have either zero *trans* fat or are low in *trans* fat although high in saturated fat. Due to the high lauric content of the CBS, these fats have essentially no compatibility with cocoa butter and require a low fat cocoa powder for compound chocolate coating formulations.

Cocoa butter replacers (CBR) are another class of alternatives which are sourced from soybean, cottonseed and /or palm oils. The traditional CBRs are hydrogenated and fractionated, thus are high in trans fat (40 to 50%). CBRs do have limited compatibility with cocoa butter so a compound coating incorporating CBR can have up to 25% (of total fat) cocoa butter in that formula.

Both CBS and CBR are non-tempering fats as they spontaneously crystallize in a stable crystal form. The new varieties of CBRs are low in *trans* fats and are sourced from palm oil which has been either fractionated, interesterified and/or lightly hydrogenated.

Cocoa butter equivalents (CBE) are sourced from fractionated palm oil blended with a *hard* fraction which is sourced from the either an exotic fats, such as, shea, sal, illipe, kokum or a kokum fraction. Or this *hard* fraction may also be made from an enzymatically interesterified sunflower or safflower oil. The CBE are chemically & physically identical to cocoa butter and thus require tempering to develop a stable crystal form.

E. Margarine and Spreads

Margarine and spreads are water in oil emulsions prepared by blending an oil phase with an aqueous phase. Oil phases typically contain solid fats or a blend of solid fats and liquid oils, along with fats soluble ingredients such as lecithin, mono- and diglycerides, colorants, flavorings, or other nutrient components, and vitamin A.

The oil phase typically are formulated using a solid component composed either of a non-hydrogenated shortening or, to a lesser extent, a partially hydrogenated stocks, and/or hard fractions of certain fats that are blended with a liquid oil, usually either soybean or canola, to deliver the desired structure and melting properties. Recently, interesterified shortening can be employed in the oil phase to further tailor the final product character.

Aqueous phases typically contain water soluble ingredient such as non fat milk solids, salt, preservatives, and chelating agents. The two phases are mixed to create a homogeneous blend then crystallized in a scraped surface heat exchanger to give a stabile emulsion with desired physical properties such as solid yet spreadable at room temperature.

Margarine is defined by a standards of identity per Code of Federal Regulations[1] and must contain at least 80% fat and 15,000 IU units of Vitamin A. Products that contain <80% fat must be named *spread* by the same federal regulations.

Margarines and spreads are available in stick, tub, liquid, and spray forms for retail markets and in block and bulk tub containers for the food processing industry.

Table X indicates typical ingredients used in spreads and margarines.

F. Butter

Butter must contain not less than 80% by weight of butterfat. The butterfat in the product serves as a plastic matrix enclosing an aqueous phase consisting of water, casein, minerals, and other soluble milk solids. These solids usually constitute about 1% of the weight of the butter. Frequently, salt is added at levels from 1.5-3.0% of the weight of the product. Butter is an important source of vitamin A, and to a lesser extent, of vitamin D.

TABLE X
Typical Ingredients Used in Spreads and Margarines

Fat Soluble	Water Soluble
Emulsifiers (Mono-and Diglycerides)	Salt
Lecithin	Preservatives (K Sorbate, Na Benzoate)
Colorant (Beta-Carotene)	Acids (Phosphoric, Citric Acid etc.)
Flavors	Vitamins (B and C)
Vitamins (A, D, E and K)	EDTA
	Milk, Milk Powder

G. Dressings for Food

Mayonnaise and salad dressing are emulsified, semi-solid fatty foods that by federal regulation must contain not less than 65% and 30% vegetable oil, respectively, and dried whole eggs or egg yolks. Salt, sugar, spices, seasoning, vinegar, lemon juice, and other ingredients complete these products. Pourable and spoonable dressings may be two phase (e.g., vinegar and oil) or the emulsified viscous type (e.g., French). There is a great variety of products available of varying compositions with a wide range in their oil content. Salad oils exclusively are used for dressing products; typical choices include soybean, canola and olive oils.

X. CONCLUSION

This publication has reviewed a broad scope of topics including the importance of dietary fat as an essential nutrient and the usage of fats and oils in a variety of food products. Much research continues on the role of dietary fat in relation to health. As a service to the professional communities, the Institute of Shortening and Edible Oils, Inc., intends to revise this publication as needed to keep the information as current and useful as possible.