Canola Oil:

Nutritional Properties

by Dr. Bruce E. McDonald

Developments over the past few years on the nutritional properties of dietary fats has created considerable excitement, not only in medicine and health care but in the vegetable oil industry as well. Several of these developments have important implications for the canola industry in Canada and worldwide. Of particular significance to the canola industry are:

- the recommendation that dietary fat be reduced to 30% and saturated fat to less than 10% of the total energy in the diet;
- the finding that monounsaturated fatty acids are as effective as polyunsaturated fatty acids in lowering blood cholesterol; and
- the finding that omega-3 fatty acids are essential nutrients and that they may help prevent coronary heart disease.

Dietary fat serves several important functions. It is an important source of energy. For example, it makes up 45 to 50% of the calories for the breast-fed infant. Fat also serves as the source of essential fatty acids and as a carrier for the fat-soluble vitamins. It contributes to the palatability of food and to the feeling of satiety. In addition, it has important culinary properties.

No one disputes the importance of fat in the diet. Until recently, however, most of the interest in dietary fat stemmed from its implication in the etiology of chronic diseases such as cardiovascular disease, cancer, hypertension and obesity. Interest has centered on the role of both the amount and type of fat in the development of these diseases.

Recommended Level of Fat in the Diet

Nutrition recommendations in North America and Europe call for a reduction in total fat intake to 30% and saturated fat intake to less than 10% of total energy. Fat intake has decreased over the past decade. Recent nutrition surveys in Canada indicate the average intake may be as low as 34 to 35% of the total energy intake. Dietary fat occurs in two forms: visible fat (e.g., margarine, butter, salad dressings, etc.) and invisible fat (e.g., fat in meats, cheese, nuts, eggs, potato chips, milk, etc.). Invisible fat accounts in large part for the difficulty compiling accurate data on consumption.

There has been a major shift away from fats of animal origin to fats from vegetable sources over the past 30 years. In Canada this shift has been accompanied by a marked increase in the consumption of canola oil which currently accounts for nearly 75% of all vegetable oils processed in Canada. The shift to vegetable oils has resulted in a modest reduction in the intake of saturated fat but it also has resulted in an associated increase in the intake of *trans* fatty acids. *Trans* fatty acids are produced during the hydrogenation of vegetable oils, a process used to convert liquid vegetable oils into solid fats such as margarine and shortening. Like saturated fatty acids, *trans* fatty acids increase plasma cholesterol level, especially low-density lipoprotein (LDL) cholesterol.

Fatty Acid Composition of Canola Oil

Canola oil is characterized by a very low level of saturated fatty acids, a relatively high level of monounsaturated fatty acids and an intermediate level of polyunsaturated fatty acids, with a good balance between the omega-6 and omega-3 fatty acids (see dietary fat chart).

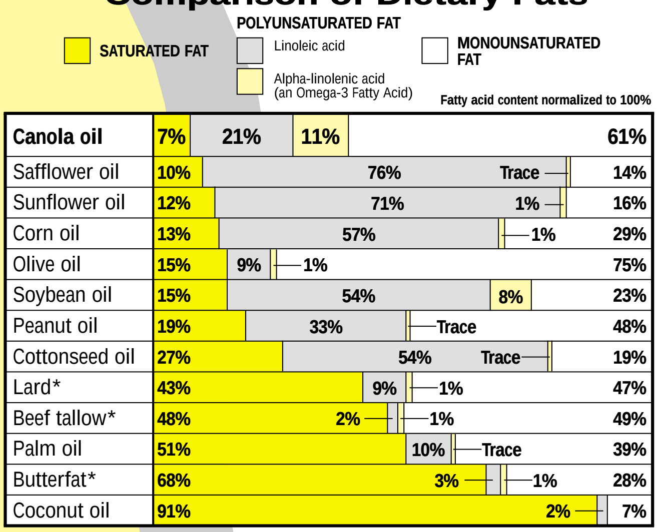
Saturated Fatty Acids.
Canola oil contains only 7% saturated fatty acids; about half the level present in corn oil, olive oil and soybean oil and about one-quarter the level present in cottonseed oil.

Monounsaturated Fatty Acids.
The most abundant fatty acid in nature is the monounsaturated fatty acid (MUFA), oleic acid. It is present in virtually all fats and oils and in some, such as olive oil and canola oil, it is the major fatty acid. Oleic acid makes up 61% of the total fatty acids in canola oil. Among the common vegetable oils, canola oil is second only to olive oil in oleic acid content. Studies over the past 15 years have shown dietary oleic acid is equally as effective in lowering plasma cholesterol level as dietary polyunsaturated fatty acids (viz., linoleic acid). Humans and other species are able to synthesize oleic acid so it is not required in the diet; in other words, it is not an essential fatty acid.

