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# **Trans Fat Elimination, An Annotated Bibliography**

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## 1. Introduction

This bibliography is intended as a resource to support the design and implementation of national *trans*-fatty acid (TFA) fat elimination programs, and is useful for policy development, implementation of monitoring systems, trans fat replacement and food reformulation efforts. The aim is to provide a brief overview of the scientific basis of key aspects of TFA elimination strategies. This list is not representative of all aspects of trans fat elimination and is largely drawn from the scientific literature published in English.

## 2. Science linking TFA intake to Cardiovascular Disease (CVD)

**Wang, Afshin et al. (2016) N. Global Burden of Diseases and G. Chronic Diseases Expert (2016). "Impact of Nonoptimal Intakes of Saturated, Polyunsaturated, and Trans Fat on Global Burdens of Coronary Heart Disease." J Am Heart Assoc 5(1).**

High intake of TFA (above 0.5% of energy) resulted in an estimated 537,000 deaths due to coronary heart disease in 2010. 45% of those deaths were in people under 70 years of age. Globally, high TFA intake was responsible for 7.7% of coronary heart disease mortality. The high impact of TFA on coronary heart disease mortality is striking given that it only accounts for 1.4% of energy intake globally.

**Mozaffarian and Clarke (2009). "Quantitative effects on cardiovascular risk factors and coronary heart disease risk of replacing partially hydrogenated vegetable oils with other fats and oils." Eur J Clin Nutr 63 Suppl 2: S22-33.**

Based on trial evidence, replacing 1% of energy from TFA with either saturated fat, mono-unsaturated fat or poly-unsaturated fat significantly reduced the total cholesterol to HDL cholesterol ratio and increased HDL cholesterol, with the greatest changes from poly-unsaturated fat and the smallest from saturated fat. In addition, replacing TFA with mono- or poly-unsaturated fat also significantly decreased LDL cholesterol levels. Based on observational evidence, replacing 2% of energy from TFA with saturated fat led to a 17% reduction in the risk of coronary heart disease; replacement with mono-unsaturated fat led to a 21% risk reduction and poly-unsaturated fat to a 24% risk reduction. Results from trial and observational evidence were strikingly similar and showed that replacing TFAs with other fatty acids (including saturated fat) has benefits on cardiovascular health.

**de Souza, Mente et al. (2015). "Intake of saturated and trans unsaturated fatty acids and risk of all cause mortality, cardiovascular disease, and type 2 diabetes: systematic review and meta-analysis of observational studies." BMJ 351: h3978.**

*"Consumption of trans unsaturated fatty acids... was associated with a 34% increase in all-cause mortality, a 28% increased risk of CHD [coronary heart disease] mortality, and a 21% increase in the risk of CHD."* Similar associations with coronary heart disease and coronary heart disease mortality were found in the studies that looked at industrial TFA only. While no evidence was found to support associations between ruminant TFA and coronary heart disease, studies were limited and consumption

was low. Overall, a 2% increase in percent of energy from TFA was associated with a 25% increased risk of coronary heart disease and a 31% increased risk of coronary heart disease mortality.

**Mozaffarian, Aro et al. (2009). "Health effects of trans-fatty acids: experimental and observational evidence." *Eur J Clin Nutr* 63 Suppl 2: S5-21.**

In addition to the well-documented relationships between TFA, lipid levels and coronary heart disease events, there is consistent trial and observational evidence that TFA increases inflammation and endothelial dysfunction. In addition there is some limited evidence that TFA may also increase insulin resistance. Based on trial evidence, it appears that ruminant and artificial TFAs likely have similar impacts, but real-world intake of ruminant TFA is too low to see an effect.

