— **Minireview** —

Trans Fatty Acids: Properties, Benefits and Risks

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Trans fatty acids have several beneficial aspects for processed foods owing to their characteristic structures. These very characteristic structures, in turn, have been suspected to be associated with the possibility that *trans* fatty acids affect the development of several health problems, including coronary heart disease, and fetal and infant neurodevelopment and growth, and childhood allergies.

Key words —— *trans* fatty acids, dietary intake, coronary heart disease, metabolism, epidemiology, labeling

INTRODUCTION

Lifestyle improvements are fundamental in addressing the health problems of many advanced countries, including Japan. Especially in the United States, where, unlike Japan, heart disease is the leading cause of death, control of the risk factors for cardiovascular disease has been a major factor in disease prevention activities. Although the relationship between fat intake and cancer are inconclusive and still under investigation, dietary fats have received more attention from health professionals and the public than any other nutrient in the food supply. Not only the quantity, but also the quality of dietary fat has been studied in relation to the development of coronary heart disease in European countries and America. In the present article, I review papers concerning *trans* fatty acids associated with the structures, metabolic studies and epidemiological investigations which support a connection with heart disease. Recently, the Food and Drug Administration (FDA) proposed to amend its regulations on nutrition labeling to require that the amount of *trans* fatty acid in a food be included in the Nutrition Facts panel. It is also noteworthy that the term *trans* fatty acid appeared for the first time in the 5th edition of the Standard Tables of Food Composition in Japan.

Chemistry of *Trans* Fatty Acids

Dietary fats are composed of fatty acids and glycerol. Fatty acids are generally classified as saturated, monounsaturated or polyunsaturated, and properties of fats depend on the fatty acids composing them. Within an unsaturated fatty acid molecule, one of two configuration forms can occur around one double bond. The *cis* form has the two parts of the carbon chain bent towards each other, and the *trans* form has the two parts almost linear, similar to saturated fatty acids. Linear molecules can pack together closely in a given space, and give the substance a higher melting point, while bent molecules cannot pack together easily, so that fats of these molecules have a lower melting point. In general, fats containing a majority of saturated fatty acids are solid at room temperature, and those containing mostly unsaturated fatty acids are usually liquid at room temperature and are called oils. Some common saturated fatty acids in foods include palmitic, stearic and myristic acids. One common monounsaturated fatty acid is oleic acid, and the most common polyunsaturated fatty acid in food is linoleic acid.

Most naturally occurring dietary unsaturated fatty acids in vegetable oils or polyunsaturated fatty acids of fish oils are of the *cis* configuration.[1,2] Some of the unsaturated fatty acids ingested by ruminants are partially hydrogenated by bacteria in the rumen. In consequence, milk fat, dairy products and beef

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and mutton fat also contain *cis* and *trans* fatty acid isomers, although the proportions are somewhat different. In ruminants, the main component of the *trans* fatty acid is *trans*-vaccenic acid (18 : 1 *t*11).[3] A small amount of *trans* fatty acids is also present in poultry and pork fat, derived from the feed.

Chemical hydrogenation is the process of adding hydrogen atoms to unsaturated sites on the carbon chains of fatty acids, thereby reducing the number of double bonds. The reaction is applied to food industries as partial hydrogenation, by heating vegetable oils (fish oils occasionally) in the presence of metal catalyst and hydrogen. The process of partial hydrogenation accompanied by thermal isomerization, represents incomplete saturation of the double bonds, in which some double bonds remain but may be moved in their positions on the carbon chain, and produces several geometrical and positional isomers.

