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A REVIEW ON TRANS FATS, THE SUGARCOATED CULPRIT

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ABSTRACT

Trans fats or hydrogenated fats or trans fatty acids are unsaturated fatty acids in trans configuration. Trans fats are used predominantly in food industries for their desirable taste and texture. However, extensive usage of trans fatty acids has adverse health effects including cardiovascular disease, diabetes mellitus, obesity and cancer. To keep the track of usage and consumption of trans fats various regulations are stringently being followed all across the world.

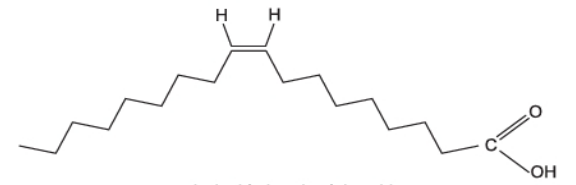
KEYWORDS: Trans fats, Cardiovascular disease, Food industry, Public health regulation.

INTRODUCTION

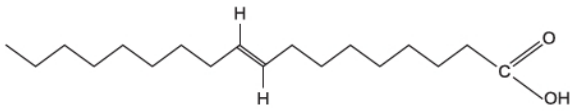
The palatability of a food is contributed by the fats and oils present in it. Dietary fats are composed of fatty acids and glycerol. Fatty acids could be either saturated, monounsaturated or polyunsaturated depending on the presence of a double bond. In general, saturated fats are devoid of double bonds and are solid at room temperature. On the other hand, unsaturated fatty acids have one or many double bonds presented in *cis* or *trans* configuration and mostly are liquid at room temperature. Trans fatty acids or trans fats are produced when a vegetable oil undergoes a chemical process called partial hydrogenation. Hydrogenation is a chemical process that is used to convert liquid oils to semi-solid or solid fat in the presence of metal catalysts and hydrogen (Semma, 2002). The introduction of trans fats took place in the early 20th century as an alternative to animal fats including butter and lard (WHO, 2018). Trans fats were created in 1902 by Wilhelm Normann for which he was awarded a patent later. Procter and Gamble were the first to introduce the commercial hydrogenated shortening called Crisco in the year 1911 (CNN Health, 2018). Industrially, trans fats are employed for deep frying and baking thereby improving the texture and taste besides prolonging the shelf-life of the products (Oteng and Kersten, 2020; WHO, 2018). Trans fatty acids are considered to be the worst of all the fats since, it increases low density lipoprotein accompanied by a decrease in high density lipoprotein and is found to be highly associated with coronary heart disease (Uauy et al., 2009).

Definition

Bio-chemically, trans fats are similar to unsaturated fatty acids having at least one double bond in the trans configuration. However, trans fatty acids tend to behave more like saturated fatty acids than unsaturated fatty acids (Rogers et al., 2001). According to Food and Drug Administration (2003), "Trans fatty acids are unsaturated fatty acids that contain one or more isolated (non-conjugated) double bonds in a trans configuration". While, Codex guidelines on nutrition labelling (2015) defined trans fats as "the geometrical isomers of monounsaturated and polyunsaturated fatty acids having non-conjugated, interrupted by at least one methylene group, carbon-carbon double bonds in the trans configuration".



cis double bond : oleic acid



trans double bond : elaidic acid

Source: Żbikowska.A (2010)

Sources

Dietary trans fats can come from two major sources: (i) Natural or Ruminant sources (ii) Industrial or Artificial sources.

Natural or Ruminant source of trans fatty acid: A small amount of trans fatty acids are produced naturally in the rumen of ruminant animals such as cows and are found in their products. Micro-organisms including *Butyrivibrio fibrisolvens* and *Megasphaera esdenii* present in the rumen of the animals cause the isomerization of polyunsaturated fatty acids (linoleic acid and α linolenic acid) leading to the formation of conjugated linoleic acid. Further bio-hydrogenation of conjugated linoleic acid yields vaccenic acid. Vaccenic acid is considered to be the primary natural trans fatty acid. Fats and meats obtained from ruminant animals and dairy products including milk, cheese and cream are found to be the major source of trans fatty acids (Dhaka et al, 2011; Żbikowska, 2010; Bhardwaj et al, 2011).

