Trans Fatty Acids : Their Dietary and Health Implications

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The hydrogenation of edible oils and fats has been a well accepted processing technique since 1940s. Its importance can be related to the economic significance of the process. In the United States alone of the nearly 4.54 million tonnes of visible fats and oils consumed annually, almost 2.72 million tonnes (60%) are subjected to partial hydrogenation. The importance of this processing is further underscored when it is recognized that soyabean oil provides about 60% of the total visible fat in the American diet.

Hydrogenation converts the liquid oils to a semi-solid form, primarily by the addition of hydrogen directly to the unsaturation in the fatty acids. This helps to increase the stability of the fat or oil, protecting it against oxidative rancidity and most importantly enabling the use of liquid oils in the formulation of margarines, shortenings, bakery and frying fats.

As a result of hydrogenation, fatty acids including oleic (18:1), linoleic (18:2) and linolenic (18:3) are isomerized either as geometrical or positional isomeric fatty acids which are generally referred to as *trans* fatty acids. For example, unsaturated fatty acids exist as the *cis* isomer in the natural state but are configured as *trans* isomers following hydrogenation. Elaidic and oleic acids are geometric isomers: in the former the double bond is in the *trans* configuration while in the latter, it is in the *cis* configuration. Similarly, positional isomerization of fatty acids also occur. Obviously, the number of isomers increases with the number of double bonds in the fatty acid chain. Common examples of such isomers include *cis-cis, cis-trans, trans-cis* and *trans-trans*. These geometrical isomers have the effect of altering the melting point of the fatty acid and this property is clearly demonstrated in the case of C18:1. Oleic acid (*cis*) is a liquid at temperatures lower than room temperature whereas elaidic acid (*trans*) is a solid even at temperatures above the room temperature. Hence hydrogenated liquid (monounsaturated and/or polyunsaturated) oils used in many food formulations are able to exhibit the physical characteristics of a solid fat because of the higher melting point of the *trans* fatty acids which contribute substantially to the solid-fat content of the finished product.

Formulations containing hydrogenated products have long been accepted by the food industry as means to further enhance the otherwise limited applications of liquid polyunsaturated oils which are prone to oxidative rancidity and even cyclic polymerization when heated. Unlike the saturated fats, hydrogenated oils and fats have not been plagued by the cholesterol-heart disease controversy. Nevertheless, there has always been a nagging concern about the true efficacy of *trans* acids in the human diet. Dr. L.S. de Villers aptly summarizes these thoughts: he pondered that had hydrogenated fats been exposed to the same criteria of testing as pharmaceutical products or even saturated fats, they would never have been allowed on the market in the first instance. Let us review some of the nutritional studies on trans fatty acids.

Animal studies indicate that *trans* fatty acids do not exert deleterious effects on growth when fed together with other fats. However, in the presence of essential fatty acid deficiency, *trans* fatty acids can aggravate the condition since the essential fatty acid activity is strictly confined to the *cis* isomers of linoleic (C18:2 n-6) and linolenic (C18:3 n-3) fatty acids. From rat studies it is also evident that the increased ingestion of hydrogenated vegetable oils can alter blood and tissue lipid levels and ultimately cause altered tissue and enzymatic functions. For these reasons the consumption of *trans* fatty acids must always be accompanied by adequate amounts of essential fatty acids.

In the past there have been several controlled human feeding trials that evaluated the effects of fats containing *trans* or isomeric fatty acids fed to groups of subjects and then measuring blood lipid levels, primarily serum cholesterol. Emken (1979) summarized the results from 14 such studies with hydrogenated oils (*Table 1*). In general, the majority of these studies suggested that hydrogenated oils caused an increase in plasma lipid levels, especially those of serum cholesterol. Surprisingly, however, the authors concluded that these increases were moderate and even normal. They even diluted these findings by suggesting that hydrogenated fats such as those found in margarines normally have a lipid lowering effect compared to highly saturated fats such as butter and coconut oil.

Fortunately, for the general public, there appears to be a renewed desire to re-examine the nutritional properties of hydrogenated fats. This has also been facilitated by newer analytical tools that can provide greater clarity in understanding *trans* fatty acids. For example, Dr. Scott Grundy, a highly respected lipid nutritionist now acknowledges that *trans* fatty acids may not be entirely harmless to health while others like Drs. Kummerow and Holub advocate that *trans* fatty acids should be quantitatively labelled so as not to mislead the consumers.

The study of Mensink and Katan (1990) is largely credited for turning the tide against hydrogenated fats and oils. In this study, subjects were randomly allocated to consume diets containing 10 energy percent as natural monounsaturated fat (18:1), saturated fat or *trans* fatty acids (mainly elaidic acid). The *trans* diet not only increased LDL-cholesterol and serum cholesterol, but also decreased HDL-cholesterol. As a result the important atherogenic ratio of total cholesterol: HDL-cholesterol was significantly increased on the *trans* diet compared to both the monounsaturated and saturated diets. The net result of this study indicated, quite convincingly that *trans* fatty acids may detrimentally alter these cardiovascular risk factors.

Subsequently studies by Nestel *et al.* (1992), Zock *et al.* (1992) and Wood *et al.* (1993) also provided similar results associating *trans* fatty acids with increased LDL-cholesterol levels and decreased HDL-levels. In the Wood study, a 29% *trans* fatty acid diet (hard margarine) additionally caused a decrease in apolipoprotein AI and B levels.

