THE AMERICAN COUNCIL ON SCIENCE AND HEALTH PRESENTS

Trans Fatty Acids and Heart Disease

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ACSH PRESENTS

Trans Fatty Acids and Heart Disease

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Executive Summary

- Most of the *trans* fatty acids (TFAs) in the U.S. food supply are derived from partially hydrogenated vegetable oils. TFAs also occur naturally in beef, lamb, and dairy products. TFAs accounted for about 2.5 percent of the energy (calorie) content of the U.S. diet prior to any changes prompted by the 2006 requirement for the inclusion of *trans* fat in nutrition labeling.

- TFAs are one of several dietary factors that affect blood lipid levels, and blood lipid levels are one of several factors that influence the risk of heart disease.

- Until the early 1990s, scientists generally believed that the impact of TFAs on blood lipid levels was minimal, and that fats that contain TFAs were a desirable replacement for saturated fats. More recent research indicates, however, that TFAs raise blood levels of undesirable low-density lipoprotein (LDL) cholesterol to an extent comparable to that produced by saturated fatty acids and that TFAs, particularly at high levels of intake, may also lower levels of desirable high-density lipoprotein (HDL) cholesterol, an effect that saturated fatty acids do not share.

- Based on the effects of TFAs on lipid levels, it has been estimated that replacing all of the TFAs from partially hydrogenated vegetable oils in the U.S. diet with *cis* unsaturated fatty acids could lead to as much as a 3 to 6 percent reduction in heart disease risk. This value should be regarded only as a rough estimate because there are multiple sources of uncertainty in the data used to calculate it. Moreover, the reduction achievable in practice is likely to be substantially lower than calculated estimates because *cis* unsaturated fatty acids cannot replace TFAs in some food applications for reasons related to texture or stability.

- Much higher estimates of the benefit that could be achieved by removing TFAs from the diet have occasionally appeared in the scientific literature and the news media. These estimates are based on epidemiological data that may not reflect a cause-and-effect relationship.

- Contrary to some reports in the news media, the calorie counts of fats containing TFAs are no higher than those of other fats. The scientific rationale for limiting the consumption of TFAs is related to effects on blood cholesterol levels, not effects on obesity. All types of fat are equally high in calories.

- As part of an overall effort to reduce risk factors for heart disease, advice to the public to limit consumption of both saturated fatty acids and TFAs by

substituting polyunsaturated or monounsaturated fats whenever possible is justified by the scientific evidence. Scare tactics, including claims that there should be zero tolerance for TFAs in the food supply, are not justified.

- Overstating the health effects of TFAs is harmful to public health because it promotes an overemphasis on this single dietary factor as opposed to other aspects of diet, other risk factors for coronary heart disease, and other public health priorities. By drawing attention away from other, more significant health risks, the current exaggerated focus on TFAs may actually cause more problems than it solves.

Introduction

The recent addition of *trans* fat information to the Nutrition Facts labels on food products, combined with news media reports and activists' warnings, have brought these fats to the forefront of public concern. In a national survey conducted in November 2005, 81 percent of a representative sample of U.S. consumers reported being aware of *trans* fats, and 54 percent indicated that they were trying to decrease their *trans* fat consumption (IFIC Foundation, 2006).

Putting the role of *trans* fatty acids (TFAs) into perspective can be difficult, both because of the intensity of the rhetoric surrounding them and because of widely varying claims about the extent of the health risk they pose. Should American consumers believe the Food and Drug Administration's claim that between 600 and 1,200 heart attacks per year will be averted by *trans* fat labeling on food products? Or should they believe the predictions by some scientists that removal of TFAs from the food supply could prevent more than 200,000 heart attacks per year? Is some number between these two extremes more realistic? Or are the data insufficient to justify confidence in any numerical estimates at all?

In this report, the American Council on Science and Health (ACSH) reviews the scientific evidence on the health effects of TFAs in foods, explaining the origins of the widely divergent estimates of the health impact of TFAs and providing perspective on the relative importance of TFA intake in comparison with other aspects of diet and other risk factors for coronary heart disease.

Chemical Nature and Origin of *Trans* Fatty Acids

The fats in foods are made up of *triglycerides*—molecules consisting of three fatty acids chemically bonded to an alcohol called glycerol. Each fatty acid consists primarily of a linear chain of carbon atoms with hydrogen atoms bound to them. Different types of fatty acids have different physical properties. The fats in foods consist of a multitude of fatty acids, with different types of fatty acids predominating in fats from different sources.

The carbon atoms in a fatty acid chain may be linked to each other by either single or double bonds. (See Figure 1.) If all of the links in the carbon chain are single bonds, the fatty acid is *saturated*. If one or more of the links is a double bond, the fatty acid is *unsaturated*. A fatty acid with one double bond is called *monounsaturated*; one with two or more double bonds is called *polyunsaturated*.

The term *saturation* refers to whether or not the fatty acid contains as many hydrogen atoms as possible. Saturated fatty acids contain the maximum possible number of hydrogen atoms; unsaturated fatty acids contain fewer. This is illustrated in Figure 1. The two carbon atoms involved in the single bond in the figure are bound to a total of four hydrogen atoms, but the two carbon atoms involved in the double bond are bound to only two hydrogen atoms.

The double bonds in an unsaturated fatty acid can have either of two configurations, *cis* or *trans*. If the hydrogen atoms are on the same side of the double bond, the configuration is called *cis*; if they are on opposite sides, it is called *trans*. (See Figure 2.)

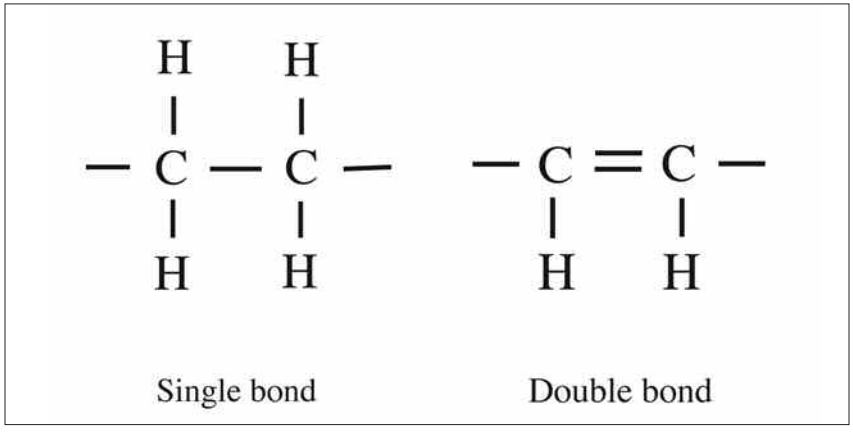

Figure 1: The carbon atoms in a fatty acid may be linked to each other by single or double bonds. In saturated fatty acids, all of the bonds are single bonds. Unsaturated fatty acids have one or more double bonds. A saturated fatty acid contains the maximum possible number of hydrogen atoms; an unsaturated fatty acid contains fewer hydrogen atoms.

Because hydrogen and other atoms cannot rotate freely around carbon-to-carbon double bonds, the difference between *cis* and *trans* is a meaningful one. The physical properties of TFAs, such as their melting point, differ from those of *cis* fatty acids. The double bond angle of a TFA is smaller than that of a *cis* fatty acid, resulting in a more linear chain and a higher melting point—properties that are more similar to those of saturated fatty acids than those of *cis* unsaturated fatty acids.

