ican Health Organization.

Table III shows the physicochemical standards in Brazilian legislation (from Latin American Code of Food and Pan American Sanitary Laws of Food).

REFERENCES

1. Gomes, P., "A Soja," Nobel Printing Co. and Book Shop, 1975, p. 11.
2. "Norm and Pattern National Food Committee," Resolution 22/77, 6/8/77.
3. "Latin America Code of Food," 2nd Edition, 1964, p. 99.
4. "Sanitary Norms of Food," Organizacion Panamericana de la Salud Printing Co., 1968, p. 1152.

Relative Nutritional Value of Various Dietary Fats and Oils

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ABSTRACT

The dietary and nutritional role of fats and oils is quite complex, as evident in the new biological findings about some of their components that are essential to man. Fats and oils must be considered for both their quantitative and qualitative aspects, their fatty acid compositions and relationships with average diets in different countries should be emphasized. Because of some adverse physiological effects ascribed to saturated fatty acids, a tendency to increase the intake of polyunsaturated vegetable oils has occurred to provide a good source of essential fatty acids, mainly linoleic acid. However, saturated fats still are an important part of the diet in developed countries, especially "invisible" fats. Research must continue that is related to modifications fats and oils undergo during industrial processes which affect their nutritional value. Compositions of many fats and oils are provided.

INTRODUCTION

Edible fats and oils have several nutritional roles in the human organism, in addition to being the main source of calories. Fats and oils are normal constituents of cellular structure and membrane function. They are the unique source of essential fatty acids and, for this reason, they are important to prostaglandin synthesis. They regulate the lipid blood level, are vehicles for liposoluble vitamins and transport other important compounds, such as carotenoid pigments and sterols.

In this context, relative nutritional values of the main "visible" and "invisible" fats and oils are presented in relation to their linoleic acid (18:2ω6) content, with a discussion of biological significance.

PRINCIPAL FATTY ACIDS IN EDIBLE FATS AND OILS

Saturated Fatty Acids

The more common saturated fatty acids have straight chains and even carbon numbers, although some odd-carbon-number and branched-chain have been detected in small amounts in several animal and marine edible fats. The chain length is between 4 and 22 carbons in the more common edible fats and oils.

Saturated fatty acids are an important part of solid fats; because of their spatial configuration, they have high melting points (mp). Only the low molecular weight (MW) acids are liquid, i.e., between butyric (4:0) and caprylic acids (8:0), and the others are solid. As an example, the mp of capric acid (10:0) is 31.6 C, and that of stearic acid (18:0) is ca. 70 C. Among the saturated fatty acids, palmitic (16:0) is one of the most widespread in nature. It has been found in practically all fats and oils analyzed.

The presence in the diet of fats with a high content of saturated fatty acids has been related to several physiological disturbances. Among these are the tendencies to increase blood cholesterol level, to favor heart disease, atherosclerosis and arterial thrombosis (1).

Unsaturated Fatty Acids

In unsaturated fatty acids, a double bond is contained in the carbon chain. The molecule becomes more rigid at this point, and has two types of isomers: positional and geometric, *cis,trans*. The presence of a double bond and its spatial configuration has a remarkable influence on the mp. In nature, most fatty acids are *cis*-. For this reason, they are liquid at room temperature. As an example, oleic acid (18:1,9-*cis*) has a mp of 14 C, and its *trans*-isomer, elaidic acid (18:1,9-*trans*) melts at ca. 32 C. This difference is due to the *trans* configuration of the isomer only.

These *trans*-isomers usually are formed during catalytic hydrogenation of liquid fats to form solid fats (2). Also, these compounds are produced in small amounts in the rumen of ruminants.

Unsaturated fatty acids can be monounsaturated with only one double bond in the molecule, or polyunsaturated with two or more double bonds. The more common monounsaturated or monoethenoid fatty acids found in edible fats have chain lengths between 10 and 22 carbons; polyunsaturated or polyethenoid acid chain lengths are between 16 and 22 carbons.

The presence of the double bond creates families of fatty acids. Each family has the same end structure which produces different biological roles and properties.

If the last methyl group of the fatty acid chain is designated omega (ω), and we count the carbons before the first double bond, we have the oleic acid family (18:1ω9), linoleic acid family (18:2ω6), linolenic acid family (18:3-

ω3) and cetoleic acid family (22:1ω11).

Another nomenclature system for these fatty acid families is n-m, where m is the first double bond from the methyl terminal group of the carbon chain. In this case the oleic acid family is written 18:1(n-9); linoleic is 18:2(n-6); linolenic is 18:3(n-3); and cetoleic is 22:1(n-11). This last notation will be used in this paper.

