Nutritional and health aspects of vegetable oils

Edible oil can be of plant, animal or microbial origin, which is suitable for food use. After carbohydrates, oils are the second most important source of edible calories in the human diet. Edible vegetable oils are foodstuffs which are composed primarily of glycerides of fatty acids being obtained only from vegetable sources. They may contain small amounts of other lipids such as phosphatides, unsaponifiable constituents and of free fatty acids naturally present in the fat or oil (CODEX STAN 210-1999).

Dietary fats are derived from two sources *viz.*, the invisible fat present in plant and animal foods; and the visible or added fats and oils (cooking oil). They are insoluble in water but soluble in most organic solvents like diethyl ether, hexane, benzene, chloroform and methanol. They have lower densities than water. When they are solid-appearing at normal room temperature (RT), they are referred to as "fats," and when they are liquid at RT, they are called "oils."

Sources and properties of edible oils

Primary sources

- Rapeseed-mustard: Rich in monounsaturated fatty acids and alpha-linolenic acid
- Groundnut: It contains α, β and δ tocopherols and resveratrol a phytoalexin which is an anticancer agent, a platelet antiaggregation agent, and an antioxidant
- Soybean: Oil is rich in α-linolenic acid and gamma tocopherols
- Sunflower: MUFA (monounsaturated fatty acids) and PUFA (polyunsaturated fatty acids) rich; also contains α-tocopherol
- Safflower: It contains highest linoleic acid (PUFA) and is rich in α-tocopherol
- Niger: PUFA rich oil
- Sesame: Contains almost equal amount of oleic (PUFA) and linoleic (MUFA) acids. Sesame lignans (sesamin, sesmolin and sesmol) are having high antioxidant activity. Useful for salad dressing
- Linseed: Conditional edible, richest source of α-linolenic acid

Secondary sources

- Oil palm: Rich in tocopherols, tocotrienols and carotenoids
- Coconut: Contains easily digestible short chain fatty acids
- Cotton seed oil: Contains high amount of palmitic acid
- Corn oil: Contains high amount of α tocopherol

- Rice bran oil: Rich source of γ oryzanol (known to decrease LDL cholesterol) and also contains α linolenic acid
- Tree borne oils: TBOs (olive, mahua, kokum, sal, simarouba, cheura)
- Other sources: Amaranth, *Nigella sativa*, Microalgae

Table 1 depicts the fatty acid composition and oil content of major primary and secondary sources of oils. Coconut oil is the most saturated oil (91.4 %) followed by palm kernel oil (83.9%). Mustard oil and safflower oil the richest source of MUFA and PUFA, respectively. Linseed oil is having highest amount of α-linolenic (ω-3 fatty acid).

Table 1: Fatty acid composition and oil content of major sources of oils

Oil	**8:0 (CL)**	**10:0 (C)**	**12:0 (L)**	**14:0 (M)**	**16:0 (P)**	**16:1 (PL)**	**18:0 (S)**	**18:1 (OL)**	**18:2 (LA)**	**18:3 (ALA)**	**20:0 (AA)**	**20:1 (I)**	**22:1 (E)**	**Oil content (%)**
Coconut	8.0	6.4	48.5	17.6	8.4		2.5	6.5	1.5		0.1	-	-	63-70
Palm kernel	3.9	4.0	49.6	16.0	8.0		2.4	13.7	2.0		0.1	-	-	40-52
Palm	-	-	-	-	45.1	0.1	4.7	38.8	9.4	0.3	0.2	-	-	
Olive	-	-	-	-	13.7	1.2	2.5	71.1	10.0	0.6	0.9		-	25-30
Groundnut	--	-	-	0.1	11.6	0.2	3.1	46.5	31.4		1.5	1.4	-	40-55
Rice bran	0.1	0.1	0.4	0.5	16.4	0.3	2.1	43.8	34.0	1.2	0.5			15-20
Mustard	-	-	-	1.4	3.8	0.2	1.1	11.6	15.3	5.9	-	6.2	41.1	35-42
Corn	-				12.2	0.1	2.2	27.5	57.0	0.9	0.1	-	-	3-5
Cottonseed	-	-		0.9	24.7	0.7	2.3	17.6	53.3	0.3	0.1	-	-	18-20
Sunflower	-	-	0.5	0.2	6.8	0.1	4.7	18.6	68.2	0.5	0.4	-	-	30-42
Safflower	-	-	-	0.1	6.5		2.4	13.1	77.7	-	0.2	-	-	28-35
Soybean	-	-	-	0.1	11.0	0.1	4.0	23.4	53.2	7.8	0.3	-	-	18-22
Linseed	-	-	-	-	4.8		4.7	19.9	15.9	52.7	-	-	-	30-45
Sesame	-	-	-	-	9.9	0.3	5.2	41.2	43.1	0.5	-	-	-	45-53
Niger	-	-			7.2	0.1	5.3	31.1	56.3	0.2	-	-	-	35-45