Most of the unsaturated fatty acids in foods contain only *cis* double bonds. The less common TFAs in foods come from two sources:

- Some TFAs are produced naturally by microorganisms in the digestive tracts of ruminant animals and are, therefore, present in the fats in foods derived from these animals, such as beef, lamb, and dairy products. Their presence in these foods is natural; it is not a result of food processing. Between 2 and 8 percent of the fatty acids in dairy products and between 2 and 11 percent of the fatty acids in meats derived from ruminant animals are TFAs; by contrast, less than 0.5 percent of the fatty acids in pork fat, which is derived from a nonruminant animal, are *trans* (Pfalzgraf et al., 1994). Foods derived from ruminant animals account for approximately 20 to 25 percent of the total TFAs in American diets, according to an analysis of national survey data (from the Continuing Survey of Food Intakes by Individuals [CSFII]) collected in 1989-1991 (Allison et al., 1999).

- The remaining TFAs (75 to 80 percent of the total) come from vegetable oils, most commonly soybean oil, that have been processed by p*artial hydrogenation*. In this procedure, hydrogen is added to the fatty acids, resulting in conversion of some of the unsaturated fatty acids to saturated ones. During this process, some of the *cis* fatty acids that are not hydrogenated are converted to TFAs. The hydrogenation process is used to convert liquid oils into semisolid forms that are more suitable for some types

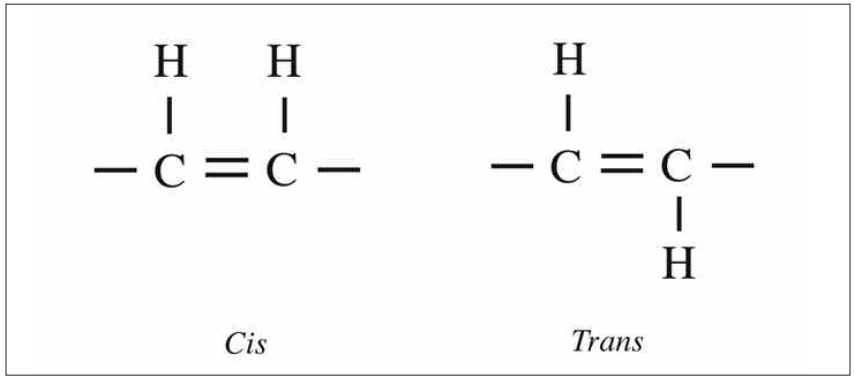

Figure 2: The double bonds in a fatty acid can be in either the *cis* or the *trans* configuration. The shapes of *cis* fatty acids and TFAs differ, with resulting differences in physical properties such as melting point.

of food processing, such as baking (ISEO, 2006). It also increases the stability of oils that would otherwise become rancid easily (ISEO, 2006). Thus, partially hydrogenated vegetable oils can be used for some purposes for which animal fats such as lard were traditionally used. The quantity of TFAs in partially hydrogenated oils varies depending on the degree and conditions of hydrogenation. Typically, the partially hydrogenated fats used in commercial baking or frying contain 14 to 18 percent TFAs (United Soybean Board, undated). It is noteworthy that TFAs are formed only during *partial* hydrogenation. If a fat is fully hydrogenated, all of the unsaturated fatty acids are converted to saturated fatty acids.

There are a variety of different TFAs, with different chain lengths and different numbers and locations of double bonds. Although the health effects of individual TFAs have not been studied in humans, the results of studies in cell culture suggest that differences among the individual TFAs may exist (Chen et al., 2006). The exact mix of TFAs naturally present in ruminant animal products differs from that in partially hydrogenated vegetable oils. Thus, the health effects of the TFAs from the two sources may not be identical.

Partially hydrogenated oils began to be used early in the twentieth century, and their use increased steadily throughout most of the century (ASCN/AIN Task Force on *Trans* Fatty Acids, 1996). In the United States, the partially hydrogenated oils used in foods are of vegetable origin, with soybean oil most commonly used; in other parts of the world, however, partially hydrogenated fish oils have also been used.

Partially hydrogenated vegetable oils are used in a wide variety of foods, often as replacements for fats of animal origin, such as butter, lard (pork fat), or tallow (beef fat). The initial impetus for their use was usually cost; for example, margarines (also called oleomargarines) made from partially hydrogenated vegetable oils were less expensive than butter. Later, when the link between high intakes of saturated fatty acids and higher blood cholesterol levels became evident, partially hydrogenated vegetable oils were also regarded as a good substitute for the more saturated animal fats for health reasons. For example, in a 1988 issue of its publication *Nutrition Action*, the Center for Science in the Public Interest (CSPI) stated[1] (Blume, 1988):

> Despite the rumors, there is little good evidence that trans fats cause any more harm than other fats...All told, the charges against trans fat just don't stand up. And by extension, hydrogenated oils seem relatively innocent.

These statements accurately reflected the scientific knowledge at that time.

Fats rich in TFAs provide the same amount of energy (calories) as other fats do—about 9 calories per gram (45 calories per teaspoon), which is more than

1. CSPI is now one of the strongest opponents of partially hydrogenated oils.

twice the energy provided by the same amount of protein or carbohydrate. Substituting other types of oils for partially hydrogenated vegetable oils will not reduce the total fat or total calories in foods. Unfortunately, misconceptions about this point seem to be common. News reports sometimes describe *trans* fat as "fattier" or more caloric than other types of fat.[2] This is incorrect.

The major food sources of TFAs for American adults (prior to any changes in food formulations prompted by the recent inclusion of TFAs in nutrition labeling) were cakes, cookies, crackers, pies, bread, etc. (40 percent of total intake); animal products (21 percent); margarine (17 percent); fried potatoes (8 percent); potato chips, corn chips, popcorn (5 percent); household shortening (4 percent); salad dressing (3 percent); breakfast cereal (1 percent); and candy (1 percent) (FDA, 2003a). Of course, all of these values are subject to change, and many may have already changed with the recent reformulations of food products.

Intakes of TFAs

Estimating the intake of TFAs is not easy because the amounts of TFAs in particular foods have changed over time and because, until very recently, data on the TFA contents of foods were limited. As the FDA noted in its 2003 document requiring the listing of TFAs on food labels starting in 2006, there are multiple sources of uncertainty in published estimates of TFA intake. The available data suggest that average TFA intakes of U.S. consumers probably fall within the range of 1.3 g to 12.8 g per day (FDA, 2003b). When trying to pinpoint U.S. TFA intakes more closely, researchers have often relied on intake data from national diet surveys, particularly the CSFII surveys. Based on 1994-1996 CSFII data, the FDA calculated the average total *trans* fat intake for adults to be 5.84 g/day, or 2.55 percent of total energy (calories) (FDA, 2003b). This estimate is reasonably consistent with values obtained from other studies.

It has been reported that the TFA content of Americans' diets changed little between the 1970s and the early 1990s (ASCN/AIN Task Force on *Trans* Fatty Acids, 1996). During this period, the use of vegetable fat increased. However, at the same time, changes in the processing of vegetable fat led to substantial decreases in TFA content. The two trends counterbalanced each other. For example, soft tub margarines with lower *trans* fatty acid content became increasingly popular, replacing hard stick margarines with higher levels of

2. For example, an article on the ABC News website about a lawsuit against KFC concerning the *trans* fatty acid content of its products was headlined "KFC Sued for Fattening Menu." Similarly, an Associated Press story about different levels of TFA in fast foods in different countries carried the headline "Fast-Food Fries, Chicken Fattier in the U.S." In reality, neither of the issues discussed in the stories (both of which will be described later in this report) had anything to do with the calorie or total fat levels in the food products.

