PRB 05-21E

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TRANS FATS: THE HEALTH BURDEN

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16 August 2005

PARLIAMENTARY INFORMATION AND RESEARCH SERVICE
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TRANS FATS: THE HEALTH BURDEN

INTRODUCTION

Fats and oils comprise a significant proportion of our total caloric intake. While most nutritionists recommend that the proportion be approximately 30%, for almost everyone it is higher, an average of 38%.

The general public has been concerned about the fat content of food for many years. Recently, however, specific attention has been focussed on *trans* fatty acids, or *trans* fats as they have come to be called. *Trans* fats, which are ubiquitous in baked and processed foods, are being targeted as a significant contributor to heart disease. This paper explores the chemistry of *trans* fats, describes the difference between their natural and industrial production, and examines the evidence that links them to heart disease. Opportunities and options for reducing *trans* fat levels in foods both in Canada and abroad are also discussed.

TRANS FATS – WHAT THEY ARE AND HOW THEY ARE PRODUCED

All fatty acids contain carbon and hydrogen atoms (the fat part) and carboxyls (the acid part). There is enormous variation, however, in the way in which these atoms are bonded; the bonds determine whether a fatty acid is saturated or unsaturated.

- Saturated fatty acids contain exclusively single bonds between carbon atoms, and are saturated with a maximum amount of hydrogen atoms bound to the carbon chain. The resulting "hydrogenated" fat is a solid at room temperature; common examples are butter and lard.

- Unsaturated fatty acids may be monounsaturated or polyunsaturated. Monounsaturated fatty acids have one double bond between two of the carbon atoms. Introduction of the double bond reduces the number of hydrogen atoms bound to the carbon, thus also reducing the hydrogen saturation. Polyunsaturated fatty acids contain two or even more double bonds along the carbon chain. Unsaturated fat is a liquid at room temperature; common examples are pure vegetable oils.

Trans fatty acids are fats that were originally unsaturated, but that have had some of their double bonds weakened by either natural or industrial processes. As a result, the structure of the unsaturated fat is transformed to resemble that of a saturated fat. (For a more detailed account of this structural transformation, please refer to the appendix.)

Naturally occurring *trans* fats can be found in some animal products such as dairy products and beef fat, since the *trans* isomer is produced by bacteria in the gastrointestinal tract of cattle and other ruminants. These naturally occurring *trans* fats may account for as much as 21% of the food sources for American adults, according to the U.S. Food and Drug Administration.

The majority of *trans* fat in our diet is industrially produced. It is consumed primarily as shortening and margarine, or in foods that are baked or fried using these substances, such as cakes, cookies, bread, potato chips and commercial french fries. *Trans* fats are produced industrially when hydrogen is added to unsaturated oil (usually vegetable), a process known as hydrogenation. Full hydrogenation would produce exclusively saturated fatty acids that are too waxy and solid to use in food production. Even beef tallow and butter contain some unsaturated fatty acids. Consequently, the process used by the industry does not eliminate all of the double bonds and is called partial hydrogenation. Partially hydrogenated oils give foods a longer shelf life and more stable flavour. Food manufacturers use partial hydrogenation not only to harden oils into shortening and margarine, but also to eliminate some of the fatty acids that tend to oxidize and cause fat to become rancid.

TRANS FATS AND THE CONNECTION TO HEART DISEASE

Most natural fats are complex mixtures of triglycerides (see the appendix). Triglycerides and cholesterol combine with protein to form lipoproteins, which are fat-protein packages that travel through the bloodstream, delivering nutrients to the body. Low-density lipoprotein (LDL) consists of as much as 75% cholesterol. In fact, the majority (60-75%) of the cholesterol circulating in the blood is in the form of LDL. Consequently, LDL contains a smaller proportion of protein than other lipoproteins.

