ABSTRACT

What a Fat Debacle: Saturated and Trans Fatty Acids Effect on Health and the Future of Food Manufacturing Processes

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The recommended consumption of fat has been changed multiple times by the USDA's Dietary Guidelines for Americans in the past decade due to expanding nutrition knowledge. Not only the amount of fat, but the type of fat in the American diet is considered for recommendations to health and food production. Saturated fats in general have long been shown to contribute to chronic diseases such as cardiovascular disease, cancer, and obesity. In response to consumers' demands for healthier food products, food manufacturers started using the hydrogenation process to lower the saturated fat content of foods. However, research on health implications and subsequent policy changes of these trans fatty acids, such as listing trans fat content on food label nutrition facts, led the same food companies to re-evaluate the hydrogenation process, or production of trans fat, and begin using alternatives to partially hydrogenated oils. Fifteen food companies were contacted through their websites and surveyed about what kinds of oils and/or methods they used to replace the previously used partially hydrogenated oils in their food products to maintain standards for taste and texture. This research and literature review reveals that food companies are back to using saturated fats and tropical oils, especially coconut oil, instead of the cheap trans fats in their products. Contradicting facts on saturated fats and coconut oil are further explored, with the emphasis on the beneficial functions of coconut oil. Putting research in perspective, the future of food manufacturing processes is dependent on continued research on the health implications and differences between these types of fats in the American diet.

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WHAT A FAT DEBACLE: SATURATED AND TRANS FATTY ACIDS EFFECT ON HEALTH AND THE FUTURE OF FOOD MANUFACTURING PROCESSES

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DEDICATION

For my Father, my favorite researcher in the world.

CHAPTER ONE

Introduction of Fats in the American Diet

Big Macs. Chocolate chip cookies. Cheese casseroles. Double Java Chip Frappuccinos. What is the common denominator of these delicious sounding foods? They have some kind of fat, mostly saturated, mixed in to produce the texture, taste, and mouth feel that we are so familiar with. With the increasing amount of packaged and fast food items in the American diet, Americans have already started to be concerned with the amount of fat in their diets. Back in the days of homemade cooking and baking where grandma used real butter, real sugar, real flour, and real eggs, times were good. Now with the changing society using pre-packaged convenience foods, Americans are consuming more and more food not prepared at home. In these days, "consumers rely on the food industry to provide a bounty of food products that are convenient and pleasant to eat, while also providing the nutrients their bodies require" (McWilliams 2008, p. 3). Unlike the grandma days of food shortage, there is a surplus of food available to Americans, so "now the food industry is challenged with helping consumers alter their food practices and choices to bring about weight loss and to improve health" (McWilliams 2008, p. 3). Traditionally, Americans have eaten three square meals a day with a snack, but now more snack foods and packaged foods are available along with everyone's busy schedules so typical meals and snacks are randomly eaten on the go. The availability of these prepared foods and snacks for consumption at work, school, home, or anyplace in between "has prompted people to eat frequently, if not always wisely" (McWilliams 2008, p. 6).

Fats are a touchy and controversial subject. On one hand, they provide the immediate satisfaction of taste on food and nutrition and give food items the desired look and consistency. On another, the general public belief is that more fat consumption directly correlates to more body fat accumulation. Americans are experiencing an epidemic of overweight and obesity related to physical inactivity and poor diet which leads to certain diseases and death. Overweight is defined as "a state in which weight exceeds a standard based on height; a body mass index of 25 to 29.9 or greater," whereas obesity is "a state of adiposity in which body fatness is above the ideal; a body mass index of 30 to 39.9" (Mahan and Escott-Stump 2008, p. 533). According to the *Dietary Guidelines for Americans, 2010*, "the most recent data indicate that 72 percent of men and 64 percent of women are overweight or obese, with about one-third of adults being obese." These numbers put a damper on enjoying high-fat packaged foods, though with some modification, lower-fat alternatives can be achieved. Saturated fats have been looked down upon by Americans as artery-clogging, correlating to heart disease and atherosclerosis, a disease "characterized by thickening and narrowing of the arterial walls caused by inflammation and the accumulation of oxidized cholesterol, smooth muscle cells, and fibroblasts below the intima, or innermost layer of the artery" (Mahan and Escott-Stump 2008, p. 833).

Therefore, the recent phenomenon of trans fatty acids have taken over the products at grocery stores to produce the mouth feel, taste, and texture that saturated fats provide for foods. Hydrogenation of vegetable oils produces trans fatty acids. However, studies have shown that trans fatty acids are similar to saturated fats in causing obesity and chronic illnesses, so more recent aims at reducing trans fatty acid content in

packaged items and margarine have been taken. These include alternatives to the hydrogenation process and exploring whether or not butter and coconut oil deserve the negative connotations associated with saturated fats.

Consumption of Fat Since 1900's – Changes on Dietary Recommendations

Over the past century, dietary recommendations have changed to keep pace with the current research on health and nutrition. The U.S. Department of Agriculture (USDA) first published its dietary recommendations in 1894 although certain vitamins and minerals had not been discovered yet (Davis and Saltos 1996, p. 33). In the past, nutritional deficiencies and infectious diseases have been the concern in nutrition-related problems. Excessive total fat intake was not a problem due to Americans not even getting enough food to eat previous to technological advances in agriculture. After World War 2, advances in technology made farming more efficient and provided the means of mass transportation of food. This provided Americans a steady supply of food as the shortage of food slowly decreased, which improved health tremendously. However with the improving health conditions, "chronic diseases such as heart disease, cancer, and stroke have become more prevalent causes of death" (Davis and Saltos 1996, p. 33). Research on excessive fat, saturated fat, cholesterol, and sodium began to show the correlation to chronic health conditions. Immediately after World War 2, the basic seven food groups were introduced in 1943, which was condensed to basic four food groups in 1956 (Lichtenstein 2010). Foods high in saturated fat along with legumes and peanut butter (high in unsaturated fat) were included. At this time, the emphasis was to get undernourished people fed instead of having excessive fat intake. Fat intake was not a problem during these years of food shortage and hunger, and there was little guidance

about the use of fats and sugars. The food guide intended to help people deal with limited supplies of food and recommended a minimum number of foods from each of the groups – milk, meat, fruits and vegetables, and grain products (Page and Phipard 1956).

However with the increasing supply of food available, dietary recommendations started to morph. In 1977, *Dietary Goals for the United States* by the Senate Select Committee on Nutrition and Human Needs shifted the focus "from obtaining adequate nutrients to avoiding excessive intakes of food components linked to chronic diseases" (Davis and Saltos 1996, p. 36). The new guidance on health and nutrition specified goals for intakes of macronutrients – protein, carbohydrate, and fatty acids along with cholesterol, sugars, and sodium. The U.S. Department of Agriculture began addressing the role of fats, sugars, and sodium in risks for chronic diseases in its 1979 publication, *Food* (USDA 1979). They added a fifth food group including "fats, sweet, and alcohol beverages – targeted for moderation" (Davis and Saltos 1996, p. 37). Since 1980, the Dietary Guidelines for Americans provide the major shift in emphasizing moderation rather than the minimum nutrients. The Dietary Guidelines for Americans has "been revised and issued jointly by USDA and DHHS every 5 years" (Davis and Saltos 1996, p. 40). The focus on the total diet rather than the foundation diet provided guidance to Americans on meeting nutrient intakes as well as moderating intake of dietary factors that are related to chronic diseases. It suggested servings from the five major food groups (bread, cereal, rice, and pasta; vegetable; fruit; milk, yogurt, and cheese; and the meat, poultry, fish, dry beans, eggs, and nuts) while recommending sparing use of a sixth food group including fats, oils, and sweets (Davis and Saltos 1996, p. 37).

Another change occurred in 2000 when the emphasis shifted from the amount of fat to the type of fat. The recommendation was to "choose a diet low in saturated fat and cholesterol, and moderate in total fat" (Lichtenstein 2010) based on the findings that indicated that very-high fat diets caused dyslipidemia (high triglycerides and low HDL cholesterol concentrations). Since 2000 other groups have shifted their guidance from amount to type of fat as well. The American Heart Association (AHA) recommended limiting saturated and trans fatty acids which are known to be cholesterol-raising. The National Cholesterol Education Program changed their recommendation to the Therapeutic Lifestyle Changes (TLC) diet to 25% to 35% energy from total fat and less than 7% from saturated fat **(**Lichtenstein 2010). The Dietary Reference Intake (DRI) panel, issued somewhat broader guidelines; 20% to 35% of intake from total fat, with an emphasis on keeping saturated and trans fat as low as possible. In 2005 the Dietary Guidelines for Americans was reissued, for the most part mimicking the DRI recommendations. Finally, in 2006 the American Heart Association reissued their guidelines that emphasized the harm of saturated fats and trans fats over total fat (Lichtenstein 2010).

Chemical Structure and Importance

In order to understand how certain kinds of fats are associated with certain diseases and how different kinds of fats can be used in the food processing industry, one must know the basics of the biochemistry of fats. Chemically, fats are triglycerides, which are three fatty acids joined to a glycerol. Glycerol is a "polyhydric alcohol containing three carbon atoms, each of which is joined to a hydroxyl group" (McWilliams 2008, p. 2008, p. 237), whereas a fatty acid is an "organic acid containing

usually between 4 and 24 carbon atoms" (McWilliams 2008, p. 2008, p. 237). Fats are solid or liquid at room temperature, depending on their composition and structure. The term "oil" is used for fats that are liquids at room temperature, usually unsaturated. "Fats" are solids at room temperature, usually saturated like butter, lard, or any other animal fat. Fats are vitally important for living organisms, humans included. The vitamins A, D, E, and K are fat-soluble, meaning that they can only be absorbed if fat is present in the diet (Dietary Guidelines for Americans 2010). Fats provide energy stores for the body with 9 calories per gram of fat, which are broken down to release glycerol and free fatty acids. The glycerol can be then converted to glucose by the liver and used as a source of energy. In addition, they are useful buffers toward diseases by storing substances of unsafe levels in new fat tissue. Fats help protect vital organs until these substances can be metabolized or removed from the body by excretion or other means. Essential fatty acids can't be produced in the body from compounds and need to be consumed in the diet for proper growth and brain development.

Saturated Fats

Saturated fats are mostly solid at room temperature, including butter, the tropical oils (coconut oil, palm kernel oil, palm oil, rice bran oil), lard, and other animal fats. Animal fats are "fats in the food supply that are obtained from animal sources [and] include beef tallow and butterfat (milk fat) from cattle and lard from pigs" (McWilliams 2008, p. 260). The only plant fats that are mostly saturated are the tropical oils, which are even more saturated than animal fats. Chemically, saturated fats are fatty acids in which all available carbon binding sites are saturated with hydrogen, therefore giving them the name "saturated" fats.

