

## **Chemistry of Oils & Fats and their Health Effects**

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### **Abstract**

Fats and oils are considered as essential nutrient in our diet. All fats are not bad, in fact, healthy fats are essential to manage our body systems, maintain our mental health, fight fatigue and even control weight. They provide us with the most concentrated source of energy along with essential fatty acids that act as precursors to important hormones, the prostaglandins. They act as carriers for many fat soluble vitamins and make our food more palatable. Healthy fats are vital for proper brain development and function as the human is nearly 60% fat. So our first task is to understand the chemistry of fat, type of fatty acids contained in fat from which we can decide which fat is good and which is bad for health. According to public health recommendations in 1977 in US, fat intake should be reduced to as low as 30% of calories to lower the incidence of CAD. Whereas according to current recommendations the Trans fats, saturated fats and cholesterol intake should be kept as low as possible while consuming a nutritionally adequate diet. This review summarizes chemistry of fats and oils along with findings and observations on the role of good fats however also discussing the harmful effects of saturated and trans fats and the oils rich in certain kind of fats so that one can choose the right oil.

### **INTRODUCTION**

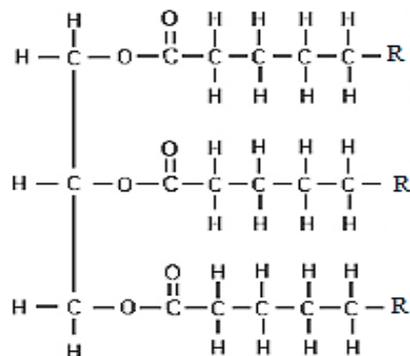
Chemically fats are triesters of glycerol and fatty acids. The words fats, oils and lipids are all used to refer to fats with different characteristics especially physical state. Word fat is generally used to refer to fats which exists as solids at normal room temperature and word oils is used to refer to fats which exists as liquids at normal room temperature while word lipids is used to refer to both solid and liquid fats (Anther 1993).

The major component of most of the fats and oils are triacylglycerols while minor components comprise mono- and diacylglycerols, free fatty acids, phosphatides, fat soluble vitamins such as vitamin A & D, sterols, tocopherols, fatty alcohols, carotenoids & chlorophyll etc. (Strayer 2006). The levels of free fatty acids, carotenoids & chlorophyll and phosphatides are reduced during refining of oils [1-4].

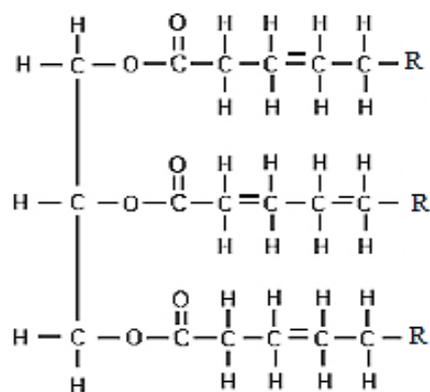
## THE CHEMICAL STRUCTURE OF FATTY ACIDS

Fatty acids may be either saturated or unsaturated.

**Saturated Fats:** Some fatty acids exist saturated (i.e. do not contain double bond) in nature so they cannot be made further harder than they are in nature. The proportion of saturated fats is usually higher in those fats which exist as solid at normal room temperatures [11]. Saturated fatty acids are very stable and have good shelf life i.e. they do not readily become rancid. Most of the animal fats such as meat, butter, cream and cheese contain comparatively high proportion of saturated fat so should be consumed with restraint. Baked goods such as cakes, biscuits and pastries also have high amounts of saturated fat. However, Government recommendations advise consumers to limit their consumption of saturated fats because they may increase blood cholesterol levels causing heart disease [23, 24].



Saturated Fat



Unsaturated Fat

**Unsaturated Fats:** Unsaturated fats contain unsaturated fatty acids combined with glycerol i.e. fatty acids may contain one or more double bonds.

There are three types of unsaturated fatty acids:

**1. Monounsaturated Fatty Acids (MUFA):** Fatty acids in this category have one double bond in their hydrocarbon chain. They are considered as the best type of fat to eat in nutritional terms since they are comparatively stable to oxidation and the development of rancidity. The olive oil and rapeseed oils are the most common source of monounsaturated fatty acids [5, 6, 28].

**2. Polyunsaturated Fatty Acids (PUFA):** Polyunsaturated fatty acids contain two or more double bonds in their hydrocarbon chain. They are least stable fatty acids and are highly prone to oxidation. So they are best used in cold applications. The sunflower seed oil is the most common source of polyunsaturated fatty acids [7,8,38].

