AHA Conference Proceedings

Understanding the Complexity of *Trans* Fatty Acid Reduction in the American Diet

American Heart Association *Trans* Fat Conference 2006

Report of the *Trans* Fat Conference Planning Group*

Robert H. Eckel, MD, FAHA, Immediate Past President of the AHA; Susan Borra, RD, Co-Chair; Alice H. Lichtenstein, DSc, FAHA, Co-Chair; Shirley Y. Yin-Piazza, MS, MBA

***Abstract*—**A 2-day forum was convened to discuss the current status and future implications of reducing *trans* fatty acids without increasing saturated fats in the food supply while maintaining functionality and consumer acceptance of packaged, processed, and prepared foods. Attendees represented the agriculture and oilseed industry and oil processing, food manufacturing, food service, government, food technology, and health and nutrition disciplines. Presentations included food science behind fatty acid technology, the health science of dietary fatty acids, alternatives to *trans* fatty acids, and the use of alternatives in food manufacturing and food service. The reduction of *trans* fatty acids in the food supply is a complex issue involving interdependent and interrelated stakeholders. Actions to reduce *trans* fatty acids need to carefully consider both intended and unintended consequences related to nutrition and public health. The unintended consequence of greatest concern is that fats and oils high in saturated fats, instead of the healthier unsaturated fats, might be used to replace fats and oils with *trans* fatty acids. Many different options of alternative oils and fats to replace *trans* fatty acids are available or in development. Decisions on the use of these alternatives need to consider availability, health effects, research and development investments, reformulated food quality and taste, supply-chain management, operational modifications, consumer acceptance, and cost. The conference demonstrated the value of collaboration between the food industry and health and nutrition professionals, and this conference model should be used to address other food development, processing, and/or technology issues. **(*Circulation*. 2007;115:2231-2246.)**

Key Words: AHA Conference Proceedings ■ diet ■ fatty acids ■ nutrition ■ *trans* fat ■ *trans* fatty acids

In recent years, scientific studies, public and regulatory policy activity, and media coverage have focused extensively on issues related to *trans* fatty acid reduction in the American diet and potential benefits with respect to health outcomes. To discuss and address *trans* fatty acid reduction in the food supply with input from the agricultural and oilseed industry and oil processing and manufacturing, food manufacturing, food service, government, food technology, and

*The American Heart Association *Trans* Fat Conference Planning Group was composed of Robert H. Eckel, MD, FAHA, Immediate Past President of the AHA; Susan Borra, RD, Co-Chair; Alice H. Lichtenstein, DSc, FAHA, Co-Chair; Shelley Goldberg, MPH, RD; Bill Layden; Rose Marie Robertson, MD, FAHA; Brigid McHugh Sanner; Kimberly F. Stitzel, MS, RD; and Shirley Y. Yin-Piazza, MS, MBA.

This article represents a summary of a conference sponsored by the American Heart Association. The opinions expressed in this article are those of the authors and do not necessarily represent those of the editor or the American Heart Association. The publication of these proceedings was approved by the American Heart Association Science Advisory and Coordinating Committee on February 27, 2007.

The conference focused on approaches to decrease the amount of *trans* fatty acids in the US food supply through reductions in the use of partially hydrogenated fats. Company-specific information is intended to reflect practical experiences and the expertise of the speakers. The presentations and subsequent information in the report do not necessarily reflect the opinions, support, or endorsement of the American Heart Association. The information is not intended to be exhaustive but to be informative of the barriers and success to the reduction of *trans* fatty acids in the food supply—a necessary step in the fight against cardiovascular disease.

The following speakers presented at the conference: Susan Borra, RD (International Food Information Council Foundation); Deanne Brandstetter, MBA, RD (The Compass Group); Robert Brown, PhD, MPH (Frito-Lay North America); David Dzisiak (Dow AgroSciences); Robert H. Eckel, MD (University of Colorado at Denver and Health Sciences Center); Brent D. Flickinger, PhD (Archer Daniels Midland Company); Pete Friedman, MS (ACH Food Companies); Peter D. Goldsmith, PhD, MBA (University of Illinois Urbana-Champaign); William Hitz, PhD (DuPont Pioneer Hi-Bred International); David M. Klurfeld, PhD (USDA); Michael Lefevre, PhD (Pennington Biomedical Research Center); Alice H. Lichtenstein, DSc (Tufts University); Gary List (USDA); Willie H. Loh, PhD (Cargill); Debe Nagy-Nero, MS, RD (The Holland Inc.); Ravinder Reddy, PhD (Unilever North America); Julie Reid, MS (Ruby Tuesday); Frank Sacks, MD (Harvard School of Public Health); David Stark, PhD (Monsanto Company); Brian L. Strouts (American Institute of Baking International); Kathleen Warner, PhD (USDA); Pamela White, PhD (Iowa State University); and Richard F. Wilson, PhD (USDA).

A single reprint is available by calling 800-242-8721 (US only) or writing the American Heart Association, Public Information, 7272 Greenville Ave, Dallas, TX 75231-4596. Ask for reprint No. 71-0326. To purchase additional reprints, call 842-216-2533 or e-mail kelle.ramsay@wolterskluwer.com. To make photocopies for personal or educational use, call the Copyright Clearance Center, 978-750-8400.

Expert peer review of AHA Scientific Statements is conducted at the AHA National Center. For more on AHA statements and guidelines development, visit http://www.americanheart.org/presenter.jhtml?identifier=3023366.

***Circulation* is available at http://www.circulationaha.org** **DOI: 10.1161/CIRCULATIONAHA.106.181947**

health and nutrition disciplines, the American Heart Association convened the *Trans* Fat Conference from October 10 to 11, 2006, in Washington, DC.

The key objective of the conference was to provide an interactive and collaborative forum to discuss the current status and future implications of reducing the intake of *trans* fatty acids without increasing saturated fats as part of a balanced dietary approach to reduce the risk of cardiovascular disease while maintaining functionality and consumer acceptance of packaged, processed, and prepared foods.

History of *Trans* Fatty Acids in Health

The process of hydrogenation was first discovered around the turn of the 20th century by French chemist Paul Sabatier using a nickel catalyst. Shortly after, German chemist Wilhelm Normann developed a hydrogenation process using hydrogen gas. Modifications in the processing and formulation of hydrogenated fats continued through the mid-20th century. It was the partial hydrogenation of fats that introduced *trans* fatty acids (or *trans* fats) into fats of vegetable origin.

The use of partially hydrogenated fats accelerated in the 1960s, 1970s, and 1980s as food producers responded to public health recommendations to move away from animal fats and tropical oils. At the time, partially hydrogenated fats seemed to be a good alternative, particularly because of their stability, cost, availability, and functionality. Before the 1990s, limited data were available on the health effects of *trans* fatty acids, and the data often were contradictory. For example, an article published in 1957[1] found no significant effect between coconut oil (iodine value 9) and hydrogenated coconut oil (iodine value 5.2) on plasma cholesterol levels of 9 healthy males, probably because, independently of hydrogenation, the fat was composed of predominantly saturated fatty acids. (Iodine value is a measure of the total number of double bonds present in fats and oils. It is generally expressed in terms of number of grams of iodine that will react with the double bonds in 100 g of fats and oils.) In this same study, researchers reported that compared with coconut oil, the hydrogenated whale oil (iodine value 83) was similar in its effect on plasma cholesterol levels, whereas the nonhydrogenated whale oil (iodine value 118) was found to be hypocholesterolemic. One year later, researchers reported that within the context of a 35% butterfat diet, there was no significant difference between supplemental corn oil and hydrogenated corn oil.[2]

Between 1960 and 1990, numerous additional studies were published with inconsistent results. This variability is likely attributable to differences in the background diets, starting fatty acid profile of the test oil, differences in the degree and type of hydrogenation, and less-than-optimal comparison fats.

In 1990, Mensink and Katan[3] compared the effect of diets rich in oleic acid, saturated fatty acids, and *trans* fatty acids. They reported that relative to a diet rich in oleic acid, total cholesterol and low-density lipoprotein (LDL) cholesterol levels were higher after subjects consumed diets rich in saturated or *trans* fatty acids. In contrast, relative to the diet rich in *trans* fatty acids, high-density lipoprotein (HDL) cholesterol levels were higher after subjects consumed the diets rich in saturated fatty acids or oleic acid. The differential effects on LDL and HDL cholesterol levels resulted in the least favorable total-to-HDL-cholesterol ratio after the subjects consumed the diet rich in *trans* fatty acids.

TABLE 1. Consumer Awareness and Understanding of Fats

Term	Awareness of Term,* %	Understanding of Cardiovascular Risk,† %
Saturated fats	92	67
Trans fats	84	53
Partially hydrogenated oils	68	33

Values are percent of 1000 respondents. Source: AHA Consumer Survey (Spring 2006).

*Based on answer to the question, "Please check all of the types of fats and oils that you have ever heard of."

†These are the percentages of respondents who answered "Increased risk of heart disease" to the question, "To the best of your knowledge, what effect, if any, do each of the following have on your risk of heart disease?"

