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TRANS FATTY ACIDS

What are *trans* fatty acids (TFA)?

Fatty acids found in foods can be saturated (SFA, no double bonds), monounsaturated (MUFA, 1 double bond) or polyunsaturated (PUFA, 2 or more double bonds). The double bonds provide rigidity to the molecule and result in specific molecular configurations. Naturally occurring fatty acids in foods usually have the *cis* configuration, i.e. the hydrogen atoms with respect to the double bond are on the same side of the molecule. This results in the molecule having a “V” or bent shape. In *trans* fatty acids (TFA), the hydrogen atoms are on the opposite sides of the molecule, and the molecule assumes a nearly linear configuration similar to that for saturated fatty acids (SFA). Thus TFA behave more like SFA than MUFA or PUFA, and this has consequences when they are incorporated into membranes and other cellular structures.

Major TFA include isomers of oleic acid (9 *cis* C18:1), including elaidic acid (9 *trans* C18:1), primarily found in partially hydrogenated vegetable oils, and vaccenic acid (11 *trans* C18:1), primarily found in meat and dairy products. However, many isomers are found in foods.

TFA are also present as conjugated linoleic acid (CLA, C18:2) that contains both *cis* and *trans* double bonds. Two of several CLA isomers (*cis* 9 *trans* 11, and *trans* 10 *cis* 12) possess biological activity as TFA.

In which foods are they found, and at what levels?

Unsaturated fatty acids in vegetable oils are normally in the *cis* form. Partial hydrogenation, which is carried out to alter the plasticity and functional properties of the resulting fat, produces several *cis* and *trans* fatty acids from intramolecular rearrangements. However, not all TFA are produced by commercial hydrogenation. Some unsaturated fatty acids are biohydrogenated by rumen bacteria in ruminant animals such as cows and sheep, producing TFA in meat (beef, lamb) and dairy products. Foods containing TFA include:

- milk, cheese and butter
- some meat and meat products
- eggs (trace levels depending on feed)
- some oils and fats, especially when partially hydrogenated
- biscuits (cookies), cakes, pastries, doughnuts
- pies, sausage rolls, chips, French fries.

TFA can be determined in foods by several techniques, including Fourier-transformed infrared (IR) spectroscopy, gas-liquid chromatography (GLC), high-performance liquid chromatography (HPLC) and silver ion thin-layer

chromatography (TLC). Current techniques cannot reliably distinguish between naturally occurring TFA in ruminant products from those resulting from partial hydrogenation of fats and oils (EFSA 2004). While more recent GLC methods can detect and quantify a greater range of TFA, they show high inter-laboratory relative standard deviations, especially at low ($\leq 1\%$) TFA levels (Delmonte and Rader 2007).

There is wide variability in TFA levels both between and within foods. While some processed foods may contain TFA levels at 20-40% of total fatty acids, levels from natural sources are generally $<10\%$ of total fatty acids and 2-5% of total fat. TFA levels in foods can vary widely, even in the same fast foods from the same chain within a country and among countries. Unfortunately, some foods are not routinely analysed for TFA in food composition studies.

TFA levels in foods in the USA varied from very low (0.01 - 0.7 g/serving) for products such as vegetable oils, RTE breakfast cereals and white bread, to high (up to 4 g/serving) for margarines, doughnuts, French fries and chocolate chip cookies (USDA 1995).

The Transfair study in the EU during 1995 -1996, involving 14 countries and 1300 foods, showed that oils and fats, dairy products, biscuits and cakes contributed most to TFA intakes. Pork and poultry contained $<1\%$ TFA (of total fatty acids), meat and dairy products 3-6%, while bakery products (1-30%), breakfast cereals, French fries and snacks (20-40%) contained higher levels (EFSA 2004).

In a survey conducted for the Australian Consumers Association, 18/55 foods (pies, cakes, confectionery, biscuits, deep-fried fast foods) contained TFA levels $>2\%$ of total fat (ACA 2005).