**3. Trans Fatty Acids (TFA):** The two common sources of trans fatty acids are hydrogenated vegetable oils and animal fats. They are Trans geometrical isomers of various fatty acids.

Two types of Trans fatty acid (TFAs) isomers can be found in fats as naturally and industrially produced fatty acids.

TFA in tallow and milk fat is vaccinic acid C<sub>18:1</sub> (n-7t) which is naturally formed during bio hydrogenation and isomerization of PUFAs in rumen guts.

Catalytic hydrogenation of polyunsaturated fatty acids in an industrial modification process applied to reduce some of the double bonds of polyunsaturated fatty acids in order to improve oxidative stability of oils and increasing their hardness produces TFA, which are almost unavailable in natural fats. TFA levels and isomeric distribution depend on processing factors such as hydrogen pressure and concentration, nickel catalyst type, stirring speed, and reaction temperature, fatty acid composition of original oil, and degree of saturation (partially or fully hydrogenation)[20,33,35].

Partial hydrogenation yields generally geometrical and positional trans-18:1 isomers mostly elaidic acid during reducing the amount of PUFA. Deodorization process of edible oils produces a small amount of trans-linoleic and trans-linolenic acid [18].

Recent scientific research recommends that consumptions of trans fats should be avoided because they are considered to enhance blood cholesterol levels leading to heart diseases. TFAs elevate the amount of LDL cholesterol and lower the level of HDL cholesterol which are the main causes for cardiovascular diseases [23, 26]. TFAs in a diet have also been found to increase the risk of chronic diseases such as inflammatory, autoimmune diseases and cancer [19, 21].

New regulations on TFA labeling, have banned the use of industrially produced trans fats in foods[ 18,20]. but still in some foods such as confectionery coatings and fillings, biscuits , pie crusts, toffees, and dairy products such as butter, cream, and toppings etc. trans fat is being used.

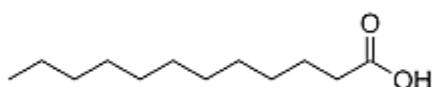
## **CLASSIFICATION OF OILS AND FATS BASED ON FATTY ACIDS**

**Medium-Chain Fatty Acids (C<sub>6</sub> to C<sub>10</sub>):** This group of oils (MCTs) is significant in providing an instant source of energy for the body. These fatty acids having small size and higher solubility are mainly transported directly via portal circulation. They are metabolized in the liver, while longer-chain fatty acids are absorbed via the lymphatic

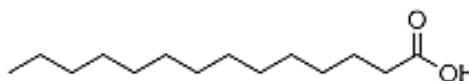
system after micellar transport at the intestinal wall. MCTs have no effect on LDL-, HDL-cholesterol or triacylglycerol concentration in serum and can be helpful in checking obesity.

### Lauric Acid and Myristic Acid

Lauric acid and myristic acid are observed to be the most blood cholesterol and LDL-cholesterol increasing fatty acids among saturated fatty acids. This effect is found to be higher in case of myristic acid than lauric acid[11]. Coconut oil and palm kernel oil are considered in this subgroup [8, 43].



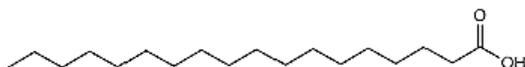
**Lauric Acid (C-12)**



**Myristic Acid(C-14)**

### Palmitic Acid

The palmitic acid has lower effect on increasing serum cholesterol and LDL cholesterol as compared to lauric acid and myristic acid. Palm oil and lard belong to this group [8, 35].



**Palmitic Acid (C-16)**



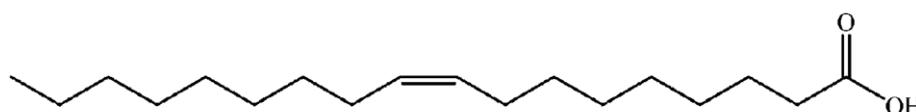
**Stearic Acid (C-18)**

### Stearic Acid

Among saturated fatty acids, stearic acid has been found to have no harmful effect on plasma lipids. Cocoa butter and shea butter contain about 40% of stearic acid so considered to belong to this subgroup [8].