The negative effect of partial hydrogenation and resulting *trans* fatty acids on serum cholesterol levels bears out consistently in multiple research studies conducted throughout the 1990s. A 1999 study[4] found that partial hydrogenation had a linear, positive relationship with LDL cholesterol levels in that increasing dietary intake of *trans* fatty acids increased the levels of LDL cholesterol. In contrast, HDL cholesterol levels remained relatively constant with increasing hydrogenation and decreased only with the highest level of hydrogenation, resulting in the least favorable total-to-HDL-cholesterol ratio. A recent meta-analysis of available data found that a 2% increase in energy intake from *trans* fatty acids was associated with a 23% increase in the incidence of coronary heart disease.[5]

The US Food and Drug Administration (FDA) mandated that as of January 1, 2006, the Nutrition Facts panels of all packaged food labels must indicate the quantity of *trans* fatty acids in a serving of the food product. Since the phasing in of this information, it appears that the regulatory action has catalyzed food manufacturers to reformulate many of their products to decrease levels of partially hydrogenated fats. This regulatory action also has resulted in an increased awareness about dietary *trans* fatty acids in the general public and in efforts by a number of cities and states to limit the *trans* fatty acid content of restaurant foods.

Value of Addressing *Trans* Fatty Acid Issues to Help Consumers

To address improvements in the health of the public related to *trans* fatty acid consumption, it is helpful to assess consumer understanding of dietary fats. The American Heart Association conducted an online consumer research survey in spring of 2006 with a national sample of 1000 adults 18 to 65 years of age. Results of this market research indicate that when asked if they had heard of the term "*trans* fats," 84% of the respondents said yes. However, close to half of the respondents lacked understanding of the health effects of *trans* fats (Table 1).[6–10]

Other highlights of the survey include the following:

TABLE 2. Major Fatty Acids Found in Food

Fatty Acid	Structure	Physical Property	Functionality Trait	Health Effect
Palmitic	C16:0 Saturated	Solid at room temperature Stable in storage and during frying	Used to form margarines, shortenings, and spreads As a cream base for baked products Desirable smooth mouth feel	Increases LDL cholesterol and elevates the risk for heart disease[6]
Stearic	C18:0 Saturated	Solid at room temperature Stable in storage and during frying Relative large percent converted to oleic acid	Used to form margarines, shortenings, and spreads As a cream base for baked products Promotes more of a grainy mouth feel	Little effect on serum cholesterol levels because a high proportion is desaturated to oleic acid[7]
Oleic	C18:1 Monounsaturated with 1 *cis* double bond	Liquid at room temperature Relatively stable in storage and during frying	High stability generally a positive feature Oils containing very high amounts of oleic acid tend to produce undesirable fried-food flavor, sometimes described as bland or waxy, caused by a lack of breakdown products	Lowers cholesterol and may slow progression of atherosclerosis[8]
Linoleic (omega-6)	C18:2 Polyunsaturated with 2 *cis* double bonds	Liquid at room temperature Unstable in storage and during frying	Small amount is acceptable to food flavors	Inverse association between n-6 polyunsaturated fatty acids intake and the risk of coronary heart disease[9]
Linolenic (omega-3)	C18:3 Polyunsaturated with 3 *cis* double bonds	Liquid at room temperature Unstable in storage and during frying	Main source of off-flavors because of its tendency to oxidize and contribute to rancidity in packaged and fried foods	Increased consumption of n-3 fatty acids from fish or fish oil supplements, but not of α-linolenic acid, reduces the rates of all-cause mortality, cardiac and sudden death, and possibly stroke[10]

- Fewer than half of those surveyed could identify any 1 food as typically containing *trans* fats, even when asked to choose from a list of foods. The top food identified as containing *trans* fats was doughnuts (44% of consumers). This compares with the higher knowledge that consumers exhibited regarding foods they thought contained saturated fats. Approximately 70% of consumers surveyed could correctly identify at least 3 foods containing saturated fats from the same list of foods.
- Consumers were more likely to report specific "good" behaviors regarding saturated fats than regarding *trans* fats. For example, 50% of the respondents reported "using cooking sprays or vegetable oils instead of butter" compared with 23% who reported "reviewing information on *trans* fats specifically before making purchasing decisions."
- Americans are more likely to make healthy dietary changes when at home or in the supermarket than at restaurants. Most consumers (95%) surveyed did not ask about healthy food options or request nutrition information when eating out. Close to half of the respondents reported "never" or "rarely" ordering a menu item marked as being "healthy" in some way.

Food Science Behind Fatty Acid Technology

Overview

Most fats and oils consumed on a regular basis are a combination of several fatty acids. No fat or oil contains only 1 type of fatty acid. Saturated fatty acids are more stable than polyunsaturated and monounsaturated fatty acids. This stability is important in terms of the shelf life of packaged foods and the retardation of the rancidity of frying oils.

The major fatty acids found in food are palmitic, stearic, oleic, linoleic, and linolenic acids. Their structures, physical properties, functionality traits, and health effects are summarized in Table 2.

Trans fatty acids occur naturally at relatively low levels in meat and dairy products as a result of the fermentation process in the animal's rumens. In the US diet, a large proportion of *trans* fatty acids ($\approx$80%) is contributed by the partial hydrogenation of fats. Partial hydrogenation increases the shelf life and flavor stability of foods containing fats and gives the fat a higher melting point. Compared with fatty acids with *cis* bonds, *trans* fatty acids tend to be more stable in storage and during frying. Partially hydrogenated fats tend to be more solid than unsaturated fats but less solid than saturated fats. The major dietary sources of *trans* fatty acids are traditional vegetable shortenings and solid margarines, crackers, candies, cookies, snack foods, fried foods, baked goods, and other processed foods. The actual amount coming from any of these products is changing rapidly as a result of efforts by food producers to decrease the level of *trans* fatty acids in their foods.

Measurement of *Trans* Fatty Acids

Two methods approved by the FDA for measuring fatty acid composition to declare the amount of *trans* fatty acids in the food on food labels are summarized next. There are advantages and disadvantages to both processes.

- Gas chromatography, Association for Official Analytical Chemists method 996.06. In this process, fat is extracted from the food product and converted to fatty acid methyl esters before being injected onto a gas chromatography column ≈100 m long. It takes about 1 hour to run a sample with this process, and the method can measure individual *trans* fatty acid isomers to ≈0.1 g per serving. The advantage of this method is the ability to measure individual *trans* fatty acid isomers to as low as 0.1 g per serving, but the disadvantages are the long sample preparation and gas chromatography run times.
- Attenuated total reflection–Fourier transform infrared spectroscopy (ATR-FTIR), American Oil Chemists' Society method Cd 14d-96. In this process, fat is extracted from a food sample, and the neat (without solvent) sample is placed in an infrared cell. It takes ≈1 minute to read the sample with an accuracy of 0.5 g *trans* fatty acids per serving. The minimum *trans* fatty acid content of the sample must be 0.8% to 1% to get an accurate reading, depending on sample size. This method makes no distinction among the different *trans* fatty acid isomers and therefore can give a value only for the total *trans* fatty acids. Different *trans* fatty acid isomers may have different effects on health. For example, although *trans* fatty acids created through partial hydrogenation have been linked with an increased risk of coronary heart disease,[5] vaccenic acid, a naturally occurring *trans* fatty acid in the fat of ruminants, is converted in human beings to rumenic acid, an isomer of conjugated linoleic acid.[11] Conjugated linoleic acid has been shown to protect against some types of cancer in animals and humans.[12] Therefore, the lack of sensitivity to different *trans* fatty acid isomers limits the usefulness of ATR-FTIR as an assessment method for other purposes. There are also limitations regarding the type of oil being measured; for example, the oil cannot contain large quantities (>5%) of conjugated unsaturated fatty acids (eg, tung oil), and the oil cannot contain functional groups around the isolated *trans* double bonds, all of which interfere with the ATR-FTIR measurement. The sample also must be liquid during measurement. Despite its limitations, most food manufacturers use this method because of its speed.

Fats and Oils for Human Consumption

Fats and oils for human consumption are usually separated into 3 categories: salad and cooking oils, frying oils, and solid fats. The quality issues of edible oils include oxidative stability, nutrient composition, and functionality.

Salad and Cooking Oils

Bland flavor, light color, good stability, and manufacturing processing and packaging flexibility are important for salad and cooking oils. Good choices to meet these requirements are polyunsaturated and monounsaturated oils. Less polyunsaturated fat is preferred to minimize the likelihood of rancidity and the need for refrigeration. This type of salad or cooking oils also is suitable for in-home 1-time deep frying and pan frying. The need for *trans* fatty acid reduction in this type of liquid oils is not an issue because most salad or in-home cooking oils on the market today do not contain *trans* fatty acids and cooking this type of oil in one's kitchen does not produce *trans* fatty acids.

Frying Oils

Commercial frying applications include restaurant frying such as the preparation of deep-fried foods and packaged foods such as snack chips.

Oils for commercial frying require stability related to the thermal deterioration processes of oxidation, hydrolysis, and polymerization. For consumer acceptance, the fatty acid composition of the oils needs to have 20% to 30% linoleic acid to produce a desirable full deep-fried flavor to the foods; however, higher levels of linoleic acid might introduce "off"-flavors from oxidation. For restaurant use, oils need to be stable because a long fry life is required and the oil has to withstand the high temperatures of commercial frying. Food manufacturers prefer stable oils that can also tolerate high temperatures and allow an extended shelf life for foods after they are packaged.

Stable frying oils are characterized by increased amounts of oleic acid (preferably in the moderate range of 50% to 65%), decreased amounts of linoleic acid (preferably in the 20% to 30% range), and decreased amounts of linolenic acid (preferably no more than 3%). It has been common to acquire stable commercial frying oils by changing the fatty acid composition by partial hydrogenation. Potential alternatives to partially hydrogenated oils for commercial frying include naturally stable oils such as corn, cottonseed, palm, peanut, and rice bran and modified fatty acid oils such as mid-oleic corn, high-oleic/low-linolenic canola, high-oleic sunflower, mid-oleic sunflower, low-linolenic soybean, and mid-oleic/low-linolenic soybean oils (Figure 1). In choosing *trans* fatty acid–free frying oils, consider the cost, availability, oxidative stability, functionality in terms of the appearance and texture, flavor, and nutrient composition of the option. Specifically, some of these oils such as animal fats and tropical oils contain high amounts of saturated fats and should not be considered as replacements.