Recently Food Standards Australia New Zealand (FSANZ) released a risk assessment report of TFA in the food supply (FSANZ 2009a,b). A total of 456 samples of takeaway and processed foods from a range of supermarkets and takeaway shops were analysed, and then categorised in terms of foods with and without ruminant TFA. Of the 349 food products without ruminant TFA, 33% contained non-detectable levels of TFA, 49% contained $\leq 2\%$ TFA, and 18% contained $>2\%$ TFA.

The Food Safety Authority of Ireland reported a comprehensive TFA survey of fast foods in Ireland (FSAI 2008). One hundred and fifty samples of fast food were collected from 12 restaurants and analysed for total fat content and fatty acid profile including TFA. The samples comprised a cross-section of fast-food products which would be expected to contain industrial TFA (I-TFA) present as a result of the manufacturing processes or ingredients and those which would contain ruminant TFA. However, the contribution naturally occurring TFA (i.e. from sources of animal origin) make to overall levels of TFA in fast foods was not the focus of the current survey. Similar to the findings of a previous FSAI survey examining levels of TFA in retail products, levels of TFA in fast foods in Ireland were found to be low. Nearly 77% (115/150) of samples were low in TFA, having 2% TFA as a proportion of total fat. Just over 23% (35/150) of fast-food products surveyed had high levels of TFA. Of the 23% of products with high levels of TFA, beef burger products make up the highest proportion of this total with 60% (21/35) of the samples having $>2\%$ TFA (as % of total fat). However, the highest level of TFA was found in a portion of fish and chips which provided 0.6 g of TFA per/100 g or 4.8% of total fat. However, taken together the results of the current survey suggest that in the majority of the products produced and prepared by fast-food outlets in Ireland, the use of ingredients containing I-TFA has been modified, limited or reduced.

TFA intakes

TFA intakes by consumers vary widely, depending on how the intake is measured. Early US data showed intakes of 2.6 -12.8 g/day, while more recent data indicate average intakes of 1.5-2.2% of energy intake, with a mean of 2.6% of energy intake. In the EU, TFA intakes were 0.5-2% of daily energy intake (with saturated fat 10.5-18%, and total fat 36% of energy intake). The mean intake was 2.8 g/day or 1.3% of energy intake. TFA intakes by EU consumers have decreased in recent years, with lowest intakes in the Mediterranean countries (EFSA 2004). In Canada, TFA intakes appear to be 1-2% of energy intake.

Intakes of I-TFA in Australian adults and children are on average 0.3 g/day and 0.5 g/day, respectively. In New Zealand the results are similar for adults (0.5 g/day) and children (0.6 g/day) (FSANZ 2009a,b). Ruminant TFA are the dominant source of TFA in consumer diets of both countries.

What are their effects on human health?

Concerns about the health effects of TFA have concentrated on their role in changing various metabolic risk parameters related to coronary heart disease (CHD), and several studies have also examined their effects on type 2 diabetes, some cancers, strokes and food sensitivities.

Coronary heart disease

Little direct evidence of the role of TFA on CHD emerged during the 1960s–1970s. In the 1980s, the hypercholesterolemic effect of TFA was noted in animal studies. During the 1990s, however, clear evidence emerged from human and animal studies and from epidemiological data that TFA have an adverse effect on the risk of CHD because of their affect on blood lipids (Harvard School of Public Health 1999). TFA not only increase the levels of low density lipoprotein (LDL or ‘bad’) cholesterol, as do SFA, but also decrease the levels of high density lipoprotein (HDL or ‘good’) cholesterol in the blood. An increase of 1% in TFA as total energy is reported to decrease HDL by ~1%, and increase LDL by ~1%. There is also some evidence for an elevation of blood triacylglycerols (triglycerides), another risk factor for CHD, and TFA may also increase blood lipoprotein (a) levels in individuals with elevated initial levels.