### Oleic Acid

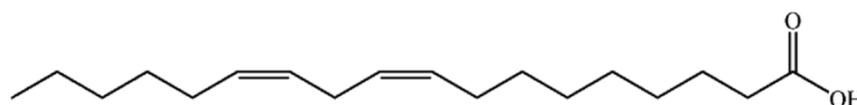
Olive oil contains about 80% of oleic acid so is considered as the best participant of this subgroup followed by canola oil with about 65% oleic acids [27,29]. Hazelnut oil and macadamia oil are rich in oleic acid.



**Oleic Acid(C-18)**

### Linoleic Acid

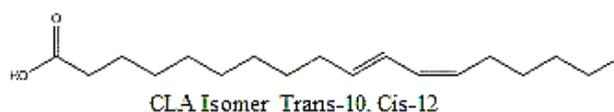
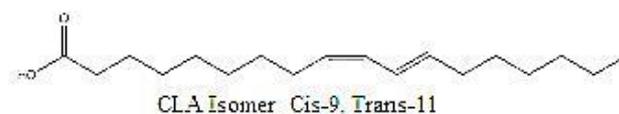
This fatty acid, linoleic acid is essential for good health and is termed as an essential fatty acid [9]. It cannot be synthesized by human body from food components. The common vegetable oils considered in this group are evening primrose oil, grape seed oil and safflower oil [8].



**Linoleic Acid (C-18)**

### Conjugated Linoleic Acid

Conjugated linoleic acid (CLA) is a name given to refer to positional and geometric isomers of linoleic acid. These are found in animal fats such as lamb, beef, and dairy products. CLA are obtained on microbial fermentation of PUFAs and isomerization of linoleic acid.



In linoleic acid double bonds are present between the ninth and tenth carbons and the twelfth and thirteenth carbons whereas CLA contains conjugated double bonds at carbon atoms 10 and 12 or 9 and 11, with cis and trans combinations. have shown that conjugated linoleic acid have been found in many clinical studies to have physiological effects such as anticarcinogenic, antiatherogenic, checking of type II diabetes, and immunomodulating properties of CLA. Conjugated linoleic acid has been observed to be quite effective to inhibit the growth and metastasis of prostate and breast cancers in some clinical studies on animals [17-19].

In case of dietary fat, the type of fat we eat matters the most. In past the intake of low fat diets were advocated in dietary advice, but recent research shows that healthy fats are necessary and beneficial for health. Because in an effort to reduce the intake of fat some other unhealthy food items are consumed for instance, food manufacturers in an effort to reduce fat, usually replace it with Carbohydrates from sugar and refined grains. As Human body digests these refined carbohydrates and starches very quickly, so blood sugar and insulin levels increase resulting in weight gain and diseases. Also

It has observed from the Nurses' Health Study and the Health Professionals Follow-up Study that there is no link between the overall percentage of calories from fat and any significant health outcome, such as cancer, heart disease and weight gain[19,23].

Hence it is more significant to emphasise on eating beneficial good fats and avoiding harmful bad fats rather than adopting a low-fat diet[12].

**Good unsaturated fats:** Eating monounsaturated and polyunsaturated fats in food lower the risk of disease. Foods rich in good fats include vegetable oils such as olive, canola, sunflower, soy, corn etc, nuts, seeds, and fish[12,27,29,37,38].

**Bad fats:** Trans fats increase risk of disease, even when consumed in small quantities. Trans fats are produced as a side effect of hydrogenation of animal fat e.g. margarine or vegetable fat e.g. Vanaspati ghee. In case of incomplete hydrogenation i.e. partial hardening, the comparatively high temperatures used in the hydrogenation process have tendency to flip some of the carbon double bonds into the trans form. These particular bonds will still be present in the final product as trans-fatty acid if they escape hydrogenation in the process. It is the most harmful type of fat for health and has been related with development of CAD because TFA also lowers HDL in addition to increasing LDL like SFA[20,23,24].

The net increase in LDL/HDL ratio with TFAs is about 7 which is almost double than that due to SFAs. Eating diets containing TFA may also increase the risk of other chronic health complications such as Alzheimer's disease, cancer, diabetes, obesity, liver dysfunction, infertility and depression in addition to CV risk. Rich sources of trans fatty acids are processed fried foods like bhujia, biscuits, confectionary items, samosas, etc.[20]

Saturated fats, though not as harmful as trans fats, but as compare to unsaturated fats, they adversely influence health and should be consumed with restraint. Foods having large amounts of saturated fat comprise red meat, butter, ice cream, cheese etc.[12]