Industrial or Artificial source of trans fatty acid: Most of the trans fats consumed in the diet are produced industrially as a result of either hydrogenation or thermal processes as in refining of oil and frying at higher temperature. Firstly, trans fats are produced by partial hydrogenation in which the liquid vegetable oil is converted to solid or semi-solid fats using a metal catalyst. Elaidic acid that is produced during partial hydrogenation is regarded as the major industrial hydrogenated trans fatty acid. Secondly, in the refining industry vegetable oils undergo a process called deodorization to improve the organoleptic properties of oils. During deodorization, oils are subjected to higher temperatures which results in the formation of trans fatty acids. Thirdly, during deep-fat frying at higher temperatures, the oil undergoes various chemical changes including polymerization, oxidation, isomerization etc leading to the formation of trans fatty acids. The major dietary trans fats obtained through industrial sources are fat substitutes and replacers including

margarine, household shortening and vanaspati. Food products such as baked foods (Cakes, biscuits, pies, crackers, breads, cookies and muffins), fried foods (fried potatoes, potato chips, doughnuts and fried chicken) and sweets contain trans fats in it (Dhaka et al, 2011, Żbikowska, 2010; Jisha, 2016; Bhardwaj et al, 2011; Gashaw and Getasetegn, 2018).

Effect on health

High consumption of dietary trans fats has several detrimental effects on the health of the individual. It is estimated that approximately 540,000 deaths occur every year due to the intake of industrially produced trans fatty acids (WHO, 2018). Trans fat is found to be a major risk factor for the development of cardiovascular diseases including coronary heart disease, atherosclerosis, stroke and hypertension. In addition, the consumption of trans fat causes cancer, diabetes, obesity, allergy, inflammation, ovulatory infertility and also has an ill effect on fetal development (Dhaka et al., 2011; Bhardwaj et al., 2011; Jisha, 2016; Uauy, 2009; Semma, 2002; Gashaw & Getasetegn, 2018).

Cardiovascular diseases

Consumption of trans fat leads to atherosclerosis, altered plasma LDL to HDL ratio and elevated proatherogenic inflammatory markers (Ganguly & Pierce, 2012). In view of this fact, various studies were carried out to validate the effect of trans fats on cardiovascular diseases. Administration of trans fatty acids in animal models has been shown to accelerate atherosclerosis by inducing inflammation (Dhibi et al., 2015; Monguchi et al., 2017). Wang et al., (2016) pointed out that intake of trans fatty acids even at low concentrations results in a high CHD mortality rate. A prospective study conducted with female nurses in the United States showed a significant positive association between erythrocyte trans fatty acid content and the risk for the development of coronary heart disease. This association could be partially due to the plasma LDL to HDL ratio (Sun et al, 2007). Yaemsiri et al., (2013) found that serum trans fatty acids are positively associated with particular ischemic stroke subtypes among postmenopausal women in the United States. Mozaffarian et al., (2007) pointed out that the intake of trans fats was found to be higher among the Iranian population which contributed about 8 to 39% of events associated with coronary heart disease. Iqbal (2014) reported that high consumption of Vanaspati, an industrially produced trans fatty acid is one of the risk factors for cardiovascular disease in Pakistan. Contrary to these studies, a study conducted in India did not show a significant association between trans fatty acid and cardiovascular risk markers among industry employees. The investigators suggested that this non-significant result could be due to the inadequate sample size (Gupta et al., 2019). From these evidences, it is found that consumption of trans fat among different populations showed a positive association with the risk of progressive cardiovascular diseases.

Diabetes mellitus

Consumption of trans fatty acids acts as a risk factor in type 2 diabetes mellitus (Steyn et al., 2004). However, the evidences available to prove this fact is limited. Misra et al., (2009) found that dietary intake of trans fatty acids increased the risk of type 2 diabetes mellitus among South Asians and Asian Indians. The investigators further added that South Asians and Asian Indians consume high amounts of trans fatty acids incorporated in a variety of foods. Angelieri et al., (2012) obtained a significant association between trans fatty acid intake and Homeostasis Model Assessment – Insulin Resistance (HOMA-IR) among type 2 diabetes mellitus patients in Brazil. Animal models demonstrated that consumption of high industrially produced trans fatty acids contributes to insulin resistance (Zhu et al., 2019). Saravanan et al., (2005) suggested several mechanisms that are associated with insulin resistance in animal models including down-regulation of peroxisome proliferator-activated receptor γ (PPAR γ) and upregulation of

resistin gene expression, in addition to alteration in adipocyte plasma membrane phospholipid fatty acid composition and adipocyte plasma membrane fluidity. Thus, it is understood that trans fatty acid plays a vital role as one of the causative factors in type 2 diabetes mellitus.