Polyunsaturated Fatty Acids.
Canola oil is intermediate among the vegetable oils in polyunsaturated fatty acid (PUFA) content. It contains appreciably higher levels of PUFA than palm oil or olive oil but lower levels of PUFA than corn oil, cottonseed oil, safflower oil, soybean oil and sunflower oil. Interest in PUFA stems from their role as essential fatty acids and their effectiveness in lowering plasma cholesterol level, a major risk factor in coronary heart disease. Linoleic acid has long been recognized as an essential fatty acid. Animals, including humans, are unable to synthesize it and, therefore, it is required in their diets. However, they are able to convert linoleic acid to arachidonic acid and other members of the omega-6 (also known as the n-6) family of fatty acids. Arachidonic acid is important in membrane structures and is the starting material for the synthesis of "hormone-like" substances, such as prostaglandins, thromboxanes, prostacyclins and leukotrienes. These substances, which are referred to collectively as eicosanoids, are intimately involved in a wide variety of physiological reactions ranging from blood clotting to immune response.

Recent studies have indicated that α-linolenic acid and other members of the omega-3 (also known as n-3) family of fatty acids likewise are essential. Like, linoleic acid, linolenic acid can be converted to other members of the omega-3 family, namely, eicospentaenoic acid (EPA) and docosahexaenoic acid (DHA). DHA is a major constituent of lipids in the brain and the retina of the eye. In addition, the long-chain, highly unsaturated members of the omega-3 family act as precursors for the synthesis of an analogous but different series of eicosanoids. Canola oil contains an appreciable amount (11%) of linolenic acid. Hence, there is a very favorable balance (approx. 2:1) between linoleic acid (omega-6 PUFA) and linolenic acid (omega-3 PUFA) in canola oil. Soybean oil is the only other major edible oil that contains a significant amount of linolenic acid (approx. 8%). However, the ratio of linoleate-to-linolenate in soybean oil is nearly 7:1. The importance of the linoleate/linolenate ratio in the diet is yet to be firmly established but concern has been expressed with the relatively high intake of linoleic acid in some diets.

Comparison of Dietary Fats



* Cholesterol Content (mg/Tbsp): Lard 12; Beef Tallow 14; Butterfat 33. No cholesterol in any vegetable-based oil.
Source: POS Pilot Plant Corporation, Saskatoon, Saskatchewan, June 1994

The significance of the low level of saturated fatty acids, the high level of MUFA and the balance among PUFA in canola oil in relationship to chronic diseases, in particular coronary heart disease, is discussed in the following sections.

Dietary Fat and Coronary Heart Disease

A major reason for the current interest in dietary fat relates to the evidence linking high fat intakes, especially saturated fat, to coronary heart disease (CHD). High levels of blood cholesterol, in particular LDL cholesterol, constitute a major risk factor in CHD. Dietary recommendations in Canada and the United States supported dietary modification as the principal intervention for lowering blood cholesterol levels and the risk of CHD. Nutrition recommendations call for a reduction in total fat intake to 30% and saturated fat intake to less than 10% of total energy intake. Although there is appreciable evidence supporting the beneficial effects of a reduction in saturated fat intake, a reduction in total fat intake was not found to result in lower blood cholesterol levels unless there was an accompanying reduction in saturated fat intake (1).

Dietary Fat and Plasma Cholesterol.
Interest in dietary fat and CHD centered primarily on saturated and polyunsaturated fatty acids until 1985 when Mattson and Grundy (2) reported that monounsaturated fatty acids, namely oleic acid, were as effective as PUFA in reducing plasma total and LDL cholesterol levels. These observations coincided with the relatively low incidence of CHD observed among populations consuming the so-called "Mediterranean diet," which is characterized by a high intake of fat but primarily from olive oil. The prevailing theory at the time argued that saturated fatty acids raised blood cholesterol, PUFA lowered blood cholesterol and MUFAs were neutral, they neither raised nor lowered blood cholesterol (3, 4). The demonstration that vegetable oils high in oleic acid were effective in reducing blood cholesterol (2, 5) sparked interest in the nutritional properties of canola oil.

Considerable interest has been expressed in the effect of fish oils, which are rich sources of long-chain omega-3 fatty acids (viz., EPA and DHA), on plasma cholesterol levels. Although EPA and DHA are effective in reducing blood triglyceride levels, they are not particularly effective in reducing blood total cholesterol or LDL levels. By contrast, α-linolenic acid, the plant source of omega-3 fatty acids, has been found equally as effective as oleic acid and linoleic acid in reducing plasma total and LDL cholesterol levels (6, 7, 8).