High-density lipoprotein (HDL) contains a much larger proportion of protein than does LDL. HDL consists of only 20-30% cholesterol. Unlike LDL, the job of HDL is to remove excess cholesterol from cells and arterial walls and transport it back to the liver for disposal. Overall, HDL, also called "good cholesterol," may actually slow or even reverse the hardening of the arteries (atherosclerosis). Epidemiological studies have provided considerable evidence of the link between a high LDL/HDL ratio and development of coronary heart disease (CHD).

A certain level of LDL in the blood is normal and healthy, since LDL is responsible for delivering cholesterol to the parts of the body that need it. Excess LDL, however, can cause a build-up of cholesterol in the walls of the arteries, and this contributes to the development of atherosclerosis. Coronary atherosclerosis is the primary cause of CHD. LDL-cholesterol is therefore referred to as "bad cholesterol."

The investigations that demonstrated this relationship date back to the 1970s and include: case-control studies; comparisons of populations with low and high rates of CHD; migrant studies; and international studies comparing diet, atherosclerosis, serum cholesterol, serum cholesterol levels, and CHD. These investigations have consistently shown that cholesterol, primarily associated with LDL, is an independent predictor of CHD, and that reducing cholesterol levels in the blood lowers CHD risk.

Saturated fats have long been associated with increased risk for heart disease. Several dietary studies have shown that saturated fats cause increased total cholesterol and LDL-cholesterol.(1) Conversely, diets higher in polyunsaturated fats have been found to yield lower levels of total and LDL-cholesterol in the blood.

Research studies have shown that *trans* fats are similarly linked to heart disease, but there have been conflicting results. While smaller studies have not confirmed a link between *trans* fats and CHD, prospective studies(2) involving large numbers of people, as well as randomized control studies, have clearly established the link. In general, *trans* fats appear to increase LDL-cholesterol as well as decrease HDL-cholesterol. Some work has also suggested that increased dietary *trans* fat levels may adversely affect essential fatty acid balance and growth in infants. No research has yet established the mechanism by which saturated and *trans* fat produce the increase in LDL-cholesterol, nor the manner by which *trans* fats decrease HDL-cholesterol.

Scientific research on the health impacts of fat reveals that the primary effect of dietary fat as a risk factor for heart disease is restricted to saturated and *trans* fat only. Reduction of total fat and cholesterol in the diet does not reduce the risk of heart disease as clearly as does a reduction specifically of saturated and *trans* fats.

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(1) This capacity to increase LDL level may be limited to specific saturated fatty acids: lauric, myristic, palmitic and stearic fatty acids.

(2) Prospective studies are designed to observe outcomes or events that occur subsequent to the identification of the group of participants to be studied.

TRANS FATS AND OTHER HEALTH CONCERNS

While the connection between CHD and *trans* fats has been exhaustively researched, other adverse health effects associated with *trans* fats have also been proposed but not yet conclusively established.

a) Diabetes

Some studies have indicated a link between intake of *trans* fatty acids and the development of type 2 diabetes. These studies suggest that the mechanism involves increased insulin resistance, possibly due to changes in ion channels in cell membranes. Other studies, however, have not found this association, so the issue has yet to be resolved.

b) Fetal and Infant Development

Research has shown that *trans* fats ingested by the mother are transferred to the developing fetus. In addition, lactating Canadian mothers have been found to have among the world's highest levels of *trans* fats in breast milk, as high as 7.2% of total fatty acids. Animal studies have shown that high maternal intakes of *trans* fats inhibit the formation of long-chain polyunsaturated fatty acids, which are important in fetal and infant growth as well as visual and central nervous system development. Although human studies have yet to conclusively establish this association, some studies have reported an inverse relationship between cord blood levels of *trans* fatty acids and birth weight and height.

c) Neurological Damage

Trans fats may have a detrimental effect on the brain and nervous system. Neural (nerve) tissue has a large fat component. Myelin, the protective sheath that covers communicating neurons, is composed of 30% protein and 70% fat. Studies show that *trans* fatty acids in the diet are incorporated into brain cell membranes, including the myelin sheath that insulates neurons. The *trans* fats replace the *cis* fats[(3)] in the membrane, and this appears to affect the electrical activity of the nerve cell. *Trans* fatty acid molecules may alter the ability of neurons to communicate, and thus cause neural degeneration and diminished mental performance.

d) Cancer

Some studies have demonstrated a positive association between *trans* fats and the rising incidence of breast and colon cancers. Other studies have not been able to establish such a link.