**Omega-3 fatty acids:** Omega-3(N-3) fatty acids are a group of PUFA, which are considered good for health. They are one of the two essential fatty acids which cannot be synthesized in human body and it has to be taken from food. N-3 fatty acids are predecessors to anti-inflammatory compounds in the body. Oily fish from near polar regions are a good source of omega-3 fatty acid. Seeds of the Brassica family, such as mustard (6- 11%), canola / rapeseed (7%) and turnip, have high amounts of omega-3 fatty acid. Flax oil is the richest source of plant based omega-3 fatty acid (55%) followed by hemp oil (20%) but these oils are not commonly used for cooking due to their low smoke point. Soybean oil contains 6% omega-3 but has over 50% omega-6 which competes with the function of omega-3. If omega-6 intake is low, humans can convert the plant-based omega-3 into omega-6, the one found in fish oils i.e. eicosapentaenoic acid, in some amounts thus making a useful source of eicosapentaenoic acid for vegetarians[13,19].

**Omega-6 fatty acids:** Omega-6 fatty acids (N-6) are also vital for good health. They comprise the essential fatty acid linoleic acid (LA), which is ample in vegetable oils like corn (60%), sunflower (50%) oil and cottonseed (50%). Margarine is very high in omega-6 fatty acids. N-6 fatty acids are precursors to pro-inflammatory compounds in the body. Moreover, large quantities of omega-6 decrease the effect of omega-3[13,19].

**N-6: N-3 ratio:** N-6 and N-3, both are essential for proper functioning of body, but they should be present in balanced proportion in the body. N-6 and N-3 compete for the enzymes which convert them into biologically more active compounds. Hence, when more omega-6 is consumed, it uses proportionately more of those enzymes, eventually resulting into a more pro inflammatory environment. As per Institute of Medicine an appropriate intake (AI) for N-6 is about 10 to 15 grams a day. The AI for N-3 is at least 1 to 2 grams per day. Although appropriate intakes are estimations and are found to vary with age, gender, life stage, activity level etc., but the ratio in the diet is recommended to be less than 4:1. World Health Organization (WHO) recommends N-6: N-3 ratio to be 5:4 and many organisations consider optimum ratios to be closer to 1:1[22].

Fats/oils	Saturated Fatty acid	Mono-unsaturated Fatty acid (MUFA)	Linoleic acid (Omega-6 PUFA)	Alpha-linoleic Acid(Omega-3PUFA)	N-6/N-3 ratio
Mustard	8	70	12	10	1.2:1
Canola	4	62	22	10	2.2:1
Ghee	65	32	2	<1	3:1
Soybean	15	27	53	5	10.6:1
Red palm	50	40	9	<.5	18:1
Olive oil	13	76	10	<.5	20:1
Palm oil	45	44	10	<.5	20:1
Rice bran	22	41	35	1.5	23:1
Groundnut	24	50	25	<.5	50:1
Sunflower	13	27	60	<.5	120:1
Safflower	13	17	75	<.5	140:1

Source: POS Pilot Plant Corporation, Saskatoon, Saskatchewan, Canada, June 1994; National Institute of Nutrition, India, 1995.

### Getting the best from our oil

Presence of light, temperature and air causes oils to oxidize, become rancid and break down thus altering the flavour and colour of the oil. For example olive oil is generally

good three to twelve months after it has been bottled. After about two years due to the oxidation and formation of new products in the oil, the fruity flavours gradually disappear and some of the bad or bitter flavours appear.

Oil's stability (i.e. how fast it oxidizes) depends upon numerous factors including how refined it is and the proportion of saturated and unsaturated fats contained in it. So we should buy oils as local and fresh as possible, in smaller quantities and store them properly to best preserve all oils. Oil should be kept cool, sealed and away from light.

### **Undesirable reactions**

The refined oils, such as plain olive oil, canola and sunflower are recommended for cooking as heat causes oils to oxidise faster. Also refined oils have a higher smoke point, so they can be heated to a higher temperature before beginning to burn and smoke [24].

Heating oil too much i.e. up to its smoking point may change the chemical composition of the oil which becomes harmful to our health when we ingest it and even inhale its fumes. When we heat fats and certain foods such as fatty meats at very high temperatures i.e. deep-frying, or barbecuing and stir-frying on very hot surfaces, polycyclic aromatic hydrocarbons (PAHs) may be formed which are supposed to be carcinogenic [25]. Advanced Glycation End Products (AGEs) are also formed when foods mainly meat and potato chips are browned. These chemicals are believed to be related with an enhanced risk of age-related diseases such as Alzheimer's, heart disease, stroke and cataracts [16].