ESSENTIAL FATTY ACIDS

The term "essential" fatty acids can be used to consider two fatty acids: linoleic, 18:2(n-6); and α-linolenic, 18:3(n-3) (3,4). These are called "essential" because if they are lacking, a deficiency syndrome is produced because the animal organism cannot introduce double bonds between the terminal methyl group and the first double bond situated in the carbon chain of the respective fatty acid. The only alternative the animal has is to introduce acetyl groups to elongate the carbon chain and to form new double bonds between the last double bond and the carboxylic group of the fatty acid.

This shows the importance of the fatty acid families already described, since their terminal structure stays unchanged. For this reason, it is not possible to transform a fatty acid of one family into a fatty acid in another family.

The animal organism which has this basic terminal structure can synthethize long chain fatty acids with a 20-22 carbon number, and 3, 4, 5 or 6 double bonds belonging to the n-6 or n-3 families. These fatty acids are essential to form cellular structures and to maintain the normal functions of all the tissues for the synthesis of, e.g., prostaglandins (5). The more important acids are arachidonic (20:4-[n-6]) and docosahexaenoic (22:6[n-3]). It is absolutely necessary that the diet supply their precursors: linoleic (18:2[n-6]); and linolenic (18:3[n-3]). This situation precisely defines their "essential" characteristic.

If this basic terminal structure is absent, the animal organism must synthethize long chain fatty acids. For this purpose, it takes stearic acid (18:0) in order to produce oleic acid (18:1[n-9]), with one unsaturation at the 9-position. The chain is then elongated as new double bonds appear. As a result of this process, eicosatrienoic acid (20:3[n-9]) is formed and because it comes from oleic acid (18:1[n-9]), it belongs to that family.

The main fatty acid families and their formation products are shown in Table I (6).

When enough linoleic acid is present in the diet, the amount of oleic acid transformed into eicosatrienoic is small, but this acid is synthethized in larger amounts when essential fatty acids are lacking. The ratio between eicosatrienoic and arachidonic acids can be used as information about deficiency (7) and is measured in serum lipids. A normal value is about 0.1; the smaller this ratio, the better the essential fatty acid supply. A ratio of 0.4 indicates essential fatty acid deficiency. Another ratio studied is monoenoic: dienoic acid, in which a value of 1.5 indicates essential fatty acid deficiency (8,9).

Related to requirements in children, dermatological symptoms disappear when 1% or more of the total calories is supplied by linoleic acid. Presently, intake of 3% of the total energy supplied by linoleic acid is considered suitable. The same figure is indicated for adults, with suggested levels of 4-5% in pregnancy and 5-7% during lactation (10-12). This means the adult male requires at least 7.5 g daily of linoleic acid, which is ca. 2% of total calories for a diet of 3,000 calories daily. This value is not difficult to reach in a nutritionally adequate diet (13,14).

Recommendations for linolenic acid have not been made. The 20- and 22-carbon-number derivatives are involved in brain and retina functions. The figures given as requirements are quite general and can change with respect to other components of the diet and different physiological situations.

Actually, it is recommended that the ratio of saturated fatty acid:polyunsaturated fatty acids in the diet be 1:1; however, it has been calculated that in the normal diet, the ratio of saturated:monoenoic acids is 1:1. For this reason, it is helpful if ca. 1/3 of the total intake of fatty acids be polyunsaturated. If it is considered that fats supply ca. 30% of the total calories, this figure will be near 10% as caloric percentage. As evident from all these considerations, quantitative aspects of fat in the diet are important, as well as qualitative ones.

It should be pointed out that an excessive intake of polyunsaturated fatty acids can represent health risks, according to some researchers (8,15,16) who have described potential adverse effects such as increased tumor incidence in mice, increased vitamin E requirements associated with premature aging, changes in oxidative capacity of the organism and greater incidence of gallstones. This higher intake of polyunsaturated fatty acids has encouraged researchers to determine vitamin E requirements for adults (17-20). This requirement has been correlated to the polyunsaturated fatty acid in cellular structures. Harris and Embree (21) have estimated that the more suitable daily ratio will be 0.6 mg α-tocopherol/g polyunsaturated fatty acids. The tocopherol content of some fats and oils are listed elsewhere (20,22).

TABLE I

Principal Families of Fatty Acids and Their Formation Products

Linoleic acid 18:2(n-6)	α-Linolenic acid 18:3(n-3)	Oleic acid 18:1(n-9)
↓	↓	↓
γ-Linolenic acid 18:3(n-6)	Octadecatetraenoic acid 18:4(n-3)	Octadecadienoic acid 18:2(n-9)
↓	↓	↓
Dihomo-γ-linolenic acid 20:3(n-6)	Eicosatetraenoic acid 20:4(n-3)	Eicosadienoic acid 20:2(n-9)
↓	↓	↓
Arachidonic acid 20:4(n-6)	Eicosapentaenoic acid 20:5(n-3)	Eicosatrienoic acid 20:3(n-9)
↓	↓	↓
Docosatetraenoic acid 22:4(n-6)	Docosapentaenoic acid 22:5(n-3)	Docosatrienoic acid 22:3(n-9)
↓	↓	
Docosapentaenoic acid 22:5(n-6)	Docosahexaenoic acid 22:6(n-3)	

FATTY ACID COMPOSITION OF PRINCIPAL EDIBLE FATS AND OILS, VISIBLE AND INVISIBLE

Fats and oils are one of the more important caloric sources; however, the amount in which they are present in the common diet has a quite wide range in quantity and in quality. In some countries, the caloric supply due to fats and oils can be as low as 10% of total calories, and in others, can reach 35-45% of total calories. These last values are common in developed countries, where there is a preference for animal foods with high fat content and where more saturated fats than vegetable and marine fats are consumed (6).

