Dietary Trans Fatty Acids: Impact on Serum Lipoproteins and Coronary Heart Disease

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Abstract

Recently, there has been considerable concern on the atherogenic potential of Trans Fatty Acids (TFA) present in food products produced with hydrogenated vegetable and marine oils. Hydrogenated fats containing TFAs are harmful for heart. Health authorities and Food regulatory agencies across the world, including WHO and FAO, have suggested food manufacturers to lower TFA content in their food products and called for a mandatory food labeling on packs for consumer information and protection.

Introduction

Occlusive arterial disease of the heart, called Coronary Heart Disease (CHD) is very common in the developed countries and is the single most common cause of premature death. Its incidence is increasing rapidly and in an alarming fashion in the underdeveloped and developing countries also. CHD has a multifactorial etiology, among which dyslipidemias are well explained. Dietary lipid, frequently resulting from faulty dietary habits, plays a very important role in causing dyslipidemias and consequently CHD. Role of saturated animal fat and cholesterol in inviting an unfavorable lipoprotein profile and that of unsaturated vegetable oil, a favorable lipoprotein profile is well accepted. Recently, there has been considerable concern on the atherogenic potential of Trans Fatty Acids (TFA) present in food products produced with hydrogenated vegetable and marine oils. The negative impact of TFAs on cardiovascular system has been highlighted only during the last two decades. In 1990s, several studies around the world concluded that hydrogenated fats containing TFAs are harmful for heart. Health authorities and Food regulatory agencies across the world, including WHO and FAO, have suggested food manufacturers to lower TFA content in their food products and called for a mandatory food labeling on packs for consumer information and protection.

Trans Fatty Acids

Unsaturated fatty acids exhibit geometric isomerism on the orientation of atoms or groups around its double bond axis. Atoms or acyl groups, present on the same side of the double bond forms a cis-configuration, whereas those present on the opposite side of the double bond forms a trans-configuration. Oleic acid is a cis isomer while Elaidic acid is a trans isomer (Fig 1). Trans fatty acids are a group of “deviant” fatty acids with the bulk of its members occurring as the $\Delta^{9,11}$ isomers of Elaidic acid. Dietary TFAs come from two main sources. Firstly, through fermentation by bacteria in the gut of ruminants with TFA appearing in the milk and dairy products
(milk, butter, cheese etc.). Secondly, during commercial hardening, by partial hydrogenation of edible liquid (vegetable) oils, for enhancement of product shelf-life (stabilizes the oil and prevents rancidity) or for use by the food industries in solid-fat applications such as in margarines, vegetable ghee, Vanaspati (dalda), shortenings, confectionary fats etc., and as frying media for fast foods items.

**TFAs, Atherosclerosis and CHD**

Occlusion of coronary arteries usually occurs due to atherosclerosis and it’s complications. Though some basic characteristics of atherosclerosis are still poorly understood, it is well accepted that some generalized risk factors like, smoking, obesity, blood lipid disorders, hypertension, faulty dietary habits, insulin resistance, dietary deficiency of antioxidants, physical inactivity, lifestyle etc.\(^1,2\) predispose to it’s development. However, among these risk factors abnormalities of plasma lipoprotein and derangements in lipid metabolism are more firmly established and best understood risk factors for atherosclerosis. Thus, hypercholesterolemia and other abnormalities in lipid metabolism contribute a major risk factor in atherosclerosis as well as CHD.

Almost all lipoprotein disorders or dyslipidemias (hyperlipidemia) result from a complex interaction between genetic predisposition and dietary indiscretion\(^7\). Diets rich in cholesterol and saturated fats (mostly animal) tend to raise serum Total Cholesterol (TC) and Low Density Lipoprotein-Cholesterol (LDL-C). Conversely, a diet low in cholesterol and low in the ratio of saturated-to-polyunsaturated fats lower plasma cholesterol level. Thus, dietary modification remains the first line management of primary hyperlipidemia. Often, intake of SFA is discouraged and that of unsaturated fat (UFA) is encouraged, by doctors. But, probably none of the advices is complete because not all SFAs are hypercholesterolemic and atherogenic. For example, palmitic acid (16:0) and stearic acid (18:0), comprising respectively 90% and 10% of total SFAs in palm oil, are neutral and does not elevate blood cholesterol level\(^4,5,6,7,8\). Although it has been established that dietary SFAs tend to raise serum cholesterol levels, studies suggest that palm oil, despite a high concentration of SFAs (mainly palmitic acid), is not hypercholesterolemic and is an exception to this general concept.\(^9,10,11\)

In fact, the position of SFA and UFA in triglyceride (TG) backbone of the fat molecule dictates the hypercholesterolemic nature of the fat\(^12,13,14,15\). In palm oil 75% of UFA chains are found at second carbon atom position of the TG backbone molecule\(^16,17\) and this could explain the non-hypercholesterolemic and non-atherogenic effects of palm oil.

![Figure 1: Estimated Per Capita TFA Consumption in Some Countries.](image)

![Figure 2: Effects of high-trans diet and low-trans diet on serum lipids and lipoproteins.](image)

On the other hand excessive consumption of UFAs, in comparison to SFAs, may result in increased susceptibility of body lipids being oxidized (lipid peroxidation) by the highly reactive free oxygen radicals. Lipid peroxidation, in turn,
may increase the risk of cell membrane damage as well as accumulation of oxidized LDL (oLDL) particles in the sub-endothelial layer of blood vessels – a step in the genesis of atherosclerosis.