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(3) *Cis* fats are differently configured from *trans* fats; see the section entitled "Fatty Acids: *Cis* and *Trans*" in the appendix.

ALTERNATIVES TO *TRANS* FATS

In order to eliminate or minimize *trans* fat consumption, there must first be a viable alternative.(4) Many types of food would be either unavailable or unappealing if *trans* fats were outlawed without another compound or class of compounds first being developed. Considerable research is being done to discover new, healthier fats and oils for food production.

One approach that is being investigated involves a process called "interesterification," through which fatty acids are manipulated so as to solidify oils without using hydrogenation.(5)

Another approach in the search for *trans* fat alternatives involves "fractionation," which involves separating oils into their different components. For example, canola oil, which is a common vegetable oil used in cooking, contains 62% by weight oleic acid, a monounsaturated fatty acid. It also contains 22% linoleic acid and 10% linolenic acid, which are polyunsaturated fatty acids, the "healthy" type. The remaining 6% is composed of saturated fatty acids (stearic and palmitic), the "unhealthy" type. This assortment of fatty acids becomes packaged as triglycerides naturally in every possible combination, each exhibiting its own particular physical properties. Fractionation separates the oil into triglyceride portions characterized by different physical properties.

Researchers are also investigating the conditions under which hydrogenation is performed and determining whether these can be modified in order to minimize *trans* fat formation. Scientists at the U.S. Department of Agriculture have developed a hydrogenation process that requires a higher pressure of hydrogen gas but enables the temperature of the reaction to be reduced. They have found that the resultant hydrogenated oils contain less than half the level of *trans* fat produced under traditional hydrogenation conditions. The researchers point out, however, that commercializing this process would require substantial investment by manufacturers to retrofit their equipment.

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(4) Technically, alternatives to partial hydrogenation already exist. For example, hydrogenation could be carried out to completion so that triglycerides are completely saturated. However, as noted above, saturated fats are associated with CHD as well. Abandoning *trans* fats only to return to a higher saturated fat consumption, which for most people is already above the recommended level, would not yield the health benefits that are sought.

(5) Fatty acids are bound to a glycerol "backbone" with an ester bond; interesterification means that one type of fatty acid residue is replaced with another type within the triglyceride until one with desirable physical properties is discovered. For further details on the structure of fatty acids, please refer to the appendix.

ACTION TO REDUCE CONSUMPTION OF *TRANS* FATS

A. Canada

1. Current Action

New labelling requirements for food were published on 1 January 2003 that mandate greater nutritional information on pre-packaged foods. The new regulations will require that most food labels carry a mandatory "Nutrition Facts Table" that contains calorie and nutrient information. Information on the levels of 13 key nutrients is required and, for fat, includes: total fat, saturated fat, *trans* fat and cholesterol. Further, with respect to *trans* fat, the label will be able to claim that a diet low in saturated and *trans* fat reduces the risk of heart disease. Manufacturers have until 31 December 2005 to comply with these regulations.