***Trans* Fatty Acids and Plasma Cholesterol**.
Trans fatty acids are produced when fats and oils are hydrogenated (hardened) for use in the manufacture of margarines and shortenings. The report by Mensink and Katan (9) that high intakes of *trans* fatty acids not only increased plasma LDL cholesterol levels but lowered plasma high-density lipoprotein (HDL) cholesterol levels triggered an intense debate over the physiological effects of hydrogenated fats, particularly in relation to CHD. The study also brought into question the wisdom of replacing saturated fats with hydrogenated products. A subsequent study by Zock and

Katan (10) with lower intakes of trans fatty acids confirmed the earlier results. A study by Judd et al. (11) confirmed the results by Katan and his associates. In addition, the two studies by Zock and Katan (9,10) suggested that there is a linear relationship between the dietary intake of *trans* fatty acids and their effect on plasma LDL and HDL cholesterol. Lichtenstein et al. (12) also found a linear increase in plasma total and LDL cholesterol levels with increased *trans* fatty acid intakes. These studies and other studies (13, 14) suggest that hydrogenated fats do not offer a benefit over saturated fats in terms of their effects on plasma cholesterol and lipoprotein levels.

Hypocholesterolemic Effect of Canola Oil

Studies in Canada, Finland, Sweden and the United States have found canola oil equally as effective as vegetable oils rich in PUFA in reducing blood total and LDL cholesterol levels (Table 1). These studies found canola oil as effective as sunflower oil (15, 16), soybean oil (6) and safflower oil (17) in reducing total and LDL cholesterol levels in subjects with normal blood lipid levels. All diets resulted in significant decreases in plasma total cholesterol (mean of -0.47 to -0.88 mmol/L) from the levels on the baseline diets. This decrease in total cholesterol was due primarily to a decrease in LDL cholesterol (mean of -0.43 to -0.74 mmol/L). These changes are consistent with the primary objective of intervention programs aimed at reducing the risk of coronary heart disease--elevated plasma cholesterol level, in particular LDL cholesterol, is a major risk factor in CHD.

Table 1: Comparison of the Effect of Canola Oil and Polyunsaturated Fatty Acid Sources on Plasma Total and Lipoprotein Cholesterol Levels of Human Subjects

Dietary PUFA* Source	Plasma Lipid Parameter	Baseline (mmol/L)	Change From Baseline Canola Diet	PUFA Diet	Reference
Sunflower	Total cholesterol	4.42	-20%	-15%	
	LDL** cholesterol	2.76	-25%	-21%	15
Sunflower	Total cholesterol	5.35	-15%	-12%	
	LDL cholesterol	3.17	-23%	-17%	16
Soybean	Total cholesterol	4.40	-18%	-16%	
	LDL cholesterol	2.98	-25%	-18%	6
Safflower	Total cholesterol	5.39	-9%	-15%	
	LDL cholesterol	3.71	-12%	-15%	17

* PUFA = polyunsaturated fatty acid
** Low-density lipoprotein

It is generally accepted that HDL protects against CHD. None of the diets in the studies cited in Table 1 had any effect on plasma HDL cholesterol levels even though PUFA provided 13 to 22% of the total energy intake on the PUFA diets. Very high intakes of PUFA (29% of energy) have been reported (2) to decrease HDL levels whereas a similar high intake of MUFA had no effect on HDL. The lack of effect on HDL in the studies summarized in Table 1 is consistent with the finding by Mensink and Katan (5) that relatively high intakes of PUFA, compared to intakes on the average diet, had no effect on serum HDL levels.

Canola oil also has been found effective in reducing the plasma total and LDL cholesterol levels in hyperlipidemic subjects (i.e., subjects with elevated blood lipid levels). Lichtenstein et al. (18) found that canola oil, corn oil and rice bran oil were equally effective in lowering plasma total (18% decrease) and LDL (23% decrease) cholesterol in subjects fed a low fat (30% of energy), low saturated fat (< 7% of energy), low cholesterol diet where the test fat provided two-thirds of the dietary fat. Olive oil also resulted in a decrease in plasma total and LDL cholesterol but the decrease was less (-14% and -19%, respectfully) than for the other fat sources. By contrast, Nydahl et al. (19) found canola oil and olive oil equally effective in lowering plasma total and LDL cholesterol levels in hyperlipidemic subjects. Miettinen and Vanhanen (20) also found canola oil effective in lowering blood lipid levels in hyperlipidemic subjects; replacing 50 g of fat in the regular diets of the subjects with 50 g of canola oil mayonnaise resulted in a decrease in serum total and LDL cholesterol levels.