Abbreviations: CL-Caprylic acid, C- Capric acid, L-Lauric acid, M- Myristic acid, P- Palmitic acid, Pl-Palmitoleic acid, S- stearic acid, Ol- Oleic acid, La- Linoleic acid, ALA- αlinolenic acid, AA- Arachidic acid, I- Iicosenoic acid, E- Erucic acid

Saturated fatty acids are classified into four subclasses according to their chain length (Table 1)

1. Short-chain fatty acids: Fatty acids with from 3 to 7 carbon atoms
2. Medium-chain fatty acids: Fatty acids with from 8 to 13 carbon atoms
3. Long-chain fatty acids: Fatty acids with from 14 to 20 carbon atoms
4. Very-long-chain fatty acids: Fatty acids with 21 or more carbon atoms

The unsaturated fatty acids are also classified into three sub-groups according to their chain lengths

1. Short-chain unsaturated fatty acids: Fatty acids with 19 or fewer carbon atoms.

2. Long-chain unsaturated fatty acids: Fatty acids with 20 to 24 carbon atoms.
3. Very-long-chain unsaturated fatty acids: Fatty acids with 25 or more carbon atoms.

The energy yield from a gram of fat catabolism is 9 Kcal, compared with 4 Kcal from protein or carbohydrates. Fatty acids are less efficiently used for energy production than carbohydrates, and are preferentially stored in the adipose tissue. In general, long-chain fatty acids are oxidized more slowly and unsaturated fatty acids oxidized more rapidly than saturated fatty acids. Oxidation of saturated fatty acids decreases with increasing carbon chain length.

Essential fatty acids

Linoleic (LA) and α-linolenic (ALA) acids cannot be synthesized by mammals because they cannot introduce double bonds between $\Delta 10$ and the methyl terminal end. LA and ALA are necessary precursors for the synthesis of long chain PUFA and eicosanoids such as, (prostaglandins (PG), prostacyclins (PGI), thromboxanes (TX), leukotrienes (LT), hydroperoxytetraenoic acids (HPETE), hydroxyeicosatetraenoic acids (HETE) and lipoxins. Hence, they are essential fatty acids and they must be obtained from the diet.

Major functions of essential fatty acids

- Regulate pressure in the eyes, joints, and blood vessels, response to pain, inflammation, and swelling
- Play a role in modulating immune functions and inflammatory processes
- Regulate steroid production and hormone synthesis
- Regulate bodily secretions and their viscosity, smooth muscle and autonomic reflexes
- Dilate or constrict blood vessels
- Are primary constituents of cellular membranes
- Necessary for the transport of oxygen from the red blood cells to tissues
- Necessary for proper kidney function and fluid balance
- Prevent red blood cells from clumping together
- Regulate the rate at which cells divide and nerve transmission

Once LA and ALA are obtained from the diet, they can be converted to long chain PUFA by a series of alternating desaturation and elongation reactions. The long-chain omega-3 fatty acids, eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), can be synthesized from ALA, but due to low conversion efficiency, it is recommended to obtain EPA and DHA from additional sources. EPA and DHA from fish are more effectively incorporated into plasma lipids than when administered as capsules.

Some environmental factors like dietary cholesterol, high fat diet, liver cirrhosis, low insulin levels, deficiency of protein and minerals such as iron, zinc, copper and magnesium affect the activity of desaturases, and therefore, the conversion of LA and ALA to their long chain PUFA. Alcohol consumption, cigarette smoking and high intake of LA in diet also decrease tissue long chain PUFA concentrations.

