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. Additional detail may be found in the references listed at the end of the publication which are arranged in the order of topic discussion. A glossary is also provided.

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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 cal/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 contributing 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 medum for food preparation. Fats and oils are present naturally in many foods, such as meats, dairy products, poultry, fish, and nuts, and in prepared foods, such as baked goods, margarines, and 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" 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
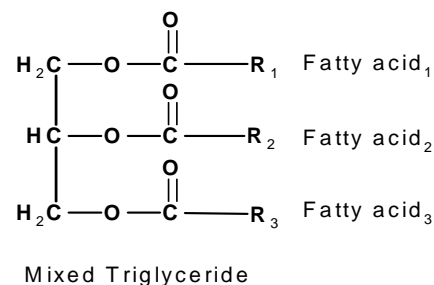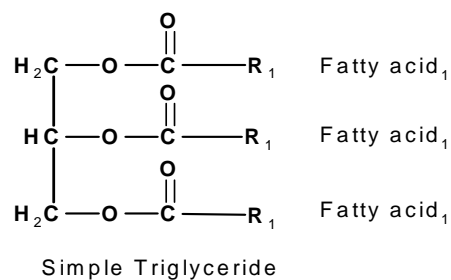
The fatty acids in a triglyceride define the properties and characteristics of the molecule and are discussed in greater detail in Section IV.

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
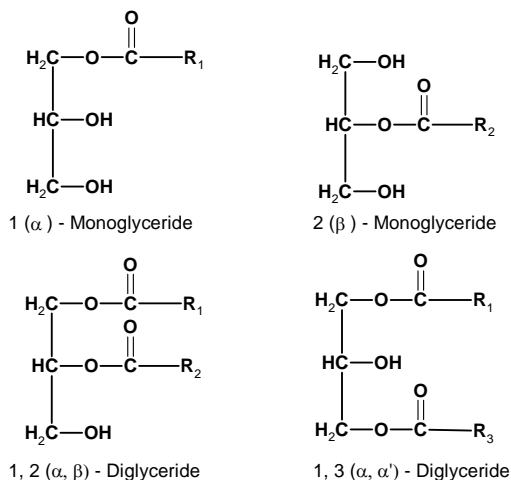
2. Free Fatty Acids. As the name suggests, free fatty acids are the unattached fatty acids present in a fat. Some unrefined oils may contain as much as several percent free fatty acids. The levels of free fatty acids are reduced in the refining process. (See Section VI.) Fully refined fats and oils usually 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 refining. 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 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 and/or salad dressings. 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. Tocotrienols are mainly present in palm oil, and can also be found in rice bran and wheat germ oils.

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

TABLE I [1]
Some 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	$15,050 \pm 7100$	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	$3 \pm$	30 ± 30

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:

$$CH_3 - (CH_2)_x —COOH$$
Saturated carbon chain   carboxyl group
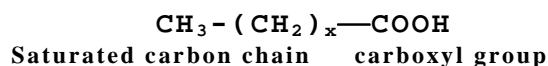
Edible oils also contain minor amounts of branched chain and cyclic acids. Also odd number straight chain acids are typically found in animal fats.

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 included in the table.

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

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.

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:
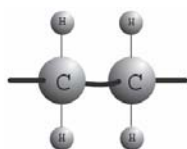
Saturated Bond
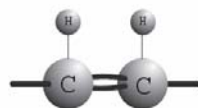
Unsaturated Bond

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, found in many fish oils, is an omega-3 (n-3) fatty acid. Alpha-linolenic acid, found in certain vegetable oils, is also an omega-3 (n-3) fatty acid.

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 oils
13-Docosenoic	Erucic	1	22	33.4	Rapeseed oil
4,7,10,13,16,19-Docosahexaenoic	-	6	22	-	Some fish oils

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

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 polyunsaturated fatty acids, linoleic, linolenic, arachidonic, eicosapentaenoic, and docosahexaenoic acids containing respectively two, three, four, five, and six double bonds are of most interest. The nutritional importance of the first three named fatty acids is discussed in Section VII, Part B, "Essential Fatty Acids."

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 oils contain large quantities of a variety of longer chain fatty acids having three or more double bonds including eicosapentaenoic and docosahexaenoic acids.

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.
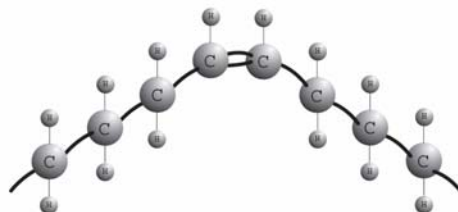
cis

Trans

Elaidic and oleic acids are geometric isomers; in the former, the double bond is in the *trans* 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 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 Fatty Acids

Food fats and oils are made up of triglyceride molecules which may contain both saturated and unsaturated fatty acids. Depending on the type of fatty acids combined in the molecule, triglycerides can be classified as mono-, di-, tri-saturated, or tri-unsaturated as illustrated in Figure 3.

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 unhydrogenated soybean oil is 125-140, for foodservice salad and cooking oils made from partially hydrogenated soybean oil it is 105-120, for semi-solid household shortenings made from partially hydrogenated soybean oil it is 90-95, and for butterfat it is 30.

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

Figure 3

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

H_2C——Saturated Fatty Acid	H_2C——Saturated Fatty Acid	H_2C——Saturated Fatty Acid	H_2C——Unsaturated Fatty Acid
HC——Unsaturated Fatty Acid	HC——Saturated Fatty Acid	HC——Saturated Fatty Acid	HC——Unsaturated Fatty Acid
H_2C——Unsaturated Fatty Acid	H_2C——Unsaturated Fatty Acid	H_2C——Saturated Fatty Acid	H_2C——Unsaturated Fatty Acid
Monosaturated	**Disaturated**	**Trisaturated**	**Triunsaturated**

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 37% 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. Oleic acid is liquid at temperatures considerably below room temperature, whereas elaidic acid is solid even at temperatures above room temperature. Isomeric fatty acids in many vegetable shortenings and margarines contribute substantially to the semi-solid form of these products.

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 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 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 (such as rearranged lard) tend to remain indefinitely in lower melting crystal forms, whereas fats containing a relatively limited assortment of molecules (such as soybean stearine) transform readily to higher melting crystal forms. Mechanical and thermal agitation during processing and storage at elevated temperatures tends to accelerate the rate of crystal transformation.

Controlled polymorphic crystal formation is often applied to partially hydrogenated soybean oil to prepare household shortenings and margarines. In order to obtain desired product plasticity, functionality, and stability, the shortening or margarine must be in a crystalline form called "beta-prime" (a lower melting polymorph). Since partially hydrogenated soybean oil tends to crystallize in the "beta" crystal form (a higher melting polymorph), beta-prime promoting fats like hydrogenated cottonseed or palm oils are often added.

Beta-prime is a smooth, small, fine crystal whereas beta is a large, coarse, grainy crystal. Shortenings and margarines are smooth and creamy because of the inclusion of beta-prime fats.

VI. PROCESSING

A. General

Food fats and oils are derived from oilseed 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 methods which give 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

The process of refining (sometimes referred to as "alkali refining") generally is performed on vegetable

oils to reduce the free fatty acid content and to remove other impurities such as phosphatides, proteinaceous, and mucilaginous substances. By far the most important and widespread method of refining is the treatment of the fat or oil with an alkali solution. This 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. Oils low in phosphatide content (palm and coconut) may be physically refined (i.e., steam stripped) to remove free fatty acids. After alkali refining, the fat or oil is water-washed to remove residual soap.

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.

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. In the case of vegetable oils, sufficient

tocopherols remain in the finished oils after deodorization to provide stability.

F. Fractionation (Including Winterization)

Fractionation is the removal of solids by controlled crystallization and separation techniques involving the use of solvents or dry processing. Dry fractionation encompasses both winterization and pressing techniques and is the most widely practiced form of fractionation. It relies upon the differences in melting points to separate the oil fractions.

Winterization is a process whereby material is crystallized and removed from the oil by filtration to avoid clouding of the liquid fraction at cooler temperatures. The term winterization was originally applied decades ago when cottonseed oil was subjected to winter temperatures to accomplish this process. Winterization processes using temperature to control crystallization are continued today on several oils. A similar process called dewaxing is utilized to clarify oils containing trace amounts of clouding constituents.

Pressing is a fractionation process sometimes used to separate liquid oils from solid fat. This process presses the liquid oil from the solid fraction by hydraulic pressure or vacuum filtration. This process is used commercially to produce hard butters and specialty fats from oils such as palm and palm kernel.

Solvent fractionation is the term used to describe a process for the crystallization of a desired fraction from a mixture of triglycerides dissolved in a suitable solvent. Fractions may be selectively crystallized at different temperatures after which the fractions are separated and the solvent removed. Solvent fractionation is practiced commercially to produce hard butters, specialty oils, and some salad oils from a wide array of edible oils.

G. Partial Hydrogenation/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. It is an important process to our food supply, because it provides the desired stability and functionality to many edible oil products.