The strongest epidemiological evidence for a link between TFA intake and the risk of heart disease comes from major prospective studies involving about 150,000 subjects monitored for 6-14 years: the Health Professionals Follow-up Study (USA, 1996), the Alpha-Tocopherol Beta Carotene Cancer Prevention Study (Finland, 1997), the Nurses’ Health Study (USA, 1997), and the Zutphen Elderly Study (Netherlands, 2001) (Danish Nutrition Council 2003). All studies found a positive association between TFA intake and the risk of heart disease, and this was later confirmed by studies of Mozaffarian *et al.* (2009).

Data compiled by the Danish Nutrition Council show that TFA, when substituted for PUFA in the diet, increase the LDL / HDL ratio to an extent about double that for saturated fatty acids (DNC 2003). The same study reported a significant decrease in mortality from CHD of both men and women in Denmark during the period 1977–96, during which time TFA in the diet of these consumers decreased from an average of nearly 8 g/day to less than 3 g/day. This correlation does not, however, prove that a reduction in TFA consumption alone is responsible for the observed decrease in cardiovascular morbidity.

There is some evidence that the naturally-produced TFA found in meats and dairy products do not contribute to the same negative effects, unlike those derived from partially hydrogenated vegetable oils used in processed foods (Jakobsen *et al.* 2006, Pfeuffer and Schrezenmeir 2006), but this may be due to the low intake of TFA from animal sources compared to manufactured products.

Based on the recommendations of the DNC and the decision by Denmark to legislate for reductions in TFA levels in a range of foods, the European Union requested a scientific opinion on TFA and their effects on the health of consumers from the European Food Safety Authority (EFSA) Scientific Panel on Dietetic Products, Nutrition and Allergies. This opinion, published on 8 July 2004, details considerable information available at that time on the occurrence of TFA in foods, the health effects of TFA consumption, and methods of analysis (EFSA 2004). The Panel concluded that “....TFA, like SFA, raise LDL (or ‘bad’) cholesterol levels in the blood, thereby increasing the risk of CHD at equivalent dietary levels, the effect of TFA on heart health may be greater than that of SFA. However, current intakes of TFA are generally more than 10-fold lower than those of SFA whose intakes in many European countries exceed dietary recommendations”.

Recent studies (Crupkin and Zambelli 2008) have indicated that stearic acid-rich fats, such as palm or fully hydrogenated oils, may be suitable substitutes for TFA without the negative health effects. While the body of clinical evidence (Clemens and Bidlack 2009) indicates that “... a reduced risk of CHD occurs upon replacement of dietary SFA with PUFA the AHA [American Heart Association] specifically recommends that the SFA

intake equal <7% of total daily calories". The latter authors suggest that "... not all SFA have the same functions or effects on CHD risk factors".

There appears to be no consistent evidence that TFAs elevate blood pressure, contribute to arrhythmia, interfere with haemostatic function (platelet aggregation, coagulation, fibrinolysis), increase the susceptibility to LDL oxidation, or have a role in strokes (EFSA 2004).

Cancers

There is conflicting evidence concerning the role of TFA and CLA in cancers (DNC 2003, EFSA 2004, IFST 2007). The Nurses' Health Study in the USA, involving nearly 89,000 women who were free of cancer in 1980 and followed up for 14 years, suggested that TFA intake was negatively associated with the risk of breast cancer, and no evidence was found that lower intake of total fat or specific types of fat decreased the risk of breast cancer, while a Netherlands study showed a weak association between total TFA intake and postmenopausal breast cancer.

In part of the EURAMIC (European Community Multicentre Study on Antioxidants, Myocardial Infarction and Breast Cancer) study a positive association was found between TFA intake and adipose tissue levels and the incidence of breast and large intestinal cancers, while there was no association with prostate cancer. Some recent studies have shown that high intakes of TFA may increase the risk of colorectal neoplasia (Vinikoor *et al.* 2008), while other studies indicate there is insufficient and inconsistent evidence linking specific TFA isomers to cancers of the prostate, colon and breast (Thompson *et al.* 2008, Smith *et al.* 2009).