### **3. Legislation or regulation**

**L'Abbé, Stender et al. (2009). "Approaches to removing trans fats from the food supply in industrialized and developing countries." *European Journal of Clinical Nutrition* 63(S2): S50-S67.**

Early efforts to eliminate artificial TFA followed multiple strategies. Denmark passed legislation to limit artificial TFA to 2 grams per 100 grams of fat/oil in all food in 2003. Canada combined mandatory labeling with voluntary limits and regular, public monitoring; they also promised to regulate if industry did not meet levels by 2009. Argentina invested in the development of high oleic sunflower oils, a healthy alternative to TFA. In the absence of national regulations limiting TFA in food, New York City and other US municipalities passed regulations to limit TFA to <0.5 grams per serving in restaurants and food service establishments.

Common factors include: assessment of TFA exposure, support of scientific bodies for TFA elimination, media engagement which increased public awareness and put pressure on industry, and government commitment/involvement.

**Downs, Thow et al. (2013). "The effectiveness of policies for reducing dietary trans fat: a systematic review of the evidence." *Bull World Health Organ* 91(4): 262-269H.**

Mandatory limits on TFA are the most consistent and effective way to eliminate artificial TFA. While all types of TFA policies (voluntary limits on TFA, mandatory limits at the national level, local bans, and TFA labeling) reduce TFA levels in the food supply, labeling and voluntary efforts had more variable effects.

**Angell, Silver et al. (2009). "Cholesterol control beyond the clinic: New York City's trans fat restriction." *Ann Intern Med* 151(2): 129-134.**

In 2005, 50% of New York City restaurants surveyed were cooking with artificial TFA. To address this, New York City undertook a voluntary, educational approach to TFA reduction including education of restaurants, suppliers and consumers. A 2006 survey indicated no change in restaurants' TFA use, prompting the city's Board of Health to regulate to restrict TFA in restaurants. The regulation was enforced via the food safety system, with restaurant inspectors checking labels for TFA, and fines of

\$200 - \$2,000. By the end of 2008, 99% of restaurants were in compliance, and fears of increased cost to consumers or limited supply of TFA-free oils were not realized.

**Dietz and Scanlon (2012). "Eliminating the use of partially hydrogenated oil in food production and preparation." *Jama* 308(2): 143-144.**

*"Efforts to eliminate partially hydrogenated oils in all packaged foods and foods prepared and sold in restaurants and other food service outlets will help to ensure that consumers are no longer exposed to the industrially produced TFAs that can increase their risk of CHD [coronary heart disease]."* While the US has seen declines in population intake of TFA, they mask higher intakes in population sub-groups. Based on an estimation by the Food and Drug Administration (FDA), eliminating artificial TFA may prevent an additional 10,000 - 20,000 coronary events and 3,000 - 7,000 coronary heart disease deaths annually in the US. Evidence from the US and Canada suggests that concerns that eliminating TFA will lead to direct substitution with saturated fat are not warranted.

#### **4. Health impact of elimination of artificial TFA**

**Brandt, Myerson et al. (2017). "Hospital Admissions for Myocardial Infarction and Stroke Before and After the Trans-Fatty Acid Restrictions in New York." *JAMA Cardiol* 2(6): 627-634.**

Restricting TFA in restaurants and food service establishments reduced myocardial infarction and stroke hospitalizations in New York State. Declines in the three years after the restrictions were enacted were 6.2% greater in New York State counties with restrictions compared to those without.

**Restrepo and Rieger (2016) "Denmark's Policy on Artificial Trans Fat and Cardiovascular Disease." *Am J Prev Med* 50(1): 69-76.**

*"Our analysis revealed a rapid effect of Denmark's trans fat policy on population-level CVD [cardiovascular disease] mortality rates."* In the 3 years after Denmark limited artificial TFA in 2003, Denmark's cardiovascular disease mortality rate was reduced by 14.2 deaths per 100,000 more than comparable OECD countries (a 4.2% difference). The policy prevented 1 death due to cardiovascular disease per 100,000 population under age 55 and 75 deaths per 100,000 over age 55.