TFAs (ASCN/AIN Task Force on *Trans* Fatty Acids, 1996). Data from an ongoing series of surveys in Minnesota indicate that TFA intakes have been gradually decreasing in recent decades as part of a general decrease in fat intake (Harnack et al., 2003); however, it has been suggested that the groups of people studied in these surveys may not be representative of the overall U.S. population (Thorpe, 2003).

The FDA's 1999 proposal requiring the TFA content of foods to be listed on food labels (FDA, 1999) and the 2003 regulation that actually required *trans* labeling, effective in January 2006 (FDA, 2003b), have prompted some food manufacturers to take steps to reduce or eliminate TFAs in their products (the ways in which this is being done are described later in this report). The impact of such changes on average TFA intake has not yet been assessed.

Coronary Heart Disease

Although TFAs have been investigated in relation to a variety of health conditions, the principal concern is their possible link to cardiovascular diseases, especially coronary heart disease. Cardiovascular diseases (a category that includes stroke, congenital heart defects, heart failure, rheumatic heart disease, and several other ailments in addition to coronary heart disease) is the leading cause of death in the U.S., accounting for 37.3 percent of all deaths. Coronary

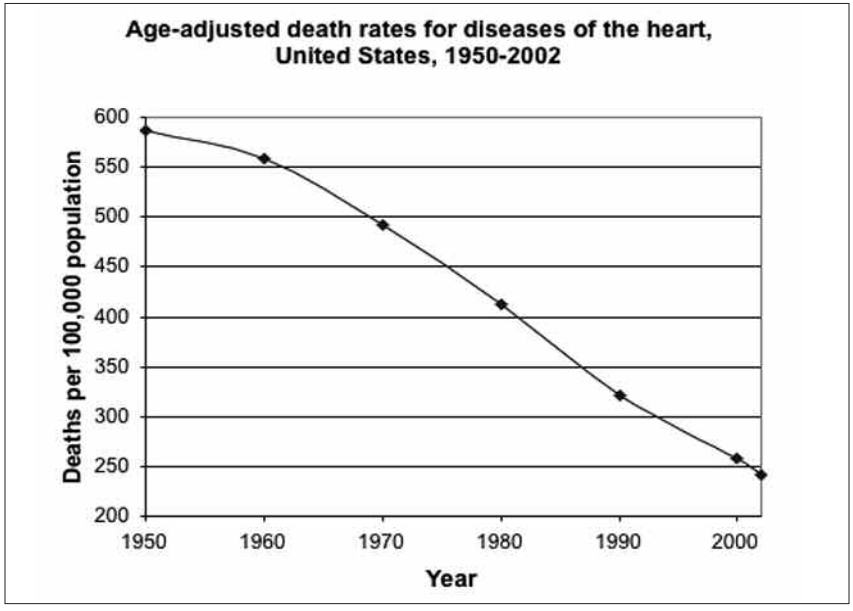

Figure 3: Data from Table 36 in *Health, United States, 2005*, published by the National Center for Health Statistics (updated March 2006). Available online at http://www.cdc.gov/nchs/data/hus/hus05.pdf#036

heart disease alone accounts for 53 percent of cardiovascular disease deaths and about one in every five total deaths. It is the single largest killer of both men and women in the U.S. (All statistics in this paragraph from AHA, 2006.)

Because coronary heart disease is such a common and serious problem, much research has been devoted to identifying factors that influence the risk of this disease and to devising ways to counteract these risk factors. These efforts have met with considerable success. Although the death rate from heart disease is still high, it is much lower than it used to be. Between 1950 and 2002, as shown in Figure 3, the heart disease death rate in the U.S. dropped by almost 60 percent, from 586.8 to 240.8 per 100,000 people (National Center for Health Statistics, 2005).

Evolving Views on the Health Effects of TFAs

Researchers have been investigating the health effects of TFAs for several decades. In the 1960s and 1970s, some studies showed that TFAs had a modest elevating effect on blood cholesterol, while others seemed to indicate no effect (reviewed by Korver and Katan, 2006). In the 1980s, independent reviews of the scientific evidence by the U.S. Federation of American Societies of Experimental Biology (Senti, 1985) and the British Nutrition Foundation (British Nutrition Foundation, 1987) both concluded that at the levels of intake that prevailed at that time, consumption of TFAs posed no measurable health risk. Both reports called for additional research. In the mid-1990s, three expert panels reached conclusions similar to those of a decade earlier (Allison et al., 1995; ASCN/AIN Task Force on Fatty Acids, 1996; British Nutrition Foundation, 1995) and again called for continued research on this topic.

In general, until the early 1990s, the evidence indicated that the effects on blood cholesterol levels of partially hydrogenated vegetable oils containing TFAs were more desirable than those of animal fats or tropical oils (which are rich in saturated fatty acids) but less desirable than those of unmodified vegetable oils (which are rich in *cis* unsaturated fatty acids) (Allison et al., 1995). It was pointed out that since partially hydrogenated oils were typically used to replace fat sources rich in saturated fatty acids, their use helped to reduce saturated fat intake (ASCN/AIN Task Force on Fatty Acids, 1996). Moreover, experts noted that the amount of TFAs in the U.S. diet was far less than the amount of saturated fatty acids, and that concerns about *trans* fat should not be allowed to detract from the well-established goal of reducing intake of saturated fat (ASCN/AIN Task Force on Fatty Acids, 1996). One expert panel recommended that people with high cholesterol should limit their intake of TFAs (National Cholesterol Education Program, 1994), but no official recommendations were

made for the general public. (It is customary and reasonable for health authorities to give stronger advice to those with preexisting risk factors for heart disease than to the general population.)

More recently, expert panels and official recommendations have expressed a greater degree of concern about TFAs, reflecting newer evidence, to be discussed in detail later in this report, indicating that the adverse effect of TFAs on heart disease risk may be comparable to, or possibly greater than, that of a similar quantity of saturated fatty acids.

In 2002, the FDA was developing a regulation for TFA labeling of food products. They asked the Food and Nutrition Board (FNB) of the Institute of Medicine, which was nearing completion of its report on Dietary Reference Intakes for fats and other macronutrients, to release the section of the report pertaining to TFAs several months early so that the FDA could take its findings into consideration.

The released section of the FNB report (FNB, 2002a) stated: "There is a positive linear trend between TFA intake and total and LDL cholesterol concentration [in blood], and therefore increased risk of CHD [coronary heart disease], thus suggesting a Tolerable Upper Intake Level (UL) of zero." The report noted that achieving a zero intake of TFAs would not be feasible because it would require extraordinary changes in dietary intake that could introduce other undesirable effects and risks, such as inadequate intake of nutrients. Therefore, the FNB recommended that "TFA consumption be as low as possible while consuming a nutritionally adequate diet" but did not recommend zero intake.[3] The wording of these conclusions is clearly more negative than those of the expert reviews in the 1980s and 1990s.

The evolution of the views about TFAs is also illustrated by the wording of the discussion of these fatty acids in three successive editions of the federal government's Dietary Guidelines for Americans. The pamphlet that presented the 1995 edition of the Guidelines (USDA/HHS, 1995) stated:

> Partially hydrogenated vegetable oils, such as those used in many margarines and shortenings, contain a particular form of unsaturated fat known as trans-fatty acids that may raise blood cholesterol levels, although not as much as saturated fat.

In 2000, the Guidelines (USDA/HHS, 2000) no longer said that TFAs would raise cholesterol levels to a lesser extent than saturated fat, but instead said the following:

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3. Some activist groups and news media have used the FNB report to justify claims that "the only safe intake of *trans* fat is zero." However, it is clear from a full reading of the report that the FNB did not intend for people to eliminate *trans* fatty acids from their diets at all costs. Nor did the FNB intend to place a higher priority on *trans* fatty acids than saturated fatty acids. In the full version of its report on fats and other macronutrients (FNB, 2002b), which was published several months after the excerpt on *trans* fats was released, the FNB issued recommendations on saturated fatty acid intake that were worded in almost exactly the same way as its recommendations on *trans* fatty acids.