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:
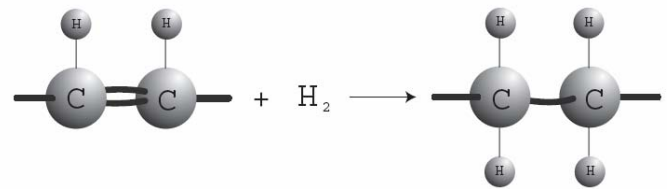
The hydrogenation process is easily controlled and can be stopped at any desired point. As hydrogenation progresses, there is generally a gradual increase in the melting point of the fat or oil. If the hydrogenation of cottonseed or soybean oil, for example, is stopped after only a small amount of hydrogenation has taken place, the oils remain liquid. These partially hydrogenated oils are typically 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 an oil is hydrogenated completely, the carbon to carbon double bonds are eliminated. Therefore, fully hydrogenated fats contain no *trans* fatty acids. The resulting product is a hard brittle solid at room temperature.

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 4 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 4*

Trans and Saturate Formation During Hydrogenation

Legend:
- % *Trans* Content in Hydro Soybean
- % Saturate Content in Hydro Soybean
- % Sats + %*Trans* in Hydro Soybean

X-axis: Iodine Value (140, 120, 100, 80, 60, 40, 20, 0)
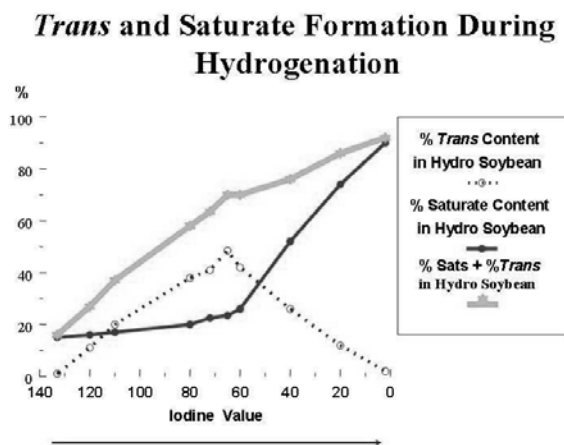
* Source of Chart: Cargill Dressings, Sauces and Oils

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.

The second process is enzymatic interesterification. This process rearranges the fatty acids (can be position specific) on the glycerol backbone of the triglyceride through the use of an enzyme. Higher temperatures will result in inactivation of the enzyme. After interesterification, the oil is deodorized to make finished oil products.

The predominant commercial application for interesterification in the US is the production of specialty fats. These processes permit further tailoring of triglyceride properties to achieve the required melting curves.

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 regulations governing levels, mode of addition, and product labeling. Typical examples of industry practice are listed in Table IV.

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 V. Use of processing aids also must comply with federal regulations which specify good manufacturing practices and acceptable residual levels.

TABLE IV
SOME DIRECT FOOD ADDITIVES USED IN FATS AND OILS

Additive	Effect Provided
Tocopherols Butylated hydroxyanisole (BHA) Butylated hydroxytoluene (BHT) Tertiary butylhydroquinone (TBHQ) Propyl Gallate (PG)	Antioxidant, retards oxidative rancidity
Carotene (pro-vitamin A)	Color additive, enhances color of finished foods
Dimethylpolysiloxane (Methyl Silicone)	Inhibits oxidation tendency and foaming of fats and oils during frying
Diacetyl	Provides buttery odor and flavor to fats and oils
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 V
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.	Diffusion, vaporization
Silica hydrogel	Adsorbent	Filtration

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. Lack of stability results in separation of the oil and water phases. Some emulsifiers also provide valuable functional attributes in addition to emulsification. These include 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 VI.

VII. HEALTH ASPECTS OF FATS AND OILS

A. General

Fats are a principal and essential constituent of the human diet along with carbohydrates and proteins. Fats are a major source of energy which supply about 9 calories per gram. Proteins and carbohydrates each supply about 4 calories per gram.

In calorie deficient situations, fats together with carbohydrates are used instead of protein and improve growth rates. Some fatty foods are sources of fat-soluble vitamins, and the ingestion of fat improves the absorption of these vitamins regardless of their source. Fats are vital to a palatable and well-rounded diet and provide the essential fatty acids, linoleic and linolenic.

TABLE VI
EMULSIFIERS AND THEIR FUNCTIONAL CHARACTERISTICS
IN PROCESSED FOODS

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

B. Essential Fatty Acids

"Essential" fatty acids have been generally regarded as those which are required by humans but are not synthesized by the body and must be obtained through the diet. Linoleic and linolenic acids are essential fatty acids. They serve as substrates for the production of polyunsaturated fatty acids used in cellular structures and as precursors for the production of the body's regulatory chemicals such as glycerolipids, long chain polyunsaturates and hormone-like compounds called eicosanoids. The lack of alpha-linolenic acid has been associated with neurological abnormalities and poor growth. A lack of linolenic acid is associated with scaly dermatitis and poor growth.

The Institute of Medicine of the National Academies in 2002[2] established the first recommended daily intake (RDI) values for linoleic acid at 17 grams for adult men and 12 grams for adult women. The RDI for alpha-linolenic acid was set at 1.6 grams for adult men and 1.1 grams for adult women. RDI's were also established for children, and pregnant and lactating women.

C. Fat Soluble Vitamins (A, E, D and K)

Because they are soluble in fats, the vitamins A, E, D and K are sometimes added to foods containing fat (e.g., vitamin A and D in milk, vitamin A in margarine) because they serve as good carriers and are widely consumed. Vegetable oils are a major source of vitamin E (tocopherols) which act as antioxidants in promoting anti-atherogenic properties such as decreasing LDL cholesterol uptake. Soybean oil and canola oil are important dietary sources of vitamin K. Fats are not generally considered good sources of other fat soluble vitamins.

D. Metabolism of Fats and Oils

In the intestinal tract, dietary triglycerides are hydrolyzed to 2-monoglycerides and free fatty acids. These digestion products, together with bile salts, aggregate and move to the intestinal cell membrane. There the fatty acids and the monoglycerides are absorbed into the cell and the bile acid is retained in the intestines. Most dietary fats are 95-100% absorbed. In the intestinal wall, the monoglycerides and free fatty acids are recombined to form triglycerides. If the fatty acids have a chain length of ten or fewer carbon atoms, these acids are transported via the portal vein to the liver where they are metabolized rapidly. Triglycerides containing fatty acids having a chain length of more than ten carbon atoms are transported via the lymphatic system. These triglycerides, whether coming from the diet or from endogenous sources, are transported in the blood as lipoproteins. The triglycerides are stored in the adipose tissue until they are needed as a source of calories. The amount of fat stored depends on the caloric balance of the whole organism. Excess calories, regardless of whether they are in the form of fat, carbohydrate, or protein, are stored as fat. Consequently, appreciable amounts of dietary carbohydrate and some protein are converted to fat. The body can make saturated and monounsaturated fatty acids by modifying other fatty acids or by *de novo* synthesis from carbohydrate and protein. However, certain polyunsaturated fatty acids, such as linoleic acid, cannot be made by the body and must be supplied in the diet.

Fat is mobilized from adipose tissue into the blood as free fatty acids. These form a complex with blood proteins and are distributed throughout the organism. The oxidation of free fatty acids is a major source of energy for the body. The predominant dietary fats (i.e., over 10 carbons long) are of relatively equal caloric value. The establishment of the common pathway for the metabolic oxidation and the energy derived, regardless of whether a fatty acid is saturated, monounsaturated, or polyunsaturated and whether the double bonds are *cis* or *trans*, explains this equivalence in caloric value.

E. Dietary Fat and Disease

1. *Cardiovascular Disease*

Cardiovascular disease (CVD), which includes heart attack and stroke, is the leading cause of death in the U.S. accounting for 38% of all deaths in 2002.[3] Of the three forms of CVD, the most predominant is coronary heart disease or "heart attack," and it is responsible for over 656,000 deaths per year. The second, strokes, are generally the blockage or hemorrhage of a blood vessel leading to the brain causing inadequate oxygen supply and often long-term impairment of sensation or functioning of part of the body. Atherosclerosis, the third, is the gradual blocking of the arteries with deposits of lipids, smooth muscle cells and connective tissue.

Cardiovascular diseases are chronic degenerative diseases commonly associated with aging. A number of risk factors for CVD have been identified as follows: positive family history of CVD, tobacco smoking, hypertension (high blood pressure), elevated serum cholesterol, obesity, diabetes, physical inactivity, male sex, age and excessive stress. While these factors are not proven to be causative of CVD, they have been shown by epidemiological studies to have certain relationships to the incidence of CVD.

Diet is thought to influence the levels of serum cholesterol which is a major risk factor for CVD. Health experts have advised diet modification to reduce serum cholesterol levels. These modifications include reducing the consumption of total fat, saturated fat, *trans* fat and cholesterol. Recent research has indicated that the quality or type of fat may be more important than the quantity of fat in reducing CVD risk.[4]

Serum cholesterol is composed largely of two general classes of lipoprotein carriers, low density lipoprotein (LDL) and high density lipoprotein (HDL). Elevated levels of LDL cholesterol are associated with increased risk of coronary heart disease due to an association with cholesterol deposits on artery walls. HDL cholesterol on the other hand, is recognized as beneficial because it apparently carries cholesterol out of the bloodstream and back to the liver for breakdown and excretion.