Type 2 diabetes

A positive association was observed in the Nurses Health study between TFA intake and the risk of developing type 2 diabetes, especially for obese women. It was reported that a reduction in TFA intake from 3% to 1% of energy could reduce the incidence of type 2 diabetes by 40%. Elaidic acid (9 *trans* C18:1) produced higher blood insulin levels than oleic acid at the same blood sugar levels (DNC 2003). However, inconsistencies across studies and some methodological problems make it premature to draw definitive conclusions about the role of TFA in type 2 diabetes development (Odegaard and Pereira 2006).

Food sensitivities

Positive relationships have been observed between the prevalence of asthma, allergic rhinoconjunctivitis and atopic eczema with TFA intake but not with *cis* MUFA and *cis* PUFA in teenagers around the world (EFSA 2004).

Alternative fat sources and manufacturing techniques

Several possibilities exist to reduce TFA levels in foods and thus reduce intakes. Vegetable oil composition can be modified by:

- interesterification or molecular rearrangement, and blending with TFA-free vegetable oils (Hunter 2006);
- modifying the hydrogenation process, such as using electrocatalysis (lower temperatures), precious metal catalysts (platinum, palladium) or supercritical fluids states (List 2004, Jang *et al.* 2005); and
- genetically modifying the fatty acid profile, e.g. to produce high(er) oleic acid levels (Flickinger 2007).

Vegetable oils can also be substituted for animal fats in food formulations, and in frying (Zevenbergen *et al.* (2009). In some countries (e.g. Australia and New Zealand), regulatory authorities have approved the addition of cholesterol-lowering food additives, such as plant sterols (phytosterols), to foods such as margarines and spreads, some breakfast cereals, low-fat yoghurt and low-fat milk.

In recent times, several national and international food manufacturers have launched a variety of low or virtually TFA-free products in response to consumer and activist pressures.

Regulatory approaches to control TFA levels in foods

Different regulatory approaches to control TFA levels in foods and thus reduce intakes have been used.

USA

In 1993, the US Food and Drug Administration changed labeling laws to require SFA and cholesterol levels to be included in the Nutrition Facts panel on all labels. In April 2004 the FDA Advisory Committee recommended that TFA intake be reduced to "...<1% of energy intake...". Subsequently (January 2006), the FDA required TFA levels also to be included on food labels, with % SFA equal to the sum of SFA + TFA. Foods containing <0.5 g/serving are defined as containing no TFA, while those foods containing >4 g SFA + TFA cannot carry a health claim (USFDA 2009a,b,c). The FDA decided not to distinguish between I-TFA and those derived from rumen hydrogenation, thus dairy products must be labeled with TFA levels.

In 2008 New York City mandated restaurants and food service establishments, including fast food outlets, from serving food with >0.5 g TFA/serve. Other US cities (e.g. Philadelphia, Boston, Louisville) have since also mandated controls on TFA in restaurant and fast foods, and some states have banned TFA in foods provided by schools. In 2008 California became the first state to ban TFA in restaurants (Anon. 2009).

Canada

Nutrition information changes to Food and Drug Regulations were made in January 2003, requiring compliance by 12 December 2005 for large manufacturers, and by 12 December 2007 for small manufacturers. Total fat, SFA and TFA are now required on food labels. If claims are made (e.g. 'reduced TFA levels'), immediate compliance is required. In June 2007 Health Canada adopted Task Force recommendations to limit TFA in vegetable oils and margarine spreads to ≤ 2% of total fat and all other foods to ≤ 5% of total fat, including ingredients sold to restaurants (CFIA 2006, 2008).

In January 2008 Calgary became the first city to ban TFA from restaurants and fast-food chains, and in September 2009 British Columbia became the first Province to mandate the June 2006 Task Force recommendation of a limit of 5% TFA in all products sold to consumers (2% for tub margarines and spreads).

European Union

Except for Denmark, TFA levels are required on labels only if a TFA claim is made (e.g. 'low in TFA').

Denmark: In 2003 the Danish Nutrition Council recommended restrictions on and phasing out of the use of I-TFA in foods. By 1 June 2003, oils and fats were limited to < 2% TFA, and from 1 June to 31 December 2003, < 5% TFA were permitted in oils and fats used in processed foods. From 1 January 2004, < 2% TFA were permitted in oils and fats used in both local and imported processed foods, effectively banning partially hydrogenated fats (Stender *et al.* 2006).