> Foods high in trans fatty acids tend to raise blood cholesterol. These foods include those high in partially hydrogenated vegetable oils, such as many hard margarines and shortenings. Foods with a high amount of these ingredients include some commercially fried foods and some bakery goods.

The 2005 edition of the Guidelines (USDA/HHS, 2005), unlike its predecessors, made a specific recommendation to limit TFA intake, as follows:

> Consume less than 10 percent of calories from saturated fatty acids and less than 300 mg/day of cholesterol, and keep trans fatty acid consumption as low as possible.

In June 2006, the American Heart Association (AHA) became the first to set a quantitative recommendation pertaining to *trans* fatty acid intake.[4] In a new version of its dietary and lifestyle guidelines, the AHA recommended that *trans* fat consumption be limited to less than 1 percent of total energy (calories) (Lichtenstein et al., 2006). This is roughly 1 gram per day for a person consuming 2000 calories daily and is less than half the average intake reported in the CSFII survey in the mid-1990s (Allison et al., 1999). It has been estimated that eliminating partially hydrogenated oils would lead to a dietary intake of TFAs of about 1 percent of calories; the remaining TFAs would come primarily from meat and dairy products and from the small amounts of TFAs produced during the deodorizing of vegetable oils (Lichtenstein et al., 2006). The same set of guidelines also called for a more stringent limitation on saturated fatty acid intake than had previously been recommended for the general population—to less than 7 percent of total calories rather than the 10 percent recommended in previous AHA guidelines (previously, such low levels of saturated fatty acids had been recommended only for those on therapeutic diets). It also addressed many other issues pertaining to diet/lifestyle and heart disease. However, news coverage of the new recommendations focused on the *trans* recommendation, with headlines such as "American Heart Association urges limit on *trans* fat in diet" (*USA Today*) and "Heart group offers guideline on *trans* fat" (*Chicago Tribune*).

It is important to note that all current recommendations in the U.S., including the new AHA recommendations, call for people to limit their intake of saturated fatty acids as well as TFAs. It has long been established that saturated fatty acids elevate blood levels of LDL cholesterol,[5] and limiting the amount of sat-

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4. Although the 2005 Dietary Guidelines for Americans did not include a quantitative recommendation for *trans* fat intake, the committee of experts that makes recommendations to the federal agencies that issue the guidelines did suggest an intake of not more than 1 percent of calories (Dietary Guidelines Advisory Committee, 2004). This recommendation was not adopted in the final Dietary Guidelines report. An FDA advisory committee made the same quantitative recommendation (discussed in Lichtenstein et al., 2006), but no official FDA policy statements that include a quantitative goal for *trans* fatty acid intake have been made.
5. For the purposes of dietary guidance and public health recommendations, it is customary to group all saturated fatty acids together. However, individual types of saturated fatty acids differ in their effects on blood lipid levels. Notably, stearic acid (a saturated fatty acid with 18 carbon atoms), does not raise LDL cholesterol (Kris-Etherton et al., 2005). As will be discussed later in this paper, it may be possible for food technologists to exploit this property of stearic acid when reformulating products to decrease their *trans* fatty acid content.

urated fatty acids in the diet has been a public health priority for decades. Americans typically consume four to five times as much saturated fatty acids as TFAs; thus, experts advise that continuing to make an effort to choose foods low in saturated fatty acids is a top priority. This viewpoint is expressed, for example, in the 2005 Dietary Guidelines for Americans (USDA/HHS, 2005), which state:

> Population-based studies of American diets show that intake of saturated fat is more excessive than intake of trans fats and cholesterol. Therefore, it is most important for Americans to decrease their intake of saturated fat. However, intake of all three should be decreased to meet recommendations.

Authorities in some other countries have taken different views toward TFAs. A notable example is Denmark, where the use of fats containing 2 percent or more of industrially produced TFAs has been banned. The Danish scientific report that served as the official basis for this decision (Danish Nutrition Council, 2003) did not mention what fats would be substituted for TFAs in the Danish diet or consider how the resulting changes would affect overall dietary patterns.

People sometimes ask whether it would be better to use butter rather than margarine in order to avoid the TFAs that may be present in margarine. The answer is no. Although butter contains smaller amounts of TFAs than many margarines do, it is also much higher in saturated fatty acids. When both saturated fatty acids and TFAs are taken into consideration, margarine is the better choice (FDA, 2003c). Among margarines or "spreads," the softer tub or liquid varieties are the best choices because they are lowest in both saturated and TFAs. In fact, some products currently on the market contain no TFAs at all.

How Great Is the Impact of TFAs?

So how detrimental is the effect of TFAs? Or, to put the question in more positive terms, how great is the benefit that could be achieved by reducing dietary intake of TFAs? The answer depends upon the interpretation of a complex body of scientific evidence, including 1) studies in experimental animals; 2) controlled diet studies in which human volunteers were fed diets containing different types and proportions of fatty acids while blood levels of cholesterol and related lipids were measured; and 3) epidemiologic studies in which the association between TFA intake and heart disease risk was assessed in populations of people consuming their ordinary diets. The answer also depends on what assumptions are made about the types of fat or other food components that will replace any TFAs eliminated from the food supply.

Experimental Animal Studies

Studies in experimental animals are not as relevant to the human situation as are studies of human populations, but they offer the unique advantage of allowing researchers to examine all of the animals' tissues at the end of the experiment. The number of animal studies of TFAs and heart disease is limited. The available evidence from animal studies indicates that TFAs have effects on blood cholesterol and other lipids similar to those of saturated fatty acids, but that TFAs do not worsen the arterial damage (atherosclerosis) that leads to heart attacks (Chen et al., 2006). Whether these findings are applicable to humans has not been established.

Controlled Diet Studies

The earlier impression that TFAs had a lesser impact on cholesterol levels than saturated fatty acids do has been revised as scientists develop a deeper understanding of the health implications of different cholesterol fractions, including the undesirable low-density lipoprotein (LDL) cholesterol and desirable high-density lipoprotein (HDL) cholesterol. Improved techniques have made it possible to measure the impact of dietary changes on these specific fractions.

Several studies have been conducted in which people were fed controlled diets with different fatty acid contents for various periods of time, with blood levels of cholesterol and related lipids measured before and after the administration of the test diets. The results of these studies have consistently indicated that, in comparison to diets containing *cis* unsaturated fatty acids, diets containing TFAs raise levels of LDL cholesterol to an extent roughly similar to that produced by a similar amount of saturated fatty acids (reviewed in FDA, 1999 and FNB, 2002a). It is uncertain whether this effect results from specific effects of TFAs, or from the accompanying decrease of cholesterol-lowering *cis* fatty acids, or both (Nicolosi and Dietschy, 1995). There does not appear to be a threshold level below which substituting *trans* or saturated fatty acids for *cis* unsaturated fatty acids does not influence LDL cholesterol levels (FNB, 2002a, see especially Figure 1 in that document). Therefore, quantitative recommendations for saturated or TFA intake usually reflect what is potentially achievable without compromising other aspects of the diet, such as adequate intakes of nutrients, rather than any evidence for a specific optimal intake.

The effect of TFAs on LDL served as the principal justification for the FDA proposal to require TFA labeling on food products (FNB, 2002a). Since TFAs have been consistently shown to elevate LDL cholesterol and since LDL cholesterol is a well-established indicator of heart disease risk, the FDA concluded that providing consumers with information about the TFA content of food products was justified.