In November 2004, Health Canada, in partnership with the Heart and Stroke Foundation of Canada, announced the creation of the Task Force On Trans Fats, which includes representatives from health associations, government, academia, and industry. The Task Force will make recommendations both for an appropriate regulatory framework and for the introduction and widespread use of healthy alternatives to achieve the objective of limiting *trans* fat content in foods sold in Canada to the lowest levels possible. These recommendations are expected by the end of 2005. An interim report, issued in August 2005, focused on public education, labelling and opportunities for the food service and food processing industries to reduce *trans* fats.(6)

2. Possible Directions for Further Action

Many people feel strongly that labelling *trans* fats is not only ineffective, but also inappropriate. They cite the observation that there is no nutritional benefit attributable to *trans* fats, as concluded by the Institute of Medicine of the U.S. National Academies. While fat is an important component of the diet in terms of calories, transport and storage of micronutrients and requirement for proper cellular integrity, *trans* fats are largely excluded from these roles. It is argued that in the absence of nutritional benefit, and in light of increasing evidence that *trans* fats contribute to the risk of CHD, *trans* fats should be eliminated from food. Additionally, *trans* fats are in so many different foods that it is difficult, even with labelling, for individuals to intentionally reduce their intake.

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(6) The interim report and Government Response may be found on-line at: http://www.hc-sc.gc.ca/fn-an/nutrition/gras-trans-fats/index_e.html.

As noted above, the current regulations will soon require labelling of *trans* fat content in food. This could lead to an overall reduction in *trans* fat in food as consumers become more aware and begin to demand products that are *trans* fat free. This tendency has already been seen, for example, in the evolution of the Becel™ products, promoted as "*trans* fat free." This approach to *trans* fat reduction, however, might require a public awareness campaign on the health effects of *trans* fats to be more effective.

Reducing or banning *trans* fats could be accomplished through the *Food and Drugs Regulations*. The *trans* fat content of pre-packaged or processed foods could be regulated to be below a certain level, expressed as a percentage of total fat. This approach would entail more costs for the food industry than labelling. It would necessitate changes in manufacturing practices, as different chemical processes would be required.

B. Other Countries

To date, the only country that has taken steps to officially eliminate industrially produced *trans* fats is Denmark. On 11 March 2003, Denmark issued an executive order that stated that: "From 1 June 2003, the content of *trans* fatty acids in the oils and fats covered by this Executive Order shall not exceed 2 grams per 100 grams of oil or fat." This Order specifically omits naturally occurring *trans* fats. In Denmark, *trans* fats have essentially been replaced by interesterification or fractionation of palm oil, an oil which has a relatively high content of saturated fatty acids, about 50%.

In the Netherlands, *trans* fat consumption has dropped because of publicity regarding the health effects. The *trans* fat content of hard table margarine sold in the Netherlands has dropped from a high of 50% in the 1980s to less than 2% now.

In the European Union overall, consumption of *trans* fats has dropped significantly below that of Canadians. However, EU consumption of saturated fats has increased above that of Canadians.

In July 2003, the U.S. Food and Drug Administration issued new regulations requiring manufacturers to list *trans* fats on the Nutrition Facts panel of foods and some dietary supplements. Similar to Canada, food manufacturers in the United States have until 1 January 2006 to comply with these regulations.

CONCLUSION

The health effects of *trans* fatty acids have been well documented. It is largely accepted that they pose a risk for heart disease, and that the risk may be more significant than that posed by saturated fats. Canada has acknowledged the concern over *trans* fatty acids by including them in the new labelling requirements for a Nutrition Facts Table. This requirement, if accompanied by a public awareness campaign, may help Canadians to reduce their *trans* fat intake. Critics of this approach maintain that Canada should follow the initiative of Denmark and institute a ban on *trans* fats. They insist that it is unacceptable to label a component of food that is of no nutritional value and poses a risk to health, and of which the industrial production can be avoided. It is unlikely, though, that a ban would be either acceptable or possible until appropriate and affordable alternatives become available.