The levels of total serum cholesterol and the LDL and HDL fractions in the blood are influenced by several factors, including age, sex, genetics, diet and physical activity. Since diet and exercise may be controlled by man, they are the basis for recommendations to reduce risk factors for coronary heart disease.

In general, diets high in saturated fats increase total cholesterol as well as LDL and HDL cholesterol compared to diets low in saturated fats. Palmitic, myristic and lauric fatty acids increase both LDL and HDL cholesterol, whereas stearic acid and medium-chain saturated fatty acids (6 to 10 carbon atoms) have been considered to be neutral regarding their effects on blood lipids and lipoproteins.

Monounsaturates and polyunsaturates lower serum cholesterol when they replace significant levels of saturates and *trans* fat in the diet. Clinical studies show that polyunsaturates lower LDL and total cholesterol to a greater extent.

U.S. public health officials made dietary recommendations during the 1960's to decrease the intake of saturates and cholesterol by limiting the consumption of animal fats. Food manufacturers, in response to this advice, expedited a switch to partially hydrogenated vegetable oils away from animal fats. While partially hydrogenated fats have been used successfully in many foods over the past five decades, questions have arisen as to their health effects. The principal isomeric fatty acid of interest has been *trans* fatty acids rather than the positional isomers of *cis* fatty acids. Studies on the health effects of *trans* fats have focused on their levels in the U.S. diet and their effects on parameters related to coronary heart disease risk. [See Health Effects of *Trans* Fatty Acids in Section VII, H. (2)]

Based on clinical studies, animal models, and epidemiological evidence collected during the past two decades, scientists generally agree that diets high in *trans* fats tend to increase serum LDL cholesterol, thus suggesting a positive relationship with increased risk of coronary heart disease. Although some studies have indicated diets high in *trans* fats tend to lower serum HDL cholesterol, such studies are inconsistent. In response to this body of scientific evidence on *trans* fats and their effects on blood lipids, health advisory organizations such as the National Institutes of Health (NIH) and American Heart Association (AHA). have suggested a reduction of *trans* fats along with saturated fat and cholesterol in the U.S. diet.

Food manufacturers are seeking alternatives to partially hydrogenated fats as food ingredients to help reduce *trans* fatty acid levels in the U.S. diet. Food products containing solid fats will remain available to consumers but careful thought will be necessary to address how much saturated fat may be added to foods to compensate for the functional loss of partially hydrogenated fats and what types of saturated fat will be used. Much debate is underway regarding the appropriateness of reformulating foods using palmitic or stearic acid (or some combination thereof) relative to their health effects. The preponderance of evidence suggests that stearic acid does not raise or lower serum LDL cholesterol levels while debate continues concerning the effects of palmitic acid on serum cholesterol levels.

Omega-3 fatty acids comprise a group of fatty acids receiving attention in recent years regarding their ability to reduce the risk of chronic disease such as coronary heart disease, stroke and cancer. Omega-3 fatty acids are found predominantly in cold water fish [e.g. eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA)] and to a lesser extent in walnut oil, soybean and canola oils (e.g., alpha-linolenic acid).

Fish consumption has been found to be associated with a lowered risk of coronary mortality in both men[5,6] and women.[7] Solid clinical evidence suggests that EPA and DHA reduce triglyceride levels as well as blood pressure thus reducing the risk of CVD. A recent study[8] has indicated that eating tuna and other cold water fish once or twice a week reduces the risk of developing congestive heart failure in people over 65

years of age by 20 percent and by 31 percent if consumed 3-4 times per week.

Alpha linolenic acid has been shown to offer beneficial effects in protecting against cardiovascular disease in some but not all studies. Two large prospective studies in 76,283 nurses[9] and 43,757 health professionals[10] indicated that alpha linolenic acid protected against cardiac death and heart attacks independently of other dietary or non-dietary factors.

Plant sterols are components from vegetable oils that have been recognized for their ability to lower levels of serum cholesterol. Plant sterols are known to lower serum cholesterol by inhibiting cholesterol absorption during the digestive process. Plant stanols are the saturated form of plant sterols which can be found naturally (coniferous trees) or produced from plant sterols. Due to their limited solubility when unesterified, fatty acids are combined with plant sterols/stanols to form steryl/stanyl esters which are more soluble, particularly in fats and oils, and more functional food ingredient. The FDA has granted an interim final health claim for steryl/stanyl esters reducing the risk of coronary heart disease. At this time, the FDA recognizes that plant sterols/stanols (not esterified) lower serum cholesterol but have yet to issue a final rule for the steryl ester health claim which includes plant sterols. Plant sterols/stanols are recognized to be equally effective by scientific experts that study their impact on serum cholesterol levels. Commercial food products such as margarines, spreads, and salad dressings in the E.U. and the U.S. have incorporated both sitosterol and sitostanol-based products into foods to help reduce coronary heart disease risk.

Conjugated linoleic acid (CLA), commonly found in dairy products, is another lipid-based compound which has been found to contain both antiatherogenic as well as anticarcinogenic properties and may affect body composition. "CLA" is a collective term for a group of isomers of the essential fatty acid linoleic acid. Animal studies have shown CLA to reduce the incidence of tumors induced by dimethylbenz(a)anthracene and benzo(a)pyrene.[11,12,13,14,15,16,17] Animal studies[18,19] have also shown that CLA suppresses total and LDL cholesterol and the incidence of atherosclerosis. Body composition may also be affected by dietary CLA.[20,21] Further research is necessary to elucidate the mechanisms by which CLA generates these effects and to confirm these effects in humans.

2. *Cancer*

Cancer is the second leading cause of death behind heart disease in the U.S. accounting for 557,221 deaths in 2002 or 22.8% of total U.S. mortality.[22] The three most common sites of fatal cancer in men are lung, prostate and colo-rectal. In women, the three most common sites are lung, breast and colo-rectal. In men and women, cancers at these sites account for about half of all cancer fatalities.

The American Institute for Cancer Research (AICR) has suggested that 30-40% of all cancers are linked to the diet, exercise and the incidence of obesity.[23] AICR has also estimated that cigarette smoking is responsible for about one-third of cancer deaths in the U.S. Therefore cancer risk may be modified to a certain extent by lifestyle changes. Adapting healthful diets and exercise practices at any stage of life can promote health and reduce the risk of cancer.

The risk of cancer is most commonly expressed by researchers as the probability that an individual over the course of a lifetime will develop or die from cancer. In the U.S., men have slightly less than a 1 in 2 lifetime risk of developing cancer, whereas in women, the risk is slightly more than a 1 in 3.

The American Cancer Society has established nutrition and physical activity guidelines to help Americans reduce their risk of cancer as well as heart disease and diabetes:[24] (1) Eat a variety of healthy foods with an emphasis on plant sources. Many epidemiologic studies have shown that populations that eat diets high in fruit and vegetables and low in animal fat, meat, and/or calories have a reduced risk of some common cancers. (2) Adopt a physically active lifestyle. Adults are suggested to engage in at least 30 minutes of moderate exercise on 5 or more days per week. (3) Maintain a healthy weight throughout life. Caloric intake should essentially be balanced with energy expenditure (physical activity). If overweight or obese, weight reduction is advised since overweight and obesity are associated with increased risk of breast, colon, rectum, esophagus, gall bladder, pancreas, liver and kidney cancer. Weight loss is associated with reduced levels of circulating hormones which are associated with increased cancer risk. Overweight people are advised to achieve and maintain a healthy body weight (i.e., a body mass index of less than 25 kg/m^2. (4) If you drink alcoholic beverages, limit consumption. Men should drink no more than 2 drinks per day and women no more than 1 drink per day.

During the past two decades many scientific studies including animal models, epidemiological observations and clinical trials have been conducted to address the effects of diet on cancer. Definitive evidence regarding this relationship has been difficult to document. While it was once thought that breast and colon cancer risk were linked to high fat diets, more recent large prospective studies have found little, if any, relationship between the two.[25,26] The evidence linking prostate cancer to high fat diets is even less defined. It appears that certain types of cancer in developed countries may be related more to excessive calories in the diet rather than to specific nutrients.

There has also been interest in recent years regarding the effects of individual types of fatty acids on cancer risk. A relatively recent assessment of the literature suggests that specific saturated, monounsaturated, or polyunsaturated fatty acids do not affect cancer risk.[27] Although some animal studies have suggested that polyunsaturated fatty acids may increase tumor growth, no relationship has been found between polyunsaturated fatty acids and cancer in humans.[28]

A study at Yale University of 1119 women who were breast cancer patients revealed that there were no significant trends associating any fatty acid or macronutrient to the risk of breast cancer.[29]

Little research has been conducted regarding *trans* fats' association with cancer. A comprehensive review by Ip and Marshall [30] revealed that epidemiologic data shows the intake of fat in general to have slight to negligible effect on breast cancer risk and no strong evidence linking *trans* fats to breast cancer risk. No association was made between *trans* fats and colon or prostate cancer.