Many baked goods and shelf-stable products have used butter in the past because the butyric acid in butter "contributes its distinctive quality to the flavor profile of butter" (McWilliams 2008, p. 260). While the classic bread and butter in grandma's homemade recipes, steak and butter, etc, are comforting and familiar, research has indicated that "higher intake of most dietary saturated fatty acids is a associated with higher levels of blood total cholesterol and low-density lipoprotein (LDL)" (Dietary Guidelines for Americans 2010). Because of these findings in the world of food and nutrition, people are becoming increasingly aware of the health implications of saturated fats. The recommended daily intake of saturated fats is 10% of total calories, though lowering intake to 7% can further reduce the risk of cardiovascular disease (Dietary Guidelines for Americans 2010). Sources of saturated fatty acids in the American diet include "regular (full-fat) cheese (9% of total saturated fat intake); pizza (6%); grain-based desserts (6%); dairy-based desserts (6%); chicken and chicken mixed dishes (6%); and sausage, franks, bacon, and ribs (5%)" (Dietary Guidelines for Americans 2010). To reduce saturated fats, solid fats can be replaced with vegetable oils that are rich in monounsaturated and polyunsaturated fatty acids. However, these oils are not solid at room temperature, therefore not giving some food products the same consistency as the former saturated fats.

Plant Fats – Monounsaturated and Polyunsaturated

Plant sources of fats include "olives, palm berries and palm kernels, cottonseeds, soybeans, rapeseed (canola oil), corn, sunflower seeds, safflower seeds, grape seeds, coconuts, peanuts, cacao beans, walnuts, macadamia nuts, and rice bran" (McWilliams 2008, p. 262). Most of these fats are high in polyunsaturated and monounsaturated fatty

acids, with the exception of the tropical oils which have high saturated fatty acid content. These fats are usually called "oils" because they are liquids at room temperature, and can be substituted for saturated fats in cooking. Monounsaturated fats are fatty acids containing one double bond in the sea of single-bonded carbons. Oils rich in monounsaturated fatty acids include canola, olive, and safflower oils. Studies have shown that diets rich in monounsaturated fatty acids help lower total cholesterol and support a healthy heart (Strychar et al. 2003). Polyunsaturated fats are fatty acids containing at least two double bonds in the chemical structure, and include soybean, corn, and cottonseed oils. Hydrogenating these oils produce solid fats at room temperature, which can be used to stabilize food products in the supermarket.

Fish Oils

Essential fatty acids are fatty acids that need to be consumed in the diet, as our bodies cannot physically produce them. The only specific requirement for fat in the human diet is for essential fatty acids, including n-6 fat linoleic acid and alpha-linolenic acid (Ferguson 2009). Docoshexanoic acid (DHA) is an omega-3 fatty acid containing 22 carbon atoms and six double bonds (McWilliams 2008, p. 2008, p. 239). Eicosapentanoic acid (EPA) is an omega-3 fatty acid containing 20 carbon atoms and five double bonds (McWilliams 2008, p. 2008, p. 239). These fatty acids are important in diet and nutrition because "the impetus for using omega-3 fatty acids is their possible role in reducing the incidence of coronary heart disease and strokes" (McWilliams 2008, p. 263). Given that energy intake is controlled, evidence shows that "increasing some types of lipids in the form of n-3 [polyunsaturated fatty acids] could be protective against chronic disease" (Ferguson 2009). Inflammation in the body contributes to many chronic diseases,

including cardiovascular disease, diabetes, cancer, obesity, and arthritis (Boehl 2007). In chronic inflammation, the inflammatory process produces proinflammatory mediators, primarily eicosanoids, reactive oxygen specides, and cytokines. N-6 fatty acids are generally inflammatory, whereas N-3 fatty acids are anti-inflammatory. Cytokines are small "protein mediators produced by inflammatory cells in response to exogenous stimuli" (Mahan and Escott-Stump 2008, p. 959). Omega-3 fatty acids such as EHA have been shown to act as ligands to "downregulate transcription of proinflammatory genes through modulation of cytokine production" (Ferguson 2009). Chronic inflammation contributes to a host of acute and chronic human diseases. Theoretically, reducing inflammation through consumption of fish oils and omega-3 fatty acids can possibly reduce the risk of developing these chronic diseases.

Trans Fatty Acids and Hydrogenated Oils

With the increasing reputation of saturated fats as a cause of chronic illnesses and obesity, food manufacturers turned to the hydrogenation process to include unsaturated fats in food products. Hydrogenation is "the process of adding hydrogen across the unsaturated fatty acid double bond" and "commercial hydrogenation of oils increases saturation and makes the oil more solid at room temperature" (Mahan and Escott-Stump 2008, p. 40). This process creates trans fatty acids, which are "steroisomers of the naturally occurring cis-fatty acid in which hydrogen is added back across the double bond" (Mahan and Escott-Stump 2008, p. 42). Sources of trans fatty acids in the U.S. diet are "chemically hydrogenated margarine, shortening, commercial frying fats, high-fat baked goods, and salty snacks containing these fats" (Mahan and Escott-Stump 2008, p. 54). Trans fatty acid intake has been associated with the risk of heart disease based on

epidemiologic and clinical studies. Food manufacturers first used commercial trans fatty acids as a response to lowering saturated fat intake in Americans only to create a man-made fat even more detrimental to health than the initial scare of saturation. Just like saturated fats, trans fatty acids are associated with increased risk for coronary heart disease, cancer, and other chronic disease (including type 2 diabetes and allergies [Stender and Dyerberg, 2004], possibly because of their potential to influence membrane fluidity. Furthermore, trans fatty acids have been shown in hinder the desaturation and elongation of linoleic and ALA to form long-chain essential fatty acids, which are critical for fetal brain and organ development (Mahan and Escott-Stump 2008, p. 54). More information is provided in Chapter Two, which is entirely about the hydrogenation process, trans fatty acids, and the health implications.

Functional Roles of Fat

In addition to providing energy for the human body, fats have functional properties that shape the color, flavor, texture, tenderness, and emulsification of food as well as provide a cooking medium (McWilliams 2008, p. 271). Butter provides a pleasant creamy yellow color to food products, and many brands of margarines have added beta-carotene to simulate the desired yellow color. Fats contribute a rich flavor to food that is seldom replicated. Butyric acid in butter marks the distinctive taste of butter; "olive oil and lard are examples of other types of fats that contain distinctive flavor components" (McWilliams 2008, p. 267). Fats contribute to texture in many ways. Fried foods have a crisp texture which can only be developed by adding fat as the cooking medium. Butter is creamed with sugar "to obtain a very fine cell structure of great uniformity in a shortened cake" (McWilliams 2008, p. 267). This produces a fluffy and light texture in baked

products. Fat is a tenderizing agent, and it is important in the creation of a tender baked product. Because of their "ability to interfere with the development of gluten, the structural protein complex in wheat flour products," fats are essential to baked goods. This is referred to as shortening power, the "ability of a fat to cover a large surface area to minimize the contact between water and gluten during the mixing of batters and doughs" (McWilliams 2008, p. 268). Flakiness in pastries is achieved when fat in the dough "melts during the baking period and flows, leaving a hole where steam collects and pushes upward against the upper surface of the resulting cell" (McWilliams 2008, p. 270). This is highly desirable of biscuits with thin, flaky layers. Emulsification of foods result in uniformly dispersed ingredients, which are mostly oil-in-water emulsions. Fat as an emulsifying agent is used to aid in the formation of stable emulsions, as shortenings are produced today "with added mono- and diglycerides so that the fat and milk in cake batters are emulsified, resulting in a fine-textured cake" (McWilliams 2008, p. 270). Finally, fats and oils are used as a cooking medium in deep-fat frying and stir-frying.

Steps in Manufacturing Food Fats

In manufacturing fats, the first step is extraction, removing the lipids from their nature food sources (McWilliams 2008, p. 253). For lard and tallow, rendering is used by either dry or moist heat. According to McWilliams (2008, p. 253), the hot fluids fats are separated from water, and antioxidants are added frequently to slow the development of rancidity. On the other hand, hot pressuring or cold pressure removes plant lipids.

In the next step of refining, fats are refined to a high purity level needed to place them on the market. Degumming and neutralization procedures can remove gums and free fatty acids. Bleaching is a refining process "in which coloring and flavoring

contaminants are removed from fats, often by filtration through active charcoal" (McWilliams 2008, p. 255). Deodorizing is a related process that is accomplished by steam distillation, which is important to the production of high-quality coconut and palm kernel oils (McWilliams 2008, p. 255). Finally, winterizing is a refining technique "used to remove lipid fractions with melting points high enough to cause them to become a solid at refrigerator temperatures" (McWilliams 2008, p. 255).

The next step is fractionation, which is a "process of separating oils into fractions using controlled temperature to crystallize fatty acids with high melting points and separate them from oils with lower melting points" (McWilliams 2008, p. 255). Tropical oils such as coconut and palm oil are typically very high in saturated fatty acids, which means they have higher melting points and a more solid texture at room temperature than other commercial oils. Palm oil "can be separated into fractions with different physical properties and varying ratios of fatty acids by fractionation" (McWilliams 2008, p. 255). Careful temperature control can separate fats and remove fatty crystals that form, and the oils left behind have lower melting points.

The final set in the manufacture of fats is controlling crystal size of the warm and fluid fat. Carefully controlling the temperature is important as the fat is cooling along "with an appropriate amount of agitation, can help achieve a smooth fat, with beta crystals the predominant crystal size" (McWilliams 2008, p. 255). Beta crystals are generally the most desirable. However without such control, the small beta crystals cannot form and the large beta crystals precipitate to give the fat a coarse texture. According to McWilliams (2008, p. 255), hydrogenated cottonseed oil is often used in manufacturing fats because of its propensity to form the desired beta crystals. For

manufacturing specials fats to use in the confectionery industry, fats undergo tempering, which is a process of "removing heat resulting from crystallization of fats and maintaining a selected temperature to promote the formation of stable, desirable crystals" (McWilliams 2008, p. 256).

Summary

Dietary fat is an essential part of our lives. In researching all the physical and chemical properties of fat, the history of fat consumption, the difference between kinds of fats, and how it affects the health of Americans, manufacturing companies have developed different kinds of techniques in manufacturing fats. Because of the negative associations with saturated fatty-acids, the recent development of man-made trans fatty acids has taken over products in the grocery stores. However, more research has shown that trans fatty acids also contribute to chronic diseases associated with high-fat intake. In the next chapters, the hydrogenated fats phenomenon will be explored along with replacements in food products, going back to tropical oils which consequently high in saturated fatty-acids. The future of food manufacturing depends on these kinds of research in ultimately promoting health and preventing disease.