This high fat intake, especially of saturated fats, has produced, as already indicated, physiological disturbances that have affected only populations of developed countries. As a consequence, much research has been done to elucidate the true biological role of fats and oils.

As there are too many factors that can influence a possible classification or grouping of "visible" and "invisible" edible fats and oils related to their relative nutritional value, it was intended in this section to present them according to their increasing linoleic acid contents with respect to biological importance.

"Visible" fats and oils are considered to be all those that are consumed directly, e.g., oils, butter, margarine, lard, chocolate. "Invisible" fats are those incorporated into foods and not detected easily, e.g., meats, milk, eggs, baked products, olives, avocados.

For the purpose of this work, three groups have been considered arbitrarily: Group 1–low content of linoleic acid, 0-15%; Group 2–medium content of linoleic acid, 15-35%; Group 3–high content of linoleic acid, 35-80%.

Fatty acids have been arranged as saturated, monoenoic and polyunsaturated. The total amount for each class is indicated, and the respective proportion related to total polyunsaturated fatty acid content is given for various foods in Table II. In linoleic acid content of the same order, the fats and oils have been put in decreasing amounts of total saturated fatty acids. Fatty acid compositions of the fats and oils indicated in the table correspond to averages. The data have been taken from different references and personal work, some as yet unpublished (20,23-34,35,36).

Group 1

Fats with low content of linoleic acid (0-15%) are shown in Table II. In the top portion are several vegetable and animal fats, whose linoleic acid (18:2[n-6]) content is between 1% (babassu oil) and 4.2% (tallow).

The total amount of saturated acid is high mainly because of lauric acid (palm and coconut), palmitic acid (butter, tallow, bone marrow–calf), and stearic acid (cacao butter, lamb fats and tallow). The fats with the highest content of saturated fatty acid is coconut fat (*Cocos nucifera*), with 89.9%, and the lowest in this group are bone marrow (calf) and mango oil, with 31.3 and 28.1%, respectively.

The principal monoenoic acid in these fats is oleic acid, which has a wide range of 7% (*Cocos nucifera*) to 56.6% (bone marrow–calf), except for mango oil.

The proportions for total saturated and total monoenoic acids related to total polyunsaturated fatty acids are indicated for each fat in Table II. The saturated fraction is predominant at 85:1 for babassu, decreasing to the lowest values in bone marrow (calf) and mango oil at 5.5:1 and 1.3:1, respectively.

Special mention is made for the linoleic acid content of butter fat, in which the average level is around 3.5%. This amount is not sufficient to cover the 3% calorie value recommended for children.

Fatty acid compositions of some fish oils and sea foods are shown in the center of Table II. This is a special group. Their linoleic acid contents are low, 0.4-5.5%, but they have important amounts of other polyunsaturated fatty acids, including the essential arachidonic acid, that in some species, especially freshwater fish, reaches 7.7%.

The fatty acid distribution among the groups of fatty acids is more uniform, which is clearly noted in the calculated ratios. The polyunsaturated fraction in many cases is more than monoenoic and saturated contents. Among saturated fatty acids, the main component is palmitic, for monoenoic acids, oleic, and for polyunsaturated fatty acids, the more important are eicosapentaenoic and docosahexaenoic acids.

Because of their high content of polyunsaturated fatty acids, the intake of these oils has been considered important in the diets of persons with high cholesterol blood levels, myocardium infarction, multiple sclerosis and for treatment of gallstones (37).

In the bottom position of Table II appears fat substances from vegetal and animal origin, all with linoleic content between 7 (horse fat) and 15% (human milk).

Palmitic and oleic acids also are the principal fatty acids in the first two groups and linoleic acid in the third group. The most saturated fat in this section is egg yolk, with 51.3%, and the least saturated is common rapeseed oil, with 5.2%.

Table II includes data for teaseed, olive and avocado oils, in which the oleic acid content is 77, 70.5 and 69.8%, respectively.