A study by Slattery, et al,[31] found a weak association in women but not in men between those consuming diets high in *trans* fats and the risk of colon cancer. Those women not using nonsteroidal anti-inflammatory drugs had a slightly increased risk of colon cancer.

Epidemiological evidence is accumulating that indicates there may be associations between high intakes of red meat and increased risk of colon cancer,[32,33,34] however more work is needed to gain more definitive relationships. Several mechanisms have been suggested for such relationships including the presence of heterocyclic amines formed during cooking and nitrosamine compounds in processed meats.

F. DIET AND OBESITY

The dramatic rise in obesity rates among adults and children over the past two decades has become a major public health concern since obesity is linked to several chronic diseases including heart disease, Type 2 diabetes, high blood pressure, stroke and certain cancers. It has been estimated that 65% of the adult U.S. population is either obese or overweight.[35] The percentage of overweight children has nearly tripled since 1970 with almost 16% of all children and teens (ages 6-19) being overweight.[36]

Obesity is a complex issue requiring comprehensive solutions including the strategies of altered eating habits, increased physical exercise, public health education programs, expanded nutrition research and more government/industry partnerships.

Obesity and being overweight are mainly the result of energy imbalance caused by consuming more calories than are burned off through physical exercise. Therefore obesity prevention strategies must encourage more healthy lifestyles and improved weight management practices by individuals. The Dietary Guidelines for Americans 2005[37] recognize these needs and make key recommendations regarding nutrient intake, weight management and physical activity. (See www.healthierus.gov/dietaryguidelines)

G. TRANS FATTY ACIDS

1. Source and amounts of Trans Fatty Acids in the Diet

The principal source of *trans* fatty acids in the current U.S. diet is partially hydrogenated fats and oils used as food ingredients or as cooking mediums such as deep frying fats (see "Partial Hydrogenation/Hydrogenation," Section VI, G.) Small amounts of *trans* fats also occur naturally in foods such as milk, butter, cheese, beef and tallow as a result of biohydrogenation in ruminant animals. Approximately 15-20% of dietary *trans* fatty acids are generated by ruminant sources. Traces of *trans* isomers may also be formed when non-hydrogenated oils are deodorized at high temperatures.

Typical levels of *trans* fatty acids in food products are as follows: frying oils in restaurants and food service operations may range from 0 to 35% *trans* fatty acids expressed as a percent of total fatty acids. Some operations may use unhydrogenated "salad" oils for frying which contain minimal *trans* fats, whereas

other "heavy duty" frying applications may use frying fats containing up to 35% *trans* fats. Most margarines and spreads have been reformulated to contain "no" *trans* fat per serving. Baking shortenings typically contain about 15-30% *trans* fatty acids. Beef and dairy products typically contain about 3% *trans* fats. The content of *trans* fatty acids in the U.S. diet from partially hydrogenated sources is expected to continue decreasing as food manufacturers develop alternative sources to ingredients containing *trans* fatty acids.

The level of *trans* fats available in the diet has decreased in recent years. A study conducted in 1991 by ISEO[38] using 1989 data, revealed 8.1 g *trans* fats per day to be available for consumption. This study was based on a comprehensive analysis of products made from partially hydrogenated fats and oils that were available for consumption. A study by Allison, et al[39], in 1999 using USDA's Continuing Survey of Food Intakes by individuals revealed the mean intake of *trans* fatty acids in the U.S. to be 5.3 g. per day or about 2.6% energy. Harnach, et al[40], 2003, reported that the mean intake of *trans* fatty acids in an adult population in the Minneapolis-St. Paul, MN metropolitan area decreased from 3% total energy in 1980-82 to 2.2% total energy in 1995-97. The intake of *trans* fatty acids in 14 European countries[41] has been reported in 1999 to range from 1.2-6.7 g per day or 0.5 - 2.1% total energy with an overall mean of 2.4 g per day.

2. *Health Effects of Trans Fatty Acids*

Prior to 1990 most of the studies on the biological effects of *trans* fats focused on their effects on serum cholesterol levels and the development of atherosclerosis. The findings in general did not indicate *trans* fats were uniquely atherogenic or raised total cholesterol compared to *cis* fatty acids. However, a 1990 study by Mensink and Katan[42] revealed diets high in *trans* fatty acids (11.0% energy) raised total and LDL cholesterol and lowered HDL cholesterol in humans compared to a high oleic acid diet. A subsequent study by the same researchers[43] using a lower level of *trans* fatty acids (7.7% energy) revealed similar results when compared to a high linoleic acid diet but not when compared to a high stearic acid diet.

The unexpected results of these studies stimulated other clinical trials investigating the health effects of *trans* fatty acids. One of the most comprehensive trials was conducted by Judd, et al[44] in 1992 which found that diets high (6.6% energy) and moderate (3.8% energy) in *trans* fatty acid content increased total and LDL cholesterol compared to an oleic acid diet but reduced total and LDL cholesterol

compared to a high saturated fatty acid diet. The high *trans* diet but not the moderate *trans* diet resulted in a minor decrease in HDL cholesterol.

A study by Aro, et al[45] in 1997 compared the effects on serum lipids and lipoprotein of diets high in stearic acid, *trans* fatty acids, and dairy fat. The *trans* fat diet (8.7% energy) and the stearic acid diet (9.3% energy) both decreased total cholesterol levels compared to the dairy fat diet. The *trans* fat diet, however, decreased HDL cholesterol significantly more than did the stearic acid diet. Stearic acid reduced LDL cholesterol concentrations compared to the dairy fat diet. Lipoprotein (a) [Lp(a)] concentrations increased in both experimental diets, but more so with the *trans* fat diet than the stearic acid diet. The authors concluded that both *trans* fats and saturated fats should be lowered in the diet.

Lichtenstein, et al[46] in 1999 compared the effects of 30% fat diets containing stick margarine, shortening, soft margarine, semi-liquid margarine, unhydrogenated soybean oil or butter in adults. *Trans* fat levels expressed as percent energy are as follows: stick margarine (6.72%), shortening (4.15%), soft margarine (3.30%), semi-liquid margarine (0.91%), soybean oil (0.55%) and butter (1.25%). LDL cholesterol was reduced 12%, 11%, 9%, 7% and 5% after diets enriched respectively as listed above, compared to butter. HDL cholesterol was reduced 3%, 4%, 4%, 4% and 6% respectively. Total cholesterol/HDL cholesterol ratios were lowest after the stick margarine diet. The authors concluded that consumption of foods low in *trans* fatty acids and saturated fat has beneficial effects on serum lipoprotein levels.

A study by de Roos, et al[47] (2001), compared the effects of a *trans* fat rich diet and a saturated fat diet on serum lipids. The *trans* fat diet, made from partially hydrogenated soybean oil, contained 9.3% energy as *trans* fat, whereas the saturated fat diet contained lauric acid at 6.8% energy. The LDL/HDL ratio was higher after the *trans* fat diet than after the lauric acid diet.

Miller, et al[48] (2001) developed regression equations to predict effects on total serum and LDL cholesterol levels of dietary *trans* fats and individual saturated fatty acids. The regression equations were based on four controlled studies using partially hydrogenated soybean oil and partially hydrogenated fish oil as the food sources of *trans* fats. The authors concluded that myristic acid is the most hypercholesterolemic fatty acid, and that *trans* fats are less hypercholesterolemic than the saturated fats myristic and palmitic acids. Hydrogenated fish oil was slightly

more hypercholesterolemic than hydrogenated soybean oil.

A second carefully controlled study by Judd, et al[49] was published in 2002. Subjects were fed diets containing high *trans* fat (8.3%), moderate *trans* fat (4.2%), stearic acid (10.9%), saturated fat (lauric, myristic, palmitic) (sum = 18%), and carbohydrates (54.5%). The results showed the high *trans* diet raised LDL cholesterol levels the most, followed by moderate *trans* fat and saturates, then stearic acid, carbohydrates and oleic acid. HDL cholesterol levels were lowest with high *trans* fat, moderate *trans* fat, and stearic acid diets, the highest value was with the saturated fat diet, and oleic acid and carbohydrate diets were intermediate.

In addition to clinical studies, several epidemiological studies have examined the relationship of dietary *trans* fatty acids to health. Epidemiologic studies indicate associations between two variables, but such studies do not identify cause and effect relationships. The associations identified in epidemiological studies are often useful in providing direction for clinical trials which offer "harder" scientific evidence for diet/disease relationships.

During the early 1990's a series of epidemiological studies was initiated at the Harvard School of Public Health using data from a prospective study known as the Nurse's Health Study involving a cohort of over 85,000 nurses. Willet, at al[50] reported in 1993 that there was a positive association between *trans* fatty acid intake and subsequent coronary heart disease (CHD) in women. The authors concluded that partially hydrogenated vegetable oil contributed to the occurrence of CHD.

Hu, et al[51] (1997) also using data from the Nurse's Health Study, reported that replacing 5% of energy from saturated fat with unsaturated fat was associated with a 42% decrease in CHD risk, whereas replacing 2% of energy from *trans* fatty acids with *cis* fatty acids was associated with a 53% decrease in CHD risk. Total fat intake was not related significantly with the risk of CHD. The authors concluded that replacing saturated and *trans* fats in the diet with monounsaturated and polyunsaturated fatty acids was more effective in preventing CHD in women than by reducing overall fat intake.