There is also evidence, although it is not quite as consistent, that in comparison with consumption of *cis* unsaturated fatty acids, consumption of TFAs may also decrease levels of desirable high-density lipoprotein (HDL) cholesterol. However, this effect has been seen primarily in metabolic studies in which TFAs were administered at levels much higher than those typically consumed in the U.S. (in some studies, as much as 10 percent of calories, as opposed to the 2 to 3 percent of calories typical in the U.S.); in the smaller number of studies in which TFAs were administered at levels closer to typical intakes, little if any impact on HDL cholesterol was detected (reviewed by Chen et al., 2006).[6] If a measurable effect of TFAs on HDL cholesterol occurs mainly at relatively high intakes, as this evidence suggests, then decreasing TFA intakes from 2 or 3 percent to 1 percent of total calories may not have a meaningful beneficial impact on HDL cholesterol.

Because there is uncertainty about the effect of TFAs on HDL cholesterol, the FDA did not rely on this effect when justifying its regulation requiring TFAs to be listed on food labels (FDA, 1999 and 2003b), nor did FNB rely on it when making its recommendation that intake of TFAs should be minimized (FNB, 2002a). However, if the effect occurs at realistic levels of TFA intake, then the benefit of replacing TFAs with *cis* unsaturated fatty acids might be as much as twice as great as that predicted on the basis of LDL cholesterol changes alone (FDA, 2003b).

How large could the benefit be? To answer this question, researchers have attempted to project the changes in the number of coronary heart disease deaths that might result from changes in TFA intake, using various assumptions. Such projections should be regarded as extremely rough estimates because they are based on uncertain data. Indeed, some scientists regard such projections as so uncertain that they should not be used in decision-making. ACSH presents projections of the effect of TFA on heart disease deaths primarily to show how certain numbers discussed in the news media were calculated and to compare the estimates that result from consideration of different types of data.

On the basis of effects on LDL and HDL cholesterol, one group of researchers has calculated that if almost all of the TFAs from partially hydrogenated oils in the U.S. diet were replaced by *cis* unsaturated fatty acids, the number of coronary "events" (nonfatal heart attacks or deaths from coronary heart disease) could be reduced by about 6 percent (Mozaffarian, 2006). Since about 1.2 million such events occur in the U.S. each year, this means that a projected 72,000 might theoretically be averted (Mozaffarian, 2006). About 40 percent of heart attacks are fatal (AHA, 2006); thus, one can project on the basis of LDL and HDL changes that replacement of nearly all the TFAs from partially hydro-

6. Some epidemiologic evidence also supports the idea of a lack of relationship between TFA intake and HDL cholesterol at realistic intake levels. For example, in the Netherlands, HDL cholesterol levels remained unchanged during a time period in the 1990s when TFA intake decreased significantly (Houterman et al., 2001).

genated oils in the U.S. diet could hypothetically prevent about 29,000 deaths per year.

However, even if these highly uncertain estimates prove to be accurate, they are substantially higher than what is likely to be possible in practice. Because oils consisting primarily of *cis* unsaturated fatty acids do not function well in some food processing applications such as baking, it may not be possible to replace nearly all TFAs with *cis* unsaturated fatty acids. In some applications, the only possible replacement for partially hydrogenated oils may be fats high in saturated fatty acids (the fats that partially hydrogenated oils originally replaced). Moreover, the estimates are based on the assumption that TFAs have adverse effects on both LDL and HDL cholesterol levels; however, at realistic intake levels, only the effect on LDL cholesterol has been definitively established. The projected health impact of changes in TFA intake if only LDL cholesterol is considered is about half of that projected if effects on both LDL and HDL cholesterol are assumed (FDA, 2003b). Thus, if TFAs have adverse effects only on LDL cholesterol at usual levels of intake, it can be very roughly estimated that about 3 percent of coronary events, or 36,000 total and 14,500 fatal coronary events per year, might theoretically be averted by near-total replacement of TFAs in partially hydrogenated vegetable oils with *cis*-unsaturated fatty acids.

Because TFA labeling in the U.S. and the resulting reformulation of food products are very recent developments, no data are yet available on the impact of these changes on public health. It would be of interest to collect such data in the coming years, both in the United States and in countries such as Denmark where more drastic decreases in TFA intake have occurred. The results of such data collection might prompt further refinement in dietary recommendations.

Epidemiologic Studies

Some researchers have suggested that the potential decrease in coronary events (or heart disease deaths) that could result from near-elimination of the use of partially hydrogenated oils containing TFAs is substantially greater than the 3 to 6 percent suggested by studies of effects on blood lipid levels. Decreases as great as 19 to 22 percent, or well over 200,000 coronary events per year, have been projected (Mozaffarian, 2006). These are startlingly high numbers that seem to imply that TFAs could play a role in heart disease risk comparable to that of the major risk factors for heart disease—smoking, undesirable blood lipid levels, and high blood pressure. Where do these unusual numbers come from?

These higher estimates are derived not from metabolic studies but rather from prospective observational epidemiologic studies of large population cohorts. The term *prospective* refers to studies in which information on exposure to factors that might influence the risk of illness is collected before any of the study

participants become ill; such studies are considered superior to *retrospective* studies, in which exposure data are collected after diagnosis, because they are not influenced by differences in the ways that ill and well people may recall past events.[7] In prospective epidemiologic studies, large groups of people are recruited, and each person is asked to provide extensive information about his or her health and lifestyle; the participants' subsequent health is monitored by periodic follow-up questionnaires. The relationship between consumption of TFAs (as assessed by dietary questionnaires) and subsequent coronary events has been analyzed in four studies of this type: a study of female U.S. nurses (Oh et al., 2005), a study of male U.S. health professionals (Ascherio et al., 1996), a study of male smokers in Finland (Pietinen et al., 1997), and a study of elderly people in the Netherlands (Oomen et al., 2001). In all four studies, after other factors were taken into account, coronary events were more common in people with the highest TFA intakes than in those with the lowest intakes. When the results of the four studies were pooled together using a technique called meta-analysis and other factors were taken into account (in a multivariate analysis), higher TFA intake was associated with a 23 percent increase in coronary events (Mozaffarian et al., 2006). This is substantially higher than what would be predicted based on effects on blood lipid levels alone. The high (19 to 22 percent or 228,000 to 264,000) estimates of the potential decrease in coronary events that could be achieved by reducing TFA intake are based on projections from the results of these prospective studies, combined with various assumptions about the extent to which TFA intake could be reduced and the nature of the nutrients that would replace it in the diet.

These estimates are also based on another critically important assumption, namely, that the association between TFA intake and coronary events seen in the epidemiologic studies is causal. However, this assumption may not be valid. In observational studies, associations between two factors do not necessarily reflect a cause-and-effect relationship. Instead, they may occur by random chance or because each of the factors mentioned is related to a third factor (called a confounding factor) that is truly responsible for the relationship.

To understand the impact of random chance, it is important to understand the nature of statistical tests, most of which are designed in such a way that 5 percent of all tested relationships will be "statistically significant," regardless of whether a true relationship exists. If many comparisons are made, some will be "statistically significant" simply as a matter of chance even if no association exists.