**Rubinstein, Elorriaga et al. (2015). "Eliminating artificial trans fatty acids in Argentina: estimated effects on the burden of coronary heart disease and costs." *Bull World Health Organ* 93(9): 614-622.**

A series of TFA measures and regulations were enacted in Argentina between 2004 and 2014, culminating with a regulation restricting artificial TFA to 2% of fats/oils. The estimated annual impact of this change was 300 to 1,500 lives saved, 1,100 to 5,300 coronary heart disease events averted (1.3 - 6% of total coronary heart disease events) and \$17 to 84 million dollars saved that would have been spent on health care.

## 5. Assessment of TFA levels in the food supply and in humans

### 5.a. Humans

**Micha, Khatibzadeh et al. (2014) Global Burden of Diseases and D. E. Chronic Diseases Expert Group NutriCo (2014). "Global, regional, and national consumption levels of dietary fats and oils in 1990 and 2010: a systematic analysis including 266 country-specific nutrition surveys." *BMJ* 348: g2272.**

Based on the limited available national datasets, the authors estimated that global consumption of TFA in 2010 was 1.4% of energy globally but varied widely across countries (from 0.2 to 6.5% of energy).

Only 12 countries had optimal levels of TFA intake (defined as  $\leq 0.5\%$  of energy). Highest intakes were in North America, Latin America and North Africa/Middle East.

**Wanders, Zock et al. (2017) "Trans Fat Intake and Its Dietary Sources in General Populations Worldwide: A Systematic Review." *Nutrients* 9(8).**

Global data on TFA intake is limited. Only 29 countries have assessed levels of TFA intake to date, with most being high-income countries. The percent of TFA from artificial sources varies from 20% to 80% depending on the country. In countries with available data, TFA intakes have been decreasing over the past decades, often in conjunction with policies designed to reduce artificial TFA.

**Vesper, Caudill et al. (2017). "Plasma trans-fatty acid concentrations in fasting adults declined from NHANES 1999-2000 to 2009-2010." *Am J Clin Nutr* 105(5): 1063-1069.**

Overall, concentrations of TFA in plasma in the US declined by 54% from 1999-2000 to 2009-2010. While all four fatty acids types measured decreased, elaidic acid, the major TFA in partially hydrogenated vegetable oil, decreased the most. The extent of the decrease was similar across sex and race, but differed by age with younger populations (age 20; 57% decrease) seeing greater declines than older populations (age 80; 49% decrease).

### 5.b. Food

**Stender, Astrup et al. (2016). "Artificial trans fat in popular foods in 2012 and in 2014: a market basket investigation in six European countries." *BMJ Open* 6(3): e010673.**

More than 10 years after Denmark regulated artificial TFA, TFA levels in food in Eastern Europe remain high, likely causing significant health harms. Between 2012 and 2014, the number of unique packaged baked goods containing artificial TFA almost doubled (from 226 to 434). While the amount of TFA in each product did decrease slightly over time, in products with artificial TFA, TFA made up 18% of fats/oils in 2014 (compared to the Denmark legal limit of 2%).

**Gupta, Downs et al. (2016). "Unhealthy Fat in Street and Snack Foods in Low-Socioeconomic Settings in India: A Case Study of the Food Environments of Rural Villages and an Urban Slum." J Nutr Educ Behav 48(4): 269-279 e261.**

Many of the items sold in the informal food sector in India contain high levels of TFA. Approximately 25% of snack foods sampled from vendors in rural Haryana and a slum in Delhi had TFA levels equal to more than 2% of the total fat content (the Denmark legal limit); on average, TFA made up 10% of total fats in high-TFA products. Further, mis-labeling of oils is common, with some oils having higher than expected levels of SFA and TFA.

**Ricciuto, Lin et al. (2009). "A comparison of the fat composition and prices of margarines between 2002 and 2006, when new Canadian labelling regulations came into effect." Public Health Nutr 12(8): 1270-1275.**

*"There may be limited potential to improve the trans fat content of low-cost products through a voluntary approach. Thus this strategy may have little benefit for lower-income groups."* Average amounts of TFA in margarines decreased in response to Canadian TFA labelling regulations and the percent of margarines that qualified as TFA-free rose (28 to 43%). However, lower levels of TFA were associated with higher prices and the price of TFA-free margarines rose faster than TFA margarines with TFA.