In another epidemiological study by Oomen, et al[52] (2001), the association of *trans* fats and CHD risk was assessed in a population of elderly Dutch men over a ten-year period (1985-1995). *Trans* fat intake was found to have decreased from 10.9 g/d in 1985 to 6.9 g/d

in 1990 to 4.4 g/d in 1995. After adjustment for age, body mass index, smoking and dietary covariates, *trans* fats were positively associated with heart disease. The authors also reported that the health effects of *trans* fatty acids from ruminant sources are similar to those from partial hydrogenation of vegetable or fish oils.

Some epidemiologic studies have linked *trans* fatty acids to other chronic diseases. Salmeron, et al[53] (2001), using data from the Nurse's Health Study, reported that an increase in polyunsaturated fatty acid intake and a decrease in *trans* fatty acid intake substantially reduces the risk of developing Type 2 diabetes in women. The authors estimate that replacing 2% energy as *trans* fatty acids with polyunsaturated fatty acids would result in a 40% reduction in the incidence of Type 2 diabetes in women.

Clandinin and Wilke[54] (2001) however were highly critical of Salmeron, et al's study explaining that epidemiologic evidence linking *trans* fatty acids to diabetes is lacking. They contended that error involved in the use of food frequency questionnaires limits the ability to measure a change in fat intake of only 2% energy. Other complications in interpreting the Salmeron study include the variability of *trans* fat content in similar foods over time, and the fact that some foods containing *trans* fats also contain large amounts of refined carbohydrates (e.g., baked goods) which could exacerbate the insulin-resistant state in diabetics or contribute to increased serum triglyceride levels. The authors conclude that there is no known functional or physiologic reason to relate *trans* fatty acids to the mechanisms of Type 2 diabetes.

A study by van Dam[55] (2002) examined dairy fat and meat intake relative to the risk of Type 2 diabetes in participants of the Health Professionals Follow-up Study. Intakes of total fat and saturated fat were associated with increased risk of diabetes, but these associations disappeared after adjustment for body mass index. Intakes of oleic acid, *trans* fatty acids, long chain n-3 fatty acids and alpha linolenic acid were not associated with diabetes risk after multivariate adjustment.

Relatively few investigators have studied the relationship of *trans* fatty acids to cancer. Ip and Marshall[56] conducted a comprehensive review in 1996 of over 30 reports addressing scientific data on *trans* fats and cancer. They report only slight to negligible impact of fat intake on breast cancer risk and no strong evidence that *trans* fats are related to increased risk. There also appear to be no evidence linking *trans* fat intake to colon

cancer or prostate cancer risk. In general the current available scientific evidence does not support a relationship between *trans* fat intake and cancer risk at any of the major cancer sites.

There have been a number of reviews examining the scientific literature on *trans* fatty acids and their health effects. The International Life Sciences Institute[57] (ILSI) in 1995 examined the relationship between *trans* fatty acids and coronary heart disease. This review examined epidemiologic evidence which linked *trans* fatty acids to higher total cholesterol and LDL cholesterol levels and increased incidence of death related to CHD. The authors noted that the associations between *trans* fatty acid intake and CHD risk are weak and inconsistent compared to the large body of evidence from epidemiologic observations as well as animal models and clinical trials that support a direct effect of saturated fat on CHD risk. The report emphasized that since *trans* fatty acids are often substituted for unsaturated fatty acids in clinical trials, it is unclear whether the responses reflect the addition of *trans* fatty acids to the diets or the reduction in dietary unsaturated (i.e., cholesterol lowering) fatty acids.

Another review of the literature by Katan, et al[58] in 1995 summarized the studies on the effects of *trans* fatty acids on lipoproteins in humans. The authors concluded that *trans* fatty acids raise plasma LDL cholesterol when exchanged for *cis* unsaturated fatty acids in the diet. They also suggested that *trans* fatty acids may lower HDL cholesterol levels and raise Lp(a) levels compared to *cis* fatty acids. The authors recommended that diets aimed at reducing the risk of CHD be low in both *trans* fatty acids and saturated fatty acids.

Katan[59] subsequently reviewed the literature in 2000, particularly addressing the studies of the past ten years. He concluded that diets containing high levels of *trans* fatty acids (4-10% energy) resulted in increases of LDL cholesterol and decreases in HDL cholesterol. Katan suggested that partially hydrogenated oils contributed to the occurrence of CHD. He further suggested consumers reduce intakes of both saturated and *trans* fatty acids for the prevention and treatment of cardiovascular diseases.

Another review conducted by Ascherio, et al[60] in 1999 examined nine metabolic and epidemiologic studies and concluded that *trans* fatty acids increase the risk of CHD. The authors suggested that the adverse effect of *trans* fatty acids appears to be stronger than that of saturated fatty acids. This conclusion was based on a graph depicting the change in LDL/HDL cholesterol

ratio versus the percentage of energy from either *trans* fatty acids or saturated fatty acids. The graph contained best fit regression lines through the origin for both percentage of energy from *trans* fatty acids and from saturated fatty acids. Both regression lines had positive slopes, however the slope of the regression line for *trans* fatty acids was larger than that for saturated fatty acids. This difference in slopes led to the conclusion that *trans* fatty acids may have more adverse effects on CHD risk than saturated fatty acids.

A major review of the scientific literature on the effects of dietary *trans* fatty acids is included in a report on reference intake levels of macronutrients by the National Academy of Sciences' Institute of Medicine (IOM)[61] in 2002. This report stated that similar to saturated fatty acids, there is a positive linear trend between *trans* fatty acid intake and LDL cholesterol concentration, therefore indicating an increased risk of CHD. The IOM report did not establish a "tolerable upper intake level" above which long-term consumption may be undesirable for some individuals. The IOM report noted that *trans* fatty acids are unavoidable in ordinary non-vegan diets and that eliminating them from the diet would require significant changes in patterns of dietary intake. Such adjustments may result in inadequate intake of certain nutrients (e.g., protein and certain micronutrients) and increase certain health risks. The report recommended that "*trans* fatty acid consumption be as low as possible while consuming a nutritionally adequate diet."

A meta-analysis of 60 controlled clinical trials by Mensink, et al,[62] in 2003 was conducted to examine the effects of individual fatty acids on the ratio of total to HDL cholesterol and on serum lipoproteins. The study found that the effect on the total to HDL cholesterol ratio by replacing *trans* fatty acids with a mixture of carbohydrates and *cis* unsaturated fatty acids was much greater than that of replacing saturated fatty acids. Total to HDL cholesterol is thought to be a more specific marker of coronary artery disease (CAD) than is LDL cholesterol. Lauric acid was found to greatly increase total cholesterol (mainly HDL cholesterol) and decrease the total to HDL cholesterol ratio to the greatest degree. Myristic, palmitic, and stearic acids had little effect on the ratio. The authors concluded CAD risk is reduced most effectively when *trans* fatty acids and saturated fatty acids are replaced with *cis* unsaturated fatty acids, and they emphasized the risk of relying on cholesterol alone as a marker of CAD risk.

A thorough review of the scientific literature on *trans* fatty acids was also undertaken by the International

Life Sciences Institute (ILSI) of North America[63] in 2003 which was included in its comments to FDA regarding the agency's request for information associated with the inclusion of *trans* fatty acid information on food labels. The review examined sixteen controlled intervention trials including the nine studies examined in the review by Ascherio, et al.[52] The data were analyzed to examine the relationships between *trans* fatty acid intake, saturated fatty acid intake, and serum lipids. Based on these data, ILSI concluded (1) it does not seem possible to make a meaningful distinction between the intake of *trans* fatty acids and saturated fatty acids with respect to any differential impact on LDL cholesterol, (2) nor does it seem possible to make a meaningful distinction between the intake of *trans* fatty acids and saturated fatty acids with respect to any differential impact on HDL cholesterol when *trans* fatty acid intake is less than 5% of total energy. Published data (Allison, 1999[41]) suggests that the 90th percentile of *trans* fatty acid intake falls below 5% energy in the North American diet.

In summary, the complete body of scientific evidence indicates that *trans* fatty acids when consumed at sufficient levels can adversely affect LDL cholesterol levels and the risk of CHD. There appears to be a threshold below which *trans* fat intake does not adversely affect HDL cholesterol levels. An examination by Hunter[64] of the same 9 studies reviewed by Ascherio[52] in 1999 revealed that when the effects of LDL-C and HDL-C were evaluated individually (instead of within LDL/HDL ratios) it was found that dietary trans fat is necessary at 4% of energy or higher to sufficiently decrease LDL-cholesterol and at 5-6% energy or higher to significantly decrease HDL-cholesterol when compared to *trans*-free control diets. Most data concerning the effects of *trans* fatty acid consumption address levels that exceed those typical in the U.S. (e.g., 2.6% energy or 5.8 grams per day for a 2000 calorie diet), therefore more extensive data including controlled clinical trials at lower intake levels are necessary to best arrive at meaningful conclusions regarding *trans* fatty acid health effects. In the meantime, most health professionals recommend that dietary *trans* fatty acids, saturated fatty acids and cholesterol be reduced as low as possible.