CHAPTER TWO

Hydrogenated Fat Phenomenon

Introduction of the Hydrogenation Process

With recent food technology, food manufacturers have utilized the process of hydrogenation of polyunsaturated fats to include in everyday food items. Hydrogenation is the "addition of hydrogen to an unsaturated fatty acid in the presence of a catalyst to reduce the unsaturation of the molecule and raise the melting point" (McWilliams 2008, pg. 257). This process started in the early 20th century that led to the introduction of commercial trans fats into the American diet. It was first described by Paul Sabatier, a French chemist, and "uses a nickel catalyst to hydrogenate – or saturate – double bonds in vegetable oils" (Remig et al. 2010). In between hydrogenation and unsaturated fatty acids, partial hydrogenation of vegetable oils produces both cis and trans fatty acids. Partially hydrogenated oils also withstand repeated heating without breaking down or going rancid, making them ideal for frying fast foods (Frenk 2012). Partially hydrogenated oils became popular in restaurants and the food industry for many uses, including frying, baking, and processing snack foods and margarines.

Along with the functional aspects of hydrogenated oils, the food industry wanted to find a healthier substitute for using animal fats in food products. Because of the health concerns of saturated fats and cholesterol, food manufacturers wanted to find a replacement to use in food products that would reduce saturated fats and cholesterol content. Unsaturated vegetable oils are usually liquid at room temperature, but with this hydrogenation process, the unsaturated vegetable oils can be modified to solids and used

as margarines and shortenings. Hydrogenation is also used to process peanut butter from its original state of oil separation to remain "homogenous even during extended shelf storage" (McWilliams 2008, pg. 257). With this hydrogenation process, food manufacturers believed that it would be "healthier" to suit the needs of people trying to reduce their saturated fat and cholesterol intake while providing the same qualities as the saturated fat counterparts. Although some undesirable results occur with partially hydrogenated fats because "some unsaturated fatty acids undergo isomerization, which results in trans configuration of some double bonds rather than the cis form" (McWilliams 2008, pg. 257), completely hydrogenated oils are sometimes used since they do not contain double bonds.

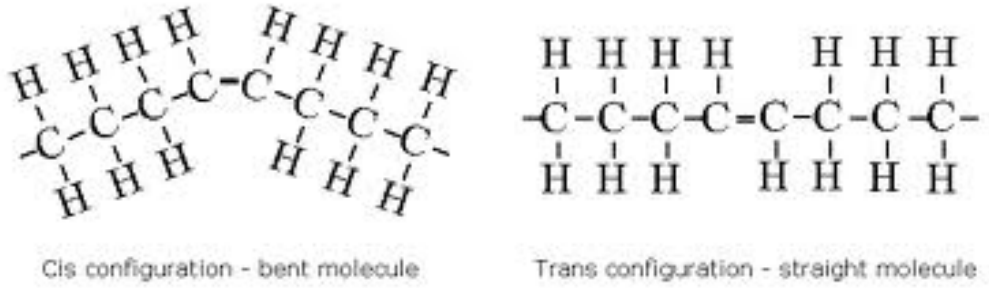
Manufacturing of Trans Fatty Acids

Hydrogenating vegetable oils can be manufactured to solid fats by using a nickel catalyst to add (hydrogenate) hydrogen to the double bonds in polyunsaturated oils (Remig et al. 2010). Unsaturated bonds have alkenic double C=C bonds, whereas saturated bonds have C-C bonds. Adding hydrogen to the unsaturated bonds results in saturated bonds, which increases the melting point of the polyunsaturated oil and hardens it, creating substances like saturated fats at room temperature. According to Claek (2009), this is due to the increase in van der Waals forces between the saturated molecules compared with the unsaturated molecules. Due to health implications of completely saturated fats, the hydrogenation process is controlled so that only enough C-C bonds are created to produce the desired texture. Because of this, food products such as margarines and shortening are said to be "partially hydrogenated." Sometimes, other metal catalysts are used in place of nickel, such as palladium (Baker et al. 1997). When hydrogenation is

not complete, as with partial hydrogenation, the high temperatures used in this process flip some of the C=C double bonds into the "trans" form.

FIGURE 1

Cis and Trans Configuration



Source: http://www.hidden-diabetes-cures.com/fats-and-oils.htm

Types of Cholesterol – LDL and HDL

Allison et al. (1999) estimated the mean intake of trans fatty acids by Americans daily was 5.3 grams, of which between 20 and 25 percent was comprised of naturally occurring trans fatty acids (from MNT book). The American Heart Association recommends that trans fats be <1% of total energy. Research has shown that trans fatty acids elevate LDL (low density lipoprotein), which may potentially raise the risk of coronary heart disease. Cholesterol can't dissolve in the blood and has to be transported to and from the cells by carriers called lipoproteins. Low-density lipoprotein or LDL is known as "bad" cholesterol since it is associated with plaque buildup in arteries. High density lipoprotein or HDL is known as "good" cholesterol since it is associated with protection against heart disease. These two types of lipids and other lipid components make up total cholesterol count.

When too much LDL cholesterol circulates in the blood, it can build up in the inner walls of heart and brain arteries. Along with plaque and other substances, a hard deposit forms that narrow the arteries, a condition known as atherosclerosis. On the other hand, HDL cholesterol carry cholesterol away from the arteries and back to the liver, where it is excreted from the body. HDL removes excess cholesterol from arterial plaque, reversing some damage that LDL may create (American Heart Association, Inc. 2012).

Health Implications of Trans Fatty Acids

Cardiovascular disease remains the leading cause of death in the United States along with other chronic diseases, despite governmental efforts to "decrease tobacco smoking and [manage] hyperlipidemia with dietary changes and statins" (Remig et a. 2010). Risk factors for cardiovascular disease such as hypertension, obesity, and diabetes are directly correlated to diet. In the Nurses Health Study (1993), trans fats were associated with increased cardiovascular risk. According to Remig et al. (2010) more specifically, "a 2% absolute increase in energy intake from trans fat has been associated with a 23% increase in cardiovascular risk." This is due in part to their effects on the lipoprotein profile, lowering high-density lipoprotein (HDL) cholesterol while raising low-density lipoprotein (LDL) cholesterol, as well as "inflammatory mechanism and interference with fat metabolism" (Remig et al. 2010).

Trans fats are associated with heart disease, affecting total serum cholesterol and inflammatory markers such as C-reactive protein and interleukin-6 (Remig et al. 2010). Cardiovascular disease is an inflammatory disease, therefore increasing inflammation in the body directly correlates to the incidence of heart disease. According to Ascherio et al. (1999), trans fats have been shown to "adversely affect lipoprotein metabolism,

presumably through increased activity of cholesteryl-ester transfer protein", resulting in higher levels of LDL, very-low-density lipoprotein, triglycerides, and lipoprotein (a), as well as concomitant reductions in LDL size and HDL concentration.

Another study by Niu et al. (2005) showed that trans fatty acid phospholipids have a 40-80% cholesterol affinity than their cis analogues. This means that trans fatty acids are more likely to stick to cholesterol. The results demonstrate that the incorporation of trans fatty acid in phospholipids leads to an increase in membrane cholesterol and a reduction in membrane receptor activation. These are contributing factors in cholesterol homeostasis and may be why LDL cholesterol is elevated by a trans fatty acid rich diet.

According to Lichtenstein (1997) and a majority of studies, trans fatty acid intake increases lipoprotein (a) levels. A position relationship has been reported between lipoprotein (a) levels and a risk of cardiovascular disease.

Hu et al. (1997) showed that replacing 2% of energy from carbohydrates with trans fat nearly doubled the relative risk of coronary heart disease. In this study, replacing 5% of energy from carbohydrates with saturated fat was associated with a 1.47-fold increase in relative risk, thus "on a gram-for-gram basis, *trans* fat was associate with an approximately 15 times greater risk of coronary heart disease than saturated fat (Remig et al. 2010). In another study, increases in *trans* fats was associated with a higher cardiovascular risk than increases in saturated fats (Ascherio et al. 1999). These results are ironic since commercial *trans* fats were originally introduced into the diet as a means of lowering the risk of cardiovascular disease from saturated fat intake.

Cardiovascular disease is an inflammatory disease. Therefore, trans fats have be shown to increase inflammatory markers: C-reactive protein, interleukin-6, and tumor necrosis factor-a, "possibly through modulation of monocytes and macrophage activity (Remig et al. 2010). These inflammatory factors may play an important role in the development of diabetes, atherosclerosis, plaque rupture, and ultimately sudden cardiac death" (Ascherio et al. 1999). Other possible adverse effects of *trans* fats include inhibition of the incorporation of other fatty acids into cell membranes, interference with elongation and desaturation of essential fatty acids, increased platelet aggregation, decreased birth weight, increased body weight, decreased serum testosterone, and abnormal sperm morphology (Simopoulos 2008).

Types of Trans Fatty Acids

Several types of trans fatty acids exist, both in natural sources and from commercial products. According to Remig et al. (2010), biohydrogenation of 18-carbon polyunsaturated fatty acids, such as linolenic acid, forms vaccenic acid (11-*trans* 18:1) and conjugated linoleic acid (9-*cis*, 11-*trans* 18:2). **Vaccenic acid** is a trans fatty acid isomer of oleic acid occurring naturally in butterfat and does not elevate LDLs. Vaccenic acid is "a major trans fatty acid in the fat of ruminants" and is "produced in the rumen and converted in tissues to rumenic acid" (Turpeinen et al. 2002). **Elaidic acid**, a different trans isomer of oleic acid, elevates LDL levels and lowers HDL levels. It is the major trans fatty acid found in hydrogenated vegetable oils and "occurs in small amounts in caprine and bovine milk" (Alonso et al. 1999). As much as different types of fatty acids matter in general health, the different types of trans fatty acids contribute to opposite effects in the body. Vaccenic trans fatty acid is naturally occurring and does not

increase LDL cholesterol, whereas elaidic trans fatty acid is man-made, elevating LDL levels and lowering HDL levels.

Sources and Biochemistry of Trans Fatty Acids

In biochemistry, saturated fats have C-C single bonds. This means that all the carbons on the fatty acid are "saturated" with hydrogen, giving the fatty acid stability. Unsaturated fats have C=C double bonds. The cis forms of polyunsaturated fatty acids are oils which are liquid at room temperature. Trans fatty acids "produce more rigid configuration that requires much less space than the cis double bond, resulting in a melting point around room temperature" (Remig et al. 2010). This provides a desirable texture and mouth-feel along with enhancing product shelf life.