The highest value for linoleic acid is in human milk. A special comment is notable related to this fat. The literature for human milk gives a wide range for linoleic acid, between 9 and 15% (38-41). These values provide infants with their essential fatty acid requirements and are superior to the linoleic acid content of butter fat. These findings related to nutritional value of human milk stimulated reviews of milk formulations used as substitutes for human milk, and also of the use of cow's milk in feeding infants. Research in this area has been done in Chile in which the results obtained with a group of wetnurses indicated that linoleic acid is in optimal levels for infant requirements, with an average of 15% at the fourth week of lactation. These values show the influence of dietary fat in fatty acid composition of human milk, because the fat intake was principally polyunsaturated edible oils, such as soybean oil (42).

As a result of these studies on human milk lipids, the trend is to promote mother lactation to feed infants, and if that is not possible, to develop milk formulations with a fatty acid composition close to human milk fat. Some formulations to substitute human milk are made with, e.g., soybean, sunflower, coconut and corn oil. Their linoleic acid contents are between 13 and 55% (38). Hydrogenated vegetable fats, such as soybean and cottonseed, and animal and marine fats can be used, as well (20,43,44). For this reason, the ratio among fatty acid groups cannot be indicated.

The principal saturated acids are stearic and palmitic in hydrogenated products. Oleic acid is the main monoenoic acid. Linoleic acid content varies from 0 to 15% in such products. According to their origin, long chain fatty acids with a 20-22 carbon number appear in the composition. It is possible to say that margarines are higher in polyunsaturated fatty acids than butter fat. This situation has produced an increase in margarine consumption. In the U.S. in 1900, the intake per capita of margarine was ca. 1.5 lb and 19.5 lb per capita for butter fat; in 1976, these figures changed to 4.5 lb and 12.5 lb per capita, respectively (43).

TABLE II

Fats with Low Linoleic Acid Contents (0-15%)

Fat	Ref.	Total saturates	Total monoenes	Total polyunsaturates	Ratio sat/mono/polyunsat
Babassu	24	85.0	14.0	1.0	85/14/1
Palm kernel	24	84.8	13.0	1.7	50/8/1
Coconut	24	89.9	7.2	2.0	45/4/1
Cocoa butter	24	59.5	38.5	2.0	30/19/1
Lamb fat	34	57.5	37.7	2.4	24/16/1
Mango	36	28.1	50.5	21.1	1.3/2.4/1
Coconut	34	69.2	24.6	3.0	23/8/1
Marrow (calf bone)	24	31.3	63.0	5.7	5.5/11/1
Butter	26	64.0	30.1	5.7	11/5/1
Tallow	26	53.7	41.6	4.2	13/10/1
Macha fish	34	38.4	26.4	33.4	1.1/0.7/1
Svallopsea	25	31.7	9.1	55.2	0.5/0.1/1.1
Tuna	25	41.3	27.6	29.6	1.3/0.9/1
Hake	25	28.3	42.9	24.9	1.1/1.7/1
Sardine	25	30.0	26.0	41.7	0.7/0.6/1
Herring	25	20.0	59.0	16.0	1.2/3.6/1
Blue crab	25	27.4	32.2	33.3	0.8/0.9/1
Piure	32	29.3	36.2	28.3	1/1.2/1
Prawns	35	42.5	24.8	29.0	1.4/0.8/1
Anchovy	33	41.9	24.3	31.7	1/0.8/1
Menhaden	28	37.0	26.0	32.0	1/0.8/1
Perch	29	24.7	40.4	29.8	0.8/1.4/1
Pink salmon	29	17.2	30.5	50.6	0.3/0.6/1
Rainbow trout	29	20.6	23.5	53.0	0.4/0.4/1
Horse fat	34	31.3	41.7	26.0	1.2/1.6/1
Lard	26	41.3	49.6	8.5	5/6/1
Hazel nut	27,34	6.2	81.1	11.1	0.6/7/1
Palm	34	49.2	40.5	10.2	5/4/1
Teaseed	24	8.4	77.1	10.7	0.8/7/1
Avocado	34	12.1	74.5	12.5	1/6/1
Shinianut	24	40.0	49.0	11.0	4/4/1
Rapeseed	26	5.2	72.2	22.6	0.2/3/1
Egg yolk	34	51.3	31.9	13.4	4/2/1
Olive oil	26,23	12.9	72.6	14.5	0.9/5/1
Human milk	42	48.0	33.2	16.1	3/2/1

TABLE III

Fats with Medium Linoleic Acid Contents (15-35%)

Fat	Ref.	Total saturates	Total monoenes	Total polyunsaturates	Ratio sat/mono/polyunsat
Almond	24	8.5	72.0	19.0	0.4/4/1
Rapeseed	26	7.4	6.5	26.7	0.3/2.5/1
Broiler chicken	34	30.0	47.5	21.8	1.4/2/1
Lupine	34	12.6	57.1	30.3	0.4/2/1
Peanut	23,24,34	22.5	42.4	35.0	0.6/1.2/1

Group 2

Table III lists some common fats and oils whose linoleic acid content is between 15 and 35%, such as rapeseed oil (low erucic acid), almond oil, deposit fat of broilers, lupine seed oil (which is being promoted in Peru and Chile) and peanut oil. For soft margarines (20,26) made with hydrogenated vegetable oils, the range varies, but some highly unsaturated margarines can have more than 35% of linoleic acid. The most saturated fat in this group was the deposit fat of broilers with 30%, and the least saturated was rapeseed (low erucic acid), which is 7.4%.