Solid Fats

Functionality parameters in solid fats (spreads and baking shortenings) include the melting point, lubricity, moisture barrier, and creaming ability. The parameters of fat content, emulsifiers, solid fat in blending, and melting point need to be in place before product development is begun. In the development of solid shortenings to reduce *trans* fatty acids, functional parameters such as plasticity for extrusion into dough and creaming properties are important. The dough should not be sticky or "oil out" (have the fats separate from the dough) at high temperatures. Solid shortenings packed in cubes need to allow handling without deformation.

Partially hydrogenated fats have been effective in achieving functionality and stability requirements in solid fats. To meet the functionality and stability requirements in solid fats while minimizing *trans* fatty acids, many of the current

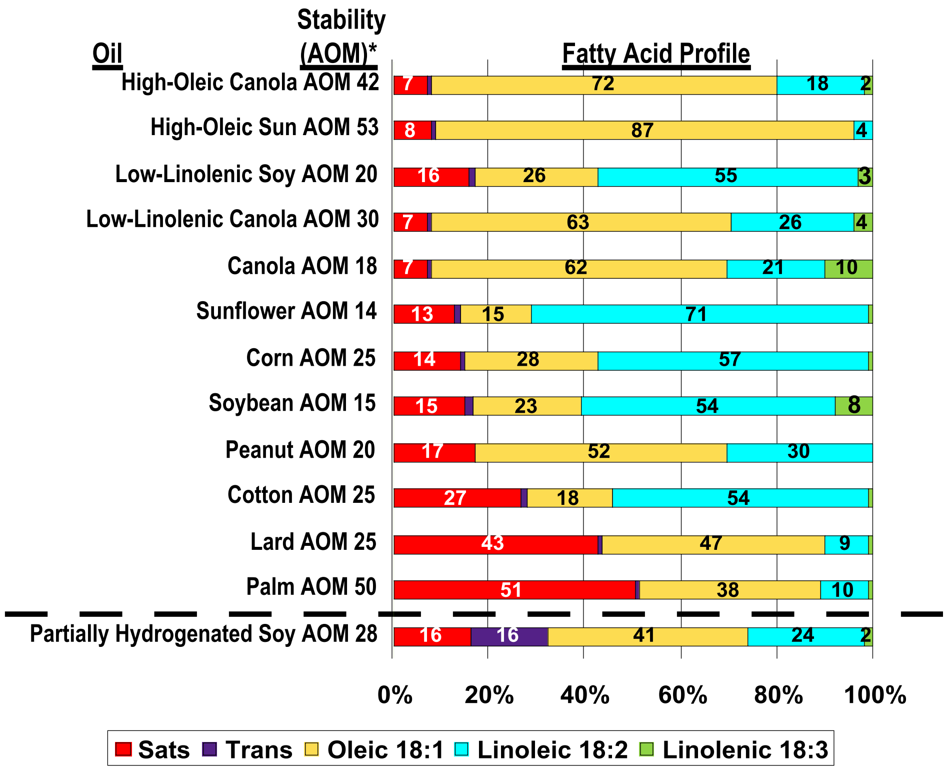

Figure 1. Fatty acid profiles of selected alternatives to partially hydrogenated soybean oil. AOM indicates antioxidative measurement of oil stability (in hours).

options typically include significantly increasing saturated fatty acids.

Several consumer brands of solid *trans* fatty acid–free margarines have become available in recent years, as have solid shortenings. The availability of these products for commercial use is uncertain at this time.

Health Sciences of Dietary Fatty Acids

Trends in Fatty Acid Supply and Intake in the United States

The US Department of Agriculture (USDA) Economic Research Service has maintained food supply data since 1909. The saturated fat content in the food supply has remained relatively stable between 1909 and 2000. Monounsaturated fats became the primary source of dietary fats in the 1950s and have shown a steady increase from 1960 through 2000. There also has been a steady increase in polyunsaturated fats in the US food supply during this same time.

In terms of per capita spread consumption, US margarine consumption was minimal before World War II, but after World War II, there was a significant increase. Margarine consumption surpassed the intake of butter during the 1960s, 1970s, and 1980s. In the 1990s, the consumption of margarine decreased, and the intake of butter remained constant. Today, there is essentially an equal intake of margarine and butter. On the basis of a proprietary analysis of AC Nielsen sales data conducted by the National Association of Margarine Manufacturers, there also has been a shift away from stick margarine to soft and liquid margarines, with soft and liquid margarines accounting for 72% of the margarine sales in 2006 compared with 46% in 1990.

The use of shortening increased steadily throughout the 20th century. Salad and cooking oils were separated from other edible oils in the USDA *Census Bureau for Added Fats and Oils* in the mid-1960s, and they represent the largest single source of fat in the US diet today.

World vegetable oil consumption is about 106 million metric tons, with soybean and palm oil representing ≈60% of this consumption (Table 3).[13] The breakout of edible oil use

TABLE 3. World and US Edible Oil Consumption

Oil	World,[13] %	US,[14] %
Soybean	30	75
Palm	29	2
Rapeseed (canola)	15	7
Sunflower seed	8	. . .
Peanut	5	. . .
Cottonseed	4	3
Palm kernel	3	. . .
Coconut	3	2
Olive	3	. . .
Corn	. . .	7
Edible tallow	. . .	1
Lard	. . .	1
Other	. . .	3
Total, million metric tons	106	10.4

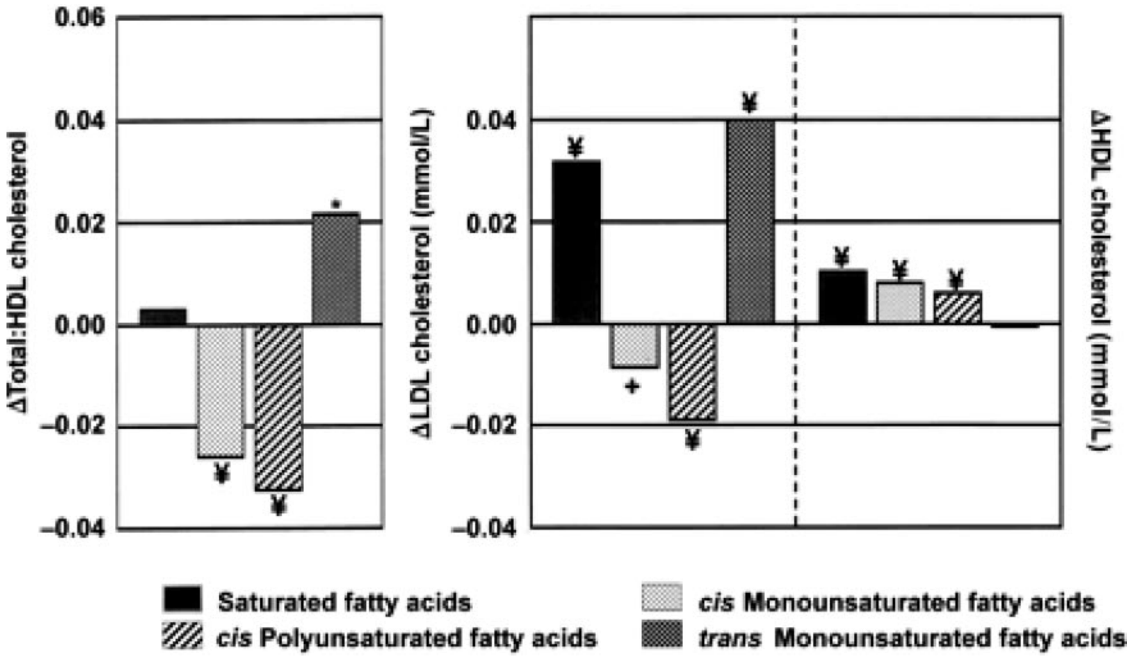

Figure 2. Meta-analysis of 60 controlled trials of dietary fats and blood lipids: effect of replacing carbohydrate with fat. Predicted changes (Δ) in the ratio of serum total to HDL cholesterol and in LDL and HDL cholesterol concentrations when carbohydrates constituting 1% of energy are replaced isoenergetically with saturated, *cis* monounsaturated, *cis* polyunsaturated, or *trans* monounsaturated fatty acids. **P*<0.05; †*P*<0.01; ‡*P*<0.001. Reprinted from Mensink et al,[20] with permission from the American Society of Nutrition.

in the United States is quite different. Americans consume ≈10% of all the edible oils in the world, and ≈75% of this is soybean oil.[14] Key uses for soybean oil in the United States include baking and frying (44%), salad and cooking oils (44%), and margarine (7%).

Trans fatty acids have been included in the USDA *National Nutrient Database for Standard Reference* only since 1994,[15] and only since 2002 was national randomized sampling conducted to derive *trans* fatty acid values. The database now contains *trans* fatty acid values for >800 food products, but this is only a fraction of the total products in the database. In addition, ≈50% of these 800-plus products are branded, and many of them have been reformulated since being added to the database. The rapid changes in product formulation led to challenges in maintaining accurate *trans* fatty acid consumption data.