Fat and fatty acid requirements for adults

Apart from the caloric and nutritional value, fats enhance the taste, acceptability and palatability of foods. The lipid components enhance and release the flavours and aroma of other food components. Due to slow gastric emptying and intestinal motility, lipids impart the feeling of satiety. FAO, WHO and American heart association have recommendations for consumption of fats (Table 3) and fatty acids (Table 2) in human diet. The World health organization (WHO) recommends an ideal intake a ratio of poly unsaturated fatty acid to saturated fatty acid as 0.8 to 1 and ω -6 to ω -3 fatty acids as 5 to 10. The acceptable range for total fat intake for adults is between 20% and 35% of energy (E) and it should be greater than 15% E to ensure an adequate intake of essential fatty acids and to facilitate the absorption of lipid-soluble vitamins A, D, E and K. The absorption of these vitamins is impaired at very low fat intakes. While for moderate physically active individuals 30% E is recommended, for those associated with a high physical activity level it can amount to 35% E. For an adult moderate worker requiring 2730 Kcal/day, the recommended dietary intake of visible fats is of 30 g per day (ICMR-NIN).

Table 2: Fatty acids requirement

Saturated (SFA)		Monounsaturated (MUFA)		Polyunsaturated (PUFA)	
1	:	1	:	1	American Heart Association
1	:	1.5	:	1	Japan’s Ministry of Health & Welfare
1	:	1.5	:	0.7	WHO

Table 3: Calories requirement for different age groups

Gender	Age (years)	Sedentary	Moderately Active	Active
Child	2-3	1,000	1,000-1,400	1,000-1,400
Female	4-8	1,200	1,400-1,600	1,400-1,800
	9-13	1,600	1,600-2,000	1,800-2,200
	14-18	1,800	2,000	2,400
	19-30	2,000	2,000-2,200	2,400
	31-50	1,800	2,000	2,200
	51+	1,600	1,800	2,000-2,200

Male	4-8	1,400	1,400-1,600	1,600-2,000
	9-13	1,800	1,800-2,200	2,000-2,600
	14-18	2,200	2,400-2,800	2,800-3,200
	19-30	2,400	2,600-2,800	3,000
	31-50	2,200	2,400-2,600	2,800-3,000
	51+	2,000	2,200-2,400	2,400-2,800

During the first 6 months of life, dietary total fat should contribute 40–60% E to cover the energy needed for growth and the fat required for tissue deposition (Table 4). DHA plays a critical role in normal retinal and brain development. However, it can be synthesized from ALA given its limited and highly variable formation (1-5%) it should be considered conditionally essential for the first 6 months of life.

Cereals contain only 2-3% of invisible fat. However, their contribution to overall fat intake is significant as they contribute to bulk of our Indian diets. The small amounts of invisible fat present in various foods add up to a substantial level in our daily diet (about 15 g in rural population and 30g among urban middle-income and high-income groups). Most animal foods provide high amounts of invisible fat.

Table 4: Fatty acids requirement for different age groups

Component	0-6 months	6-24 months	2-18 years	Adult
Total fat (E%)	40-60	35	25-35	20-3
SFA (E%)	-	-	8	10
Total PUFA (E%)	-	<15	11	6-11
AA (E%)	0.2-0.3	-	-	
n-6 (LA) (E%)	-	3-4.5	3-4.5	2.5-9
n-3 (ALA) (E%)	0.2-0.3	0.4-0.6	0.5-2	0.5-2
DHA	0.1-0.18 E%	10-12mg/kg	-	-
TFA(E%)	For all age groups<1			
MUFA	total fat [%E] - SFA [%E] - PUFA [%E] - TFA [%E]			

Nutraceuticals in oils and their uses in human health

Oryzanol

Oryzanol is the important compound naturally found in rice bran oil. It is an antioxidant compound and is associated with decreasing lowering serum cholesterol, plasma cholesterol, decreasing cholesterol absorption and decreasing platelet aggregation. Oryzanol has also been used to increase the muscle mass, disorders of menopause and to treat hyperlipidemia. γ-oryzanol component of rice bran oil was first presumed to be a single component. However, later it was determined to be a fraction containing ferulate (4-hydroxy-3-methoxy cinnamic acid) esters of triterpene alcohols and plant sterols.