To understand the impact of confounding factors, it may help to consider this simple example: Assume that you observe several thousand people on the

7. The relationship between *trans* fatty acid intake and heart disease risk or various markers of heart disease risk has also been examined in retrospective and other types of epidemiologic studies. The designs of these studies are weaker than the design of prospective studies, and thus their findings (which have been inconsistent) are less persuasive. These other epidemiologic studies are not discussed further in this report.

streets of an American city. You record information on two factors: 1) whether or not the individual is wearing a skirt; and 2) whether or not the individual is bald. You will almost certainly discover that there is a strong negative relationship between the two factors, i.e., very few bald people are wearing skirts, and very few skirt-wearers are bald. But this does not prove that skirt-wearing prevents baldness or vice versa. As you undoubtedly realize, the relationship is due to a third factor: gender. Baldness is much more common among men than women, and (at least in the United States) far fewer men than women wear skirts.

In real observational epidemiologic studies, researchers make an attempt to measure obvious potential confounding factors (such as gender) that might influence the results of a study and take these factors into account when analyzing the results of their research. They also ask questions that are designed to help determine whether the association between two factors is likely to be causal, such as the following:

- *Is the relationship a strong one?* If a relationship is very strong, such as the more than tenfold increase in the risk of dying from lung cancer associated with cigarette smoking (Sherman, 1992), it is relatively easy for researchers to be confident that it is a true association, rather than a result of confounding factors or chance. For weaker relationships, making this distinction is much more difficult. Some weak relationships are indeed causal but others are not.
- *Does the relationship occur consistently in different populations and under different circumstances?* If it does not, a causal relationship is less likely.
- *Is the relationship biologically plausible?* It is very difficult to envision a biological mechanism by which skirt-wearing might protect against baldness; on the other hand, the possibility that inhaling tobacco smoke into the lungs might cause a disease of the lungs is certainly plausible.
- *Do other types of scientific evidence support the relationship?* For example, if evidence from studies in experimental animals is consistent with the findings of observational epidemiologic studies, the case for causality is strengthened. However, it is also important to remember that people are not giant rats; there may be important differences between species that preclude extrapolation of findings from animal studies to the human situation.
- *Is the methodology of the epidemiologic studies of high quality?* For example, in studies that evaluate the relationship between dietary factors and other variables, the quality of the method used to assess dietary intake and the accuracy of the food composition data used in the study are important.

Even if the answer to each of these questions is yes, it does not prove that a relationship observed in an observational study is causal. The best way to determine causality is to conduct an intervention study—that is, a study in which people are randomly assigned to be exposed to the agent under investigation or an inac-

tive placebo for a period of time (this is usually set up in such a way that the study participants do not know whether they are getting the active agent or the placebo), and changes in their health are monitored (ideally, by physicians who also do not know whether the participant is receiving the active agent or the placebo). Studies of this type are expensive and they are not always possible for ethical or practical reasons. In instances when intervention studies have been conducted, however, they have sometimes had surprising results. In some well-known instances, intervention studies failed to support hypotheses that had been proposed on the basis of high-quality observational epidemiologic studies with consistent, biologically plausible findings.

For example, during the 1980s, observational studies suggested that beta-carotene, an antioxidant pigment found in vegetables, might protect against lung cancer. The evidence was consistent in different population groups, there were plausible mechanisms for such an effect, and evidence from animal and test-tube studies seemed to support the hypothesis. Yet controlled trials of beta-carotene supplementation, completed during the 1990s, not only failed to show a protective effect against lung cancer, they actually showed that beta-carotene slightly increased the risk of lung cancer among smokers (Alpha-Tocopherol, Beta Carotene Cancer Prevention Study Group, 1994; Omenn et al., 1996).

Another instance in which a prediction was proven wrong involved the use of the hormones estrogen and progestin by postmenopausal women. A large body of observational evidence suggested that women taking these hormones had a 40 to 50 percent reduction in heart disease risk, and other types of evidence, including animal experiments, supported this association. But when researchers conducted a large trial in which women were randomly assigned to take the hormones or an inactive placebo, those taking hormones actually had a slightly higher risk of heart disease than those taking placebos (Writing Group for the Women's Health Initiative Investigators, 2002).

These are only two examples of many instances in which observational findings have been contradicted. Some analyses indicate that the findings of the majority of studies of this type will not be confirmed by further research (Ioannidis, 2005).

How can observations turn out to be so wrong? One possibility is that the variables measured might have been merely markers for other factors that truly do influence disease risk. For example, one can speculate that the beneficial effects once thought to be due to beta-carotene might actually be attributable to the consumption of a healthful diet that includes ample amounts of vegetables, and that beta-carotene, which is found in vegetables, serves as a marker for this type of diet. Similarly, the use of postmenopausal hormones might be a marker for seeking medical care and complying with doctors' instructions (the use of hormones involves regular doctor's appointments and taking daily doses of med-

ication). In the case of TFAs, one can speculate that high intakes might be a marker for more general dietary patterns—such as frequent consumption of high-calorie fried foods and bakery products, perhaps in place of more nutritious choices such as fruits and vegetables—or for other aspects of lifestyle associated with these dietary patterns.

It is unlikely that a long-term intervention study of TFAs will ever be conducted because of both ethical considerations and the large number of confounding factors. So the question of whether TFAs have an effect on heart disease risk greater than that predicted by their effects on serum lipids alone may never be answered definitively.

Some scientists, particularly those in the research group from the Harvard School of Public Health that conducted the two largest epidemiologic studies, have argued strongly that the relationship seen in these studies is likely to be causal and that therefore the reduction in heart disease risk that could be achieved by reducing dietary TFA intake is likely to be far greater than would be predicted by effects on blood lipid levels alone (Mozaffarian et al., 2006). They base their argument largely on biological plausibility and consistency with other types of scientific evidence, noting that TFAs may have other effects, in addition to their impact on blood lipid levels, that might contribute to heart disease risk. If TFAs influence heart disease risk by several mechanisms, it is plausible that their impact on heart disease risk might be greater than that predicted by lipid effects alone.

On the other hand, some aspects of the epidemiologic data on TFAs cast doubt on the likelihood of a causal relationship. The association between TFAs and heart disease, though potentially very important in public health terms because heart disease is extremely common, is not particularly strong; in the epidemiologic studies, people with high TFA intakes had a risk of heart disease only about 23 percent higher than that of those with low TFA intakes. For associations of this magnitude, it is difficult to distinguish real effects from those due to confounding factors. In general, increases of risk of less than 100 percent (a doubling in risk) are considered relatively weak effects; epidemiologists do not consider such weak associations to be as reliable as stronger ones. This is particularly true in cases where assessment of exposures is difficult, as in the case of diet, which is very challenging to evaluate.[8]

Questions can also be raised about the methods used to assess exposure to TFAs. In large epidemiologic studies, diet is usually assessed using food frequency questionnaires, in which respondents are asked to indicate how often

8. Examples of exposures that are much easier to evaluate are cigarette smoking, use of a specific medicine, or travel to a specific country. Researchers can get reasonably accurate information about a person's exposure to such factors by asking only a few questions (e.g., Have you ever taken Drug X? For how long? At what dose?). In contrast, extensive questioning is needed to obtain even an approximate picture of an individual's dietary habits.

they consume specified amounts of each of a large number of different foods. The three largest prospective studies that examined the relationship between TFA intake and heart disease risk used this method (the much smaller Zutphen Elderly Study used a different technique [Oomen et al., 2001]). Food frequency questionnaires, although they correlate reasonably well with more intensive methods of assessment, are relatively crude, and people may have difficulty remembering the information called for on the questionnaire. Assessing TFA intake with these questionnaires is even more difficult than assessing intakes of many other food components because 1) TFAs are found in a wide variety of foods, 2) adequate data on the TFA content of various food products have been difficult to obtain, and 3) the levels of TFAs present in foods may vary from brand to brand and from year to year. As the FNB noted in its report on TFAs (FNB, 2002a):

> Estimating the amount of TFAs in the food supply has been hampered by the lack of an accurate and comprehensive database on which to derive the data and the trend towards the reformulation of products over the past decade to reduce levels...Additionally, the variability in the TFA content of foods within a food category is extensive and can introduce substantial error when the calculations are based on food frequency questionnaires that heavily rely on the grouping of similar foods.