Hydrogenation heightens the melting point of fats, which makes it possible to convert fats in liquid form to semi-solids and solids that are useful in many dietary products, increasing shelf life and the flavor stability of unsaturated fatty acids. Cottonseed oil was first hydrogenated in 1911 in the United States to produce vegetable shortening. The partial hydrogenation process became more popular in the 1930's with the development of margarine.[1] Through hydrogenation, oils such as soybean, safflower, and cottonseed oil, which are rich in unsaturated fatty acids, are converted to margarines and vegetable shortenings.[4]

Thus, *trans* fatty acids are produced artificially and commercially today. They are present in variable amounts in a wide range of foods, including most foods made with partially hydrogenated oils such as baked goods and fried foods, and some margarine products. Structures of related C18 fatty acids are illustrated in Fig. 1. Table 1 exhibits typical composition of hydrogenated margarines compared with vegetable oils and animal fats.[5]

Content of *Trans* Fatty Acids in Food

Trans fatty acids contained in food have been analyzed using gas–liquid chromatography with long polar capillary columns, which permits the separation of the *cis* and *trans* isomers. The amount of *trans* fatty acids in foods which may contain hydrogenated oils ranged from 0 to 34.9%.[6] *Trans* fatty acid content varied considerably among foods, reflecting differences in the fat and oils used in the manufacturing or preparation process.[7]

Occasionally, gas–liquid chromatography was combined with silver nitrate thin-layer chromatography to characterize the detailed profiles of *trans* fatty acid positional isomers contained in foods or in adipose tissue.[8,9] Thus, in French foods, the predominant isomer was delta 9-18 : 1 (elaidic) acid, with the delta 10 isomer ranked second; and the content of the delta 11 isomer (*trans*-vaccenic acid) was lower than unresolved delta 6 to delta 8 isomers.[9] In adipose tissue of French women, *trans* 18 : 1, *trans* 18 : 2 and *trans* 16 : 1 fatty acids were detected in relation to their dietary sources.[10]

With regard to fish oil, it was reported that *trans* fatty acid content in partially hydrogenated oil was 30%, while the content of *trans* fatty acid in highly hydrogenated oil and no hydrogenated oil was 3.6% and 0.5%, respectively.[11]

Dietary Intake of *Trans* Fatty Acids

The daily intake of *trans* fatty acids and other fatty acids in 14 European countries has been stud-

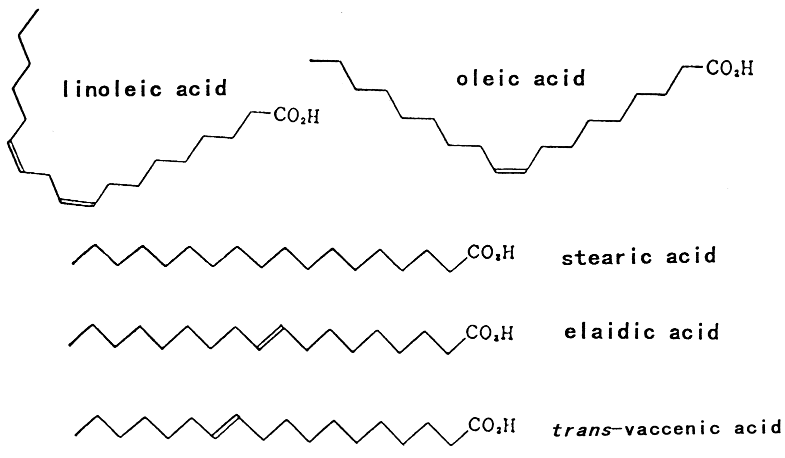

Fig. 1

Table 1. Fatty Acid Composition (%) of Vagetable Oils and Animal Fats

Vegetable oils and shortening	Polyunsaturated fatty acids	Monounsaturated fatty acids	Total unsaturated fatty acids	Saturated fatty acids
Safflower oil	75	12	82	9
Sunflower oil	66	20	86	10
Corn oil	59	24	83	13
Soybean oil	58	23	81	14
Cottonseed oil	52	18	70	26
Canola oil	33	55	88	7
Olive oil	8	74	82	13
Peanut oil	32	46	78	17
Margarine, soft tub*	31	47	78	18
Margarine, stick*	18	59	77	19
Shortening, vegetable*	14	51	65	31
Palm oil	9	37	46	49
Coconut oil	2	6	8	86
Palm kernel oil	2	11	13	81
Animal fats				
Tuna fat	37	26	63	27
Chicken fat	21	45	66	30
Hog fat (lard)	11	45	56	30
Mutton fat	8	41	49	47
Beef fat	4	42	46	50
Butter fat	4	29	33	62