Lecithin (Phospholipids)

Found in all vegetable oils but oil derived from rice bran, soybean, mustard and sunflower are good sources of lecithin. Lecithins are phospholipids, made up primarily of fatty acids, glycerine, phosphoric acid and choline. Physiologically, it stabilizes cell membranes, stimulates metabolic activity and acts as a antioxidant. In industry it is being used as an emulsifier, dispersant, separating agent and to encapsulate flavour. Lecithin combines with fats and oils just as well as with water. The amphiphilic nature makes lecithin ideal for making soft-spread margarine, crispy pasta, flavourful chocolates and readily soluble cocoa powders.

Tocopherols and Tocotrienols

Edible oils are the major natural dietary sources of tocopherols and tocotrienols, collectively known as tocols (commonly known as vitamin E). Tocopherols and tocotrienols are monophenols, and exist as four homologues (alpha, beta, delta and gamma), which differ from each other by the number and location of methyl groups in their chemical structures. α-tocopherol, which is the most common homologue, is the major tocopherol in many edible oils. However, canola, corn, camelina, linseed, soybean, and walnut have high γ- tocopherol content. Palm oil is the richest source of tocotrienol and contains three tocotrienol homologues (alpha, gamma, and delta). Tocopherols are among the most important lipid-soluble antioxidants in food as well as in human and animal tissues. Tocopherols are found in lipid-rich regions of cells (e.g., mitochondrial membranes), fat depots, and lipoproteins such as low-density lipoprotein cholesterol. Because of their antioxidant activity, tocols play a major role in protecting mono- and polyunsaturated fatty acids (PUFAs) from oxidation, which may also explain the high concentration of these phenolic antioxidants in highly unsaturated edible oils.

Phytosterols

Phytosterols (sterols and stanols) are high value compounds present in seed oils having cholesterol-lowering properties. Phytosterols are structurally similar to the body's cholesterol, and when they are consumed they compete with cholesterol for absorption in the digestive system. As a result, cholesterol absorption is blocked, and blood cholesterol levels are reduced.

Sterols

Plant sterols are C-28 or C-29 sterols, differing from cholesterol (C-27) by the presence of an extra methyl or ethyl group on the cholesterol side chain. In vegetable oils, phytosterols occur as free sterols or as steroyl esters. They present a significant part of the organism membrane biomass, while their functional role is evident through the participation in the control of membrane-associated metabolic processes, such as regulations of membrane permeability and fluidity, signal transduction events and the activity of membrane-bound enzymes. Sterols are the precursors of steroid hormones and bile acids in humans. Plants have a variety of more than 40 well-identified and studied sterols, which are termed phytosterols and are predominantly present in oilseed plants. The most abundant phytosterols are sitosterol, campesterol and stigmasterol. Phytosterols are with respect to their physiological function and their chemical structure, similar to the major and only animal produced sterol – cholesterol.

Stanols

Saturated derivatives of plant sterols are called plant stanols. Plant stanols are virtually unabsorbable, which make them more ideal hypocholesterolemic agents than plant sterols. In 1995, the Finnish introduced plant stanol esters in margarine, as dietary adjuncts to lower cholesterol.

Phenolic compounds

Phenolics (hydroxytyrosol, tyrosol, vanillic acid, p-coumaric acid, ferulic acid and vanillin) are the most reported antioxidative compounds in oilseeds, probably due to their presence in large quantity in mature seeds. Olive oil, sesame oil and groundnut oil are rich in phenolic compounds. Sesame has a unique class of phenolic compounds called lignans (sesamin, sesamol and sesmolin).

Omega-3 and omega-6 fatty acids

As discussed, human body cannot synthesize LA and ALA, which are necessary precursors for the synthesis of long chain PUFA and eicosanoids. LA is predominant fatty acid in majority of oils. Safflower oil contains the highest LA content and linseed contains maximum ALA content.