Similarly, in its original proposal for TFA labeling of food products, the FDA (1999) noted that one of the reasons why the epidemiologic studies of TFAs and heart disease must be interpreted with caution is "the imprecision associated with the dietary collection methodologies used."

Another limitation of the epidemiologic studies is that they focused narrowly on coronary heart disease, rather than taking a broader look at the relationship between TFA intake and overall health. In future research, it would be of interest to examine the relationship between TFA intake and total deaths because the total death rate is what determines longevity in population terms.

Putting the Scientific Findings into Perspective

Because it is uncertain whether the relationship between TFA intake and heart disease risk observed in the epidemiologic studies is causal, it would not be prudent to rely solely on the results of these studies for quantitative prediction of the benefits to be gained by reductions in the use of partially hydrogenated vegetable oils. Instead, it is more appropriate to rely on the more reliable, though more modest, predictions of benefit derived from metabolic studies, while recognizing the possibility that decreasing TFA intake might have a greater benefit than the metabolic studies predict if mechanisms of action other than effects on blood lipid levels prove to be involved. In addition, the overall effect of decreasing TFA intake could even be detrimental depending on what substitu-

tions are made. For example, substituting a cooking fat containing a much higher level of saturated fatty acids for one that contained a relatively small amount of TFAs would not improve the quality of the diet.

Overstating the potential benefit to be gained from decreasing TFA intake could be harmful to public health by promoting an overemphasis on this single dietary factor as opposed to other aspects of diet and other risk factors for coronary heart disease. A variety of factors—including modifiable ones such as cigarette smoking, high blood pressure, obesity, diabetes, physical inactivity, and blood cholesterol levels, as well as factors that cannot be modified, such as age and family history—all play roles in the causation of heart disease. Food choices influence several of the modifiable risk factors. An exaggerated focus on the role of TFAs, not backed up by solid data, could prompt people to pay less attention to other aspects of diet and other measures important in reducing their risk of heart disease, such as smoking cessation or weight loss.

Even with regard to lipid levels alone, TFAs are not the only or the most important determinant. Data from U.S. national surveys show that LDL cholesterol levels in men aged 50 to 74 and women aged 60 to 74 years decreased between the mid-1970s and 2002 (Carroll et al., 2005), a period when TFA intake is believed to have changed very little. Clearly, other factors—such as changes in other aspects of diet or the increased use of lipid-lowering drugs—must have been responsible for this change.

Concern about overemphasizing TFA intake to the exclusion of other factors prompted the FDA to make a change in its original proposal for TFA labeling before the regulation was even put into place. The FDA had originally planned (FDA, 1999) to accompany the listing of the amount of TFAs on the nutrition label with a footnote stating, "Intake of *trans* fat should be as low as possible." In the final version of the rule, however, the footnote was omitted because of concerns that it might place undue emphasis on TFAs relative to other heart-unhealthy fats, thereby potentially undermining official recommendations that call for consumers to limit their intakes of *both* saturated fatty acids and TFAs, in the context of a nutritionally adequate diet (FDA, 2003b).

The idea that TFA intake is only one of multiple factors that need to be taken into account in planning a healthful diet often seems lost in a sea of inflammatory rhetoric, presumably prompted by the "unnatural" or technological origin of most TFAs in a manufactured product rather than a "natural" agricultural commodity. The New York City health commissioner has likened *trans* fat to asbestos and lead (Santora, 2005), and in 2005, the New York City Department of Health and Mental Hygiene (DOHMH) asked restaurateurs and food suppliers in the city to eliminate the use of partially hydrogenated vegetable oils (DOHMH, 2005). In September 2006, New York City proposed a regulation

that would require all restaurants to phase out the use of "artificial *trans* fats" (i.e., *trans* fats from partially hydrogenated vegetable oils) over an 18-month period (DOHMH, 2006). A supermarket chain in the United Kingdom recently announced with great fanfare that it was removing all hydrogenated fatty acids from its house-brand products (Fletcher, 2006). Recent articles in the *New York Times* about the presence of TFAs in chicken nuggets and Girl Scout cookies, respectively, carried the provocative titles "Nuggets of Death" (Teicholz, 2006) and "Killer Girl Scouts" (Kristof, 2006). It is understandably difficult for people to put concerns about TFAs into perspective when confronted with this type of journalistic excess and fearmongering.

One of the most prominent opponents of TFAs is CSPI (the same group that expressed moderate and reasonable views about TFAs in 1988). This organization recently sued KFC over its use of partially hydrogenated frying oils, claiming in the lawsuit that KFC is exposing the public to "deadly dangers" inherent in "the worst oil available and imaginable" and that the restaurant chain's conduct is "outrageous and performed with evil motive, intent to injure, ill will, and without legal justification or excuse" (Hoyte v. Yum! Brands Inc., 2006). The organization has also petitioned the FDA to ban partially hydrogenated oils (CSPI, 2004a) and (somewhat contradictorily) to require restaurants to disclose their use (CSPI, 2004b). In 2004, in response to the McDonald's restaurant chain's not meeting its self-imposed deadline for reformulating its frying oils to contain less *trans* fat, CSPI ran a full-page advertisement in the *New York Times*: half the ad consisted of a graphic photograph of a man receiving cardiopulmonary resuscitation (CSPI, 2004c). This type of alarmism does not represent science and is not in the public interest.

The need to consider aspects of a food product other than TFAs when evaluating its healthfulness is sometimes overlooked even by scientists. For example, in April 2006, a much-publicized letter to a medical journal reported that the amounts of TFAs in potato and chicken products sold by the McDonald's and KFC restaurant chains differed greatly from country to country (Stender et al., 2006), apparently reflecting the use of different types of frying fat. Both the letter and related news reports seemed to assume that the products with the lowest TFA levels would automatically be the most healthful. This assumption is not necessarily valid, however. A product low in TFAs would not be considered healthful if it is high in saturated fatty acids (as it would be, for example, if it were fried in coconut or palm oil). To properly compare the healthfulness of the fat content of the various chicken and potato products, it would be necessary to have information on *both* their saturated and TFA contents. Unfortunately, no saturated fatty acid data were reported in the fast food study. Therefore, the statement made by Michael Jacobson of CSPI in response to this study (CSPI, 2006) that "McDonald's and KFC's products are much healthier [in Denmark] than they are here" cannot be supported by the actual data provided by the researchers.

Product Reformulation

It is sometimes suggested that food manufacturers and restaurants could instantaneously improve the healthfulness of their products by substituting unmodified vegetable oils that contain no TFAs for partially hydrogenated oils that do contain them. Reality, as usual, is more complex.