Dietary trans fats, first of all, are formed "naturally by bacteria present in the rumens of ruminant animals" (Remig et al. 2010). Generally speaking, dairy and meat products have trace amounts of trans fats. In a man-made process of hydrogenation or partial hydrogenation, trans fats are formed from liquid vegetable oils high in unsaturated fatty acids. These sources of trans fat include but not limited to stick margarines, soft or tub margarines, whipped margarines, and shortening. Stick margarines are spreads "made by hydrogenating plant oils and adding water, milk solids, flavoring, and coloring to achieve a produce similar to butter" (McWilliams 2008, pg. 264). Soft or tub margarines are similar spreads, but with lower melting points than those of stick margarines due to more polyunsaturated fatty acids. These margarines are less hydrogenated, so not as many saturated C-C bonds form, giving them a less solid structure than harder, more hydrogenated margarines. Whipped margarines have been whipped mechanically into foam; therefore the increased volume gives whipped margarines less calories per volume

in comparison to the rest. Shortening is the "hydrogenation of vegetable oils to achieve the desired consistency" (McWilliams 2008, pg. 266). In batters and doughs, mono- and diglycerides are added to shortening for forming better emulsions. Commercial hydrogenation generates the majority of the trans fats found in the American diet today. However, the negative effects of trans fatty acids in the diet have brought about changes to produce healthy spreads with reduced amounts of trans fatty acids (McWilliams 2008, pg. 258).

Policy Changes on Trans Fatty Acids

In the 1990s, the average American was eating about six grams of trans fats a day, mostly from partially hydrogenated oils in commercially prepared baked goods, margarines, snack foods, processed foods, French fries, and other fried foods prepared in restaurants and fast food franchises (Allison et al. 1999).

Finally in 2003, the Food and Drug Administration issued a ruling that "the amount of trans fat in the serving must be listed in a separate line under saturated fat on the Nutrition Facts panel (unless the total fat in a serving is less than 0.5 gram per serving and no claims are made about fat, fatty acid, or cholesterol content)" (McWilliams 2008, pg. 257). A footnote must be added if trans fat is not listed to say the food is "not a significant source of trans fat." This ruling went into effect in 2006. Today, the American Heart Association recommends that trans fats not exceed 1% of total energy of a person's daily intake. In addition, the American Dietetic Association, the Institute of Medicine, US Dietary Guidelines, and the National Cholesterol Educational Program all recommend that trans fatty acid consumption be as low as possible (Remig et al. 2010). While these

recommendations are valid and based on sound research, Americans still consume significant amounts of trans fats especially in processed goods.

As of January 2006, trans fat must be listed on food labels along with saturated and unsaturated fats. “The FDA once estimated that approximately 95 percent of prepared cookies, 100 percent of crackers, and 80 percent of frozen breakfast products contained trans fat” (Frenk 2012) Because of this policy, many food companies have made attempts to remove trans fats from their products.

Recently, Vesper et al. (2012) reported that American’s blood levels of trans fats dropped 58 percent from 2000 to 2009, evidence that the labeling law has a desired effect. Fear that food makers would replace trans fat with saturated fat appeared to be a concern. However, based on a 2010 survey of 83 major-brand grocery store products and restaurant dishes, food products did not have increasing saturated fat when cutting back on trans fat (Mozaffarian et al. 2010).

However, because some foods sold in bakeries, cafeterias, schools, and restaurants do not contain labels, consumers are not aware of the trans fat content or total calories. Many cities and states have passed or are considering laws to eliminate trans fats in these foods. As the first state to do so, California’s governor recently signed legislation to phase out trans fat from restaurants by 2010 and from baked goods by 2011. Restaurants, cafeterias, and schools in New York City and Boston are beginning to go “trans free.” New York City has a “Trans Fat Help Center” to assist in compliance to these new requirements (Frenk 2012).

Food manufacturing companies have started to find ways to make their products without partially hydrogenated oils in fear of sale loss. Consumers now have more information on food labels and trans fats, consciously choosing to purchase foods containing lower to no trans fat content. Some margarines have been almost trans fat-fat for several years. Other trans-free food products are on the market, including tortilla chips, crunchy snacks, frozen fried chicken products, and shelf-stable baked goods (Frenk 2012).

However, due to the food labeling rules, a product claiming to have zero trans fat can actually contain up to a half gram. The ingredients list is the best way to watch out for "partially hydrogenated vegetable oil" and "vegetable shortening," along with variations of these phrases. The hydrogenated fat phenomenon in the past couple of decades continues to provide questions and research on the origins, benefits, negative effects, and policy changes of trans fatty acids. What seemed to be a cheap and effective way to produce food without saturated fats and cholesterol has led to more health implications than benefits. This popular method of hydrogenating polyunsaturated oils has been under scrutiny, with research to support the negative association of trans fatty acids.

CHAPTER THREE

Alternatives to Trans Fatty Acids

Background

As chapter one and two previously stated, Americans are increasingly more concerned about the health implications of trans fatty acids in their diets. In the beginning, hydrogenated oils served two main purposes: to lower saturated fat content (which lowers cholesterol as well) and to make shelf life longer on shelf stable food products by turning oils into solid fats without disrupting the integrity of the product. Its use was also to provide a solid fat from which food can be made without having cholesterol. Food manufacturers wanted their food products to appeal to consumers' health concern and taste buds. In addition, manufacturers also used these trans fats because they are cheaper in mass production.

However, these trans fatty acids have merited much research on the ill effects of hydrogenated oils in the American diet. Associated with cardiovascular disease, diabetes, and other chronic illnesses, trans fats have developed a stigma of promoting disease. Within the past decade, food manufacturers started to lower the trans fatty acid content of their products in order to meet the demands for healthier oils.

Alternatives to trans fatty acids are becoming more available and widespread. Food companies are exploring a number of options for replacing trans-fat-containing partially hydrogenated oils. These options include "changes in oils used, extent of

hydrogenation, interesterification, alterations in diacylglyceride levels, adding short- and medium-chain fatty acids, and changing the fatty acids in plants through selective breeding and genetic alterations" (McWilliams 2008, pg. 260).

Many food companies are going back to butter and animal fat, what trans fatty acids were supposed to replace in the first place (Frenk 2010). Although saturated fats and cholesterol in these products concern the public, recent research has shown that saturated fats are not the enemy in chronic diseases, such as cardiovascular disease, cancer, and obesity.

Coconut and palm oils were "more widely used in prepared food until 1988" when Americans began to worry that high-saturated fat oils were the cause of chronic disease (Frenk 2010). This caused food companies to replace these tropical oils with partially hydrogenated oils made from soy, corn, sunflower, and rapeseed. Recent research shows that coconut oil strongly increases HDL cholesterol, which may make it a good choice when hard fat is needed (Norton et al. 2004). More research on saturated fats and tropical oils are provided in the next chapter.

Another alternative to partially hydrogenated oils is to use fully hydrogenated vegetable oils. In exposing liquid oils rich in unsaturated fats to hydrogen gas for a longer time, a hard, waxy, full hydrogenated fat is produced. This means the oil has become a saturated fat, and is trans-fat free. Combining fully hydrogenated vegetable oils and liquid vegetable oils "yields a semi-soft fat that is trans fat free and can be used for margarines, baking and other types of cooking" (Frenk 2010).

Using traditional liquid vegetable oils is another healthy alternative to using trans fats. Olive, canola, corn, and soy oils spoil faster than partially hydrogenated oils and don't have a long shelf life. They don't hold up as well as partially hydrogenated oils to the high temperatures needed for commercial deep drying. However, "the food industry is rapidly changing its practices and food formulations so that more vegetable oils can be used successfully in foods" (Frenk 2010) by substituting partially hydrogenated oils for pure vegetable oil. However, this is more expensive to using trans fats, and the unsaturated oils do not produce the same texture and quality in food products due to being liquid in room temperature.

Another alternative is to use new liquid vegetable oils from new seeds. Linolenic acid, an omega-3 fatty acid is most responsible for spoilage in oils because it is easily oxidized. Alpha-linolenic acid is a carboxylic acid with an 18-carbon chain and three cis double bonds, an essential fatty acid only acquired through diet. Iowa State University and other universities started selective breeding programs to create soybeans and other seeds with very low levels of linolenic acid (Frenk 2010). High levels of linolenic acid will make products more susceptible to oxidation, therefore becoming rancid quicker. However, this process eliminates healthful alpha-linolenic acid, one of the healthiest components of many vegetable oils so it will be important to get omega-3 fats from other sources, such as fatty fish or walnuts.

Remig et al. (2010) states that food manufacturers use genetically modified plants that produce low-linoleic, mid-oleic, or high-oleic oils as another option. "Frito-Lay (Pepsico, Purchase, NY), for example, now uses mid-oleic sunflower oil for its potato

chips" (Remig et al. 2010). However, developing a reliable supply of these oils is a challenge due to lower crop yields.

Interesterification, a process that repositions the fatty acids on triglyceride molecules, can replace partially hydrogenated oils used in food production. According to McWilliams (2008, pg. 259), interesterification is "treatment of a fat, usually lard, with sodium methoxide or another agent to split fatty acids from glycerol and then to reorganize them on glycerol to form different fat molecules with less tendency to form coarse crystals." This does not reduce trans fats if they are already present before the treatment, and health implications of this new commercial fat are not known. Interesterification can produce shortenings and margarines with higher melting points and good spreading characteristics without partially hydrogenating the oils. NovaLipid, based on interesterification, uses "a mix of approximately 1 part fully saturated soybean oil (high in stearic acid with a melting point of ~70 degrees C) and 3 parts liquid soybean oil" (McWilliams 2008, pg. 259). This fat is solid at room temperature and used in baking. Stearic acid is useful in this product because it does not appear to influence LDL blood levels along with contributing a high melting point.

Stanol and sterol esters have emerged as the effective compounds in alternative spreads. Phytosterols (beta-sitosterol) have similar cholesterol structures but with different side chains that alter their action in the body (McWilliams 2008, pg. 265). Esterifying phytosterols with a fatty acid and hydrogenating them is necessary for incorporation into margarines. On the other hand, phytostanols (beta-sitostanol or campestanol) are known as "tall oils" since they are derived from pine tree pulp. Like phytosterols, phytostanols have to be esterified with a fatty acid, though hydrogenation is

not required (McWIlliams 265). Some products that use stanol and sterol esters include Take Control and Benecol. Take Control, a spread developed by Lipton, Unilever's subsidiary, contains a plant sterol ester derived from soybeans (McWilliams 2008, pg. 265). Benecol (marketed by NcNeil Consumer Healthcare) is a plant stanol ester. These products work by preventing the absorption of LDL cholesterol, which helps reduce the risk of coronary heart disease (McWilliams 2008, pg. 265). LDL cholesterol is synthesized in the liver and circulates through the bloodstream, depositing in the walls of arteries. Fortunately, two servings of these spreads a day is effective since these products are expensive compared with regular margarines.