The most important group of fatty acids are monounsaturated, such as oleic acid. The highest value is presented by almond oil with 71.5%. Polyunsaturates are mainly linoleic and linolenic acids which are present in rapeseed oil and lupine seed oil. The ratio between saturated:polyunsaturated acids is reversed, with the exception of the deposit fat of broilers.

Group 3

Table IV lists principal edible vegetable oils, such as sesame, corn, cotton, soybean, sunflower, grape seed, safflower, some seeds, nuts and bran oils. The saturated fatty acid content is low, between 9.5% (safflower oil) and 27.6% (cottonseed oil). Oleic acid decreases from 42% (kapoc oil) to about 10% (safflower oil). On the contrary, linoleic acid increases from 37% to almost 80% for these same oils. This variation is clearly observed in the respective ratios, i.e., 1:1 to 0.15:1.

General Comments

From data about the fatty acid composition of different fats and oils shown in Tables II-IV, it is easy to understand the qualitative importance of fatty acid composition of different fats and oils commonly present in the diet. If the diet is preferably of animal origin, saturated fatty acid will be predominant; if it is of vegetable origin or many vegetable oils are consumed, polyunsaturated fatty acids, especially linoleic, will be predominant. Fish oils constitute a special group due to the presence of important amounts of highly polyunsaturated fatty acids other than linoleic acid. On the contrary, some vegetable fats have high saturated fatty acids contents and the lowest amounts of linoleic acid, such as babassu, coconut and cocoa butter.

The idea is to try and obtain a balance in the dietary fats related to the different groups of fatty acids that are present in it. For this reason, it is considered necessary to encourage fatty acid research to determine the real qualitative fatty acid composition of diets and principal foods consumed by different populations in the world. The presence in the diet of vegetable oils, as noted in Table IV, secures an adequate supply of essential linoleic acid.

PRESENCE OF LONG CHAIN FATTY ACIDS

Other problems related to fatty acid composition and nutritional value of fats and oils are concerned with the presence of long chain fatty acids.

The discovery of histopathological lesions in many species of animals, especially in the myocardium, triggered restrictions for using rapeseed oil (*Brassica napus*, *Brassica campestris*) with high erucic acid content of 35-50% used for human consumption (45-48).

New varieties of rapeseed have been developed with zero or low erucic acid content (0-3%). This is the type of rapeseed used in many countries for edible oil. Research in this area continues. In general, there are recommendations that suggest, in the case of high erucic acid varieties, mixing the rapeseed oil with other vegetable oils to reduce the amount of erucic acid.

Marine Oils

Marine oils are commonly consumed as part of the human diet, i.e., as fish and seafood.

However, large amounts of fish oil are obtained as byproducts of the fish meal industry, and after hydrogenation and refining, they are used in many countries as a base for shortenings and margarines. Also, fractionation processes have been developed in order to obtain liquid oil to be used directly for human consumption mixed with vegetable oils.

Experiments with animals fed hydrogenated fish oils have given contradictory results. In some cases, partially hydrogenated fish oils have produced cardiac lipidosis in experimental animals, especially when the fish oil contains high values of cetoleic acid (49,50). Hydrogenated marine oils are not permitted to be incorporated in any processed food in the U.S.

CHANGES IN FATTY ACID COMPOSITION WITH PROCESSING

Hydrogenation

Some vegetable and marine oils are selectively hydrogenated for different purposes: to improve stability, to produce new solid fats with controlled consistency that can be used as a base for shortenings or plastic fats, margarines for baking products, table margarines, coatings, or frostings.

In this industrial process, the mp of the original liquid oil is increased by saturation of the double bonds with hydrogen and by changes in the geometric configuration of the molecule in the space around the double linkage, i.e., the natural *cis*-configuration is changed to *trans*-. Positional isomers also are produced.

Natural polyunsaturated fatty acids with biological activity have *cis*-configuration and, during the hydrogenation process, variable amounts of *trans*-isomer are produced. So, when vegetable oils rich in linoleic acid are hydrogenated, unquestionably, a loss of essential fatty acids is produced, and a decreasing of the original biological value of the product (51,52).

The amount of *trans*- that is found in commercially hydrogenated products is variable between 5 and 45% (20,51). For some types of margarines, values for *trans*-isomers are 15-25% and 25-35%, for shortenings, 20-30% and salad oils, 0-15%. It is estimated that the total intake of *trans*-acids in "visible" fats is ca. 8% (53).