### **Healthy Oils**

Many oils are available in the market but oils for cooking should be chosen on the basis of their proposed use, shelf life, the fat composition and the N-3, N- 6 ratio. However, many oils have some special components or characteristics which make them particularly useful. For e.g. for deep frying, oils with high smoke point should be selected. For healthy eating, the plant-based cooking oils should be selected instead of butter, lard and animal fats because most of the plant-based oils contain much lower proportion of saturated fat which is harmful for our hearts and are richer in the polyunsaturated and monounsaturated fats which are beneficial for our heart health. Some of the plant based oils are discussed here.

### **Plant based oils**

**Mustard oil:** This is oil primarily used in North India and East India. It has a hot nutty taste and pungent smell. Mustard oil contains nearly 70 % MUFA with 42 % of erucic acid and 12 % of oleic acid, it has 22 % PUFA content of which 10 % is the omega-3 alpha-linolenic acid and 12 % omega-6 linoleic acid and 8 % SFAs. Mustard oil having high levels of omega-3 (10 %) is a common, cheap, mass-produced vegetarian source of omega-3 fatty acids[8,13]. Once it was considered unhealthy for human consumption due to high percentage of erucic acid in it. However, in later

studies it was shown that in rats there is an inefficient activation of erucic acid to erucyl-CoA and a low level of activity of triglyceride lipase and enzymes of beta-oxidation for erucic acid which was possibly considered to contribute to the accumulation and retention of cardiac lipid[14]. Now a days mustard oil is considered as one of the healthiest edible oils because it contains low proportion of SFAs (only 8%) and a high proportion of MUFA and PUFA fatty acids (92%), which are good for health[33,46]. Besides, mustard oil has the N-6: N-3 ratio near ideal 6: 5 unlike that of olive oil which is ~ 20:1[22]. It has a high content of antioxidants and vitamin E and as it is cold pressed so the nutrition value of this oil is retained. Also the presence of alpha linolenic acid in mustard oil reduces the adhesion-aggregation tendency of blood platelets which leads to decrease in the risk of a heart attack [23,26].

**Rapeseed oil (Canola oil):** It is plant-based oil, considered to be a close relative of mustard (Brassica family) as it also has low in SFA content (less than 7%), high MUFA content and contains a beneficial omega-3 fatty acid profile. Hence canola oil is considered good for human consumption by many health professional organizations including the American Dietetic Association (ADA), and American Heart Association (AHA)[27,28].

**Olive oil:** Olive oil is obtained from the olive, a traditional tree crop of the Mediterranean basin. It has been considered the best oil by some because it has the highest MUFA content (75 %) among all other oils. Furthermore, there are present a large variety of valuable antioxidants (hydroxytyrol is the main antioxidant compound in olive oil) which are supposed to play a significant role in the many health benefits credited to olive oil [29-33]. The consumption of MUFA particularly oleic acid results in lowering of LDL cholesterol and elevation of HDL cholesterol which causes decrease in the risk of CAD [23, 26]. Besides, it exerts anti-inflammatory, antithrombotic, antihypertensive as well as vasodilatory effect [34]. It has been observed that the least processed forms of olive oil i.e. extra virgin or virgin olive oil have more MUFA than other olive oil. Extra-virgin olive oil contains the highest concentration of polyphenolic antioxidants (oleuropein or tyrosol) which have been linked with increased arterial elasticity which leads to decreased risk of stroke and heart attacks. It also shows a protective effect against certain malignant tumours in the breast, endometrium, prostate and digestive tract. The key limitation of this oil is its non-ideal N-6: N-3 ratio i.e. 20:1 deviating a lot from ideal 1:1 ratio [22].

**Soya bean oil:** It is one of the most widely consumed cooking oil these days. Like safflower and sunflower oil, it is also contains high content of PUFA though less than them. The major unsaturated fatty acids in soybean oil are 7–10% alpha linolenic acid (C-18:3); 51% linoleic acid (C-18:2); and 23% oleic acid (C-18:1). It has saturated fatty acids 4% stearic acid and 10% palmitic acid. As it has a high content of linolenic acid so has tendency to turn rancid earlier therefore it should be used fresh like safflower oil and sunflower oil[35-37].

**Sunflower oil:** Like safflower oil it is high in PUFA and the essential vitamin E contents and low in unwanted SFA. In addition it is rich in lecithin, tocopherols,

carotenoids and waxes. Practically, it is good cooking oil known for having a clean taste and low levels of trans- fat. However, it has a high omega-6 polyunsaturated fatty acids content[38-40]. Some studies have advocated that it may increase the likelihood of breast and prostatic cancer. Another major limitation of this oil is very poor N-6 / N-3 ratio of 120:1[22].