A 2006 review[16] showed that *trans* fatty acid consumption per person per day in the United States decreased from ≈10 g per person per day in 1984 to ≈4 g per person per day in 1995. Comparatively, in Denmark, the per capita consumption of *trans* fatty acids steadily declined through the 1980s and 1990s from slightly >2 g/d per person in 1992 to <0.5 g/d in 1999.[17,18] In June 2003, Denmark introduced protection measures concerning *trans* fatty acids in food. As of January 2004, the level of industrially produced *trans* fatty acids in oil and fats intended for the consumer, either alone or as an ingredient in foodstuffs, must not exceed 2%. As a result, *trans* fatty acids created through partial hydrogenation have virtually been eliminated in Denmark.

Although mean values are available for per-person per-day *trans* fatty acid consumption, the range is high because of the variability of the *trans* fatty acid content in foods. For example, a review of 37 different kinds of bread, cake, and related products in the Washington, DC, area showed that the average grams of *trans* fatty acids (grams per 100 g fat) ranged from 0.0 to 48.8.[19] The significant difference in the *trans* fatty acid content in products within each food category is due to differences in the type of fats and oils used in the manufacturing process.

Dietary Fatty Acids Affecting Cardiovascular Disease and Diabetes

Dietary fat profiles have a significant impact on health. Many studies have shown that *trans* fatty acids can adversely affect LDL and HDL cholesterol levels, and some data suggest that *trans* fatty acids adversely affect other outcomes.[5]

A meta-analysis of 60 controlled trials of dietary fats and blood lipids (Figure 2) show that as carbohydrates are replaced with polyunsaturated or monounsaturated fats, the ratios of total to HDL and LDL cholesterol decrease.[20] However, when carbohydrates are replaced with *trans* fatty acids, the ratio of total to HDL cholesterol increases, as does LDL cholesterol. *Trans* fatty acids also are the only type of fats that do not raise HDL cholesterol.

Strong observational and experimental evidence also exists for the increasing risk of coronary heart disease associated with *trans* fatty acids. Multiple prospective studies and case-control studies have reported a positive association between *trans* fatty acid intake and the risk of developing coronary heart disease.[21–23] A less mature data set suggests a positive association between *trans* fatty acid intake and type 2 diabetes and elevated inflammatory markers.[24,25]

TABLE 4. North American Edible Oil Consumption by Partial Hydrogenation Level

Type of Edible Oil	Amount,* 10^6 lb	% of Total	% Partially Hydrogenated†	Amount of Partially Hydrogenated Oils, 10^6 lb
Soybean	17 820	70.3	41.7	7431
Canola	2609	10.3	26.7	697
Corn	1722	6.8	36.1	622
Coconut	895	3.5	0.0	0
Cottonseed	695	2.7	17.7	123
Palm kernel	529	2.1	0.4	2
Palm	434	1.7	0.0	0
Sunflower	423	1.7	23.5	99
Peanut	233	0.9	11.6	27
Total	25 360	100.0	35.5	9001

*Based on data from the *Oil World Annual Report 2006*.
†Based on a proprietary report conducted for Dow AgroSciences.

Alternatives

The edible oil used most in North America is soybean oil, followed by canola oil and corn oil (Table 4). In 2005, of the ≈25 billion pounds of edible oils used, close to 18 billion pounds were soybean oil.

Soybean oil is commonly used because it is abundantly available, is a versatile base stock, and is cost competitive. However, liquid soybean oil is high in linolenic acid, and for rigorous applications such as commercial frying and baking, it is frequently hydrogenated to increase stability.

Alternatives to Partially Hydrogenated Fat

There are a number of alternatives to partially hydrogenated fat. Table 5 provides a summary and lists some of their advantages and drawbacks.

Summary of *Trans* Fatty Acid Alternatives Presented

To provide practical perspectives on the availability of quality edible oils that can be used to reduce *trans* fatty acids in the American food supply, representatives from 5 seed and oil processing companies spoke at the conference. They included representatives from Monsanto Company, DuPont/Pioneer Hi-Bred International, Dow AgroSciences, Archer Daniels Midland Company, and Cargill. Table 6 summarizes the *trans* fatty acid alternative commercial products presented at the conference.

On the basis of the estimates of the companies in Table 6, the national supply of these key *trans* fatty acid alternative commercial products would total ≈3.25 billion pounds in 2007, compared with the ≈9 billion pounds of partially hydrogenated oils that should be replaced in North America, as shown previously in Table 4.

Considerations for Evaluating and Choosing *Trans* Fatty Acid Alternatives

When evaluating alternatives to reduce *trans* fatty acids in the food supply, several considerations were raised in the presentations:

- There are several different needs and therefore different solutions for oils. As a result, there is not one "fix" in terms of alternative oils.
- There are various different applications with different attributes, including sensory needs, the level of nutrition benefit sought, and functionality.
- Food companies might have brand claims or product positions that drive decisions on the oil choice.
- Availability and cost considerations are paramount before a conversion can happen.

The dynamics of industrial marketing can influence the choice of commodity crops versus trait-enhanced oils. As shown in Figure 3, most (≈90%) of the soybeans and corn are currently sold as commodities for syrup (corn), meal, feed, alternative fuel, and starch.

In the meantime, trait-enhanced oils face the following challenges:

- Additional costs are incurred. A grower premium is provided to farmers as an incentive for them to grow trait-enhanced beans and seeds and to compensate growers for their efforts at the segregation of trait-enhanced and commodity oilseeds. There are also additional oil processor costs related to the need to collect, crush, refine, and store the oil separately.
- In the development of new varieties of oil seeds, long lead time is required. The decision about which specific seeds to grow is made several years in advance of oil delivery; thus, contract planting is necessary. The normal 4-year cycle begins with seed decisions in September of year 1 in anticipation of demand by the food industry in year 4. Seed production contracts are finalized in March of year 2. Farmers are contracted by January of year 3, with the delivery of oils in year 4. However, for seed companies that have ramped up production to address the rapidly growing market demand, the cycle could be shorter, from around 1 year to 20 months.
- Some individual farmers do not want crops that require contract planting and identity preservation and are un-

TABLE 5. Alternatives to Partially Hydrogenated Fat

Type of Alternative	Description	Examples	Advantages	Drawbacks
Naturally stable/ nontropical oils	Oils naturally low in linolenic acid content	Corn oil Cottonseed oil	Functionality	Very limited availability Supply further challenged by increasing demand for using corn for feed, starch, and alternative fuel Cottonseed oil high in saturated fats
Tropical oils	Oils that come from plants in the tropics	Palm oil Palm kernel oil Coconut oil	Functionality Economics Availability Past user experience	Negative health effect associated with high saturated fat content
Animal fats and edible tallow	Fats that come from animals	Beef tallow Lard Butter	Functionality Past user experience	Negative health effect associated with high saturated fat content and naturally occurring cholesterol
Trait-enhanced oils	New oilseed varieties that can yield oils that are stable without requiring hydrogenation Most developed by the oilseed industry, sometimes in collaboration with the USDA using conventional plant breeding technique	Low-linoleic soybean and canola oils[26] Mid-oleic soybean and sunflower oils High-oleic soybean, sunflower, and canola oils	Many new varieties have been developed or are in research and development pipeline Generally acceptable functionality for frying	Generally higher costs Long lead time for delivery Uncertainties regarding availability
Blending liquid soft oils with harder components	Blending partially hydrogenated vegetable oils, fully hydrogenated vegetable oils (with polyunsaturated fatty acid and monounsaturated fatty acid converted to stearic acid), or tropical fats with liquid vegetable oils	Company-specific products	Individually formulated to provide various fatty acid compositions and melting profiles Used for frying or baking depending on the fluidity of the fat	
Modified hydrogenation process	Increasing the pressure, decreasing the temperature, and/or changing the catalyst or catalyst concentration to lower levels of *trans* fatty acids	Company-specific products	Can selectively reduce the amount of *trans* fatty acids produced during hydrogenation[27] In some cases, *trans* fatty acid production has been suppressed by up to 80%	Extremely high pressure and concentrations of catalysts required can reduce commercial viability
Fractionation of tropical fats	Separating palm oil into hard fractions to be used as structuring fats for margarines and shortenings Dry multiple fractionation yields at first stage hard stearin and mostly unsaturated olein, and yields several other fractions at later stages	Company-specific products	Fractions with different solid fat profiles and melting point curves to allow versatility in formulation	Negative health effect associated with highly saturated hard fractions (including palmitic [C16:0] and palm kernel oil containing C12, C14, and C16) Process highly developed in Europe but not in the US
Interesterification	A liquid and a hard stock (eg, palm kernel oil, solid palm fraction) are blended together and interesterified Involves treating a fat with an excess of glycerol in the presence of a chemical or an enzymatic catalyst at a relatively low temperature, causing the rearrangement or redistribution of the fatty acids on the glycerol portion of the molecule, thus producing fats with different melting profiles and physical characteristics than the parent	Company-specific products	Does not change the degree of unsaturation of the fatty acids Does not convert *cis* into *trans* isomers If an enzymatic catalyst is used, resulting interesterification process is continuous and specific, with steeper solid fat curves to provide better functionality and few unidentified byproducts without the need for extensive postprocessing	High cost of the enzymatic catalyst Technology has not been fully examined for its effects on health

TABLE 6. Summary of *Trans* Fatty Acid Alternative Commercial Products Presented*