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APPENDIX

THE CHEMISTRY OF FATTY ACIDS AND *TRANS* FATS

FATTY ACIDS: SATURATED AND UNSATURATED

Most natural fats are complex mixtures of triglycerides. Triglycerides are composed of a three-carbon glycerol backbone to which three fatty acids have been bound. The complexity arises through the enormous amount of variation that exists among fatty acids. All fatty acids contain a long hydrocarbon chain (the fat part) and a terminal carboxyl group (the acid part). Fatty acids rarely occur in this "free" form, however. The acid part is usually bound to a glycerol substrate. A total of three fatty acids can bind to one glycerol molecule (see Figure 1).

Fatty acids may be saturated, monounsaturated or polyunsaturated. Saturated fatty acids contain exclusively single bonds between carbon atoms, and are therefore saturated with a maximum amount of hydrogen atoms bound to the carbon chain. Monounsaturated fatty acids have one double bond between two of the carbon atoms. Introduction of the double bond reduces the number of hydrogen atoms bound to the carbon, thus also reducing the hydrogen saturation. Polyunsaturated fatty acids contain two or even more double bonds along the carbon chain.

Fatty acids can vary not only in the number of double bonds present, but also in the length of the carbon chain. Fatty acids are described in these terms. For example, the essential fatty acid[(1)] linoleic acid has 18 carbon atoms in its long chain, with two double bonds occurring at the 3rd and 6th carbons. The shorthand nomenclature for this particular fatty acid is noted as $18{:}2^{\tilde{n}-3,6}$. The most abundant fatty acids have an even number of carbon atoms with chains between 14 and 22 carbon atoms long, with those having 16 and 18 carbon atoms being predominant.

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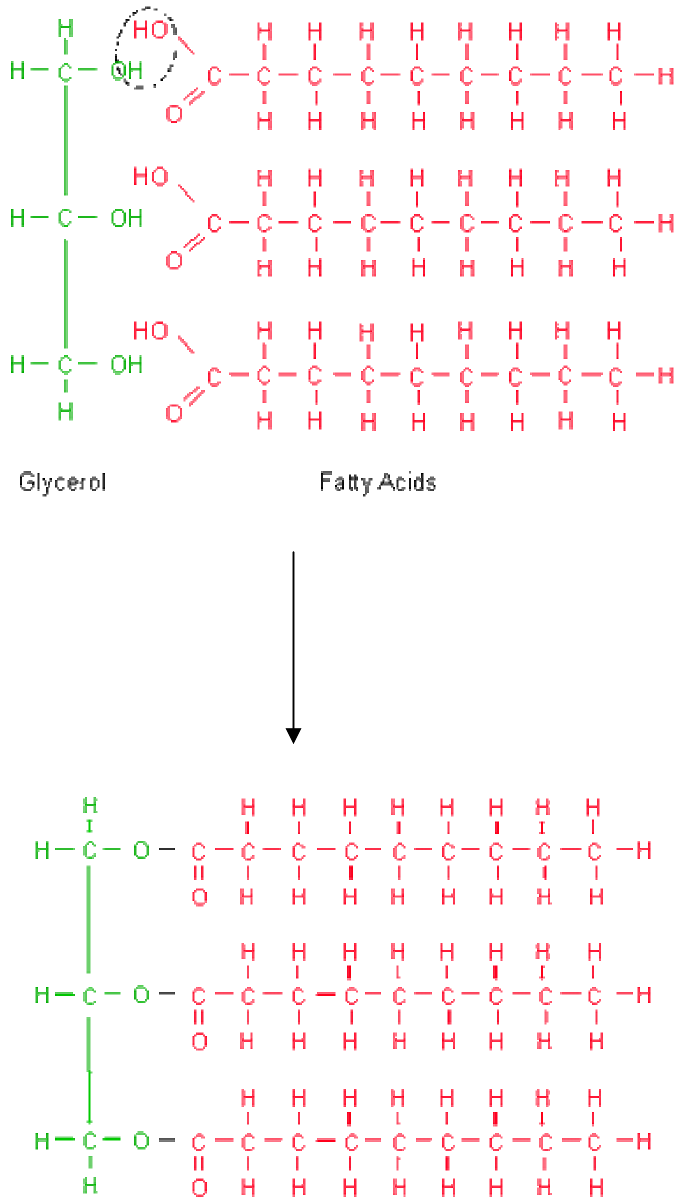
(1) Essential fatty acids are necessary in the diet for proper growth, development and health maintenance, and cannot be produced by the body from other substrates.