Chilean Reglamentation proposes that table margarines must contain a minimum of 7% linoleic acid in the finished product (54).

Controversy exists about nutritional and biological value of high amounts of *trans*-fatty acids in fats and oils. *Trans*-fatty acids have different biological functions than *cis*-. They are incorporated differently into triglycerides and phospholipids and differ in the specificity of their cholesteryl esters to cholesteryl esterases; also, they can alter membrane permeability (55-57). In some tests, it has been

TABLE IV

Fats with High Linoleic Acid Contents (35-85%)

Fat	Ref.	Total saturates	Total monoenes	Total polyunsaturates	Ratio sat/mono/polyunsat
Kapok	24	20.7	42.0	37.0	0.5/1.1/1
Rice bran	24	18.6	40.3	40.0	0.4/1/1
Sesame	23	16.1	39.6	43.8	0.3/0.9/1
Pumpkin	24,26	19.8	33.0	47.1	0.4/0.7/1
Cottonseed	23,24	27.6	21.9	50.1	0.5/0.4/1
Quinoa	34	14.9	25.0	58.3	0.2/0.4/1
Corn	24,26	14.2	32.4	53.4	0.2/0.6/1
Wheat	34	16.9	24.3	58.8	0.3/0.4/1
Tomato seed	24,34	20.3	23.5	56.0	0.3/0.4/1
Soybean	24,31	14.7	22.3	63.0	0.2/0.3/1
Walnut	24	10.0	18.0	72.0	0.1/0.3/1
Passion fruit	23,24	15.1	18.1	66.0	0.2/0.3/1
Safflower	24,34	11.5	20.8	67.7	0.2/0.3/1
Poppy seed	24	12.5	19.2	68.3	0.2/0.3/1
Sunflower	31	12.7	18.2	69.1	0.1/0.2/1
Grape seed	26	11.0	17.2	71.3	0.2/0.2/1
Nigerseed	24	17.7	7.3	74.3	0.2/0.1/1
Safflower	24,34	9.5	11.8	78.7	0.1/0.15/1

found that they increase plasma cholesterol, but not in others (58,59). Otherwise, it is believed that they increase the essential fatty acid requirement because they affect the enzymatic use of unsaturated fatty acids (60,61).

On the other hand, research with experimental animals does not indicate important changes when feeding fat substances that contain *trans*-isomers, if the essential fatty acids and other nutrient requirements have been satisfied (51). No doubt investigation will continue on this problem.

INTERESTERIFICATION

Interesterification is a process applied to fats and oils to rearrange fatty acids randomly in the presence of a catalyst such as sodium methylate or ethylate (62). One of the better known examples is with lard, done to modify its physical characteristics (63,64). Another use is to obtain substitutes of cocoa butter from palm kernel oil.

Nutritional studies with interesterified fats and oils, prepared to maintain a high level of linoleic acid, have been made with rats. Results have shown that these fats and oils are, at least nutritionally, equal to other edible fat substances with equivalent contents of essential fatty acids (52).

DEEP FAT FRYING

Another process that can affect nutritional quality of fats and oils, especially their linoleic acid content, is heating during deep fat frying. Vegetable oils usually are used, and the temperature is about 180 C. The main damages from heat are polymerization of polyunsaturated fatty acids and oxidative deterioration.

Heated oils in the presence of oxygen have been tested in experimental animals, and cellular damage, histological tissue changes and liver and kidney enlargement have been found (65-67). However, when commercial heated oils were used (68,69), adverse effects were not detected.

Some studies done in our laboratory, taking samples of commercial heated fats and oils, showed important physical and chemical damage to them, and it was concluded that they should be used not more than 40 hours in heating for deep fat frying. Longer times produced great deterioration and should be avoided (70,71). This is another subject on which research must continue.

OTHER IMPORTANT NUTRITIVE COMPOUNDS

Fats and oils also contain ca. 1-3% unsaponifiable matter that consists of a heterogenous group of substances with lipid characteristics.

Sterols

Cholesterol is the most important animal-origin sterol. Stigmasterol, campesterol, brassicasterol and sitosterol are of vegetable origin. The cholesterol and total sterols of some foods and fat substances are shown in Tables V (72) and VI (24).

Tocopherols

Tocopherols are considered natural antioxidants and very important nutrients contained in vegetable oils. Their biological role was discussed earlier.

Carotenoid Pigments

Vegetable fats and oils are a good source of carotenoid pigments; an example is palm oil. They also are present in some animal fats, such as butter, egg yolk and broiler deposit fat. Some of them have biological activity, e.g., pro-vitamin A (β-carotene).