Alternative	Company	Technology	Description	Application	Benefits	Supply
VISTIVE I†	Monsanto	Trait-enhanced	Low-linolenic (<3%) soybean	Frying Spray oil Baking when blended with other oils	Cost competitive Does not compromise taste Does not increase saturated fats	70 million lb (2005) 250 million lb (2006) 1.5 billion lb (2007)
VISTIVE II†	Monsanto	Trait-enhanced	Low-linolenic/mid-oleic soybean	Same as VISTIVE I	VISTIVE I benefits Higher stability than VISTIVE I	In development, pending FDA/USDA approvals
VISTIVE III†	Monsanto	Trait-enhanced	Low-linolenic/high-oleic soybean	Same as VISTIVE I	VISTIVE II benefits Reduced saturated fats	In development, pending FDA/USDA approvals
TREUS (low-linolenic)‡	Pioneer	Trait-enhanced	Low-linolenic (2.4%–2.8%) soybean	Most but not all frying applications	Little change in physical properties vs commodity soybean Acceptable sensory properties Integrated delivery system that is efficient in supply, transport, and quality control	250 million lb (2007) Demand driven beyond 2007
TREUS (high-oleic)‡	Pioneer	Trait-enhanced	Low-linolenic/high-oleic soybean	Heavy frying Stable base oil for blends and industrial uses	TREUS (low-linolenic) benefits Higher stability vs TREUS (low-linolenic)	Full availability after 2011
TREUS (high-stearic)‡	Pioneer	Trait-enhanced	Low-linolenic/high-oleic/high-stearic soybean	Applications requiring saturated fatty acids for functionality	Can be blended to produce usable solid fat content at minimum saturates Saturated fats, primarily stearates with a neutral health effect	Full availability after 2014
Omega-9 canola§	Dow	Trait-enhanced	High-oleic	Frying in food service	Meeting all key requirements in commercial frying oils Taste tests to show favored over low-linolenic soybean oil Measurement of polar compounds to show longer fry life than low-linolenic soybean oil Grown primarily for uses as edible oils (unlike soybean and corn) Not grown in same area as soybean and corn	Crush capacity doubled in the past year 1.5 billion lb (2007) 2.5 billion lb (2008) More beyond 2008 if driven by demand
Omega-9 sunflower§	Dow	Trait-enhanced	High-oleic	Frying in food service	Meeting all key requirements in commercial frying oils Grown primarily for uses as edible oils (unlike soybean and corn)	Small, mainly because of difficulty in disposing the meal
NovaLipid (solid fat)‖	ADM	Proprietary interesterification	Commodity soybean	Solid fat application (eg, baking)	Using commodity oilseeds that offer uniformity and extensive availability, with no need for contract growing or identity preservation Steeper melting curves that can avoid waxy taste of blending liquid oil with stearic acid	Company states >4 y to build up production infrastructure Supply still small
NuSun¶	ADM with National Sunflower Association	Trait-enhanced	Mid-oleic sunflower	Frying in food manufacturing (eg, snacks)	Adequate shelf life Grown primarily for uses as edible oils (unlike soybean and corn)	Company states >4 y to build up production infrastructure Supply still small
TransEND 390**	Cargill	Proprietary blending	High-oleic canola and fully hydrogenated cottonseed oils	Solid shortening for baking applications such as making pie crusts, powder biscuits, sugar cookies, and white cakes Each product application is unique	Eliminating *trans* fats and reducing saturated fats without sacrificing functionality	Developed in collaboration with food manufacturers

*To provide practical perspectives on the availability of quality edible oils that can be used to reduce *trans* fatty acids in the US food supply, representatives from 5 seed and oil processing companies spoke at the conference. They included representatives from Monsanto Co, DuPont/Pioneer Hi-Bred International, Dow AgroSciences, Archer Daniels Midland Co (ADM), and Cargill. Each of these companies is global in nature and has many businesses and products beyond the *trans* fatty acid alternatives discussed. The products discussed by name were some of the major brands but by no means represented a comprehensive product listing. The application, benefits, and supply data included in this table were cited by the individual seed and oil processing companies.

†See http://www.monsanto.com/monsanto/content/farmprogress/pdf/vistive.pdf.

‡See http://www.pioneer.com/llsoy/lowlin.htm.

§See http://www.dowagro.com/omega9oils.

‖See http://www.admworld.com/mktcolpdf/NovaLipid.pdf.

¶See http://www.sunflowernsa.com/oil/default.asp?contentID=43.

**See http://www.cargillfoods.com/products/product_oils.html.

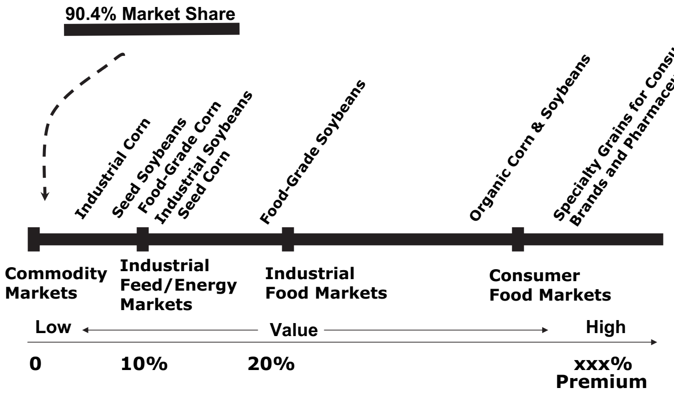

Figure 3. Soybeans as an industrial marketing problem. Used with permission from the presenter.

willing to go through the trouble of separating commodity and trait-enhanced oilseeds regardless of the grower premium provided by oilseed companies. This challenge can be magnified if the farmer can make a much higher profit by growing commodity soybean and corn for alternative fuels.

- Growing demand of ethanol as an alternative fuel can drive up corn acreage and put pressure on soybean acreage.
- Increasing demand for biodiesel/biofuels can drive up prices for soybean and palm, both attractive options given their historically low prices.

There are conceptually many pathways in generating alternatives for *trans* fatty acids. All of these pathways can lead to a significant reduction in *trans* fatty acids in the US food supply. Given that many pathways are available and factors of industrial marketing are at play, no perfect oil will dominate, and all of these options will be used.

Considerations for Food Reformulation

When food producers go through the time and expense for food reformulation, several issues should be considered:

- There is no longer a standard all-purpose oil like partially hydrogenated soybean oil. Each product application is unique, and drop-in solutions (oil/fat ingredient with equivalent performance) are rare.
- Extensive consumer testing must be conducted before the reformulated product is introduced to ensure acceptance.
- The supply chain must be managed to ensure an adequate supply of new oils.
- Transportation and storage are huge considerations that involve capital expense and lead time. Many manufacturing plants have only 1 storage tank, used for partially hydrogenated soybean oil. For reformulation, the plants may have to allow storage for various new oils.
- Packaging must be reevaluated because reformulated products may require different packaging as a result of changes in fragility and/or shelf life.
- Labels most likely need to be changed to communicate the benefits of reformulated products to consumers.
- Consumer input must be obtained to clearly define the objectives for reformulation.
- Reformulated products need to satisfy regulatory concerns in the United States and Canada because most food manufacturers cannot afford separate production lines for these 2 markets.
- Food manufacturers should consider partnering to share research and development risks and expenses.

For many applications, food reformulation to reduce *trans* fatty acids is less of a technical challenge and more of a business decision. Several factors were identified that promote the reduction of *trans* fatty acids in the food supply: (1) leadership and commitment of corporate senior management, (2) collaboration across the supply chain and ongoing interindustry dialogue, (3) adequate supply of alternative ingredients for food reformulation, (4) increased competition in the marketplace to focus on health and wellness, (5) media coverage and consumer demand, and (6) regulation to stimulate changes.

Use of Alternatives in Food Manufacturing (3 Case Studies)

Many food manufacturers have reformulated their products in the United States to address the need for *trans* fatty acid reduction. (According to the Grocery Manufacturers Association and/or company press releases, as of January 2007, food manufacturers that have made significant efforts to reduce or eliminate partially hydrogenated oils/fats from their product portfolios include Campbell Soup Co, ConAgra Foods, General Mills, The Hershey Company, The J.M. Smucker Co, Johnson & Johnson, Kellogg Co, Kraft Foods, Nestle, PepsiCo, Proctor & Gamble, Sara Lee Corp, The Schwan Food Co, and Unilever.) For some companies, this change has come in the interest of public health, and for others, it is a result of the 2006 FDA labeling requirement to indicate *trans* fatty acid content in the nutrition label on packaged foods. The transition to "zero *trans*" or "low *trans*" products has generally taken several years and involved economic, supply, formulation, packaging, and market research considerations. This conference included case studies from Frito-Lay North America, a division of PepsiCo, and Unilever North America, 2 food manufacturers that were among the first companies to reformulate their products to reduce *trans* fatty acids. In addition, a representative of the American Institute of Baking International (AIB) addressed issues related to commercially baked goods and *trans* fatty acids.

Frito-Lay North America

Summary of Presentation by Robert Brown, PhD, MPH

With the September 2002 release of the Institute of Medicine's "Report on Dietary Reference Intakes of Trans Fatty Acids,"[9] Frito-Lay responded with a strategic decision in November 2002 to ensure that all of their oils would be "*trans* fat free" within the year. The company's Nutrition and Regulatory Affairs Division had been doing research and development on options for *trans* fatty acid alternatives since the late 1990s, and by 2002, viable options had been identified. Frito-Lay based its decision on nutrition using a parameter of unsaturated-to-saturated or –*trans* fatty acid ratio, as well as considerations for flavor, stability, and cost. In 2002, corn oil was identified as a viable option, although it contributed to only 2.2% of the world supply. By July 2003, *trans* fatty acids had been eliminated from the company's most popular brands, including potato chips, which had been fried in partially hydrogenated oils. Mid-oleic sunflower oil also was identified as a viable option to replace cottonseed oil used in another brand of potato chips. However, it took 4 years of working with farmers in North Dakota to plant mid-oleic instead of regular sunflower seeds to generate an adequate supply. In 2006, the mid-oleic sunflower oil was used instead of cottonseed oil to reduce saturated fats and to increase polyunsaturated fats in one of their major brands of potato chips.