Cancer

Dietary intake of trans fatty acids from ruminants as well as partially hydrogenated vegetable and fish oils have been shown to be associated with different types of cancer in both genders (Laake et al., 2013). Vinikoor et al., (2008) found a positive association between trans fatty acids intake and prevalence of colorectal adenoma in patients. A similar association was found in women consuming fried foods away from home (Lin et al., 2004). EPIC (European Prospective Investigation into Cancer and Nutrition) studies conducted showed that high intake of trans fatty acids (particularly elaidic acid) and high serum levels of trans fatty acids (particularly palmitoleic and elaidic acids) were associated with increased risk of breast cancer (Chaje`s et al., 2008; Matta et al., 2021). Chavarro et al., (2008) found that increased trans oleic acid and trans linoleic acid levels in the blood are associated with an increased risk of non-aggressive prostate tumors. Thus, it is evident that trans fatty acid consumption increases the risk of the predominant type of cancer.

Obesity

Obesity is considered to be the primary risk factor for almost all of the non-communicable diseases. Increased intake of trans fatty acids demonstrated a positive adipogenic effect than cis isomer of monounsaturated fatty acids (Thompson et al., 2011). Bendsen et al., (2011) conducted a double-blind parallel intervention study in overweight postmenopausal women to investigate the effect of trans fatty acid intake on abdominal and liver fat deposition and blood lipid profile. The results of the study showed a significant increase in body fat, waist circumference, plasma LDL cholesterol level and LDL to HDL ratio accompanied with decreased plasma HDL cholesterol level. Administration of trans fatty acids in male African green monkeys was shown to increase intra-abdominal fat deposition and altered glucose metabolism including increased insulin resistance and impaired post-insulin receptor binding signal transduction (Kavanagh et al., 2007). Consumption of trans fatty acids is found to be associated with an increased prevalence of metabolic syndrome among overweight and obese women (Maximino et al., 2015).

Infertility

High consumption of trans fatty acids have a detrimental effect on the development of polycystic ovarian syndrome and infertility in female (Youngwanichsetha, 2020). Chavarro et al., (2007) observed an increased risk of ovulatory infertility when carbohydrates and unsaturated fats in the diet of the women were replaced by trans fatty acids. A study conducted in Iran showed a positive correlation between RBC trans fatty acids and ovulatory infertility in women with polycystic ovarian syndrome (Ghaffarzad et al., 2014). Thus, it is evident that trans fatty acid consumption has an impact on the reproductive health of women.

Inflammation and Allergy

Evidence showed that trans fatty acids are involved in the inflammatory process that is associated with several diseases (Galli and Calder, 2009; Longhi et al., 2017). Consumption of trans fat rich meal increased airway inflammation, sputum neutrophils proportions and TLR4 mRNA gene expression in sputum cells in asthma (Wood et al., 2011). Mozaffarian et al., (2004) found a strong association between trans fatty acid intake and systemic inflammation in patients with heart disease.

Fetal development

Consumption of trans fatty acids during pregnancy and lactation has been found to possess an adverse effect on the fetus (Herrera and Ramos, 2008). High intake of trans fatty acids by the mother during the second trimester of pregnancy was found to be associated with greater fetal growth which could lead to non-communicable diseases at later stages of life (Cohen et al., 2011). Specht et al., (2018) conducted a case study to study the influence of perinatal exposure of trans fatty acids among children. The investigators found that the intake of trans fatty acids by the mother leads to the development of haematopoietic neoplasms in the offspring. Thus, it could be crucial to limit and restrict trans fatty acid consumption during pregnancy and lactation period.

Analysis of Trans Fats

Several methods of analytical techniques are employed when it comes to the identification, separation and quantification of trans fatty acids. These techniques include Gas Chromatography (GC), Thin Layer Chromatography impregnated with silver nitrate (Ag-TLC), reversed-phase Liquid Chromatography (LC), reverses-phase silver ion high performance liquid chromatography, Liquid Chromatography impregnated with silver nitrate (Ag-LC), Infrared Spectroscopy (IR), Fourier Transformed Infra-Red (FTIR), Flame Ionisation Detection (FID) and Mass Spectrometry (MS) (Ledoux, Laloux and Wolff, 2000; Song et al., 2015).

Despite many analytical techniques, Gas Chromatography (GC) is the most widely used method. Shirasawa, Sasaki, Saida and Satoh (2007) suggested Gas Chromatography to be more convenient and desirable. Several studies that determined the trans fatty acid content of processed food products and bakery products utilized Gas Chromatographic technique (Saklani et al., 2022; Omar and Salimon, 2013; Reshma et al., 2012). Salimon, Omar and Salih (2013) studied the trans fatty acid content of Four different samples of vegetable oil-based margarine using Gas Chromatographic technique and concluded that GC shows a high degree of accuracy and reliability.