TABLE V

Cholesterol Content of Some Foods (72)

	Edible portion (mg/100 g)
Beef (raw)	68
Brains (raw)	2.000
Butter	250
Cheeses	30-113
Chicken (raw)	98
Chicken fat	65
Clam (raw)	50
Cod (raw)	50
Cakes	83-356
Crab	100
Milk's cream	43-133
Eggs, chicken, whole	504
Egg yolk	1.480
Herring	150
Ice cream	20-73
Kidneys (raw)	375
Lamb (raw)	71
Lard	95
Liver	300
Margarine (animal orig.)	0-50
Milk, fluid, whole	14
Milk, fluid, skim	2
Pork (raw)	62
Mayonnaise	70
Salad dressing	74
Salmon (raw)	35
Sardine, in oil	120
Sausage (raw)	65
Scallops (raw)	35
Shrimp	150
Trout (raw)	55
Tuna, in oil	55
Turkey	82

TABLE VI

Total Sterols of Some Fats and Oils (24) (mg/100 g)

Cottonseed	300
Rice bran	400
Rapeseed	500
Corn	700
Sesame	400
Almond	140
Groundnut	500
Teaseed	100
Olive	500
Palm	150
Cocoa butter	300
Palm kernel	300
Coconut	100
Grape seed	250
Soya	400
Sunflower	350
Safflower	250

Liposoluble Vitamins

In general, liver oils of some fish are good sources of vitamins A and D.

REFERENCES

1. Hegsted, D.M., R.B. McGandy, M.L. Myers and F.J. Stare, Am. J. Clin. Nutr. 17:128 (1965).
2. Lands, W.E.M., M.L. Blank, L.J. Nutter and O.S. Privett, Lipids 1:224 (1966).
3. Burr, G.O., and M.M. Burr, J. Biol Chem. 62:345 (1929).
4. Burr, G.O., and M.M. Burr, Ibid. 86:587 (1930).
5. Coots, R.H., J. Lipid Res. 6:494 (1965).
6. Las Grasas y Aceites en la Nutrición Humana, FAO, Roma, 1978.