Several significant challenges had to be overcome during the reformulation:

- The reformulation required 7200 man-hours and involved 243 analytical tests and 25 consumer tests. This resulted in more than $25 million in expenses to transition 187 product lines in 45 plants while working with only 3 oil suppliers.
- The decision to use oils with limited supplies resulted in higher raw material costs that were not passed on to consumers and the need to address oil handling, transportation, and storage issues. Because of differences in the stability of the new oils, new packaging to prevent oxidation of the products was required, along with new labeling.
- Extensive testing was necessary to ensure that the end products made with the new oils tasted the same to consumers.

Frito-Lay continues to face challenges that need to be addressed:

- Unreliable corn oil supply. Most of the corn is grown for sweeteners used in soft drinks, with oil being a secondary product. Although demand for ethanol could increase the corn supply, less consumption of sweetened soft drinks could decrease the supply.
- The supply of mid-oleic sunflower oil continues to be limited.
- The demand for *trans* fatty acid–free edible oils is growing rapidly and continues to put pressure on the supply chain.
- Oils low in *trans* fatty acids and saturated fats are not widely available in Europe, where palm oil is used extensively.
- The company's cookies and crackers line is challenged with finding functional alternatives low in *trans* fatty acids and saturated fats because many *trans* fatty acid–free alternatives are high in saturated fats.

Unilever North America

Summary of Presentation by Ravinder Reddy, PhD

Unilever is a multinational company with products in the categories of nutrition, hygiene, health, and beauty. This case study focuses on spreads, of which Unilever is the world's leading producer. With its global reach, connection with the nutrition science community, and extensive technical capabilities, Unilever was able to assess the emerging science and to act quickly to innovate. Unilever was among the first companies to reformulate spreads to reduce the amount of *trans* fatty acids.

Unilever has invested in research and development in nutrition and heart health for >40 years, including sponsoring independent research to examine the effects of foods on health. Unilever has expertise and proprietary knowledge in oil application technologies. In the early 1990s, scientific data emerged suggesting that *trans* fatty acids may have a negative impact on blood cholesterol levels. Unilever initiated an extensive research program that included sponsoring independent scientific research, and by 1993, spreads with very low *trans* fatty acid content had been developed. These products became readily available by 1995, made with tropical oils in Europe and Latin America. In North America, the science community and consumer groups did not favor using tropical oils to replace *trans* fatty acids because of concern about increasing the saturated fat content. Therefore, in North America, Unilever developed proprietary solutions using mainly nontropical oils such as soybean, canola, and sunflower oils.

Unilever developed a global position and policy on spreads to ensure that technologies be developed to minimize the combined amount of *trans* fatty acids and saturated fats for all Unilever products on the market in each country. Spreads and margarine are to be virtually free of *trans* fatty acid worldwide (<1 g/100 g or as legally defined). After reformulation, the company policy is that the combined amount of saturated fats and *trans* fatty acids must not exceed existing levels.

However, to make an impact on public health, the food products must be consumed. Unilever invested in research to ensure that these new products met consumer expectations. The products must be sufficiently easy to spread soon after being taken from the refrigerator. The spread must remain stable at room temperatures and have acceptable texture, "mouth feel," and taste. To make the transition, Unilever took a step-by-step approach by screening and sourcing novel raw materials and developing partnerships with suppliers, using technologies such as rearrangement and fractionation to produce *trans* fatty acid–free hard fats, and using extensive processing knowledge to develop *trans* fatty acid–free spreads at the lowest costs.

Since the initial phase of product reformulation in 1995, Unilever has developed new fat blends and novel processes to produce *trans* fatty acid–free spreads that have lower saturated fat and higher unsaturated fat contents. The company

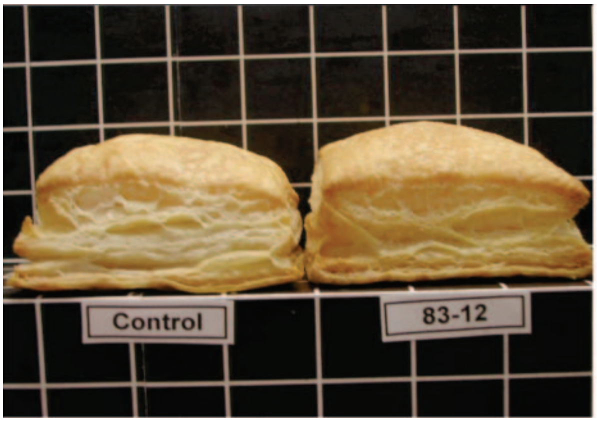

Figure 4. Puff pastry made with 2 different shortenings. *No hydrogenated or *trans* fats, low saturated fat (AarhusKarlshamn, Denmark).
This figure is included to demonstrate the importance of functionality in the selection of shortenings. It does not represent endorsement by the American Heart Association of puff pastry as part of a healthy diet. Used with permission from the presenter.

continues to have a leading role in nutrition research and has a corporate strategy to provide leadership in the industry to significantly improve public health.

The AIB

Summary of Presentation by Brian L. Strouts

Partially hydrogenated fats have been used extensively in commercial baking processes, resulting in high levels of *trans* fatty acids in commercially baked goods. AIB is primarily a research and education organization that tests and recommends shortenings and oils to food manufacturers for their baked products.

Fats and oils in baked goods serve multiple functions that are integral to the product, including tenderizing, aerating, allowing a clear definition of structure, ensuring sufficient shelf life, flavoring and flavor carrying, and emulsifying.

Typical types of shortenings include regular hydrogenated shortening, frying shortening, hard fats, emulsified hydrogenated shortening, fluid shortening, butter, and margarine. Challenges to changing from these ingredients to *trans* fatty acid–free solutions include the following:

- Functional differences with the loss of volume, any appearance change, the development of a greasy or oily character, and different interactions with the water component of a batter.
- Process issues such as achieving specific gravity in batters and cream fillings to avoid changing packaging, batter emulsification, loss of sheet-forming capability and disruption of dough film forming, and frying shortening breakdown, foaming, and darkening.
- Reduction in shelf life and changes in texture, including in some products such as cakes and muffins, loss of softness, and in others, such as cookies and crackers, loss of crispness.
- Flavor differences such as an off-flavor note in high-fat products, different eating quality, and flavor development from the frying process.

The AIB indicates that because of the different functional properties required for the wide variety of baked goods, many types of fats and shortenings may be needed, and the right ingredient may have to be obtained through trial and error. The challenge is especially formidable in the manufacturing of cakes, cookies, biscuits, pie crusts, pastries, and doughnuts.

As an example of the extensive and time-consuming experimentation that often is necessary, the AIB worked with a manufacturer to overcome the problem of a "flat puff pastry" by manipulating and adjusting different fractions of palm oil on the basis of performance for a brand of shortening. The resulting pastry was the same in quality as the one produced by an all-purpose partially hydrogenated puff pastry shortening (Figure 4). In the beginning of the process, the puff pastry was flat and unacceptable, just like the one produced with another no-*trans* alternative.

In the food service environment, restaurants and bakeries also have to go through extensive recipe reworking and product testing to ensure that their baked goods made with *trans* fatty acid–free oils and shortenings meet standards for taste, texture, and shelf life. Challenges appear to exist in finding *trans* fatty acid–free alternative shortenings without increasing saturated fats to meet the functionality requirements. In food manufacturing and food service, many companies that made a switch to *trans* fatty acid–free alternatives for their baked goods chose shortenings made with palm oil or butter.

Use of Alternatives in Food Services (1 Supplier and 3 Case Studies)

Although the packaged food industry has been greatly affected by the January 2006 *trans* fatty acid labeling requirement, the food service industry does not have a similar labeling mandate in place. However, in December 2006, the New York City Board of Health passed regulation to phase out the use of *trans* fatty acids in city restaurants. Legislative and regulatory efforts to ban *trans* fatty acids in food service also have been proposed in several other cities and states. Many notable restaurants and food service businesses have taken steps to reduce or eliminate *trans* fatty acids from menu items. (As of January 2007, restaurant chains and food service companies that have made public announcements of their intention to switch to *trans* fatty acid–free frying oils and/or *trans* fatty acid–free baked goods in their locations include Arby's, Au Bon Pain, The Cheesecake Factory, Chili's, The Compass Group, Denny's, Disney theme parks, The Holland Inc., KFC Corp, The Kroger Co [chicken fryer], Legal Sea Foods, Loews Hotels, Olive Garden, Panera Bread, Red Lobster, Ruby Tuesday, Starbucks, Taco Bell, Universal

Studios theme parks, and Wendy's.) Three case studies showcasing the *trans* fatty acid reduction experiences at a regional chain (The Holland Inc.), a national chain (Ruby Tuesday), and an international food service corporation (The Compass Group) were presented.

ACH Food Companies

Summary of Presentation by Pete Friedman, MS

The session began with ACH Food Companies, a fats and oils supplier to both the consumer and food service markets. Given the importance of frying in restaurants, fry studies are conducted by food oil companies on a regular basis. Oils are evaluated during fry tests in the laboratory or in the restaurant on parameters such as color, free-fatty-acid content, polar compound concentrations, flavor, and degree of foaming and polymerization. Of the various oil evaluation parameters, ACH indicates that color is an important measure in restaurant operations because it is fairly practical to implement an oil change schedule with the help of a color testing kit. The ideal frying oil would have a low cost while maintaining a high oil quality for a long period of time. A review of oil costs found that the RBD (refined, bleached, and deodorized) soybean oil is the least costly oil on a per-unit basis, but with the 1- to 2-hour stability under high heat, it often cannot be used in restaurants. In comparison, high-oleic canola oil and high-oleic sunflower oil tend to have the highest initial costs. However, the longer fry life of high-oleic canola oil and sunflower oil is expected to offset some of the initial higher costs to restaurants. In addition, cost is a dynamic issue that tends to change frequently. ACH anticipates that once high-oleic canola and low-linolenic soybean oils reach >1 billion pounds per year, the cost differentials will be reduced.