3. FDA Final Regulation for Labeling Trans Fats in Food

The U.S. Food and Drug Administration (FDA), after carefully evaluating scientific evidence on the health effects of *trans* fats, proposed a regulation on November 17, 1999, which would have basically included *trans* fat within the saturated fat declaration of the nutrition facts panel of food labels. After several amendments to proposals and extensions of comment periods addressing the content and format of *trans* fatty acid information on the label, FDA announced on July 11, 2003, a final regulation on the labeling of *trans* fatty acids in foods. The final rule requires an additional entry immediately below the saturated fat declaration in the nutrition facts panel declaring the amount of *trans* fatty acids in grams per serving. Foods containing less than 0.5 g. per serving must declare "0" as the amount. In lieu of declaring zero grams of *trans* fat, conventional foods containing less than 0.5 g. of *trans* fat per serving and making no claims about fat, fatty acids or cholesterol, may instead place at the bottom of the nutrient table the statement: "Not a significant source of *trans* fat." No percent daily value (% DV) is required for *trans* fat due to insufficient information available from which such a value could be determined. The final regulation became effective on January 1, 2006.

An example of a Nutrition Facts Panel:

Nutrition Facts

Serving Size 1 Tbsp (14g)
Servings Per Container 32

Amount Per Serving

Calories 100	Calories from Fat 100

	% Daily Value*
Total Fat 11g	**17%**
Saturated 2g	**10%**
Trans Fat 2g	
Polyunsaturated Fat 3.5g	
Monounsaturated Fat 3.5g	
Cholesterol 0mg	**0%**
Sodium 115mg	**5%**
Total Carbohydrate 0g	**0%**
Protein 0g	

Vitamin A 6%

*Percent Daily Values are based on a 2,000 calorie diet.

The final rule defines *trans* fat as the sum of all unsaturated fatty acids that contain one or more isolated (i.e., nonconjugated) double bonds in the *trans* configuration. Thus *trans* vaccenic and other *trans* fatty acids of ruminant origin with either a single double bond

or nonconjugated double bonds are included in the definition. *Trans* fatty acids with conjugated bonds, such as conjugated linoleic acid are not included.

H. Dietary Guidelines for Americans 2005

The U.S. Department of Health and Human Services and the U.S. Department of Agriculture jointly announced their Dietary Guidelines for Americans 2005[49] on January 12, 2005 to provide dietary health information to policy makers, nutrition educators and health providers.   The guidance offered in this document, which is updated every 5 years, concentrates on (1) dietary nutrition, (2) maintaining healthy weight, (3) achieving adequate exercise and (4) keeping foods "safe" to eat to avoid foodborne illness.

The Dietary Guidelines 2005 offer the following recommendations regarding dietary fat intake: (1) consume less than 10 percent of calories from saturated fat, less than 300 mg/day of cholesterol, and keep *trans* fat consumption as low as possible, (2) keep total fat intake between 20-35 percent of total calories with most fats coming from polyunsaturated and monounsaturated fat sources, (3) when selecting and preparing meat, make choices that are lean, low-fat, or fat-free, (4) limit intake of fats and oils high in saturated and/or *trans* fat.   The Dietary Guidelines 2005 may be found at www.healthierus.gov/dietaryguidelines.

I. USDA's MyPyramid®

The mechanism to convey the content of the Dietary Guidelines, 2005 to consumers was announced in April, 2005 by the U.S. Department of Agriculture (USDA) as the MyPyramid®, an updated version of the Food Guide Pyramid.   The name "My Pyramid"® reflects the "personalized" approach taken by USDA, which may be accessed at http://www.mypyramid.gov, It provides a wide range of information designed to advise consumers on dietary choices as well as including physical exercise in a daily regimen.   Consumers may enter age, gender and activity level and be provided with tailored dietary/exercise guidelines.

The MyPyramid® differentiates liquid oils and solid fats and encourages consumption of liquid oils. It also explains why "essential fatty acids" are important to the diet and provides charts that recommends fat/oil intake based on age and gender.

J. Nonallergenicity of Edible Oils

Food allergies are caused by the protein components of food. Most edible oils in the U.S. undergo extensive processing (sometimes referred to as "fully refined", discussed in Section VI Processing) which removes virtually all protein from the oil. Fully refined edible oils therefore do not cause allergic reactions because they do not contain clinically significant levels of allergenic protein.[65] Food products containing fully refined edible oils as ingredients are also non-allergenic unless the food products contain other sources of allergenic protein.

Some edible oils may be extracted and processed by procedures that do not remove all protein present. While the vast majority of oils found in the US are refined by processes which remove virtually all protein, mechanical or "cold press" extraction is occasionally used, which may not remove all protein. Studies using cold pressed soybean oil have shown it to be safe; however, insufficient testing has been done to ensure that all cold pressed oils can be safely consumed by sensitive individuals.

Edible oils have been blamed for causing allergic reactions in people, but adequate information to support such views is severely lacking. Many reports alleging edible oil allergenicity have been testimonial in nature. Of those reports that have been scientifically recorded, most lack evidence that edible oils were indeed the causative agent or were even ingested. For example, many investigators did not perform tests to confirm an allergic response from the oil in question nor were analyses conducted to determine if protein was present in the oil. Also many reports do not indicate the extent of processing (i.e., cold pressed vs. refined). There is also a lack of scientific data to determine the levels of proteins needed to cause an allergic reaction; therefore tolerance levels in humans have not been established. Furthermore, the sensitivities of food allergic individuals may vary widely, and allergenic foods may have widely differing abilities to cause allergic responses.

While some consumers are convinced they are allergic to edible oils, there are usually alternate explanations for these reactions. For example, foods containing peanuts, a common allergenic food ingredient, may be cooked in peanut oil. An allergic reaction experienced as a result of eating this food may be mistakenly blamed on the oil. Also foods containing inherent allergens may be cooked in edible oils resulting in traces of the allergenic protein being left behind in the oil which may be absorbed by the fried food. Restaurants and food service facilities should therefore exercise caution in cooking techniques and be able to readily identify not only the oils used but also a complete list of all foods cooked in the oil.

Research in vegetable oil allergenicity has been limited to some degree by the size of the cohorts involved in human trials. The largest trial to date was conducted by Hourihane, et al[66] (1997) involving 60 peanut allergic subjects who were fed two grades of peanut oil (crude and refined) and subsequent reactions recorded. The results of this double blind, crossover trial found that 6 of the 60 subjects exhibited mild reactions as a result of the oral crude peanut oil challenges, whereas none of the 60 subjects fed the refined peanut oil experienced allergic reactions. The authors concluded that refined peanut oil does not seem to be a risk to most people with peanut allergy, and they recommended labeling distinctions to identify refined versus blended oils that may contain crude peanut oil.

Another relatively large double blind, placebo controlled, crossover designed trial was conducted by Taylor, et al[67] (2005) in which 29 soy allergics were given oral challenges compiled from soybean oil samples collected from worldwide sources. None of the 29 subjects experienced adverse reactions to cumulative ingested doses of 16 grams of refined soybean oil. The authors suggested that the "vast majority of soybean allergic individuals can safely include highly refined soybean oil in their diets."

The vast preponderance of edible oils consumed in the US are highly refined and processed to the extent that allergenic proteins are not present in detectable amounts. The majority of well-designed and performed scientific studies indicate that refined oils are safe for the food-allergic population to consume.[68]

K. Biotechnology

Biotechnology has been defined broadly as the commercial application of biological processes. The goal of biotechnology is to develop new or modified plants or animals with desirable characteristics.

The earliest applications of genetic modification have been in the pharmaceutical, cosmetic and agricultural sectors. Agricultural applications to food crops have resulted in improved "input" agronomic traits, which affect how the plants grow. Such traits include higher production yields, altered maturation periods, and resistance to disease, insects, stressful weather conditions, and herbicides. Currently researchers and seed developers are placing more emphasis on improving "output" quality traits which affect what the plant produces. An example of this application is the custom designing of nutrient profiles of food crops for improved nutrition and reduced allergenic properties.

The more notable commercialized biotechnology applications within the oilseed industry include herbicide tolerant soybeans and canola, high and mid oleic sunflower, low linolenic soybeans, high linoleic flaxseed, and low linolenic and high oleic canola. Exciting opportunities for edible oil crop nutrient content and functionality improvement include reduction in saturated fatty acid content, improved oxidative stability resulting in a reduced need for hydrogenation, reduced calories or bioavailability, creation of specific fatty acid profiles for particular food applications, plants able to create omega-3 fatty acids, vitamin E fortified oilseeds, and creative "functional" foods for the population at large or for medical purposes. Other applications may include increased oil yield, improved extraction of oil from oilseeds through enzyme technology, industrial production of fatty acids, and improved processing methods.