Figure 3: Effects of palm diet and trans-diet on serum lipoproteins relative to PUFA-diet

Now, another deviant fatty acid species, Trans Fatty Acids, have emerged as a new cholesterolemic ‘villain’ in the field of dietary fats and have been blacklisted by medical and health professionals as contributing to coronary heart disease (CHD). In fact, TFAs have been slowly climbing to the top of infamous list of dietary fats that put us at the risk of heart attack. Though there were some dispute about the significance of TFAs in human nutrition (especially concerning their negative impact on serum lipoprotein profile enhancing atherogenesis), several studies clearly demonstrate that dietary TFAs, relative to their cis isomers, can deleteriously affect serum lipid profile by increasing LDL, decreasing HDL and raising atherogenic lipoprotein (a) \[\text{Lp(a)}\]. In earlier studies comparison were made considering metabolic effect of exchanging trans 18:1 for cis 18:1 and not SFAs. Later Judd et al (1994) included a saturated fat comparison. His study revealed that SFA raised LDL-C similar to that found with 7% energy from trans, but TFA decreased HDL-C as well. In a Norwegian study butter was used as a saturated fat control for comparison with partially hydrogenated soybean oil (PHSBO) or fish oil (PHFO), where both trans preparations elevated Lp(a), butter diet group being intermediate between the PHSBO and PHFO.

Professor Scott Grundy, in his paper, commented like this – “there is convincing evidence that trans fatty acids definitely raise LDL-C levels, in a manner similar to that of the cholesterol raising SFA.” A Dutch study concluded, “the effect of trans-fatty acids; it increases the ‘bad’ LDL-cholesterol level and lower the HDL-cholesterol level.” Professor Walter C Willett and Dr Albert Ascherio (members of the Harvard University Department of Nutrition and Epidemiology) reviewed the growing science on TFAs and CHD in May 1994 and concluded: “Although the percentage of coronary heart disease deaths in the United States attributable to intake of trans fatty acids is uncertain, even the lower estimates from the effects on blood lipids would suggest that more than 30,000 deaths per year may be due to consumption of partially hydrogenated vegetable fat. Further, the number of attributable cases of non-fatal coronary heart disease will be even larger.

Sundram et al., in his study, compared the effects of TFAs with specific SFAs on human lipoprotein profile among the Malaysian population. Finding show an elevation of total plasma cholesterol (TC) with trans-rich diet in comparison to cis 18:1-rich and 16:0-rich diets but similar TC level was found for the trans-rich and 12:0 + 14:0-rich diets. LDL-C was slightly higher during trans intake. A marked reduction in HDL-C was noted during trans consumption, which was significantly lower than cis 18:1 or 16:0 diets. These data affirm a striking difference between the effects of SFAs and TFAs on human lipid profile i.e., TFA depress HDL whereas SFA typically increase HDL along with a rise in LDL.

In addition to the deleterious effects of TFAs on CHD, much interest has been focused on the effects of TFAs on metabolism of essential fatty acids (EFA), all-cis linoleic acid (LA, 18:2n-6) and α-linolenic acid (ALA, 18:3n-3), which are vital to fetal growth and development. TFAs
consumption by pregnant women may impair uptake of these EFAs by the fetus. TFAs may also affect the metabolism of EFAs of the fetus resulting in poor development of the fetal organs and tissues. There is increasing evidence that breast milk of lactating mother, who habitually consume food products containing partially hydrogenated fats, contain significant amount of TFAs. Studies revealed that in human breast milk TFA content is inversely related with the concentration of all-cis LA ALA (displacement of these EFAs by TFAs). This FA profile of breast milk of TFA consuming mothers is supposed to affect infant growth and development, adversely. Findings of two European studies showed that there exists significant associations between low birth weights (LBW) and TFA level in blood.29,30,31

Another five-center Euramic study suggested of an association between TFAs and increasing breast cancer risk in postmenopausal women. A high trans content was found associated with a 40% increase in breast cancer risk.32

Explanation for the rise in LDL/HDL ratio, with TFA diet, is still not well explored. But this has been attributed to increased cholesteryl ester transfer protein (CETP) activity, i.e., enhanced transfer of cholesteryl ester (CE) from HDL to lower density lipoproteins, including LDL. A 10% rise in CETP was noted during hydrogenated fat based margarine consumption.50 A diet, which increases LDL/HDL ratio (especially by increasing the absolute pool of LDL), predisposes CHD risk. This is not only from LDL deposition in arteries but also from a negative effect of elevated LDL/HDL ratio on platelet aggregation and thrombogenesis, an exceedingly deleterious aspect of atherogenesis.32,33 Also there is an unhealthy link between TFA intake and the Tumor Necrosis Factor (TNF) system which activates systemic inflammation.

Conclusion
TFAs are harmful for the heart in the way that they raise LDL level, LDL/HDL ratio (atherogenic effect) as well as Lp (a) and at the same time lower protective HDL to the extent much more than that done by SFAs. TFAs also displace EFAs in human milk affecting infant growth and development. Therefore, foods containing hardened or hydrogenated vegetable and fish oils like margarines, vegetable ghee, confectionary fats etc. prepared from hydrogenated edible oils should be avoided.

References


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