The choice of frying oils is important to quick-service (fast food) restaurants because fried foods are predominant on their menus. Oil cost has driven many decisions. Customers do not usually ask for *trans* fatty acid–free oils or foods in quick-service restaurants.

Casual dining restaurants rely less on fried foods than do quick-service restaurants. The lower volume of fried foods and different cooking applications could make it easier to switch to *trans* fatty acid–free oils in this setting. Fine-dining establishments offer few fried foods, and *trans* fatty acid oil use is not a typical concern in that sector.

The Holland Inc.

Summary of Presentation by Debe Nagy-Nero, MS, RD

The Holland Inc., a regional chain of 40 quick-service restaurants in the Pacific Northwest, switched to a *trans* fatty acid–free frying oil in January 2006. The motivating factors were both their mission of "doing the right thing" based on literature documenting the deleterious effects of *trans* fatty acids and questions from their guests. The decision took 9 months to implement, starting with buying a *trans* fatty acid–free canola oil from an existing supplier, getting acceptance from the corporate committee, educating personnel about *trans* fatty acids, setting up oil testing at a pilot restaurant, deciding between current par-fried French fries containing *trans* fatty acids and *trans* fatty acid–free fries on the basis of taste, and finally laboratory testing to obtain the nutritional content of the foods. The restaurants advertise using a *trans* fatty acid–free oil in their kitchens at the front counter, and customer reactions are generally positive. The biggest challenge has involved training cooking staff on the appropriate time to change the frying oil. The Holland Inc. has used expertise from Dow AgroSciences to educate cooking staff about the appropriate schedule to change the frying oil to avoid changing it too quickly. Because The Holland Inc. purchases par-fried French fries containing *trans* fatty acids, the French fries served at the restaurants still have *trans* fatty acids. The chain is seeking *trans* fatty acid–free options for their cookies and seasonal shortcakes, which continue to contain *trans* fatty acids.

The additional cost of 6 cents per pound for the *trans* fatty acid–free oil has not been an issue with senior management and has been absorbed by the company. The customer count went up in 2006 compared with 2005. However, it is not clear whether that increase had anything to do with positive customer reactions to the oil change; there was barely any difference in the oil and French fry purchases for the first 6 months of 2006 compared with the same period in 2005.

Ruby Tuesday

Summary of Presentation by Julie Reid, MS

Ruby Tuesday is a national casual dining chain with >850 restaurants. In November 2003, Ruby Tuesday made a corporate decision to be the first major restaurant chain to switch from partially hydrogenated soybean oil to canola oil for frying. Several factors were behind the decision: (1) health consciousness of its chairman/president/founder, (2) the ability to publicize the use of a "healthy" oil for fried foods that were "better for you," and (3) the likelihood that customers would ask about *trans* fatty acids with the upcoming mandated labeling on packaged foods. An extensive public relations campaign accompanied the oil change, and Ruby Tuesday received widespread recognition and approval from the industry and the media. However, few of its customers noticed the change, and the oil change appeared to have a negligible impact on sales.

Ruby Tuesday faced 2 challenges in making the switch to canola oil: higher costs and shorter fry life. The switch cost the chain about $1 million to implement in 2003. Regarding the fry life, many Ruby Tuesday restaurants had the practice of changing oil on Thursdays to allow fresh oil for the busy weekend. Restaurant operations staff, using color as the gauge, noted that the canola oil did not last as long.

Since 2003, the number of custom-made products that contain *trans* fatty acids at Ruby Tuesday has decreased from >30 to ≈10. However, its French fries still contain some *trans* fatty acids because Ruby Tuesday continues to purchase French fries par fried in partially hydrogenated oil. A switch to *trans* fatty acid–free par-fried French fries would incur an additional $1 million cost because of a surcharge from suppliers. The chain is committed to removing *trans* fatty acids from all of its products. It encourages all chain restaurants to collaborate in a concerted effort to demand that *trans* fatty acid–free products be made available from vendors to restaurants without an increased cost.

The Compass Group

Summary of Presentation by Deanne Brandstetter, MBA, RD

The Compass Group, which operates in 90 countries, is the world's leading food service company. Its brands include Chartwells, Bon Appetit, Eurest, Canteen, Morrison, and Wolfgang Puck Catering. In the United States, The Compass Group deals with >200 distributors to provide for food service establishments, including corporate offices, hospital cafeterias, university dining halls, and sports arenas. On any given day, the company deals with thousands of different menus and faces huge challenges when making changes in ingredients.

Regarding the mission of reducing *trans* fatty acids in the foods served, The Compass Group decided to use a "push-pull" strategy, beginning with 3 countries: the United States, Canada, and the United Kingdom. In each market, The Compass Group uses sector innovators to "push" the *trans* fatty acid reduction initiative, requesting the others to be "pulled along." For example, in 2002 to 2003, The Compass Group used Bon Appetit on the West coast and Flik International on the East coast, which served "premium" sectors such as investment banks and private college cafeterias, as pilot programs to change to *trans* fatty acid–free frying oils. The initiative included a cost-benefit analysis, customer education, purchasing assistance, and audits. From October 2005 to May 2006, all North American contract food sectors transitioned their frying oils to *trans* fatty acid–free oils. Half of the sectors transitioned to low-linolenic soybean oil, and half of the sectors transitioned to high-oleic canola oil, with the goal of all sectors moving to high-oleic canola oil by year-end 2006. The transition cost The Compass Group $2.5 million, and the company is using better frying oil management and smaller portions to keep cost increases under control. The company continues to face distribution challenges in that distributors do not always deliver the *trans* fatty acid–free frying oil ordered. The Compass Group indicates that the small change in the frying oil has had a big impact on *trans* fatty acid reduction. In a case study of 1 corporate client with 28 locations, by eliminating 5 g of *trans* fatty acids per 6-oz serving of French fries, the corporate client estimates that 88 990 fewer grams of *trans* fatty acids were consumed by its employees in a typical month.

The Compass Group plans to reduce *trans* fatty acids in other foods such as baked goods and snacks by 50% in 2007 in its North American outlets. Its European sectors are testing *trans* fatty acid–free fry oil and other products; the UK sectors are closely watching the North American efforts; and in Latin America, the company is addressing overall fat reduction in foods.

Key Learnings From Conference and Breakout Session

After the plenary sessions, participants of the *Trans* Fat Conference convened into 6 preassigned groups facilitated by preappointed session leaders using a common discussion guide. The forum generated significant interactions, allowing individual attendees to contribute their expertise.

Afterward, the leaders summarized their discussions and reported back to the entire audience. The summary of the discussions and some of the conference presentations are available online at http://www.americanheart.org/presenter.jhtml?identifier=3043187.

The conference generated significant interaction and information exchange among participants and presenters. The following summarizes key learnings from the conference:

- Changing the food supply can produce tremendous improvements in public health. The January 2006 FDA labeling requirement to indicate *trans* fatty acid content on the nutrition labels of packaged foods has served as a catalyst to accelerate food reformulation.
- Since mid-2006, food service companies and restaurants have accelerated their efforts to reduce *trans* fatty acids in their foods. With the passing of the regulation to phase out *trans* fatty acids in New York City restaurants in December 2006, the pressure is on restaurants to reduce *trans* fats in the foods they serve, either via voluntary means or through regulations likely to be proposed in areas nationwide within the next few years.
- Many alternative oils and fats are available or in development to replace *trans* fatty acids in the food supply. However, decisions on which alternatives to use is complex and often time consuming, involving considerations in health effects, availability, research and development investments, food quality and taste, supply-chain management, operational modifications, consumer acceptance, and cost.
- Effective communication efforts are needed throughout the food supply chain to help increase knowledge transfer and to reduce risks related to changes. The media should be engaged so that they can play a major role in helping to educate and inform the various audiences. In addition, stakeholder groups such as the AHA, food industry trade groups, and government can help facilitate information dissemination.
- The conference showcased the value of multiple sectors and disciplines seeking solutions to improve the food supply, and conference participants showed strong support for using the conference model to tackle other issues, particularly obesity. Ongoing forums for facilitating the dialogue between nutrition, food, and agriculture sciences to understand challenges and to identify opportunities would be of value. The need for collaboration of all stakeholders from the beginning can serve as a lesson learned that can translate to other emerging food development, processing, and/or technology issues.[26,27]

Disclosures

Writing Group Disclosures

Writing Group Member	Employment	Research Grant	Other Research Support	Speakers' Bureau/Honoraria	Ownership Interest	Consultant/Advisory Board	Other
Robert H. Eckel	University of Colorado at Denver and Health Sciences Center	None	None	None	None	None	None
Susan Borra	International Food Information Council Foundation	None	None	None	None	None	None
Alice H. Lichtenstein	Tufts University	None	None	None	None	None	None
Shelley Goldberg	International Food Information Council Foundation	None	None	None	None	None	None
Bill Layden	FoodMinds, LLC	None	None	None	None	National Dairy Council*; Edelman–National Cattlemen's Beef Association*; Edelman–Kraft Foods*; Grocery Manufacturers Association*	None
Rose Marie Robertson	American Heart Association	None	None	None	None	None	None
Brigid McHugh Sanner	Sanner & Co	None	None	None	None	None	None
Kimberly F. Stitzel	American Heart Association	None	None	None	None	None	None
Shirley Y. Yin-Piazza	American Heart Association	None	None	None	None	None	None

*Modest

†Significant.