TABLE 1

Fat Replacements

<table>
<tr><th>Protein-based replacement</th><th>Carbohydrate-based replacements</th><th>Fat-based replacements</th></tr>
<tr><td rowspan="5">Simplesse – contains milk proteins and egg white in small particulates that are able to convey the mouthfeel of fat because of the way the particles move as the product is eaten</td><td>N-Lite</td><td>Salatrim</td></tr>
<tr><td>Stellar</td><td rowspan="4">Caprenin</td></tr>
<tr><td>Oatrim</td></tr>
<tr><td>Avicel</td></tr>
<tr><td>Polydestrose</td></tr>
</table>

Source: McWilliams 2008, pg. 273

As the future of food manufacturing processes stray further away from producing food products with trans fats, this research provides insight on ingredients used in producing foods with the same quality that partially hydrogenated oils provided in the past. Alternatives processes to trans fatty acids are important in meeting consumers' demands of healthier substitutes. The purpose of this qualitative descriptive study is to

investigate the kinds of oils and methods used in food manufacturing processes to eliminate the trans fat content in food products while upholding the standard quality and taste of past products.

Methods

Design and study sample

In this qualitative descriptive study, a total of 15 food companies were selected mostly, with the exception of Earth Balance, from a list provided by Sundram et al. (1995).

> *"These companies must consider not only the fat composition of their products, but also taste, texture, cost, and availability of materials when reformulating their comestibles. These companies currently include Campbell Soup Co (Camden, NJ), ConAgra Foods (Omaha, NE), General Mills (Golden Valley, MN), The Hershey Company (Hershey, PA), The J.M. Smucker Co (Orrville, OH), Johnson & Johnson (New Brunswick, NJ), Kellogg Co (Battle Creek, MI), Kraft Foods (Northfield, IL), Nestle SA (Vevey, Switzerland), PepsiCo (Purchase, NY), Procter & Gamble (Cincinnati, OH), Sara Lee Corp (Downers Grove, IL), The Schwan Food Co (Marshall, MN), and Unilever (London, UK) (2), as well as GFA Brands, Inc (Boulder, CO), which formulates products based on the fat blend described above" (Sundram et al. 1995).*

These companies included:

- Campbell Soup Company
- ConAgra Foods
- General Mills
- The Hershey Company
- The J.M. Smuker Company
- Kellogg Company
- Kraft Foods
- Nestle SA

- FritoLay
- Quaker Oats
- Sara Lee Corporation
- Unilever, GRA Brands, Inc (Smart Balance)
- Earth Balance
- Schwans (Red Baron Pizza, Freschetta, Tony's Pizza, Mrs. Smith's Products, Edwards Desserts, Pagoda Express, and Bon Appetit)

These companies have products that have a form of fat to make the products have the taste and appeal to consumers, whether they are cereals, breads, desserts, chips, margarines, chocolates, popcorn, etc.

Procedures and Measures

Companies were contacted through their websites in February 2012 using their "Contact Us" link.

TABLE 2

Contacted Companies and Websites

Company	Website
Campbell Soup Co	http://www.campbellsoup.com/
ConAgra Foods	http://www.conagrafoods.com/
General Mills	http://www.generalmills.com/
The Hershey Company	http://www.hersheys.com/
The J.M. Smuker Co	http://www.smuckers.com/

Kellogg Co	http://www.kelloggcompany.com/
Kraft Foods	http://www.kraftfoodscompany.com/home/index.aspx
Nestle SA	http://www.nestle.com/Pages/Nestle.aspx
FritoLay	http://www.friolay.com
Quaker Oats	http://www.quakeroats.com/home.aspx
Sara Lee Corporation	http://www.saralee.com/en/OurBrands.aspx
Unilever	http://www.unilever.com/
GFA Brands, Inc (Smart Balance)	http://www.smartbalance.com/
Earth Balance	http://www.earthbalancenatural.com/
Schwans	http://www.schwans.com/

The same question was asked:

> *"Because of the ongoing bad reputation and health implications of trans fatty acids, many companies such as yourself have started to use other methods of achieving the same quality foods. Continuing quality taste and texture, cost, and availability of materials also play a role in determining how to replace the trans fatty acids. Can you tell me what kinds of methods you use to replace the partially hydrogenated oils that were used previously (substituting for other fats, interesterification, using fat replacers, or any other methods)? Thank you so much and I look forward to hearing from you soon!"*

Company representatives responded between 1 day and 1.5 weeks through email.

Results and Discussion

Twelve out of fifteen companies responded through email within a week and a half.

TABLE 3

Company Responses

Company	Response
Campbell Soup Co	No response
ConAgra Foods	Thank you for your email concerning our ConAgra Foods products. We understand the importance of good nutrition, and are committed to helping people make nutritious food choices. We continue to explore ways to significantly reduce trans fat from all our products as part of an ongoing initiative to provide nutritionally responsible products. Currently, all our soft spreads under our three national brands, Fleischmann's, Parkay and Blue Bonnet, are trans fat-free per serving, and several varieties of our Orville Redenbacher's Smart Pop! Gourmet Popping Corn and ACT II 94% Fat Free have 0 grams of trans fat per serving. We appreciate your interest in our products. ConAgra Foods would like to help you with this request to the best of our ability. However, because the information you have requested is considered to be proprietary and a trade secret of ConAgra Foods, we are unable to supply this information. Thanks again for your feedback. We're listening! Sincerely, Michelle Consumer Affairs Representative ConAgra Foods
General Mills	Thank you for contacting General Mills with your inquiry. We would like to answer all the questions we receive about our company and our products, but regret we are unable to provide you with the information you requested.

	We appreciate your interest. Sincerely, Darcy Smart Consumer Services
The Hershey Company	Thank you for contacting us about our one of our products. We understand the importance of providing accurate information when responding to your nutrition and health-related questions or concerns. As you are aware, we manufacture a wide variety of products. In addition to some of our products being similar in nature, we also offer many of the same products in a variety of sizes. These factors may impact the information you've requested. Hershey products are all considered trans fat free from the standpoint of the Nutrition Facts panel being 0 grams trans fat except King Size Cookie N Crème bar. We are doing so with other types of fats that do not contain trans fats. Your interest in our company is appreciated. Sherkina Consumer Representative
The J.M. Smuker Co	Thank you for contacting The J.M. Smucker Company. We always enjoy hearing from consumers and are pleased to know you enjoy our products. To answer your question, we are able to provide some additional information regarding **Crisco®** Shortening which was reformulated to offer zero grams trans fat per serving several years ago. When vegetable oil is converted to a solid during hydrogenation, the degree of hydrogenation determines how solid the vegetable oil will become as well as the

	varying amounts of trans fat it will contain. As the vegetable oil continues to be hydrogenated, the amount of trans fat will gradually decrease, and in the case of fully hydrogenated oil, there will be no trans fat remaining. **Crisco®** Shortening includes many of the same ingredients as the previous formula, However, we have reduced the level of the partially hydrogenated soybean oil. This reduction, along with using fully hydrogenated oil has allowed us to achieve zero grams trans fat per serving in accordance with the Food and Drug Administration's regulations. Thank you for taking the time to contact us. If you should have further questions or need additional information, please visit us at www.crisco.com or contact us at 800-766-7309, Monday through Friday, 9:00 a.m. to 7:00 p.m. Eastern Standard Time. Sincerely, Kim Consumer Relations Representative
Kellogg Co	Thank you for your recent email regarding the removal of trans fats in some of our products. We appreciate your interest and are happy to provide the following information. As we are aware of the current health concerns regarding trans fat, our food scientists have been working hard to reduce or replace the partially hydrogenated oils in our products, while retaining the taste and texture you love. While specific methods concerning our recipes are proprietary, for some products we replaced the partially hydrogenated oil with a more solid plant oil such as coconut or palm oil. For products that have not had

	the trans fat completely removed, we currently use an oil blend that provides a very low level of trans fats. You can determine which type of oil is used in our products by referring to the ingredient statement found on all packages. Reformulating recipes isn't simple and we are cautious of any unwanted changes such as loss of crispy texture, change of appearance, and off-flavor in the finished product. We will continue to search for the best blend of ingredients to provide the nutrition you expect, while maintaining the same great tasting you've come to enjoy. To determine if a product will fit into your specific dietary preferences, please visit www.kelloggs.com. Please let us know if we can assist you further by calling 1-800-962-1413. Sincerely, Rebecca A Jimenez Consumer Affairs
Kraft Foods	Thank you for visiting http://www.kraftfoods.com/. I am responding to your questions about Trans Fatty Acid. As part of Kraft's overall Health and Wellness initiatives, we are working to improve the nutrition profile of our product portfolio. This includes a major effort to reduce or, wherever possible, eliminate trans fat from our products, while continuing to meet expectations for taste and quality. Where possible, we are doing this without increasing the combined amount of saturated fat plus trans fat in our products. In addition to our many reduced-fat and fat-free products, we offer a number of products that contain 0 g of trans fat per serving: including cookies, crackers, snacks, cereal, beverages and meat alternatives.

	If you would like to view a full article of how we're working to address trans fat issues in food please visit www.kraftfoods.com and search "TRANS FAT". For more information about food nutrition, visit www.kraftfoods.com and click on Healthy Living. Kim McMiller Associate Director, Consumer Relations
Nestle SA	Dear Ms. Kong, Thank you for contacting Nestlé®. As much as we would like to assist you, the information you requested is not available. We regret that we were not able to fulfill your request. We appreciate your interest and hope you will visit our website often for the latest information on our products and promotions. Tiffany Smith Consumer Response Representative
FritoLay	Thank you for contacting us about the use of trans fats in Frito-Lay snacks. Your concerns are very important to us and we appreciate the opportunity to provide you with some information. Frito-Lay removed trans fats from our snack chips, pretzels and popcorn in 2004 to provide consumers with healthier snack choices. All of our snack chips are cooked in oils without trans fats. In addition, all the snacks in our Lay's®, SunChips® and Tostitos® lines are made with all natural ingredients, no MSG, artificial flavors or "numbered" colors. We've also removed partially-hydrogenated oils from our Grandma's® Cookies and Munchies® Crackers.

	Some of our seasonings may contain trace amounts for partially-hydrogenated oils. Even though the amount is considered dietarily insignificant by the U.S. Food and Drug Administration, we understand consumers would prefer products without these oils. We're working hard to remove them from our seasonings and hope to achieve this milestone soon. In many of our snacks, it has been achieved with the replacement of canola oil. We consider you a valued consumer and hope you will continue to enjoy snacks from Frito-Lay. Best regards, Belinda Frito-Lay Consumer Relations
Quaker Oats	Thank you for contacting us about Quaker Chewy Granola Bars. We understand the presence of hydrogenated oils/trans-fats causes some consumers concern. Our goal is to continue looking for ways to eliminate or reduce trans fats in all of our products over time. For example replaceing partially hydrogenated soy bean oil with soy bean oil. Quaker has always offered nutritious products that are low in fat. The bulk of our products have relatively lower levels of trans fats (0.5 to 1 gram) and we are investigating opportunities to improve these products. Again, Liz, thank you for your interest in our products. Michael Quaker Consumer Relations A Division of PepsiCo
Sara Lee Corporation	Hi it's Christina from Sara Lee!