Most of the partially hydrogenated vegetable oil used in the United States is soybean oil; industry sources indicate that soybean oil accounts for 79 percent of all edible oil used in the U.S. Thus, reducing the TFA content of a food product usually involves substituting some other type of fat for partially hydrogenated soybean oil. However, the most readily available substitute—unmodified soybean oil—is not usually a suitable choice. Unmodified soybean oil is rich in highly unstable unsaturated fatty acids, particularly linolenic acid, which makes it poorly suited for deep-fat frying. Because it is a liquid oil, it is also unsuitable for some uses in baking, where semisolid fats are necessary. Therefore, other approaches are necessary, such as the following:

- In some instances, liquid vegetable oils that are rich in *cis* unsaturated fatty acids but not as unstable as soybean oil can be substituted for partially hydrogenated oils. However, this approach cannot be used for shortenings in baked goods, where a semisolid texture is essential.
- Another option in some situations is fully hydrogenated vegetable oils. Fully hydrogenated oils do not contain any TFAs; instead, depending on the fat they are derived from, they may consist largely of an 18-carbon saturated fatty acid called stearic acid. Unlike some other saturated fatty acids, which raise LDL cholesterol levels, stearic acid has little or no effect on blood lipids (Kris-Etherton et al., 2005). Fully hydrogenated oils, which have a hard, waxy texture, can be blended with unhydrogenated liquid oils to create a semisolid fat that can be substituted for conventional partially hydrogenated vegetable oils in some food processing applications.
- In some instances, vegetable oils processed or modified in other ways may be substituted for partially hydrogenated vegetable oils. For example, fully hydrogenated oils or oils naturally high in saturated fatty acids can be chemically combined with unhydrogenated oils by a process called *interesterification*, which rearranges fatty acids on glycerol molecules, creating products similar in texture to conventional partially hydrogenated vegetable oils but without any *trans*.
- Oils from plants bred to have more favorable fatty acid profiles may be suitable for some purposes. For example, new varieties of soybeans that produce an oil with less of the highly unstable linolenic acid have been produced.
- Additives such as gelling agents or emulsifiers may be added to unhydrogenated oils to create desired textures and other types of additives, such as

antioxidants, may be added to increase stability and retard spoilage.

- Finally, in many applications, it is possible to replace partially hydrogenated oils with fats rich in saturated fatty acids, such as lard or other animal fats or coconut or palm oils, which can provide both desired stability and texture. From a nutritional standpoint, substituting saturated fats for partially hydrogenated oils is not usually an improvement, but in some instances, particularly in baking, it may be the only way to produce a *trans*-free product acceptable to consumers.

With all of these approaches, replacing TFAs is not simply a matter of substituting a different type of fat for partially hydrogenated vegetable oil in a recipe. Many changes may need to be made in the composition and processing of a food to yield an acceptable product. Switching to replacement oils may also increase costs (which will eventually be passed on to consumers) and create supply problems. It will likely take several years before sufficient supplies of many of the newer oils are available to all the food processors who want them. Introducing new *trans*-free oils into large markets, such as fast food restaurants, is particularly difficult because the oils need to be available in large amounts—something that cannot be achieved overnight. Many food companies are in the process of reformulating products to reduce or eliminate TFAs, using one or more of the approaches described above. However, it has proven to be challenging to maintain quality attributes important to consumers, such as texture, flavor, and shelf life, while modifying the products' fatty acid contents.

Finally, it is important to note that some types of food products cannot exist without either saturated fatty acids or TFAs. An example is margarines and other "spreads." The saturated fatty acids or TFAs in these products are the source of the hardness that these products need. Sophisticated technology has allowed the amounts of these fatty acids in such products to be greatly decreased, but complete elimination is not possible (Korver and Katan, 2006). If you remove all of the saturated and *trans* fatty acids from these products, you will not have a margarine or spread; you will have an oil with a buttery flavor, or at best, a pourable/squeezable product.

TFAs and Food Labeling

In 1999, the FDA proposed requiring information on TFA content to be included in the Nutrition Facts label on food products, and in January 2006, a regulation requiring *trans* labeling went into effect. The regulation did not ban TFAs or in any way compel food manufacturers to modify their products. Nevertheless, the knowledge that this requirement was going into effect prompted many food manufacturers to take steps in advance toward reformulating their products to reduce or eliminate TFAs. The presence of TFA information on food labeling has likely also prompted some consumers to change their buying habits and perhaps even to inquire about the TFA content of unlabeled products and restaurant foods.

Based on the admittedly tentative information available before the labeling regulation went into effect, the FDA made two estimates of the potential decrease in coronary heart disease that might result from decreased intake of TFAs as a result of the labeling change. Based on the assumption that benefits would result only from changes in LDL cholesterol levels, the FDA estimated that the new rule would annually prevent 600 cases of coronary heart disease and 240 deaths; based on potential changes in both LDL and HDL cholesterol, the FDA estimated that the rule would prevent 1200 cases of coronary heart disease and 480 deaths per year in the general U.S. population (FDA, 2003b). These estimates are substantially lower than the other estimates discussed in this report because they are based on the understanding that labeling alone may result in relatively modest changes in the public's eating habits.

Summary and Conclusions

A substantial body of scientific evidence indicates that the effects of *trans* unsaturated fatty acids on LDL cholesterol levels are less desirable than those of *cis* unsaturated fatty acids. It is also likely that TFAs have undesirable effects on HDL cholesterol when consumed at high levels, but whether such effects occur at the levels of TFA intake common in the United States has not been demonstrated. Whether TFAs influence heart disease risk by other mechanisms, in addition to their effects on blood lipids, has not yet been clearly established.

On the basis of projected effects on LDL cholesterol or LDL and HDL cholesterol combined, it has been very roughly estimated— with considerable uncertainty— that replacement of nearly all TFAs from partially hydrogenated vegetable oils with *cis* unsaturated fatty acids could theoretically lead to a reduction in heart disease of 3 to 6 percent. The reduction achievable in practice is likely to be substantially lower because *cis* unsaturated fatty acids cannot

replace TFAs in some food applications for reasons related to texture or stability; in these instances, saturated fats are the only practical substitutes. Moreover, supply and cost considerations may limit the opportunities for reformulation of some food products.

Much higher estimates of the benefit that could be achieved by replacing TFAs in the diet with *cis* unsaturated fatty acids have frequently appeared in the scientific literature and the news media. These estimates are based on data from prospective epidemiological studies. Studies of this type cannot demonstrate a cause-and-effect relationship, and their results can be influenced by confounding factors and by the difficulty of assessing TFA levels in the diet. The results of the epidemiologic studies are important and should not be dismissed out of hand. However, relying too heavily on the possibly exaggerated estimates of benefit derived from these studies, which are much higher than those derived from other lines of evidence, would be unwise because it could detract attention from other aspects of diet that influence blood lipid levels, such as saturated fatty acid intake, and from other priorities in heart disease prevention, such as weight control, exercise, and abstinence from cigarette smoking.

Although scientists now agree that TFAs are not as healthful as their *cis* counterparts, exaggerated claims that TFAs pose dire health threats even in trace amounts are not supported by scientific evidence and are unwarranted. TFAs are not poison; they are simply one of several dietary factors that affect blood lipid levels, and blood lipid levels are only one of several major factors that influence the risk of heart disease. Efforts to decrease the risk of heart disease should involve a comprehensive and balanced focus on all of the major risk factors, rather than an overemphasis on one relatively minor issue to the exclusion of all others. Focusing too much attention on a single "bad" dietary factor is unwarranted and can even promote unwise dietary choices, such as selecting a food containing a much larger amount of saturated fat rather than one with a small amount of *trans* fat.

The kind of balanced perspective that is appropriate here is illustrated by the new 2006 guidelines from the American Heart Association—the same set of guidelines that made headlines because they were the first to set a quantitative goal for TFA intake. These guidelines did not specifically focus on TFAs to the exclusion of all else. Instead, they included seven diet and lifestyle goals, only one of which pertained to blood lipid levels and nine dietary recommendations for the public, only one of which dealt with the types of fat in the diet. Comprehensive recommendations of this type, which address all of the major risk factors for heart disease, including smoking, obesity, diabetes, high blood pressure, and physical inactivity as well as unhealthy blood lipid levels, reflect current scientific and medical thinking. Scare tactics and obsessive efforts to purge TFAs from the diet do not.

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