7. Holman, R.T., W.O. Caster and H.F. Wiese, J. Clin. Nutr. 14:70 (1964).
8. Holman, R.T., Prog. Chem. Fats Other Lipids 9:275,555,661 (1970).
9. Burr, G.O., and M.M. Burr, J. Biol. Chem. 82:345 (1929).
10. Paulsurd, J.R., L. Pensler, C.F. Whitten, S. Stewart and R.T. Holman, Am. J. Clin. Nutr. 25:897 (1972).
11. Soderhjelm, L., H.F. Wiese and R.T. Holman, in "Progress in the Chemistry of Fats and Other Lipids," Vol. 9, Part 4, Pergamon Press, New York, 1970.
12. Alfin-Slater, R.B., and L. Aftergood, Physiol. Rev. 48:758 (1968).
13. Collins, F.D., A.J. Sinclair, J.P. Royle, D.A. Coats, A.T. Maynard and R.F. Leonard, Nutr. Metab. 13:150 (1971).
14. Recommended Dietary Allowances, Food and Nutrition Board, National Academy of Sciences—National Research Council, 8th Edition, Publ. 2216, Washington, DC, 1974.
15. Jones, R.J.J., JAOCS 51:251 (1974).
16. Rose, G., H. Blackburn, A. Keys, H.L. Taylor, W.B. Kannel, O. Paul, D.D. Reid and Stamler, Lancet 1:181 (1974).
17. Horwitt, M.K., Am. J. Clin. Nutr. 27:1182 (1974).
18. Bieri, J.G., and R.P. Evarts, Ibid. 28:717 (1975).
19. Dunnell, R.H., E. DeRitter and S.H. Rubin, Ibid. 28:706 (1975).
20. Carpenter, D.L., and H.T. Slover, JAOCS 50:372 (1973).
21. Harris, P.L., and N.D. Embree, Am. J. Clin. Nutr. 13:385 (1963).
22. Lange, W., JAOCS 27:414 (1950).
23. Hilditch, T.P., and P.N. Williams, "The Chemical Constitution of Natural Fats," 4th Edition, 1964.
24. Bernardini, E., "The New Oil and Fat Technology," 2nd Edition, 1973.
25. Stansby, M.E., Fish Oils (1967).
26. Tabla de Composición Química de *Alimentos Chilenos*, Quinta Edición, Santiago-Chile, 1974.
27. De Tomas, M.E., R.R. Brenner and P. Cattáneo, Rev. Argent. Grasas Aceites 5:53 (1963).
28. Stansby, M.E., JAOCS 56:793A (1979).
29. Kinsella, J.E., J.L. Shimp and J. Weihrauch, Ibid. 54:424 (1977).
30. Masson, L., M.A. Castillo and A. Borzutzky, Grasas Aceites (Seville) 23:7 (1972).
31. Masson, L., M.A. Castillo and R. Viani, Ibid. 22:188 (1971).
32. Masson, L., and M. Alonso, Oli Grassi Deriv. 7:30 (1971).
33. Masson, L., and M.T. Burgos, Grasas Aceites (Seville) 24:327 (1973).
34. Masson, L., and M.A. Mella, "Tabla de Composición Química de Acidos Grasos de Materias Grasas de Consumo Habitual y Potencial en Chile," in preparation.
35. Gopakumar, K., and M. Rajendranathan Nair, J. Sci. Food Agric. 26:319 (1975).
36. Bandyopadhyay, C.H., and A. Gholap, J. Agric. Food Chem. 21:496 (1973).
37. Williams, G., B.C. Davidson, P. Stevens and M.A. Crawford, JAOCS 54:328 (1977).
38. Jensen, R., M. Ragerty and K. McMahon, Am. J. Clin. Nutr. 31:990 (1978).
39. Insull, W., J. Hirsch, J. James and E. Ahrens, J. Clin. Invest. 38:443 (1959).
40. Read, W.W., P.G. Lutz and A. Tashjian, Am. J. Clin. Nutr. 17:180 (1965).
41. Jelliffe, D.B., and E.F. Jelliffe, Ibid. 31:492 (1978).
42. Masson, L., C. Hurtado, E. Atalah, P. Bustos, H. Oliver, M. Ruz and M.A. Mella, "Revista Chilena de Pediatría," in press (1980).
43. Massiello, F.J., JAOCS 55:262 (1978).
44. Masson, L., and M.A. Mella, ISF/AOCS World Congress presentation, New York, NY, 1980.
45. Abdellatif, A.M.M., and R.O. Vles, Nutr. Metab. 12:285 (1970).
46. Abdellatif, A.M.M., and R.O. Vles, Ibid. 15:219 (1973).
47. Beare-Rogers, J.L., E.A. Nera and B.M. Craig, Lipids 7:548 (1972).
48. Beare-Rogers, J.L., E.A. Nera and B.M. Craig, Ibid. 7:46 (1972).
49. Beare-Rogers, J.L., Prog. Chem. Fats Other Lipids 15:29 (1977).
50. Ackman, R.G., Lipids 9:1032 (1974).
51. Alfin-Slater, R.B., P. Wells and L. Aftergood, JAOCS 50:479 (1973).
52. Alfin-Slater, R.B., L. Aftergood, H.H. Hansen, R.S. Morris, D. Melnick and C.M. Gooding, Ibid. 43:110 (1966).
53. Kummerow, F.A., J. Food Sci. 40:12 (1975).
54. Anteproyecto Reglamento Sanitario de Chile, 1977.
55. Sgoutas, D., and F.A. Kummerow, Am. J. Clin. Nutr. 23:1111 (1970).
56. Kummerow, F.A., JAOCS 51:255 (1974).
57. Spritz, N., and M.A. Mishkel, J. Clin. Invest. 48:78 (1969).
58. Vergroesen, A., J. Proc. Nutr. Soc. 31:323 (1972).
59. Mattson, F.H., E.J. Hollenbach and A.M. Kligman, Am. J. Clin. Nutr. 28:726 (1975).
60. Reitz, R.C., W.E.M. Lands, W.W. Christie and R.T. Holman, J. Biol. Chem. 243:2241 (1968).
61. Lands, W.E.M., M.L. Blank, L.J. Nutter and O.S. Privett, Lipids 1:224 (1966).
62. Going, L.H., JAOCS 44:414A (1967).
63. Slater, L.E., Food Eng. 25:72 (1953).
64. Quimby, O.T., R.L. Wille and E.S. Lutton, JAOCS 30:186 (1953).
65. Andia, A.G., and J.C. Street, J. Agric. Food Chem. 23:173 (1975).
66. Tappel, A.L., Fed. Proc. 32:1870 (1973).
67. Poling, C.E., W.D. Warner, P.E. Mone and E.E. Rice, J. Nutr. 72:109 (1960).
68. Nolen, G.A., J.C. Alexander and N.R. Artman, Ibid. 93:337 (1967).
69. Nolen, G.A., JAOCS 49:688 (1972).
70. Masson, L., and M. Craddock, IFT meeting presentation, Philadelphia, PA, 1977.
71. Masson, L., H. Oliver, E. Wittig, M. Lutz and E. Lucas, 5th Conferencia Internacional del Raps. Malmo, Suecia, 1978.
72. Feely, R.M., P.E. Criner and B.K. Watt, J. Am. Diet. Assoc. 61:134 (1972).

Vegetable Oils: Effects of Processing, Storage and Use on Nutritional Values

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ABSTRACT

At the present time, vegetable oils are the source of most of the visible fat in the U.S. diet. They are used as salad and cooking oils, in salad dressing, margarine and shortening. Processing methods include extraction, refining, hydrogenation and interesterification. During storage and use, the products are exposed to oxygen and/or heat, particularly during frying. Processing, storage and use are related to changes in composition, nutritive value and physical characteristics of vegetable oils. Refining removes undesirable minor