	This is company proprietary information and we will not be able to share this information. I am sorry for any disappointment this may have caused. Thank you and have a Fabulous Monday! Regards, Christina
Unilever	No response
GFA Brands, Inc (Smart Balance)	No response
Earth Balance	Thank you for taking the time to contact us here at Earth Balance. We always appreciate hearing from consumers who care enough to reach out to us with their comments or questions. The firmness of our spreads is a result of the balancing of fatty acids and the natural character of the blend to avoid hydrogenation. The level of palmitic acid, contained in the palm fruit oil, needed to maintain HDL is sufficient to provide the solids for texture. We use normal spread processing, basically chill and work, with modifications as necessary for the special characteristics of natural oil blends. No gums, starches or gelatins are used. We create a course emulsion (just like oil and vinegar) then we run it through ice cream like mixing equipment that reduces the particle size of the water droplets within the oil phase. This physical processing technique builds viscosity and makes the finished product firm - just like butter or ice cream. We recommend leaving the spread out for a short time, maybe five minutes, to soften. If substrates are warm, such as toast or vegetables, the spread will melt and spread well. You may also try scraping across the surface to get a portion.

	Thank you for supporting Earth Balance® products. We hope you continue to enjoy our products for many years to come! Sincerely, Your Friends at Earth Balance
Schwans	Thank you for contacting us. To best address your concern, you will need to contact a product specialist by calling 1-888-SCHWANS (1-888-724-9267) and asking to be transferred to Consumer Affairs. They are open non-holiday weekdays from 7am until 9pm central time. Please let us know if we can be of further assistance by visiting us at www.schwans.com or calling 1-888-SCHWANS (1-888-724-9267).

Responses from the companies were separated into six categories:

1. Information not available, "proprietary" information, or "trade secret"
2. Fully hydrogenated oils to replaced the partially hydrogenated oils
3. Tropical oils such as coconut, palm, and/or palm fruit oils
4. Oil blends – canola, soybean, and other oils
5. Canola oil
6. Soybean oil

In the first category, many companies acknowledged the concern of trans fatty acids in food products and the importance of good nutrition. ConAgra Foods responded that their soft spreads under Fleischmann's, Parkay and Blue Bonnet are trans fat-free per serving, and "several varieties of [their] Orville Redenbacher's Smart Pop! Gourmet Popping Corn and ACT II 94% Fat Free have 0 grams of trans fat per serving" (Michelle 2012). However, the information requested was considered to be "proprietary and a trade

secret of ConAgra Foods" so they were unable to supply the information. General Mills, Nestle SA, The Hershey Company, and Sara Lee Corporation also responded that they were unable to provide the requested information.

The J.M. Smuker Company replied that they use more fully hydrogenated soybean oil in their Crisco Shortening to lower the trans fat in their products. When vegetable oils are hydrogenated, "the amount of trans fat will gradually decrease, and in the case of fully hydrogenated oil, there will be no trans fat remaining" (Kim 2012). Along with the literature review, full hydrogenation proves to be a useful method in reducing trans fatty acid levels.

Tropical oils such as coconut oil, palm oil, and/or palm fruit oil can be used to replace partially hydrogenated oils. Kellogg Company responded that they have been working on reducing or replacing the partially hydrogenated oils in their products "while retaining the taste and texture you love" (Jimenez 2012). They have replaced the partially hydrogenated oil with a more solid plant oil such as coconut or palm oil. Kellogg Company conceded that reformulating recipes is not easy, and they are "cautious of any unwanted changes such as loss of crispy texture, change of appearance, and off-flavor in the finished product" (Jimenez 2012). Taste and texture appeal is essential along with good health. Earth Balance responded that they use palm fruit oil to avoid hydrogenation. Palmitic acid in the palm fruit oil "is sufficient to provide the solids for texture" (Earth Balance 2012) and needed to maintain HDL. For this, they use normal spread processing (chill and work) without using any gums, starches or gelatins.

Oil blends can be used as well. For Kellogg Co however, oil blends are used when the trans fats have not been completely removed. The oil blend can be found on the ingredients list on products that do contain some trans fats. Earth Balance uses a course emulsion, like oil and vinegar, and "run it through ice cream like mixing equipment that reduces the particle size of the water droplets within the oil phase" (Earth Balance 2012). According to the company, this physical processing technique builds viscosity and makes the finished product firm, just like butter or ice cream.

Categories 5 and 6 contains companies who use other oils, such as canola and soybean, to replace the partially hydrogenated oils in previous products. FritoLay responded that they use canola oil in their snacks, though some of their seasonings may contain traces of trans fats. Quaker Oats responded that they replace partially hydrogenated soybean oil with soybean oil in their Quaker Chewy Granola Bars. The majority of Quaker Oats' products have lower levels of trans fat and they are still looking for opportunities to improve these products.

Limitations of this study include a small sample size and dependence of company response. While some companies did not respond in time, the majority of companies provided information on how they replace partially hydrogenated oils in their food products due to the health concerns of trans fatty acids in the diet. Using fully hydrogenated oils, tropical oils, oil blends, and other vegetable oils are some ways to replace trans fats. However, the companies did not provide information on the ways they process their products, as previously discussed. Implications for future studies such as contacting more food companies about their manufacturing processes and reading food labels in field observation would be relevant.

Conclusions

The concern about trans fatty acids have prompted food companies to use alternative measures in producing their products while keeping the integrity of taste, texture, and what makes these foods desirable for consumption. Companies are going back to traditional oils and fat such as animal fats and vegetable oils as research indicates some of these fats may not be as harmful as previously thought. Tropical oils with high saturated fat content such as coconut, palm, and palm fruit are starting to become more popular food manufacturing oils. The future of food manufacturing processes in the 21st century will be based on the research behind the health implications of these oils as the population strives to achieve a balance between health and food appeal. The next chapter will focus on saturated fats, including tropical oils, and what the future holds for reduced trans fatty acids in food products.

CHAPTER FOUR

Saturated Fats and Tropical Oils – Back to the Future

Americans have shifted eating patterns and habits within the past century due to industrial, agricultural, and social changes. In the early 1900's, obesity did not concern Americans, as they were preoccupied with getting enough food and nutrients. Observed traditional eating habits such as using real butter, lard, and other fats did not seem to correlate with the average weight of Americans during this time. The Great Depression and both world wars resulted in a food supply shortage; therefore this correlation can only be speculated due to Americans not getting enough food in general to become overweight. However, the industrial and agricultural revolution provided access to mass quantities of food as food became more available to consumers. Fast food and shelf stable processed foods became more popular in the middle of the 20th century. Overweight and obesity levels in America also increased during these decades, making the issue more relevant today. The Dietary Guidelines for Americans has made attempts of reducing this problem since 1980, providing dietary guidance on the amount and percentage of the daily intake of fats, carbohydrates, and protein. Advice on eating low fat, low saturated fat, and low cholesterol foods became the trend.

Low-Fat Myth

For the past decades, low fat diets were revered as healthful ways of gaining health and achieving weight loss. By following these trends, food companies "re-engineered thousands of foods to be lower in fat or fat free, often increasing the salt,

sugar, or refined grains in these foods to make up for lost flavor and texture" (Frenk 2012). Along with lowering total fat of food products, the food companies wanted to reduce costs in manufacturing to increase business and make more money.

In the 1960s according to Frenk (2012), "fats and oils supplied Americans with about 45 percent of calories; about 13 percent of adults were obese and under 1 percent had type 2 diabetes." Due to the Dietary Guidelines for Americans and other dietary recommendations, fat intake has decreased to about 33 percent of calories, "yet 34 percent of adults are obese and 11 percent have diabetes, most with type 2 diabetes" (Wright and Wang 2010). However, with the larger portion sizes in restaurants and more available fast food/snack food, more people are overeating and getting in too many calories. Simplistically some say when people reduce fat most of the time, they often switch to high-carbohydrate foods like white bread, white rice, potatoes, and sugary drinks. Fat-free products often replace the fats with sugar and refined carbohydrates to make up for the loss of flavor and taste that fats provide the palate. Eating easily digestible carbohydrates can "raise the risk of heart disease and diabetes as much as – or more than – eating too much saturated fat" (Siri-Tarino et al. 2010).

TABLE 4

Sources of Saturated Fat

Food	Contribution to saturated fat intake (%)
Regular cheese	8.5
Pizza	5.9

Grain-based desserts	5.8
Dairy desserts	5.6
Chicken and chicken mixed dishes	5.5
Sausage, franks, bacon, and ribs	4.9
Burgers	4.4
Mexican mixed dishes	4.1
Beef and beef mixed dishes	4.1
Reduced fat milk	3.9
Pasta and pasta dishes	3.7
Whole milk	3.4
Eggs and egg mixed dishes	3.2
Candy	3.1
Butter	2.9
Potato/corn/other chips	2.4
Nuts/seeds and nut/seed mixed dishes	2.1
Fried white potatoes	2.0

Source: National Cancer Institute. Risk Factor Monitoring and Methods: Table 1. Top Food Sources of Saturated Fat among U.S. Population, 2005–2006. *NHANES*

Contradicting Facts on Saturated Fats

Saturated fats have been criticized as the root cause of many human health problems for many decades. Saturated animal fat is thought to contribute to clog arteries, raise cholesterol levels, and increase risk of atherosclerosis and death from heart disease. However, opposing research on this matter based on data from the famous Framingham study reports that fat in the diet protects against stroke. A few ecological and cohort studies in Asian populations suggest an inverse association of the intake of both fat and saturated fat with risk of stroke (Gillman et al. 1997). In these studies, intakes of fat, saturated fat, and monounsaturated fat were associated with reduced risk of ischemic stroke in men.

In a study by researchers from the Harvard School of Public Health, saturated fat intake was associated with less narrowing of the coronary artery and a reduced progression of disease in postmenopausal women with heart disease (Mozaffarian et al. 2004). Women with lower saturated fat intake had much higher rates of disease progression, even with similar levels of LDL cholesterol. Higher saturated fat intake was also associated with higher HDL and lower triglycerides.

In a cross-sectional survey study from Revonta et al. (2010), health and life style among infertile men and women were studied. Infertile women under 50 years consumed more polyunsaturated fat, less saturated fat, and experienced more hangovers than fertile women. From this study, saturated fat was not the culprit behind health of fertile women, with even an increased correlation between higher saturated fat intake and fertility. However, correlation does not equal causation, as many factors play a part in general health.

In an experiment substituting saturated fat for starch, Hays et al. (2002) found that the addition of saturated fat along with the removal of starch from a starch-restricted and high-monounsaturated fat diet were associated with weight loss and better glycemic control. However, reducing high-glycemic starches in diets in general would be associated with better glycemic control. It is surprising that a high saturated fat diet in this case did not have significant adverse effects on serum lipids.