The low level of saturated fatty acids and the relative high level of MUFA are undoubtedly major factors in the effectiveness of dietary canola oil in lowering plasma cholesterol. Its primary effect is on LDL cholesterol, which is a major risk factor in CHD. Canola oil has been found equally as effective in reducing plasma cholesterol levels as corn oil (18), safflower oil (17), soybean oil (6) and sunflower oil (15, 16) when each replaced saturated fats in the diet. Low linolenic acid canola oil, which has greater oxidative stability (better "shelf-life") than regular canola oil (21), also is effective in reducing blood cholesterol levels (22)--it was found equally as effective as regular canola oil and sunflower oil in lowering plasma total and LDL cholesterol levels.

Dietary Fat and Thrombosis

Cardiovascular disease is characterized by three major events:

- the formation of atherosclerotic plaques on the intima of blood vessels which decrease the size of the lumen of the vessel;
- thrombosis, the formation of a clot which, if it blocks a major vessel, can lead directly to a coronary attack or a stroke; and
- cardiac arrhythmias, uncoordinated contractions of the heart muscle resulting in irregular and ineffective heartbeats and in some cases death.

Atherosclerosis is a relatively slow process that develops over several years. By contrast, clot formation and cardiac arrhythmias occur in a matter of minutes. The latter two events have only recently received the attention of researchers even though dietary fat is implicated in all of these processes.

Interest in the physiological effects of the omega-3 fatty acids stemmed from the observation of a marked difference in the incidence of CHD among Danes and Greenland Eskimos even though both consumed relatively high fat diets (23). The long-chain omega-3 fatty acids of fish oils, namely EPA and DHA, have been found to inhibit clot formation (viz., platelet aggregation). The mechanism of this effect of the long-chain omega-3 fatty acids is thought to relate to their effect on the formation of "hormone-like" substances called eicosanoids. One of these compounds, thromboxane A_2, which is formed from arachidonic acid, causes platelet "stickiness" and thus clot formation. By contrast, the thromboxane formed from EPA (TxA_3) is a weak aggregating agent. The prostacyclins PGI_2 and PGI_3, other eicosanoids formed from arachidonic acid and EPA, respectively, both inhibit clot formation. These developments have led to an interest in the possible effect of linolenic acid on these processes. Several studies found canola oil alters parameters that have been linked to clot formation (Table 2).

Table 2: Effect of Canola Oil on Parameters Affecting Clot Formation

Parameter	Effect of Canola Oil on Parameter	Reference
Omega-3 fatty acid (viz., EPA) content of platelet phospholipids	Increased	24, 25, 26
Arachidonic acid content of platelet phospholipids	Decreased	24, 27, 28
In vitro platelet aggregation	Reduced	24, 25
Eicosanoid production		
- Thromboxane A_2	Decreased	15
- Prostacyclin	Increased	15
Clotting time	Increased	15

Ingestion of canola oil has been shown to alter the fatty acid composition of plasma and platelet phospholipids. In general, canola oil resulted in higher levels of EPA and lower levels of arachidonic acid in platelet phospholipids compared to sunflower oil, soybean oil or safflower oil. However, not all studies reported higher levels of EPA (27, 28) or lower levels of arachidonic acid (25). Similarly, Renaud et al. (24) and Kwon et al. (27) reported that canola oil reduced *in vitro* platelet aggregation whereas Mutanen et al. (28) found that canola oil stimulated platelet aggregation. In addition, sunflower oil was found to produce similar effects to canola oil in terms of platelet function (24, 28), clotting time (15) and eicosanoid production (15). There is no obvious explanation for the marked differences among studies, although part of the explanation for the apparent discrepancy among studies may relate to the balance between the omega-6 and omega-3 fatty acids in the diet. Chan et al. (25) found that changes in plasma and platelet fatty acid composition varied with both the level of linolenic acid in the diet and its ratio to linoleic acid (i.e., linoleate/linolenate ratio). It is perhaps worth noting, however, that an effect of dietary linolenic acid on thrombotic risk factors has not been established (29) even though dietary linolenic acid and its ratio to linoleic acid have been found to affect some of the factors associated with thrombosis.