TABLE 1. SUMMARY OF HUMAN STUDIES EVALUATING EFFECT OF TRANS FATTY ACIDS ON SERUM LIPID LEVELS

Hydrogenated oil or isomeric fatty acid		Change in Serum Level		
		Triglyceride	Phospholipid	Cholesterol
1.	Peanut	N.D.	N.D.	Increase
2.	Cottonseed	Increase	Increase	Increase
3.	Corn	Increase	Increase	Increase
4.	Corn	N.D.	N.D.	Increase
5.	Corn	Increase	Increase	Increase
6.	Sunflower	Increase	No change	Increase
7.	Margarine (6 brands)	N.D.	N.D.	No change
8.	Soyabean	No change	No change	No change
9.	Soyabean	N.D.	N.D.	No change
10.	Soyabean	No change	No Change	No change
11.	*t, t-* and *c, t-* 18:2	Increase	N.D.	Increase
12.	44% *trans* acids	No change	N.D.	No change
13.	34% Elaidic acid	N.D.	N.D.	Increase
14.	37% Elaidic acid	N.D.	N.D.	Increase

* N.D. : Not determined

Adapted from E.A. Emken. Utilization and effects of isomeric fatty acids in Humans. In Geometrical and Positional Fatty Acid Isomers Ed. E.A. Emken and H.J. Dutton. American Oil Chemists' Society 1979.

One of the factors that had long persuaded both legislators and researchers not to make recommendations against *trans* fatty acids was the perception that its actual consumption levels were very low. *Trans* isomers are estimated to constitute only 5%-6% of the dietary fat consumed in the USA but the actual proportion varies depending on the food choice. Food products can contain between 5%-30% or more of these isomeric fatty acids. The findings of Willet *et al.* (1993) published recently in the Lancet, provides a new insight into this fallacy. They calculated the *trans* fatty acid intake from dietary questionnaires completed by 85 095 healthy women. They found that *trans* fatty acids consumption was directly related to risk of coronary heart disease and this association was especially significant in 69 181 women who consumed margarines during the past 10 years. Foods containing *trans* isomers including cookies, biscuits, cakes and white bread were all significantly associated with higher coronary heart disease (CHD) risk.

Animal studies had previously indicated that *trans* acids may alter certain enzyme functions independent of its effects on serum and lipoprotein lipids. There is already mounting evidence suggesting that *trans* fatty acids can modify lipoprotein Lp(a) levels in humans. Lipoprotein Lp(a) is a very powerful and independent risk factor for ischaemic heart disease. The circulating level of Lp(a) is primarily under genetic control and attempts to modify it by drugs or diet have not been very successful. Recently it was shown that the replacement of the habitual fat in a European type (Dutch) diet by palm oil resulted in a significant decrease in serum Lp(a) levels (Hornstra *et al.* 1991). Subsequently at least two independent groups of researchers in the Netherlands (Mensink *et al.* 1992) and Australia (Nestel *et al.* 1992) have shown that diets high in *trans* fatty acids increase serum levels of Lp(a). This finding coupled with the ability of hydrogenated fats to detrimentally modify serum LDL and HDL cholesterol and their relevant ratios suggests that alternate substitutes for *trans* fatty acids must be found.

Can manufacturers formulate margarines, shortenings or bakery fats containing zero-trans? The most obvious answer lies in the use of palm oil and its fractions in these food formulations. At least in Malaysia, the above mentioned food products are manufactured with little or no *trans* fatty acids content. Obviously, the consumer must be assured of the nutritional efficacy of substituting palm oil (high in palmitic acid) for *trans* fatty acids. There is presently an emerging body of evidence that palmitic acid, the major saturated fatty acid in palm oil, does not raise blood cholesterol levels, more so in the absence of myristic acid and high dietary cholesterol intake (Sundram *et al.* 1993). We are optimistic that palm oil will be shown to be a highly desirable and nutritious edible oil and will be increasingly used as a replacement for hydrogenated oils containing *trans* fatty acids in a wide variety of food formulation.

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● *from page 20: Combined Sterilization-Stripping Process*

PALM OIL MILLING PROCESS BASED ON COMBINED STERILIZATION-STRIPPING

Figure 4 shows how the combined sterilization-stripping process concept has been incorporated into the Prototype Automated Palm Oil Mill. Fresh fruit bunch reception comprises a bunch feeder discharging into a bucket type elevator. The feeder is supported on load cells and the weight of the FFB on the feeder is automatically recorded. The weight of FFB processed is also computed. The elevator is fitted with TV cameras at its based and discharge to provide remote viewing in the central control room. There is also a bunch counter which automatically stops the elevator when a predetermined number of bunches have been discharged into the inlet hopper of the pre-sterilizer. It restarts the elevator when the bunches in the inlet hopper have been discharged into the pre-sterilizer and the upper valve is closed.

The sterilization process itself is carried out in two stages. The first stage involves simply heating up the bunches in the pre-sterilizer. At the entrance and the exit of the pre-sterilizer are specially designed piston-type valves. Steam for the pre-sterilizer comes from the sterilizer-cum-stripper. The capacity of the pre-sterilizer is much less than the sterilizer-cum-stripper; hence, there is no significant drawdown in the steam pressure in the sterilizer-cum-stripper when the pre-sterilizer is charged with steam. By sequencing the opening and closing of the upper inlet valve and the lower inlet valve, it is possible to achieve a semi-continuous flow of bunches through the system. The pre-sterilizer can be programmed for a series of automatic operations including vacuum followed by positive steam pressure. The condensate is also drained off automatically.

The second stage of sterilization takes place in the sterilizer-cum-stripper. This is automatically fed by gravity from the pre-sterilizer and consists of a conventional stripper drum rotating in a pressure vessel. Its working pressure can be controlled from 5 to 50 psig and the speed of the stripper drum varied from about 1 to 4 rpm.

The stripped fruits are passed to a digester which consists of a horizontal vessel fitted with two rotating paddle type shafts running parallel to each other. The inlet is connected via a valve to the sterilizer and likewise the outlet via a valve to the screw press.