United Kingdom: The UK government considers that mandating controls on TFA in foods is unwarranted as UK consumer average TFA intakes are only half the 2% maximum recommended intake of total energy (FSA 2008). The British Retail Consortium, including all major food retailers, removed I-TFA from all new stock of own brand products by the end of 2007.

Switzerland

Switzerland followed Denmark's ban on TFA in April 2008.

Australia / New Zealand

Mandatory TFA labeling was considered during a comprehensive review of the Australia New Zealand Food Standards Code in 1999 □ 2002, however Food Standards Australia New Zealand (FSANZ) and its precursor decided not to mandate labelling of TFA, as it was believed that TFA consumption was relatively low, and that similar reductions in SFA intake would be more likely to have a greater impact. TFA contents are required on labels only if a nutrition claim is made with respect to cholesterol, SFA, MUFA or PUFA, or TFA. Voluntary labeling is permitted, and many vegetable oil spread manufacturers include TFA levels on labels. FSANZ permits the addition of phytosterols to margarines and edible oil spreads under the Novel Food Standard (Standard 1.5.1) of the Food Standards Code, providing that SFA + TFA are < 28% of the total fatty acid content, as well as to some breakfast cereals, milk and yoghurt. Recently, manufacturers have sought approval for the addition of phytosterols to fat-reduced cheeses (FSANZ 2009a).

The National Heart Foundation of Australia (NHF 2009) runs a voluntary program ('Tick') which sets nutrient benchmarks for different food categories for the food industry. The Tick program limits TFA to < 1% of total fat for edible oil spreads and oils. For all other foods, the TFA limit is 0.2 g/100 g or less, making foods with the Tick logo virtually TFA-free.

Nutritional advice to help reduce TFA intakes

TFA-free diets are difficult to develop and maintain as ruminant-derived TFA are present in dairy foods and many meat products, and they may lead to undesirable effects such as micronutrient deficiencies from removing such animal products from the diet. Nutritionists, dietitians and health professionals recommend that consumers should reduce their TFA intake, while consuming a nutritionally adequate diet.

What can consumers do? Some suggestions include:

- use TFA-free PUFA or MUFA margarine spreads, based on canola, sunflower or olive oils, rather than butter;
- use low / reduced / modified fat milk, cheese, ice cream and yoghurt;
- have fish at least twice/week (but if pregnant, especially not predatory fish that may be high in mercury);
- have meals based on vegetables, grains and fruits, nuts and seeds every day;
- limit take-away foods to less than once per week, e.g. pastries, pies, pizzas, hamburgers, etc;
- limit fatty and sugary snack foods such as cakes, pastries, crisps, lollies and chocolate to once per week; and
- select lean meats and poultry.

Consumer education campaigns and food labels are important tools to provide consumers with factual information on current levels of TFA in foods, and how they can reduce their intake of TFA.

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Prepared by Ken Buckle on behalf of and approved by the IUFOST Scientific Council. Emeritus Professor Buckle was the Chair of the Scientific Council (2003-06), is a Past President (2001-03) and Fellow of the International Academy of Food Science and Technology (IAFoST), and is Chair of the Editorial Advisory Board of The World of Food Science; E-mail: k.buckle@unsw.edu.au . The constructive comments of Ms Anne-Marie Mackintosh and her colleagues at the National Heart Foundation of Australia, Ralph Blanchfield MBE, former President (2006-08) and a Fellow of IAFoST, and Prof Rickey Yada, Academy Fellow, are gratefully acknowledged.

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IUFOST Contact: J. Meech, Secretary-General, IUFOST, P O Box 61021, No. 19, 511 Maple Grove Drive, Oakville, Ontario, Canada, L6J 6X0, Telephone: + 1 905 815 1926, Fax: + 1 905 815 1574, e-mail: jmeech@iufost.org