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. 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
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 t11). 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. Through hydrogenation, oils such as soybean, safflower, and cottonseed oil, which are rich in unsaturated fatty acids, are converted to margarines and vegetable shortenings.

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.

**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%. Trans fatty acid content varied considerably among foods, reflecting differences in the fat and oils used in the manufacturing or preparation process.

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. 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. 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.

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.

**Dietary Intake of Trans Fatty Acids**

The daily intake of trans fatty acids and other fatty acids in 14 European countries has been stud-
ied using representative market baskets per country. Detailed data on the intake of these fatty acids by the collaborative study were recently provided.\textsuperscript{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.\textsuperscript{2}

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%.\textsuperscript{13} In the American diet, 95% of trans fatty acids come from partially hydrogenated vegetable oils while the remaining 5% come from ruminant sources.\textsuperscript{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.\textsuperscript{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 1. Fatty Acid Composition (%) of Vegetable Oils and Animal Fats

<table>
<thead>
<tr>
<th>Vegetable oils and shortening</th>
<th>Polynsaturated fatty acids</th>
<th>Monounsaturated fatty acids</th>
<th>Total unsaturated fatty acids</th>
<th>Saturated fatty acids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Safflower oil</td>
<td>75</td>
<td>12</td>
<td>82</td>
<td>9</td>
</tr>
<tr>
<td>Sunflower oil</td>
<td>66</td>
<td>20</td>
<td>86</td>
<td>10</td>
</tr>
<tr>
<td>Corn oil</td>
<td>59</td>
<td>24</td>
<td>83</td>
<td>13</td>
</tr>
<tr>
<td>Soybean oil</td>
<td>58</td>
<td>23</td>
<td>81</td>
<td>14</td>
</tr>
<tr>
<td>Cottonseed oil</td>
<td>52</td>
<td>18</td>
<td>70</td>
<td>26</td>
</tr>
<tr>
<td>Canola oil</td>
<td>33</td>
<td>55</td>
<td>88</td>
<td>7</td>
</tr>
<tr>
<td>Olive oil</td>
<td>8</td>
<td>74</td>
<td>82</td>
<td>13</td>
</tr>
<tr>
<td>Peanut oil</td>
<td>32</td>
<td>46</td>
<td>78</td>
<td>17</td>
</tr>
<tr>
<td>Margarine, soft tub(^*)</td>
<td>31</td>
<td>47</td>
<td>78</td>
<td>18</td>
</tr>
<tr>
<td>Margarine, stick(^*)</td>
<td>18</td>
<td>59</td>
<td>77</td>
<td>19</td>
</tr>
<tr>
<td>Shortening, vegetable(^*)</td>
<td>14</td>
<td>51</td>
<td>65</td>
<td>31</td>
</tr>
<tr>
<td>Palm oil</td>
<td>9</td>
<td>37</td>
<td>46</td>
<td>49</td>
</tr>
<tr>
<td>Coconut oil</td>
<td>2</td>
<td>6</td>
<td>8</td>
<td>86</td>
</tr>
<tr>
<td>Palm kernel oil</td>
<td>2</td>
<td>11</td>
<td>13</td>
<td>81</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Animal fats</th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Tuna fat</td>
<td>37</td>
<td>26</td>
<td>63</td>
<td>27</td>
</tr>
<tr>
<td>Chicken fat</td>
<td>21</td>
<td>45</td>
<td>66</td>
<td>30</td>
</tr>
<tr>
<td>Hog fat (lard)</td>
<td>11</td>
<td>45</td>
<td>56</td>
<td>30</td>
</tr>
<tr>
<td>Mutton fat</td>
<td>8</td>
<td>41</td>
<td>49</td>
<td>47</td>
</tr>
<tr>
<td>Beef fat</td>
<td>4</td>
<td>42</td>
<td>46</td>
<td>50</td>
</tr>
<tr>
<td>Butter fat</td>
<td>4</td>
<td>29</td>
<td>33</td>
<td>62</td>
</tr>
</tbody>
</table>

\(^*\) Made by hydrogenating soybean plus cottonseed oil.

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

<table>
<thead>
<tr>
<th>A(^a)</th>
<th>Milk and cheese</th>
<th>18.8</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Butter</td>
<td>5.9</td>
</tr>
<tr>
<td></td>
<td>Eggs</td>
<td>0.9</td>
</tr>
<tr>
<td></td>
<td>Meat and meat products</td>
<td>10.3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>B(^b)</th>
<th>Oils and fats</th>
<th>35.5</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Biscuits and cakes</td>
<td>16.5</td>
</tr>
<tr>
<td></td>
<td>Savoury pies, etc</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>Chips, french fries</td>
<td>4.5</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>4.1</td>
</tr>
</tbody>
</table>

| Total   |                | 100  |

\(^a\) Natural. \(^b\) Mainly resulting from hydrogenation.
Coronary Heart Disease

Many years of epidemiological research have shown that populations consuming diets high in satu-
rated fatty acids have relatively high levels of se-
rum cholesterol and carry a high prevalence of coro-

Coronary Heart Disease. Based on the evidence of
these studies, it is generally accepted that high lev-
els of serum cholesterol, particularly low density li-

Coronary Heart Disease. The concept has become widely ac-
cepted that lowering LDL cholesterol by virtually
any safe means will reduce the risk of coronary heart
disease.

One study in 1990 demonstrated that trans fatty
acids raised total and LDL cholesterol while lowering
high-density lipoprotein (HDL) cholesterol. As a
result, the net effect of trans fatty acids on the ra-
tio 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.

Strong epidemiological evidence relating dietary
factors to the risk of coronary heart disease has been
provided by large prospective studies. 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 stud-
ies reported high relative risk of coronary heart dis-
ase 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 margar-
ines free of trans fatty acids that are low in satu-
rated fats. Although these margarines are also avail-
able in the U.S., the major sources of trans fatty ac-
ids are baked good and fried fast foods, as mentioned
above, it is more difficult to replace trans fatty ac-
ids with healthier fats in such products than in mar-
garines. Based on evaluation of recent studies in hu-

Other Risks of Trans Fatty Acids

Considerable attention has focused on the po-
tential adverse effects of trans fatty acids, produced
by the method of partial hydrogenation of vegetable
oils or marine oils, which may decrease their essen-
tial fatty acid content, and raise the saturated fatty
acid content. Beyond cardiovascular disease risk,

- TFA (%)
- 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.
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.47–50 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.50 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 pursuing46) 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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**REFERENCES**