In some studies, Flame Ionization Detector (FID) is used along with Gas Chromatography for the estimation of trans fatty acid content in industrially produced 308 Jamaican food products (Perry, Henry, Bremmer, 2023) and 9 Indian fast-food items (Karn, Abraham and Ramakrishnan, 2013). Gas Chromatography – Flame Ionization Detector (GC-FID) procedure is accurate, reliable, adequate and sensitive for the detection and quantification of trans fatty acid in vegetable oils and margarine (Song et al., 2015; Salimon, Ahmed and Salih, 2014).

Although Gas Chromatography is a majorly employed method, few studies used Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR) Spectroscopy technique for the determination of trans fatty acid. Khan, Hassan and Rauf (2017) determined the trans fats content of Indian snacks including potato chips, biscuits, popcorn, pastry, namkeen, banana chips and hydrogenated fats that have been used in India using Attenuated Total Reflection Fourier Transform Infrared (ATR-FTIR) Spectroscopy technique. The results obtained using ATR-FTIR method were compared with Gas Chromatograpy – Flame Ionization Detector (GC-FID) method which showed to be in good agreement. Shah et.al., (2016) determined the trans fats content of traditional breakfast and snacks in Pakistan such as poori, cake, pratha, doughnut and puff pastry using Attenuated Total Reflection Fourier Transform Infrared (ATRFTIR) spectroscopy and suggested that this method is quick. Efficient and reliable.

Food Safety Standards Authority of India (FSSAI) in 2021 published laboratory guidelines for the analysis of trans fatty acids in which FSSAI suggested Gas Chromatograpy – Flame Ionization Detector (GC-FID) technique.

Permissible limits and legislation of trans fats in foods

Trans fatty acids in foods do not offer any health benefits and also cause serious health effects on the host. According to European Food Safety Authority (2010), the intake of trans fatty acids should be as low as possible within the context of a nutritionally adequate diet. In November 2013, Food and Drug Administration (FDA) made a preliminary determination that partially hydrogenated oils are not "Generally Recognized As Safe" (GRAS) for use in food preparation and consumption by humans. By June 2015, FDA released its final determination on GRAS of partially hydrogenated oils. World Health Organization (2018) recommended reducing trans fatty acid intake to less than 1% of total energy intake among adults and children. In addition to the recommendation WHO also developed an action package called REPLACE that supports in reduction and elimination of industrially produced trans fats (WHO, 2019).

The six components of REPLACE are:

i. **R**eview dietary sources of industrially produced trans fatty acids and the landscape for required policy change.
ii. **P**romote the replacement of industrially produced trans fatty acids with healthier oils and fats.
iii. **L**egislate or enact regulatory actions to eliminate industrially produced trans fatty acids.
iv. **A**ssess and monitor trans fatty acids content in the food supply and changes in trans fatty acids consumption in the population.
v. **C**reate awareness of the negative health impact of trans fatty acids among policy-makers, producers, suppliers and the public.
vi. **E**nforce compliance with policies and regulations.

Most countries across the globe implemented various measures to limit the usage of trans fatty acids in fats and oils as well as food products. Canada and the United States passed regulations to ban the usage of partially hydrogenated oils throughout the nation. Countries including Chile, Denmark, Ecuador, Iceland, Norway, Singapore and South Africa limit trans fats usage to 2% in all foods. A limitation of trans fat to 2% in all foods with exceptions was adopted by European countries – Austria, Hungary and Latvia. Countries such as Argentina, Colombia, Iran and Saudi Arabia limited trans fats to 2% in vegetable oils and margarines and trans fats to 5% in all other foods. Armenia, Belarus, Kazakhstan, Kyrgyzstan, Russian Federation and Switzerland have passed regulations to limit trans fats to 2% in fats, vegetable oils and margarines (WHO, 2018).

India adopted a regulation policy in 2017 to limit the usage of trans fatty acid by 5% trans fatty acid content in fats/oils. In 2019, Food Safety Standards Authority of India (FSSAI) passed an amendment to reduce trans fatty acid content in fats/oils to 3% by 2021 and to 2% by 2022. FSSAI also suggested displaying "Trans fat free" logo in food outlets and food products which use trans fat free fats or oils and have industrial trans fat not more than 0.2 g per 100 g or 100 ml.

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