This table represents the relationships of writing group members that may be perceived as actual or reasonably perceived conflicts of interest as reported on the Disclosure Questionnaire, which all members of the writing group are required to complete and submit. A relationship is considered to be "Significant" if (a) the person receives $10 000 or more during any 12-month period or 5% or more of the person's gross income or (b) the person owns 5% or more of the voting stock or share of the entity or owns $10 000 or more of the fair market value of the entity. A relationship is considered to be "Modest" if it is less than "Significant" under the preceding definition.

References

1. Malmros H, Wigand G. The effect on serum cholesterol of diets containing different fats. *Lancet*. 1957;273:1–7.
2. Beveridge JM, Connel WF, Mayer GA, Haust HL. Plant sterols, degree of unsaturation, and hypocholesterolemic action of certain fats. *Can J Biochem*. 1958;36:895–911.
3. Mensink RP, Katan MB. Effect of dietary trans fatty acids on high-density and low-density lipoprotein cholesterol levels in healthy subjects. *N Engl J Med*. 1990;323:439–445.
4. Lichtenstein AH, Ausman LM, Jalbert SM, Schaefer EJ. Effects of different forms of dietary hydrogenated fats on serum lipoprotein cholesterol levels. *N Engl J Med*. 1999;340:1933–1940.
5. Mozaffarian D, Katan MB, Ascherio A, Stampfer MJ, Willett WC. Trans fatty acids and cardiovascular disease. *N Engl J Med*. 2006;354:1601–1613.
6. Nestel P, Clifton P, Noakes M. Effects of increasing dietary palmitoleic acid compared with palmitic and oleic acids on plasma lipids of hypercholesterolemic men. *J Lipid Res*. 1994;35:656–662.
7. Aro A, Jauhiainen M, Partanen R, Salminen I, Mutanen M. Stearic acid, trans fatty acids, and dairy fat: effects on serum and lipoprotein lipids, apolipoproteins, lipoprotein(a), and lipid transfer proteins in healthy subjects. *Am J Clin Nutr*. 1997;65:1419–1426.
8. Parthasarathy S, Khoo JC, Miller E, Barnett J, Witztum JL, Steinberg D. Low density lipoprotein rich in oleic acid is protected against oxidative modification: implication for dietary prevention of atherosclerosis. *Proc Natl Acad Sci U S A*. 1990;87:3894–3898.
9. National Academy of Sciences. Dietary reference intakes for energy, carbohydrates, fiber, fat, fatty acids, cholesterol, protein, and amino acids (macronutrients). 2005. Available at: http://books.nap.edu/openbook.php?record_id=10490. Accessed February 5, 2007.
10. Wang C, Chung M, Balk E, Kupelnick B, Jordan H, Harris W, Lichtenstein A, Lau J. n–3 fatty acids from fish or fish-oil supplements, but not α-linolenic acid, benefit cardiovascular disease outcomes in primary- and secondary-prevention studies: a systematic review. *Am J Clin Nutr*. 2006;84:5–17.
11. Turpeinen AM, Mutanen M, Aro A, Salminen I, Basu S, Palmquist DL, Griinari JM. Bioconversion of vaccenic acid to conjugated linoleic acid in humans. *Am J Clin Nutr*. 2002;76:504–510.
12. Valenzuela A, Morgado N. *Trans* fatty acid isomers in human health and in the food industry. *Biol Res*. 1999;32:273–287.
13. The American Soybean Association. Available at: http://www.soystats.com/2005. Accessed February 5, 2007.
14. *Oil Crops Situation and Outlook Yearbook*. Washington, DC: Economic Research Service, USDA. Available at: http://usda.mannlib.cornell.edu/usda/current/OCS-yearbook/OCS-yearbook-03-19-2007_summary.txt. Accessed March 19, 2007.
15. USDA. USDA national nutrient database for standard reference. Available at: http://www.ars.usda.gov/Services/docs.htm?docid=8964. Accessed February 5, 2007.
16. Craig-Schmidt MC. World-wide consumption of *trans* fatty acids. *Atheroscler Suppl*. 2006;7:1–4.

17. Leth T, Jensen HG, Mikkelsen AA, Bysted A. The effect of the regulation on *trans* fatty acid content in Danish food. *Atheroscler Suppl*. 2006;7: 53–56.
18. Jakobsen MU, Bysted A, Andersen NL, Heitmann BL, Hartkopp HB, Leth T, Overvad K, Dyerberg J. Intake of ruminant trans fatty acids in the Danish population aged 1–80 years. *Eur J Clin Nutr*. 2006;60: 312–318.
19. Satchithanandam S, Oles CJ, Spease CJ, Brandt MM, Yurawecz MP, Rader JL. Trans, saturated, and unsaturated fat in foods in the United States prior to mandatory trans-fat labeling. *Lipids*. 2004;39:11–18.
20. Mensink RP, Zock PL, Kester A, Katan MB. Effects of dietary fatty acids and carbohydrates on the ratio of serum total to HDL cholesterol and on serum lipids and apolipoproteins: a meta-analysis of 60 controlled trials. *Am J Clin Nutr.* 2003;77:1146–1155.
21. Howard B, Van Horn L, Hsia J, Manson JE, Stefanick ML, Wassertheil-Smoller S, Kuller LH, LaCroix AZ, Langer RD, Lasser NL, Lewis CE, Limacher MC, Margolis KL, Mysiw WJ, Ockene JK, Parker LM, Perri MG, Phillips L, Prentice RL, Robbins J, Rossouw JE, Sarto GE, Schatz IJ, Snetselaar LG, Stevens VJ, Tinker LF, Trevisan M, Vitolins MZ, Anderson GL, Assaf AR, Bassford T, Beresford SA, Black HR, Brunner RL, Brzyski RG, Caan B, Chlebowski RT, Gass M, Granek I, Greenland P, Hays J, Heber D, Heiss G, Hendrix SL, Hubbell FA, Johnson KC, Kotchen JM. Low-fat dietary pattern and risk of cardiovascular disease: the Women's Health Initiative Randomized Controlled Dietary Modification Trial. *JAMA*. 2006;295:655–666.
22. Pietinen P, Ascherio A, Korhonen P, Hartman AM, Willett WC, Albanes D, Virtamo J. Intake of fatty acids and risk of coronary heart disease in a cohort of Finnish men: the Alpha-Tocopherol, Beta-Carotene Cancer Prevention Study. *Am J Epidemiol*. 1997;145:876–887.
23. Oomen C, Ocke M, Feskens E, Erp-Baart M, Kok F, Kromhout D. Association between trans fatty acid intake and 10-year risk of coronary heart disease in the Zutphen Elderly Study: a prospective population-based study. *Lancet*. 2001;357:746–751.
24. Lopez-Garcia E, Schulze MB, Meigs JB, Manson JE, Rifai N, Stampfer MJ, Willett WC, Hu FB. Consumption of *trans* fatty acids is related to plasma biomarkers of inflammation and endothelial dysfunction. *J Nutr*. 2005;135:562–566.
25. Salmerón J, Hu FB, Manson JE, Stampfer MJ, Colditz GA, Rimm EB, Willett WC. Dietary fat intake and risk of type 2 diabetes in women. *Am J Clin Nutr*. 2001;73:1019–1026.
26. Tarrago-Trani MT, Phillips KM, Lemar LE, Holden JM. New and existing oils and fats used in products with reduced *trans*-fatty acid content. *J Am Diet Assoc*. 2006;106:867–880.
27. List GR, Neff WE, Holliday RL, King JW, Holser R. Hydrogenation of soybean oil triglycerides: effect of pressure on selectivity. *J Am Oil Chem Soc*. 2000;77:311–314.

Circulation

American Heart Association

Understanding the Complexity of *Trans* Fatty Acid Reduction in the American Diet: American Heart Association Trans Fat Conference 2006: Report of the Trans Fat Conference Planning Group

Robert H. Eckel, Susan Borra, Alice H. Lichtenstein and Shirley Y. Yin-Piazza

Circulation. 2007;115:2231-2246; originally published online April 10, 2007;
doi: 10.1161/CIRCULATIONAHA.106.181947
Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231

Print ISSN: 0009-7322. Online ISSN: 1524-4539

Correction

In the article, "Understanding the Complexity of *Trans* Fatty Acid Reduction in the American Diet: American Heart Association *Trans* Fat Conference 2006: Report of the *Trans* Fat Conference Planning Group," by Eckel et al, which appeared in the April 24, 2007, issue of the journal (*Circulation*. 2007;115:2231–2246), an error appeared on page 2237. In the section "Considerations for Evaluating and Choosing *Trans* Fatty Acid Alternatives," the second item in the second bulleted list, which appears in the second column, should be changed to the following:

In the development of new varieties of oil seeds, long lead time is required. The decision about which specific seeds to grow is made several years in advance of oil delivery; thus, contract planting is necessary. The normal 4-year cycle begins with seed decisions in September of year 1 in anticipation of demand by the food industry in year 4. Seed production contracts are finalized in March of year 2. Farmers are contracted by January of year 3, with the delivery of oils in year 4. However, for seed companies that have ramped up production to address the rapidly growing market demand, the cycle could be shorter, from around 1 year to 20 months.

This error has been corrected in the current online version.

DOI: 10.1161/CIRCULATIONAHA.107.184950

(*Circulation.* 2007;115:e650.)

***Circulation* is available at http://www.circulationaha.org**