**WHO Europe. FEEDcities Project: the food environment description in cities in Eastern Europe and Central Asia – Kyrgyzstan & Tajikistan. 2017.**

*Kyrgyzstan* – Based on a systematic survey of street foods in the capital city, TFA levels were high in some types of both freshly prepared and industrial street food. Foods with the highest TFA content were industrial wafers (3.8 grams per serving) and two freshly made foods: manty and samsa (2.9 and 1.7 grams per serving, respectively). Just these items alone provide more than 170%, 130% and 71% of the recommended maximum TFA intake per day, respectively.

*Tajikistan* – TFA levels were slightly lower than in Kyrgyzstan, but industrial wafers sold still contained 2.5 grams per serving and more than 100% of the daily maximum intake of TFA. In addition, freshly prepared cakes and soups contained 83% and 51% of the maximum TFA intake.

**Otite, Jacobson et al. (2013). "Trends in trans fatty acids reformulations of US supermarket and brand-name foods from 2007 through 2011." Prev Chronic Dis 10: E85.**

After TFA labeling was introduced in the US, mean TFA levels declined by almost 50% between 2007 and 2011 (from 1.9 grams to 0.9 grams) among a sample of 270 products containing artificial TFA at baseline. Despite the decline, 72% of the products still contained some TFA. *"[S]ome food manufacturers have made progress in reducing TFA in their US products, but substantial variation exists by food type and by parent company, and overall progress has significantly slowed over time.... Even among this subset of national products, many products remain in the food supply that contain substantial amounts of IP [Industrially Produced]-TFA."*

## 6. TFA Replacements

**Mozaffarian, Jacobson et al. (2010) "Food reformulations to reduce trans fatty acids." *New England Journal of Medicine* 362(21): 2037-2039.**

Comparing packaged food sold in the US before mandatory labelling (2006) with food sold after 2008, TFA declined by 1.8 and 3.3 grams per serving in packaged and restaurant foods, respectively. Importantly, the total amount of unhealthy fats also declined, with TFA + saturated fat decreasing on average by 1.2 grams per serving in supermarket foods and 3.9 grams per serving in restaurant foods.

**Ratnayake, L'Abbe et al. (2009) Nationwide product reformulations to reduce trans fatty acids in Canada: when trans fat goes out, what goes in?" *Eur J Clin Nutr* 63(6): 808-811.**

Reformulation of foods in Canada in response to mandatory TFA labeling and voluntary limits on TFA did not lead to an increase in unhealthy fats. Of the reformulated products included in multiple Health Canada assessments between 2005 and 2007, none saw an increase in the total TFA + saturated fat and all but one saw increases in cis-unsaturated fatty acids.

**Bysted, Mikkelsen et al. (2009) "Substitution of trans fatty acids in foods on the Danish market." *European Journal of Lipid Science and Technology* 111(6): 574-583.**

The 2003 Danish law limiting TFA successfully decreased artificial TFA in packaged foods: TFA was above the legal limit in 26% of surveyed products in 2002 and only in 9% in 2006. On average, total TFA + saturated fat decreased by 1 gram per 100 grams of product. TFA was replaced by saturated fat 68% of the time and cis-unsaturated fat 32% of the time.

**Angell, Cobb et al. (2012). "Change in trans fatty acid content of fast-food purchases associated with New York City's restaurant regulation: a pre-post study." *Ann Intern Med* 157(2): 81-86.**

Based on repeated surveys of fast food patrons in 2007 and 2009, the mean TFA content of fast food purchases declined by 2.4 grams per purchase after New York City's regulation restricting TFA in restaurants went into effect. The sum of both saturated fat and TFA decreased by 1.9 grams per purchase, indicating that only a small fraction of TFA was replaced with saturated fat.