Genetic engineering is a specific application of biotechnology. This technique is also called recombinant DNA technology, gene splicing, or genetic modification, and involves removing, modifying, or adding genes to a living organism. New plant varieties that result from genetic engineering are referred to as transgenic plants. The most recognized examples in the U.S. are herbicide resistant soybeans, corn which is resistant to the European corn borer, and cotton which is resistant to the bollworm. The acceptance and utilization of these and other transgenic food crops in the U.S. have been very rapid. Approximately 52% of all corn, 79% of all cotton and 87% of all soybeans planted in the U.S. in 2005 were transgenic varieties.[69]

Global plantings of transgenic crops have also increased at rapid rates. While about 4.2 million acres were planted to transgenic crops internationally in 1996, about 200 million acres were planted in 2004.[70] Worldwide acreage will likely continue to expand at a rapid pace for the next several years. The most popular crops as a percent of total global acreage planted to transgenic crops are the following: soybeans (56%), corn (28%), canola (19%), and cotton (14%). The United States is the leader in agricultural applications of genetically engineered crops representing 59% of the total global acreage devoted to transgenic crops in 2004, followed by Argentina with 20%, Canada with 6%, Brazil with 6% China with 5%, and Paraguay with 2%.

In the U.S., the Food and Drug Administration has principal regulatory responsibility in coordination with USDA and EPA for approving the introduction of foods and food additives from transgenic plants into the marketplace. The agency has maintained a

biotechnology policy since 1992, which states that foods derived from new genetically engineered plant varieties will be regulated essentially the same as foods derived from plants established through conventional plant breeding methods. Labeling of such foods or food additives is not required unless the nutrient composition is significantly altered, allergenic proteins have been introduced into the new food, or unique issues have been posed which should be communicated to consumers.

While food biotechnology has been well received in the U.S., global acceptance has been somewhat slower in certain geographic regions such as Europe. The European Union, for example, maintained a five-year moratorium on the approval of new genetically modified plant varieties until 2004 at which time a relatively strict regulation was finalized requiring products from genetically modified sources to be labeled as such and that these products be traceable as to their origins as food crops. It is anticipated that global acceptance of food biotechnology will increase as its safety is better understood and its significant economic, environmental and social benefits are recognized.

One of the next challenges of the global fat and oil community will be to address a uniform method by which genetically modified edible oils of new and differing fatty acid profiles may be identified. Codex Alimentarius has undertaken the task of establishing criteria by which such oils may be named.

Biotechnology will play an important role in the development of agronomic characteristics, nutrient composition, and functionality in foods. Industrial applications of new oilseed plant varieties will also significantly expand as a result of this technology.

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. 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. In autoxidation, oxygen reacts with unsaturated fatty acids. 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 the degree of unsaturation, the presence of antioxidants, and other factors. The presence of light, for example, increases the rate of oxidation. It is common practice in the industry to protect fats and oils from oxidation to preserve their acceptable flavor and to maximize shelf life.

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 has been found that oxidatively abused fats can complicate nutritional and biochemical studies because they can affect food consumption under *ad libitum* feeding conditions and also reduce the vitamin content of the food. If the diet has become unpalatable due to excessive oxidation of the fat component and is not accepted by the animal, a lack of growth by the animal could be due to its unwillingness to consume the diet. Thus, the experimental results might be attributed unwittingly to the type of fat or other nutrient being studied rather than to the condition of the ration. Knowing the oxidative condition of unsaturated fats is extremely important in biochemical and nutritional studies with animals.

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 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). Dimethylsilicone is usually added to institutional frying fats and oils to reduce oxidation tendency and foaming at elevated temperatures. Frequently, partial hydrogenation is employed in the processing of liquid vegetable oil to increase the stability and functionality of the oil. Also, oxidative stability has been increased in many of the oils developed through biotechnological engineering, a technique which effects a change in the fatty acid composition of an oil. The stability of a fat or oil may be predicted to some degree by determining the oxidative stability index (OSI).

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 in insignificant quantities. 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. Animal studies have shown that polymers present in a fat or oil will be poorly absorbed from the intestinal tract and as such will be excreted in the feces.

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, and duration). The composition of a frying fat 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 fat while some of the frying fat will be absorbed by the food. In this manner the fatty acid composition of the frying fat will change as frying progresses. Since absorption of fat by the fried food

may be extensive, it is often necessary to replenish the fryer with fresh fat. Obviously, this replacement with fresh fat tends to dilute overall compositional changes of the fat that would have taken place during prolonged frying. Frying conditions do not, however, 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 frying fat when (1) prolonged frying causes excessive foaming of the hot oil, (2) the fat tends to smoke excessively, usually from prolonged frying with low fat turnover, or (3) an undesirable flavor or dark color develops. Any or all of these qualities associated with the fat 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°, 620°, and 670°, respectively.

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.*[71]

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

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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.

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, 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 VII. 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 monounsaturates (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.

TABLE VII

TYPICAL FATTY ACID COMPOSITION OF THE PRINCIPAL VEGETABLE AND ANIMAL FATS AND OILS IN THE U.S.[1]
(% 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
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	
Peanut								11		2	1	3	2			48		2	32	
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.

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 canola, safflower, soybean and sunflower oils, low linolenic canola and soybean oils, mid oleic sunflower oil, and linola oil (low 18:3 flaxseed oil).

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 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. Oils used in the production of these products are generally partially hydrogenated and often two or more stocks are blended in order to deliver the required performance characteristics including storage stability, creamy consistency over a wide temperature range and the ability to incorporate and hold air. 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. Hence, they are generally rather significantly hydrogenated to convey the required stability. 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)

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) and are generally characterized by a steep melting profile thereby delivering quick and complete flavor release. They are typically produced from the oils and fats common to many other food products (e.g., soybean, cottonseed, palm, palm kernel and coconut) as well as from some less familiar fats like illipe, kokum, shea, and sal. Processing techniques employed to produce these products include hydrogenation, fractionation and interesterification.

E. Margarine and Spreads

Margarine and spreads are prepared by blending fats and/or oils with other ingredients such as water and/or milk products, suitable edible proteins, salt, flavoring and coloring materials and Vitamins A and D. Margarine must contain at least 80% fat by federal regulation, however, "diet" margarines and spreads may contain 0-80% fat. They are available in stick, tub, liquid and spray forms. These products may be formulated from vegetable oils and/or animal fats, however, the vast preponderance are all vegetable.

Non-hydrogenated oils typically represent the majority of the fat phase. Lesser amounts of partially hydrogenated stocks, fats that are naturally semisolid at room temperature and/or hard fractions of certain fats are added to the blend as required to deliver the desired structure and melting properties. Interesterification can be employed to further tailor product character.

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.

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.

H. Lipids for Special Nutritional Applications

Medium chain triglycerides (MCT) containing C_6 to C_{10} saturated fatty acids have been used in particular clinical applications. Certain modifications of MCTs are soluble in both oil and water systems and are metabolized more rapidly than conventional fats and oils. Whereas conventional fats and oils are absorbed slowly and transported via the lymphatic system, MCTs are absorbed relatively quickly and transported via the portal system. Because of their unique ability to pass through the intestinal epithelium directly into the portal system, MCTs have become the standard lipid used in the treatment of various fat malabsorption syndromes. Other MCT applications include their use as rapidly available energy sources for patients with intestinal resection or short bowel syndrome and for premature infants. In certain liquid formula diets and intravenous fluids, MCTs may be combined in varying proportions with corn oil, soybean oil, or safflower oil.

X. CONCLUSION

This booklet 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.

GLOSSARY

Antioxidant	A substance that slows or interferes with the reaction of a fat or oil with oxygen. The addition of antioxidants to fats or foods containing them retard rancidity and increases stability and shelf life.
Bleaching	The purification process to remove color bodies and residual impurities from oils and fats during refining, generally through the use of an adsorbent clay material.
Biotechnology	The use of living organisms or other biological systems to develop food, drugs and other products.
Catalyst	A material which accelerates a chemical reaction without becoming part of the reaction products.
Cholesterol	A fat-soluble sterol found primarily in animal cells important in physiological processes.
Chlorophyll	A natural, green coloring agent vital to a plant's photosynthesis process which is removed from vegetable oils through bleaching and refining processes.
Cis	The term applied to a geometric isomer of an unsaturated fatty acid where the hydrogen atoms attached to the carbon atoms comprising the double bond are on the same side of the carbon chain.
Cold Press	Extraction process whereby oil bearing materials are mechanically pressed without any heat treatment.
Confectionery fat	A broad range of fats with steep melting profiles used in the formulation of sweet goods such as candy bars, bakery product coatings, cream centers, and granola bars.
Conjugated fatty acids	Polyunsaturated fatty acids exhibiting two or more of unsaturated carbons atoms not separated by a saturated carbon atom.
Crude oil	The oil product obtained from the initial extraction, either mechanical and/or solvent based, of an animal or vegetable source.
Degumming	The process that removes phosphatide compounds from crude oils prior to refining.
Deodorization	The process of subjecting oil to high temperatures in the presence of a vacuum to remove trace volatile components that may affect flavor, odor and color. It is generally the last step in the refining process.
Dewax	Removal of natural waxes from edible oils
Diglyceride	The glycerol ester containing two fatty acids.
Emulsifier	Compounds having the ability to reduce surface tension at the interface. Emulsifiers are often used to disperse immiscible liquids such as water and oil or fats in products such as mayonnaise, ice cream and salad dressings.
Ester	The condensation reaction product of an alcohol and an acid.