**Ground nut oil:** It is most often used in Chinese, South Asian and Southeast Asian cuisine. Peanut oil is appreciated for its high smoke point comparative to many other cooking oils. In addition, it has a good taste. Its main constituent fatty acids are oleic acid (MUFA), linoleic acid (PUFA), and palmitic acid (SFA). The oil also comprises some stearic acid, arachidic acid, arachidonic acid, behenic acid, lignoceric acid and other fatty acids. This is considered the heart friendly oil which is not only rich in MUFA but otherwise also has well balance of other constituents [41,42].

**Coconut oil:** Coconut oil has been used in many cultures especially in India. South Indians usually use this oil in cooking majority of their local dishes. However coconut oil contains about 90% saturated fat, which is even a higher percentage than butter (about 64% saturated fat), beef fat (40%), or even lard ( 40%) [43]. So much saturated fat in the diet is unhealthy because it raises LDL (bad) cholesterol levels, which increases the risk of heart disease. But coconut oil also has a high potential to give HDL (good) cholesterol a boost. About 50% of the saturated fat in coconut oil is the lauric acid (12-carbon) which is a higher percentage than other oils, and thus may be probably responsible for the unusual HDL effects of coconut oil. But plant-based oils contain many antioxidants and other substances in addition to being fats, so the changes in LDL and HDL can't predict their overall effect on the health. Coconut has a wonderful flavour so using coconut oil occasionally does not give much problem. As coconut oil is solid at room temperature, cooks are trying to experiment using it in place of butter or vegetable shortening to make pie crust and other baked goods that require a solid source of fat. As a conclusion, coconut oil should be used sparingly. It has been concluded from short-term studies to examine the effect of coconut oil on cholesterol levels that it is not as healthy as vegetable oils like olive oil and soybean oil, which contain mainly unsaturated fat and therefore both lower LDL and increase HDL. Though coconut oil's special HDL-boosting effect makes it less bad than the high saturated fat content indicates, but it's still not the preferred choice among the many available oils to reduce the risk of heart disease [23, 26 ].

**Butter:** It is obtained from animal source and has high SFAs and cholesterol contents. It may raise total and LDL cholesterol but may also increase HDL cholesterol [47]. Being a good flavouring agent it can be used for baking but as it has a low smoke point hence cannot be used for deep frying [51].

**Vanaspati ghee:** It is a hydrogenated refined vegetable oil [48] which has been made more stable [33, 35]. It has more shelf life and has least tendency to turn rancid. It has a relatively low smoke point so not good for deep frying. Furthermore, it is considered to be the unhealthiest of all oils [51] because it is devoid of natural vitamins and bio-active compounds [46, 52 ] due to refining and also hydrogenation

process results in the formation of an undesirable type of fat called trans-fat [22]. Consumption of trans fat leads to the worst type of lipid profile possible and has been directly linked with development of CAD [23, 26, 47].

## **CONCLUSION**

In terms of overall health benefits, extra virgin olive oil and canola oil are the best choices, says Associate Professor Catherine Itsiopoulos, head of dietetics at La Trobe University and spokesperson for the Dietitians Association of Australia.

Although extra virgin olive oil does contain saturated fat (only around 12 per cent), it is one of the few unrefined oils. This means that the antioxidants present in the original fruit are retained because the oil is extracted by machine only and not refined with chemicals or other means that can remove the goodness from the oil. While most canola oil products are refined and don't contain many antioxidants, they have the advantage of having even less saturated fat than olive oil (around eight per cent). A daily amount of these oils recommended is about two to three tablespoons which would be perfectly in keeping with a healthy balanced diet and even a weight-loss rule.

For cold dishes i.e. with salads and breads use of extra virgin olive oil is recommended in order to take advantage of the flavours and antioxidants. Refined oils such as canola, sunflower and plain olive oil are recommended for cooking i.e. casseroles, sautéing and stir-frying and peanut oil and other flavoured oils such as sesame, macadamia are suggested to be used in dishes that demand certain flavours.

Meanwhile, tropical oils, such as palm, cottonseed and coconut, should be limited because they are naturally more saturated. Also, it is generally recommended that to achieve best health benefits, oils rich in PUFA should be used in combination with those rich in MUFA like olive oil, mustard oil or groundnut oil.

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