Dietary Fat and Cardiac Arrhythmias

Studies with an experimental (rat) model (30) have shown that diets enriched in long chain omega-3 fatty acids (viz., EPA and DHA) protected against induced arrhythmias. Sunflower oil, a rich source of omega-6 fatty acids, also provided partial protection against induced arrhythmias in the rat model. Likewise, antiarrhythmic effects were observed when experimental animals were fed diets containing canola oil (31). By contrast, feeding diets containing olive oil, soybean oil and sunflower oil did not significantly decrease the incidence of induced cardiac arrhythmia in the experimental animals in this study. These findings suggest that the balance between the dietary omega-3 and omega-6 fatty acid content may be important because the soybean oil diet provided essentially the same level of α-linolenic acid as the canola oil diet but 2.5 times as much linoleic acid.

Dietary Fat and Oxidative Stability of LDL

There is evidence to support the hypothesis that oxidative changes to LDL increase its atherogenicity (32). There is also growing evidence that MUFAs protect LDL against oxidation. The LDL fraction from subjects fed diets rich in oleic acid has been found more stable to oxidation than the LDL fraction from subjects fed diets enriched with PUFA (33, 34). Thus ingestion of canola oil might be expected to result in LDL that is more stable to oxidative change than diets containing high levels of PUFA. In fact, experimental results (22) have shown LDL from subjects fed a sunflower oil diet to be more susceptible to oxidation than LDL from subjects fed a mixed fat diet or diets in which regular canola oil or low linolenic acid canola oil was the primary source of fat. Although sunflower oil is a very rich source of α-tocopherol, no differences were found in plasma vitamin E levels in subjects fed the different diets. Vitamin E has been reported to protect against the oxidation of LDL. It is perhaps worth noting that canola oil is a relatively rich source of vitamin E (21). Although canola oil contains about half the level of α-tocopherol present in sunflower oil (270 vs 610 µg/g), it contains twice the level present in corn oil (130 µg/g) and soybean oil (120 µg/g).

The Lyon Diet Heart Study - the "Mediterranean Diet"

One of the anomalies of the dietary fat-coronary heart disease relationship has been the finding that although the Cretan ("Mediterranean") diet in the Seven Countries Study was a high-fat diet, it was associated with a relatively low mortality rate due to coronary heart disease. The so-called Mediterranean diet is generally characterized as a high oleic acid (i.e., monounsaturated fatty acid) diet. However, the Cretan diet also was relatively high in linolenic acid content, particularly in relation to the level of linoleic acid. In addition, it was rich in fruits and vegetables and thus provided a relatively high intake of antioxidants.

A clinical study by de Lorgeril et al. (35) – the Lyon Diet Heart Study – which compared the effect of the Mediterranean diet to that of a prudent post-infarct diet, found a remarkable reduction in mortality due to coronary heart disease for those on the Mediterranean diet. The number of non-fatal coronary events also was markedly reduced for those on the Mediterranean diet. Canola oil and canola oil-based margarine was used in the Lyon Study to provide the level of linolenic acid in the Cretan diet. The study was terminated after a mean of 27 months follow-up on the diets. However, a recent report (36) of an extended follow-up (mean of 46 months per patient) of the subjects in the original study found the benefits of the Mediterranean diet were maintained (14 primary coronary events - combined cardiac deaths and nonfatal myocardial infarction – on the Mediterranean diet versus 44 on the prudent Western-type diet). The results of this study illustrate the importance of a cardio-protective diet. However, there is need to verify the results in further trials.

Summary

The fatty acid composition of canola oil is consistent with nutrition recommendations aimed at reducing the amount of saturated fat in the diet. Canola oil is characterized by a very low level of saturated fatty acids (< 7% of total fatty acids). It contains a relatively high level of oleic acid (61%) and an intermediate level of PUFA (32%) of which α-linolenic acid makes up approximately one-third (i.e., 11% of total fatty acids). Diets containing canola oil have been found equally as effective as those containing corn oil, safflower oil, soybean oil and sunflower oil in reducing plasma total and LDL cholesterol in both normal and hyperlipidemic subjects. Consumption of canola oil also resulted in an increase in long-chain omega-3 fatty acid (viz., EPA) levels of plasma and platelet phospholipids. Ingestion of canola oil also has been found to alter platelet activity and thrombogenesis although the research supporting these observations is not as convincing as the effectiveness of canola oil in lowering plasma cholesterol level. Preliminary studies in animal models also suggest that canola oil may protect against cardiac arrhythmias.

The effectiveness of canola oil in reducing plasma total and LDL cholesterol levels and the observation that it may alter clotting activity and protect against cardiac arrhythmias indicate a beneficial role for canola oil as part of a nutritious diet.

Dr. Bruce McDonald is Executive Director of the Manitoba Health Research Council.

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