*Made by hydrogenating soybean plus cottonseed oil.

ied using representative market baskets per country. Detailed data on the intake of these fatty acids by the collaborative study were recently provided.[12] A maximum of 100 foods per country was sampled and centrally analyzed in the period June 1995 to April 1996. *Trans* fatty acid intake ranged from 0.5% (Greece) to 2.1% (Iceland) of total energy intake. By the market basket method, the contributions of various foods to *trans* fatty acid intake in U.K. with moderate intake level were estimated as exemplified in Table 2.[2]

Table 2. The Contributions of Foods to *Trans* Fatty Acid Intake in U.K.

A*a)*	Milk and cheese	18.8
	Butter	5.9
	Eggs	0.9
	Meat and meat products	10.3
B*b)*	Oils and fats	35.5
	Biscuits and cakes	16.5
	Savoury pies, *etc*	3.5
	Chips, french fries	4.5
	Other	4.1
	Total	100

a) Natural. *b)* Mainly resulting from hydrogenation.

Independently, a similar study estimated that the mean percentage of energy ingested as *trans* fatty acids in the U.S. population was 2.6%, and the mean percentage of total fat ingested as *trans* fatty acids was 7.4%.[13] In the American diet, 95% of trans fatty acids come from partially hydrogenated vegetable oils while the remaining 5% come from ruminant sources.[14] The average consumption of *trans* fatty acids from partially hydrogenated oils has been constant since the 1960's in the U.S. As listed in Table 3, stick margarine has the highest percentage of total fat as *trans* fatty acids, but levels of these fatty acids in margarine have declined as softer margarines have become popular. Therefore, margarine is considered to be only a minor contributor of the total *trans* fatty acids.[15,16] It should be noted that increased use of *trans* fatty acids in commercially baked products and fast foods are the major sources of these fatty acids, which is a current profile of dietary fat intake in the U.S.

Table 3. Contribution of Typical U.S. Foods to *Trans* Fatty Acids[16)]

Food		TFA[a)] g[b)]	TFA[a)] %[c)]
Stick margarine	1 tbsp	3.9	17
Tub margarine	1 tbsp	1.4	10
Soy oil	1 tbsp	0.5	2
Choc chip cookie	1 large	12.1	6
Cake	1 piece	28.1	5
Potato chips	1 oz	8.9	11
French fries	1 medium svg	41.9	5
Snack crackers	10 medium	39.7	8

a) *trans* fatty acid. *b*) amount of *trans* fatty acid in the food. *c*) ratio of *trans* fatty acid to total fat of the food.

Coronary Heart Disease

Many years of epidemiological research have shown that populations consuming diets high in saturated fatty acids have relatively high levels of serum cholesterol and carry a high prevalence of coronary heart disease.[17–19)] Based on the evidence of these studies, it is generally accepted that high levels of serum cholesterol, particularly low density lipoprotein (LDL) cholesterol, promote the development of atherosclerosis and predispose to coronary heart disease. The concept has become widely accepted that lowering LDL cholesterol by virtually any safe means will reduce the risk of coronary heart disease.[20)]

One study in 1990 demonstrated that *trans* fatty acids raised total and LDL cholesterol while lowering high-density lipoprotein (HDL) cholesterol.[21)] As a result, the net effect of *trans* fatty acids on the ratio of LDL to HDL cholesterol was approximately double that of the saturated fatty acid. These adverse effects of *trans* fatty acids have been confirmed by subsequent metabolic studies.[22–25)]

Strong epidemiological evidence relating dietary factors to the risk of coronary heart disease has been provided by large prospective studies.[26–29)] Those studies assessed the intake of *trans* fatty acids using detailed food-frequency questionnaires whose results were validated by comparison with the composition of adipose tissue or food diaries. Each of these studies reported high relative risk of coronary heart disease associated with the intake of *trans* fatty acids.