According to Siri-Tarino et al. (2010), "there is insufficient evidence from prospective epidemiologic studies to conclude that dietary saturated fat is associated with an increased risk of CHD, stroke, or CVD." This does not mean that eating unlimited bacon, butter, and cheese is condoned, just that saturated fat by itself is not the culprit in all these chronic diseases. Eating touted "good fats," such as monounsaturated and omega-3 fatty acids, in place of trans fats and saturated fat can help prevent insulin resistance and cardiovascular heart disease.

Saturated fats became the scapegoat in the fight against obesity as the public shifted the focus on types of fats inducing obesity. According to the Dietary Guidelines for Americans (2010), lowering dietary intake of saturated fats to 7% of total calories can reduce the risk of cardiovascular disease. Food companies started to use hydrogenated and partially hydrogenated oils to 1) reduce saturated fats in the diet and 2) reduce food production costs as the man-made trans fatty acids provided a cheap and efficient way to produce long-lasting food products. However, food manufacturers have started to replace the trans fatty acids in their products back with traditional saturated fats due to the negative research on partially hydrogenated oils on health. Along with re-introducing saturated fats back, tropical oils are getting more attention in displaying health benefits.

Introduction of Coconut Oil

Coconut oil, the oil extracted from the kernel of meat of matured coconuts, has a high saturated fat content as with all tropical oils such as palm oil and palm fruit oil. In general, when coconut oil is mentioned, one associates it with high saturated fat content; therefore it should inevitably raise blood cholesterol and triglycerides. Mainstream knowledge tells Americans to stay away from coconut oil, though recent research indicates the many health benefits of tropical oils.

Coconut oil is widely used in the diets of Pacific Islanders. It has many uses in food, medicine, and industry since it is extremely heat-stable and slow to oxidize due to high saturated fat content.

Properties of Coconut Oil

Food manufacturers like using coconut oil in processing food products. Because it is a solid fat, coconut oil is stable at room temperatures which give products a desirable texture. Saturated fats provide long shelf-lives as they do not go rancid readily. Coconut oil contains medium-chain triglycerides (MCTs), which are more easily digested than longer fatty acids in other oils and fats (Ramirez et al. 2001). Medium-chain triglycerides can be absorbed by the mucous membrane of the small intestine and carried directly to the liver for processing. MCTs are between 6 and 12 carbons and "require less bile salt for solubilizations, are not reesterified in the enterocyte, and are transported as free fatty acids, bound to albumin, through the portal system" (Mahan and Escott-Stump 2008, pg. 57). These fatty acids are not stored in adipose tissue, but instead are oxidized to acetic

acid. Because MCTs are quickly digested, they are used in treatments for people who have steatorrhea, or fat malabsorption resulting in diarrhea.

Along with vitamin E and polyphenols (Marina et al. 2009), MCTs in coconut oil include:

- Caproic: C(6)
- Caprylic: C(8)
- Capric: C(10)
- Lauric: C(12)
- Myristic: C(14)

Instead of using partially hydrogenated oils, research has shown that consuming the medium chain lauric acid has a more favorable pattern of serum lipoproteins along with antiviral, antibacterial, and antiprotozoal functions (de Roos et al. 2001).

Processing of Coconut Oil

Two kinds of coconut oil are available commercially: **copra oil** and virgin **coconut oil (VCO)**. In processing **copra oil**, coconut flesh is dried at high temperatures in a kiln and dissolved with solvents (Grimwood et al. 1975). This production is often unhygienic and requires refining, bleaching, and deodorizing. On the other hand, **virgin coconut oil** is produced from fresh coconut meat at low temperatures and fermented. This manufacturing method is much gentler and does not damage the coconut oil with high heat (Kurian 2007).

Supporting Coconut Oil Research

The benefits of light processed virgin coconut oil have been studied in both laboratory settings and in the field. Including reducing body fat mass, virgin coconut oil is said to increase insulin sensitivity, boost energy levels, increase metabolic rate, and protect against certain diseases. Virgin coconut oil is different than copra oil in processing methods, though the two can sometimes be confused when talking about coconut oil. Research on highly refined coconut oil has been done in the food industry to shine coconut oil in general in an unattractive light. The subsequent research on virgin coconut oil and medium-chain triglycerides provide an alternate view on the benefits of coconut oil.

In a randomized, double-blind, clinical trial involving women taking supplements of either soybean oil or coconut oil, dietetic supplementation with coconut oil did not cause dyslipidemia and even seemed to reduce abdominal obesity (Assunção et al. 2009). Virgin coconut oil also contains biologically active polyphenol components which may potentially lower lipid levels in serum and tissues along with lowering LDL oxidation (KG and Rajamohan 2004). In a follow-up study by KG and Rajamohan (2004), virgin coconut oil "reduced the cholesterol and triglyceride levels and maintained the levels of blood coagulation factors." Virgin coconut oil can possibly prevent LDL oxidation from oxidants, "attributed to the presence of biologically active unsponifiable components *viz.* vitamin E. provitamin A, polyphenols and phytosterols" (KG and Rajamohan 2007).

Research on medium chain fatty acids have been conducted to indicate the health benefits that coconut oil can provide. MCTs "facilitate weight control when included in the diet as a replacement for fats containing [Long-Chain Triglycerides]" (St-Onge and

Jones 2002). These MCT in animal and human studies are readily oxidized which leads to greater energy expenditure. Thus, "MCTs may be considered as agents that aid in the prevention of obesity or potentially stimulate weight loss" (St-Onge et al. 2003). In a study involving olive oil and MCT consumption, the "MCT oil consumption resulted in lower endpoint body weight than did olive oil" (St-Onge and Jones 2008) with greater trunk fat mass loss. As previously noted, the type of dietary fat affects serum cholesterol levels. Studies have indicated that chain length also plays a role in affecting total cholesterol and triglycerides. In a randomized, double-blind crossover study conducted by Norton et al. (2004), "consumption of up to 50% of dietary fat as coconut oil does not significantly alter either total cholesterol or LDL cholesterol in other healthy young men" whereas HDL levels seemed to increase significantly.

In addition to weight control and obesity prevention, medium-chain triglyceride improves cognition "without adversely affecting adrenergic or symptomatic responses to hypoglycemia in intensively treated type 1 diabetic subjects" (Page et al. 2009). Even though the subjects were under hypoglycemic conditions, these MCTs in the study preserved brain function without causing deleterious hyperglycemia. In a previous diabetic study with medium-chain triglycerides conducted by Eckel et al. (1992), MCT-containing diets increased insulin-mediated glucose metabolism in both diabetic patients and non-diabetic patients.

Outside the laboratory setting, two populations of Polynesians living on atolls near the equator were studied to determine the effects of saturated fat and dietary cholesterol on serum cholesterol levels (Prior et al. 1981). The Pukapuka and Tokelau diets are high in saturated fat but low in cholesterol and sucrose. Coconut was determined

to be the major source of energy for both these groups, though Tokelauans had a much higher percentage of coconut intake than the Pukapukans (63% and 34%, respectively). Both groups had a high lauric and myristic acid content, present in coconuts. Even though saturated fat intake is high for these Polynesians, vascular disease is not common in both groups. No evidence from this observational study indicates that a high saturated fat intake has harmful health effects on blood cholesterol or heart disease. Therefore, coconuts and coconut oil intake should not necessarily be automatically associated with certain chronic diseases or obesity.

These studies on coconut oil, virgin coconut oil, medium-chain triglycerides, or coconut in general reveal that a high saturated fat intake from coconuts or tropical oils does not necessarily correlate with the diseases associated with saturated fat, as the media has lead the population to believe. The type of fatty acid along with the length of the fatty acid chains influence how the body reacts and metabolizes the fat. According to Muller et al. (2003), "changing the proportions of dietary fatty acids may be more important than restricting the percentage of total or saturated fat energy, at least when derived mainly from lauric and mystric acids, both of which increase HDL cholesterol."

Putting Research in Perspective – What Does the Future Hold?

Most of the research on coconut oil has been conducted in laboratory settings or using interventions. Though one study can provide appealing data in support of coconut oil benefits, one must be wary of simplifying the research. Americans cannot simply eat pounds of coconut products and expect to suddenly lose weight, lower "bad" cholesterol, raise "good" cholesterol, or be healthier. Coconut oil is not a magical pill that consumers can swallow – moderation is key.

However, the evidence supports coconut oil in replacing partially hydrogenated oils as beneficial to health. Though partially hydrogenated oil is much cheaper to use than coconut oil, consumers' demands of lowering and eliminating trans fatty acids in food products have sparked the reversal for food manufacturers to go back to using the same oils that partially hydrogenated oils were made to replace. Because coconut oil is highly saturated, it is an excellent processing oil to use in shelf-stable food products without easily going rancid. The consumer's role now is to recognize the importance of good nutrition and to eat whole foods, not man-made processed fats. Many fad diets and food trends exist in society today over-condemning certain fats. More research would be beneficial in the future on the types of fats, degree of saturation, and carbon-chain length of fatty acids rather than grouping certain kinds of fats as harmful to health.

REFERENCES

Allison, D.B., Egan, S.K., Barraj, L.M., Caughman, C., Infante, M., Heimbach, J.T. (1999). Estimated intakes of trans fatty and other fatty acids in the U.S. population. *Journal of the American Dietetic Association.* 99:166-74.

Alonso, L., Fontecha, J., Lozada, L., Fraga, M.J., Juárez, M. (1999). Fatty acid composition of caprine milk: major, branched-chain, and trans fatty acids. *Journal of Dairy Science.* 82(5): 878-884.

American Heart Association, Inc. (2010). Good vs. Bad Cholesterol. Conditions > Cholesterol.http://www.heart.org/HEARTORG/Conditions/Cholesterol/AboutCholesterol/Good-vs-Bad Cholesterol_UCM_305561_Article.jsp#.T0lRabyF9CA

Assunção, M.L et al. (2009). Effects of dietary coconut oil on the biochemical and anthropometric profiles of women presenting abdominal obesity. *Lipids*. 44(7):593-601. http://pmid.us/19437058.

Ascherio, A., Katan, M.B., Zock, P.L., Stampfer, M.J., Willett, W.C. (1999). Trans Fatty acids and coronary heart disease. *The New England Journal of Medicine.* 340:1994–1998.

Baker, C.G.J., Ranken, H.D., Kill, R.C. (1997). *Food industries manual.* 24th Edition. Springer. 285-289.

Boehl, T. (2007). Emerging science raises questions: what to tell your clients about nutritional genomics. *Journal of the American Dietetic Association,* 107 (7): 1094-1096.

Claek, Jim. (2009). The hydrogenation of alkenes: margarine manufacture. *Chemguide: Helping you to understand Chemistry*.