Esterification	The reaction of chemically combining an alcohol and an acid resulting in the formation of an ester.
Expeller pressed	Mechanically separated oil from oilseed meal.
Fat	Esters of fatty acids and glycerol which are normally solid at room temperature.
Fatty Acid	A long chain carboxylic acid, which generally contains an unbranched chain with even number of carbons.
Fully refined oil	The term used to describe an oil which has been subjected to extensive processing methods to remove: (1) free fatty acids and other impurities (refining), (2) naturally occurring color bodies such as chlorophyll (bleaching), and (3) volatile trace components which may affect color, flavor and odor (deodorizing).
Fire point	The temperature at which an oil sample, when heated under prescribed conditions, will ignite for a period of at least five seconds (spontaneous combustion).
Flash point	The temperature at which an oil sample, when heated under prescribed conditions, will flash when a flame is passed over the surface of the oil but not maintain ignition.
Fractionation	The process of separating fats and oils by differences in melt points, solubility or volatility.
Free fatty acids	The fatty acids in a fat which are not chemically bound to glycerol molecules.
Fully hydrogenated	The term describing a fat which has been hydrogenated to the completion or near completion of saturation, which results in significant chemical and physical changes. Changes include, transformation of liquids to solids at room temperature, and increase in melt point, solid content, saturation, and stability. As conversion to saturation is complete, *trans* isomers are not formed. Products containing hydrogenated fats include "heavy duty" frying fats for restaurant use, solid shortenings, confectionary coatings, peanut butter stabilizer, and solid margarines.
Geometric isomer	A type of isomer distinguished because of its structural location of certain elements.
Glycerol	A three-carbon chain alcohol molecule with chemical formula, $C_3H_8O_3$. Also known as glycerin. When combined with one, two, or three fatty acids forms a mono, di, or triglyceride, respectively.
Hydrogenated	A required term identified in the Food & Drug Administration's labeling regulations (21 CFR 101.4(b) 14) relating to hydrogenated fats and oils. The term indicates a fat or oil is completely hydrogenated. See "fully hydrogenated."
Hydrogenation	The reaction of adding hydrogen atoms to the carbon-to-carbon double bonds in unsaturated fatty acids. This process results in increased melt points, higher solid fat content, and longer shelf life without rancidity in fat-containing products.

Hydrolysis	The splitting reaction of fat with water to form glycerol and free fatty acids.
Interesterification	The reaction of rearranging the fatty acids in triglyceride molecules. It is used principally in confectionery fats, table spreads, shortenings, and margarines to maintain solid fat content at ambient temperatures while lowering the melting point.
Iodine value	An expression of the degree of unsaturation of a fat. It is determined by measuring the amount of iodine which reacts with a natural or processed fat under prescribed conditions.
Isomer	Compounds containing the same elements in the same proportions which can exist in more than one structural form; e.g. geometric, positional or cyclic.
Lauric oils	Oils containing 40-50% lauric acid (C-12) in combination with other relatively low molecular weight fatty acids. Coconut and palm kernel oils are principal examples.
Lecithin	A mixture of naturally occurring phosphatides which has emulsifying, wetting and antioxidant properties, a principal source of which is crude soybean oil.
Lipid	A broad spectrum of fat and fat-like compounds including mono-, di- and triglycerides, sterols, phosphatides and fatty acids.
Lipoprotein	Any of the class of proteins that contain a lipid combined with a simple protein.
Medium chain triglyceride (MCT)	Triglycerides containing fatty acid chains of 6-10 carbon atoms.
Mixed triglyceride	A triglyceride containing two or three kinds of fatty acids.
Monoglyceride	The glycerol ester containing only one esterified fatty acid.
Monounsaturated fatty acid	A fatty acid containing only one carbon – carbon double bond.
Non-conjugated fatty acids	Polyunsaturated fatty acids exhibiting two or more double bonds separated by at least one saturated carbon atom.
Oil	Esters of fatty acids and glycerol which normally are liquid at room temperature.
Oleate	An ester or salt of oleic acid.
Olein	The liquid fraction when an oil or fat is fractionated.
Olestra	A sucrose fatty acid polyester used as a substitute for dietary fat which is not digested or absorbed by the body.
Oxidation	The reaction of oxygen with a fat or oil resulting in the development of rancidity.
Partially hydrogenated	A required term identified in the Food & Drug Administration's labeling regulations (21 CFR 101.4(b) 14) relating to hydrogenated fats and oils. Partially hydrogenated oils are limited in degree of hydrogenation, as compared to completely hydrogenated oils. Light to moderate hydrogenation results in limited increases in melting properties, while improving stability.

Peroxides	The primary compounds formed from the oxidation of unsaturated fatty acids, which may react further to form the compounds that can cause rancidity.
Phosphatide	The chemical combination of an alcohol (typically glycerol) with phosphoric acid and a nitrogen compound; synonymous with phospholipid.
Plasticize	The process of creating a solid crystal structure in a fat or oil product resulting in a smooth appearance and firm consistency.
Polymerize	The bonding of similar molecules into long chains or branched structures.
Polymorphism	The property of a fat molecule to exist in multiple crystalline structures; mainly identified as alpha, beta and beta prime.
Polyunsaturated fatty acid	A fatty acid containing more than one carbon-carbon double bonds.
Positional isomer	An isomer distinguished by the location of a double bond.
Refining	The process of removing impurities from crude oil by way of treatment with alkali solution (chemical) or steam stripping (physical).
Saponification	The chemical reaction between a fat or oil and an alkaline compound creating glycerol and soap.
Saturated fatty acid	A fatty acid containing no carbon-carbon double bonds.
Shortening	A fat product that incorporates tenderness in the food (e.g., bakery products) in which it is used. It may carry other additives such as flavorings, colors, emulsifiers and preservatives.
Simple triglyceride	A triglyceride comprised of three identical fatty acids.
Soap	The salt of fatty acids.
Soap stock	The aqueous byproduct from the chemical refining process that is comprised of soap, hydrated gums, water, oil and other impurities.
Smoke Point	The temperature at which an oil sample, when heated under prescribed conditions, will form a thin continuous stream of smoke.
Stearine	The solid product when an oil or fat is fractionated.
Stearic acid	A saturated 18-carbon free fatty acid.
Sterol	A compound made up of the sterol nucleus, an 8-10-carbon side chain and an alcohol group.
Tocopherol	A naturally occurring antioxidant found in many vegetable oils.
Trans	The term used to describe a geometric isomer of an unsaturated fatty acid where hydrogens attached to the carbons comprising the double bond are on opposite sides of the carbon chain.

Triglyceride	The chemical combination product of glycerol and three fatty acids. Alternately known as triacylglycerol.
Unsaturated fatty acid	A fatty acid containing one or more carbon-carbon double bonds.
Wax	Hydrophobic material made of hydrocarbon, long chain fatty acids, long chain alcohols, or wax ester (ester of a long chain alcohol and fatty acid).
Winterize	The process of separating the solid fraction (stearine) from the liquid fraction (olein) of an oil by cooling and filtering.

COMMON TEST METHODS AND RELATED TERMS

Iodine value (IV)	Measures via titration the degree of unsaturation of a fat or oil, expressed as grams of iodine absorbed per 100 g of oil or fat . The values can be obtained using alternate methodology, such as FT-NIR spectroscopy, refractive index, or fatty acid composition by GC, or refractive index.
Cold test	The determination in time that an oil remains free of visible solids when immersed in a 32ºF ice-water bath.
Color, Lovibond	An analytical method used to quantify the visual color of an oil in units of red and yellow.
Dropping point	The temperature at which a solid fat softens to the point where it will flow and drop out of a specially designed container. The dropping point is an indication of the chemical and crystalline nature of the solid fat.
Fatty acid composition (FAC)	Quantitative separation and determination by chain length of saturated, monounsaturated, polyunsaturated, and cis/ *trans* isomers from fatty acid methyl esters (FAMES) of fats and oils using gas (liquid) chromatography (GC/GLC) under specified conditions.
Flavor	A sensory description experienced in taste testing of a fat or oil. A bland or neutral flavor is generally desirable.
Free fatty acid (FFA)	The amount of free fatty acids present in a fat or oil as determined by simple titration.
Melting point (MP)	The temperature at which a fat changes from solid to liquid within the specific parameters of the test.
Oil stability index (OSI)	An accelerated rancidity test that measures the rate of oxidation of a fat or oil and is expressed as an index number. The higher the index number, at a given temperature, the more stable the product is to oxidation. This method replaces the Active Oxygen Method (AOM).
Peroxide value (PV)	The determination of the extent of fat or oil oxidation by measuring the amount of peroxides present.
Solid fat index (SFI)	Provides an index or indication of the proportions of crystallized and molten fat at a given series of temperature checkpoints. Determined by measuring the dilatation when a solid fat partially melts to liquid at the temperature of interest.
Solid fat content (SFC)	A measure of the crystallized fat content measured by magnetic resonance (NMR) at a series of temperature checkpoints. Determined by measuring the portion of hydrogen nuclei in solid phase over all hydrogen nuclei at the temperature of interest.

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