A joint Food and Agriculture Organization/World Health Organization (FAO/WHO) consultation took regulatory initiatives on *trans* fatty acids in 1993. Responding to that recommendation, some European countries regulate the amount of *trans* fatty acids allowed in food products, and food manufacturers also have responded rapidly by developing margarines free of *trans* fatty acids that are low in saturated fats. Although these margarines are also available in the U.S., the major sources of *trans* fatty acids are baked good and fried fast foods, as mentioned above, it is more difficult to replace *trans* fatty acids with healthier fats in such products than in margarines. Based on evaluation of recent studies in humans, FDA concluded that under the conditions of use in the U.S., consumption of *trans* fatty acids increased the risk of coronary heart disease. In response to a citizen petition on *trans* fatty acids in food labeling, the FDA proposed to amend its regulations on nutrition labeling to require that the amount of *trans* fatty acids in a food be stated.[4)]

Other Risks of *Trans* Fatty Acids

Considerable attention has focused on the potential adverse effects of *trans* fatty acids, produced by the method of partial hydrogenation of vegetable oils or marine oils, which may decrease their essential fatty acid content, and raise the saturated fatty acid content. Beyond cardiovascular disease risk, another concern about *trans* fatty acids is theoretical at present. In both animal and human studies, dietary *trans* fatty acids have been determined to be digested, absorbed and incorporated into serum triglycerides, cholesterol esters, phospholipids, lipoproteins and adipose tissue,[10,30–32)] or platelets,[33)] in the same way as natural *cis* isomers.

Ingested *trans* fatty acids were incorporated in placenta and maternal and fetal tissues, except brain.[34)] Furthermore, *trans* fatty acids are readily passed from the mother to the infant via milk.[35–37)]

Essential fatty acids are converted in the body by a series of reactions to long chain polyunsaturated fatty acids, including arachidonic acid, which is essential for tissue growth and development. *Trans* fatty acids compete with the essential fatty acids for the enzyme systems involved in these reactions.[38–44)]

With regard to the immune system, the splenic production of prostaglandin E_2 was reduced, while both plasma IgG and CD_4^+:CD_8^+ T-lymphocytes ratio were increased by dietary *trans* fatty acids.[45)] The International Study of Asthma and Allergies in Childhood (ISAAC) assessed the prevalence of asthma, allergic rhinoconjunctivitis, and atopic eczema in children aged 13–14 years around the world.[46)] There was a positive association between the intake of *trans* fatty acids and the prevalence of those allergic symptoms. The association tended to be stronger when the analyses were restricted to estimates of *trans* fatty acid intake from sources that contain hydrogenated vegetable oils, in consideration of the data from the market baskets mentioned above.[12)]

Trans Fatty Acids in Japan

Daily intake of total fat in Japan has rapidly increased in the past 50 years, and it is well known that the proportion of people with allergic symptoms has also gradually increased during this period. Favorite foods young people and children consume have changed to baked products and fast food prepared with *trans* fatty acids. Health problems related to the intake of *trans* fatty acids, however, have not yet arisen noticeably in Japan.

The contents of *trans* fatty acids in various foods commercially available in Japan have been surveyed by the Japan Institute of Oils & Fats Other Foods Inspection, Foundation.[47–56)] Based on those data and the nutrition consumption profile of the population, the daily intake of *trans* fatty acid was recently estimated to be 1.56 g/capita/day, which corresponded to 0.7% of total energy intake.[55)] The situation concerning relatively low intake of *trans* fatty acid as well as total fat, compared with other countries, may be due to the traditional Japanese diet.

Trans fatty acids have been a typical part of the "western" diet, and the hypothesis that they may play a part in the development of childhood allergies also seems worth pursuing[46)] in Japan. It is noteworthy that the term *trans* (fatty) acid and its content in several foods appeared for the first time in the Remarks column of the 5th edition of the Standard Tables of Food Composition in Japan.

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