Davis, C. A., Saltos, E. A. (1996). The Dietary Guidelines for Americans – past, present, future. *Family Economics and Nutrition Review,* 9(2): 4-13.

de Roos, N., Schouten, E., Katan, M. (2001). Consumption of a solid fat rich in lauric acid results in a more favorable serum lipid profile in healthy men and women than consumption of a solid fat rich in trans fatty acids. *Journal of Nutrition*. 131(2):242-5.

Eckel, R.H., Hanson, A.S., Chen, A.Y., Berman, J.N., Yost, T.J., Brass, E.P. (1992). Dietary substitution of medium-chain triglycerides improves insulin-mediated

glucose metabolism in NIDDM subjects. *Diabetes, 41 (*5), 641-647. http://www.ncbi.nlm.nih.gov/pubmed/1568535

Ferguson, L. R. (2009). Nutrigenomics approaches to functional foods. *Journal of the American Dietetic Association*, 109(3):452-458.

Frenk, D.F. (2012). Fats and Cholesterol: Out With the Bad, In with the Good. *Havard School of Public Health*. The Nutrition Source > What Should I Eat? http://www.hsph.harvard.edu/nutritionsource/what-should-you-eat/fats-full-story/index.html.

Frenk, D.J. (2012). Shinning the Spotlight on Trans Fats. *Harvard School of Public Health*. The Nutrition Source > Nutrition in the News. http://www.hsph.harvard.edu/nutritionsource/nutrition-news/transfats/.

Gillman, M.W., Cupples, L.A., Millen, B.E., Ellison, R.C., Wolf, P.A. (1997). Inverse association of dietary fat with development of ischemic stroke in men. *The Journal of the American Medical Association*. 278 (24): 2145-2150.

Grimwood, B.E., Ashman, F., Dendy, D.A.V., Jarman, C.G., Little, E.C.S., Timmins, W.H. (1975). *Coconut Palm Products – Their processing in developing countries*. Rome: FAO. pp. 49–56.

Hays, J.H., Gorman, R.T., Shakir, K.M. (2002). Results of use of metformin and replacement of starch with saturated fat in diets of patients with type 2 diabetes. *Endocrinology Practice, 8* (3), 177-83. http://www.ncbi.nlm.nih.gov/pubmed/12113629?dopt=Abstract

Hidden Diabetes Cure. (2005). Cure Diabetes Naturally, Don't Just Treat it With Drugs. http://www.hidden-diabetes-cures.com/fats-and-oils.htm.

Hu, F.B., Stampfer, M.J., Manson, J.E., Rimm, E., Colditz, G.A., Rosner, B.A. (1997). Dietary fat intake and the risk of coronary heart disease in women. *The New England Journal of Medicine.* 337:1491–1499.

KG, N., Rajamohan, T. (2004). Beneficial effects of virgin coconut oil on lipid parameters and in vitro LDL oxidation. *Clinical Biochemistry, 37* (9), 830-835. http://www.ncbi.nlm.nih.gov/pubmed/15329324

KG, N., Rajamohan, T. (2007). Influence of virgin coconut oil on blood coagulation factors, lipid levels and LDL oxidation in cholesterol fed Sprague-Dawley rats. *The European e-Journal of Clinical Nutrition and Metabolism, 3* (1), e1-e8.

Kurian, Peter, K.V. (2007).*Commercial Crops Technology: Vol.08. Horticulture Science Series*. New India Publishing. pp. 202–6.

Lichtenstein, A.H. (1997). Trans fatty acids, plasma lipid levels, and risk of developing cardiovascular disease. *Circulation*. 95: 2588-2590.

Lichtenstein, A.H. (2011). The great fat debate: the importance of message translation. *American Dietetic Association,* 111(5): 672-5.

Little, T.J., et al. (2005). Dose-related effects of lauric acid on antropyloroduodenal motility, gastrointestinal hormone release, appetite, and energy intake in healthy men. *American Journal of Physiology – Regulatory, Integrative, and Comparative Physiology*. 289(4):1090-8.

Mahan, L. K., Escott-Stump, S. (2008). *Krause's Food & Nutrition Therapy, 12e*. St. Louis, Mi: Saunders Elsevier.

Marina, A.M., Man, Y.B., Nazimah, S.A., Amin, I. (2009). Antioxidant capacity and phenolic acids of virgin coconut oil. *International Journal of Food Sciences and Nutrition.* 60 Suppl 2:114-23.

McWilliams, M. (2008). *Experimental Perspectives, 6e*. Upper Saddle River, New Jersey: Pearson Prentice Hall.

Mozaffarian, D., Rimm, E.B., Herrington, D.M. (2004). Dietary fats, carbohydrate, and progression of coronary atherosclerosis in postmenopausal women. *The American Journal of Clinical Nutrition*. 80:1175-1184.

Mozaffarian, D., Katan, M.B., Ascherio, A., Stampfer, M.J., Willett, W.C. (2006). Trans fatty acids and cardiovascular disease. *The New England Journal of Medicine.* 354:1601–1613.

Mozaffarian, D., Jacobson, MF., Greenstein, JS. (2010). Food reformulations to reduce trans fatty acids. *The New England Journal of Medicine*. 362:2037-9.

Muller, H., Lindman, A.S., Branstaeter, A.L., Pedersen, J.I. (2003). The serum LDL/HDL cholesterol ratio is influenced more favorably by exchanging saturated with unsaturated fat than by reducing saturated fat in the diet of women. *The American Society for Nutritional Sciences, 133* 78-83. http://jn.nutrition.org/content/133/1/78.full

National Cancer Institute. Risk Factor Monitoring and Methods: Table 1. Top Food Sources of Saturated Fata among U.S. Population, 2005–2006. *NHANES*

Niu, S., Mitchell, DC, Litman, BJ. (2005). Trans fatty acid derived phospholipids show increased membrane cholesterol and reduced receptor activation as compared to their cis analogs. *Biochemistry*. 44(11): 4458-4465.

Norton, D., Angerman, S., Istfan, N., Lopes, S.M., Babayyan, V.K., Putz, M.C., Steen, S.N., Blackburn, G.L. (2004). Comparative Study of Coconut Oil, Soybean Oil, and Hydrogenated Soybean Oil. *PJCS, 29* (1 and 2). http://simplycoconut.com/Comparative%20Study.pdf

Page, K.A., Williamson, A., Yu, N., McNay, E.C., Dzuira, J., McCrimmon, R.J., Sherwin, R.S. (2009). Medium-chain fatty acids improve cognitive function in

intensively treated type 1 diabetic patients and support in vitro synaptic transmission during acute hypoglycemia. *Diabetes, 58* (5), 1237-1244. http://www.ncbi.nlm.nih.gov/pubmed/19223595

Page, L., Phipard, E. F. (1956). Essentials of an Adequate Diet… Facts for Nutrition Programs. *U.S. Department of Agriculture.*

Prior, I.A., Davidson, F., Salmond, C.E., Czochanska, Z. (1981). Cholesterol, coconuts, and diet on Polynesian atolls: a natural experiment: the Pukapuka and Tokelau island studies. http://www.ncbi.nlm.nih.gov/pubmed/7270479

Ramírez, M., Amate, L., Gil, A. (2001). Absorption and distribution of dietary fatty acids from different sources. *Early Hum Development.* 65 Suppl:S95-S101.

Remig, V., Franklin, B., Margolis, S., Kostas, G., Nece, T., Street, J. (2010). Trans Fat in America: A Review of Their Use, Consumption, Health Implications, and Regulation. *Journal of the American Dietetic Association.* 110 (4): 585-592.

Revonta, M., Raitanen, J., Sihvo, S., Koponen, P., Klemetti, R., Mannisto, S., Luoto, R. (2010). Health and life style among infertile men and women. *Sexual & Reproductive Healthcare,* 1 (3): 91-98. http://www.ncbi.nlm.nih.gov/pubmed/21122604?dopt=AbstractPlus

Simopoulos, A.P. (2008). The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. *Experimental Biology and Medicine (Maywood)*. 233:674–688.

Siri-Tarino, P.W., Sun, Q., Hu, F.B., Krauss, R.M. (2010). Meta-analysis of prospective cohort studies evaluating the association of saturated fat with cardiovascular disease. *The American Journal of Clinical Nutrition.* 91:535-46.

St-Onge, M.P., Jones, P. (2002). Physiological Effects of Medium-Chain Triglycerides: Potetential Agents in the Prevention of Obesity. *The American Society for Nutritional Sciences. J. Nutr., 132,* 329-332. http://jn.nutrition.org/content/132/3/329.abstract

St-Onge, M.P., Ross, R., Parsons, W.D., Jones, P.J.. (2003). Medium-chain triglycerides increase energy expenditure and decrease adiposity in overweight men. *Obesity Research, 11* (3), 395-402. http://www.ncbi.nlm.nih.gov/pubmed/12634436?dopt=Abstract

St-Onge, M.P., Bosarge, Aubrey. (2008). Weight-loss diet that includes consumption of medium-chain triacylglycerol oil leads to a greater rate of weight and fat mass loss than does olive oil. *The American Journal of Clinical Nutrition, 87* (3), 621-626. http://www.ajcn.org/content/87/3/621.abstract

Strychar, R., Ishac, A., Rivard, M., Lussier-Cacan, S. (2003). Impact of a high-monounstaurated-fat diet on lipid profile in subjects with type 1 diabetes. *Journal of the American Dietetic Association*. 104, (4): 467-474.

Sundram, K., Hayes, K.C. , Siru, O.H. (1995). Both dietary 18:2 and 16:0 may be required to improve the serum LDL/HDL cholesterol ratio in normocholesterolemic men. *The Journal of Nutritional Biochemistry*. 6: 179-187.

Turpeinen, A.M., Mutanen M., Aro, A., Salminen, I., Basu, S., Palmquist, D.L., Griinari, J.M. (2002). Bioconversion of vaccenic acid to conjugated linoleic acid in humans. *American Society for Clinical Nutrition.*76(3): 504-510.

U. S. Department of Agriculture, Science and Education Administration. (1979). Food. *Home and Garden Bulletin,* 228:64.

U.S. Department of Agriculture, U.S. Department of Health and Human Services. (2011). *Dietary Guidelines for Americans, 2010*. www.dietaryguidelines.gov.

Vesper, H.W., Kuiper, H.C., Mirel, L.B., Johnson, C.L., Pirkle, J.L. (2012). Levels of plasma trans fatty acids in non-Hispanic white adults in the United States in 2000 and 2009. *The Journal of the American Medical Association.* 307:562-3.

Wright, J.D., Wang, C.Y. (2010). Trends in intake of energy and macronutrients in adults from 1999-2000 through 2007-2008. Hyattsville, MD: National Center for Health Statistics.