Figure 1: Chemical Structure of Triglycerides

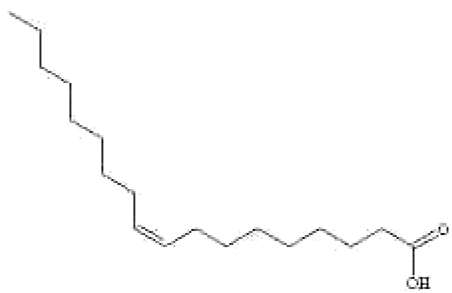


Triglyceride

Saturated fatty acids have higher melting points than unsaturated ones of the same chain length. This is because they have different three-dimensional conformations. The saturated chains are in their minimum energy form when fully extended; in this form the molecules "stack" easily and therefore require more energy to separate, causing the higher melting point. The stacked fatty acids are in a solid state, with hydrogen bonds between molecules that require energy to break and produce the liquid state.

Unsaturated fatty acids have one or more “kinks” at the sites of the double bonds within their hydrocarbon chain that produce a bend in the chain (see Figure 2). These bends result in molecules that do not stack well; therefore, the greater the number of double bonds (i.e., the more unsaturated), the more likely the fat is to be a liquid at room temperature. Thus, triglycerides that are solids at room temperature contain predominantly saturated fatty acids and are called fats, while triglycerides that are liquids at room temperature contain predominantly unsaturated fatty acids and are called oils.

Figure 2: Comparison of Fatty Acid Structures

Type	Structure	Source
Saturated fatty acid		Animal fat
Unsaturated fatty acid (*cis* double bond)		Olive oil
Unsaturated fatty acid (*trans* double bond)		Partially hydrogenated oils

FATTY ACIDS: *CIS* AND *TRANS*

Fatty acids may have the same number of carbon atoms and number and placement of double bonds (degree of saturation), but they may have different geometric configurations: *cis* and *trans*. The above description of unsaturated fatty acids having bends in their long chains is true only for the *cis* geometrical isomer,[(2)] not the *trans* isomer. In the *cis* configuration, hydrogen atoms are positioned on the same side of the carbon chain, causing a

(2) An isomer is one of two or more compounds with the same molecular formula but a different arrangement of atoms and different properties.

bend in the chain as the hydrogen atoms repel each other. However, in the process of producing semisolid cooking fats (shortening and margarines), partial hydrogenation of vegetable oils results in the *trans* isomerization of some remaining double bonds due to the extreme conditions required in the hydrogenation process. That is, the remaining double bonds become weakened and some of the *cis* configurations may change to *trans* configurations. In the *trans* isomer, hydrogen atoms end up on opposite sides of the carbon chain at the double bond. In this conformation there is no "crowding" of the hydrogen atoms, and the carbon chain is almost as straight as a saturated chain.

Figure 2 illustrates how the *trans* isomer physically resembles a saturated chain. To visualize how this translates into physical properties, compare butter (an animal fat of saturated triglycerides), margarine (a partially hydrogenated vegetable oil containing the *trans* isomer) and a vegetable oil (a mixture of polyunsaturated triglycerides containing the *cis* isomer only). Butter contains primarily saturated fat and is therefore a solid at room temperature. Margarine is industrially hydrogenated and contains the *trans* configuration, which closely resembles the saturated fat and is therefore a solid at room temperature. Finally, oil contains unsaturated triglycerides of the *cis* configuration, which do not stack and form hydrogen bonds between molecules at room temperature, and is therefore a liquid.