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Trans Fatty Acids: Sources, associated medical ailments and their alternatives - A recent advances review

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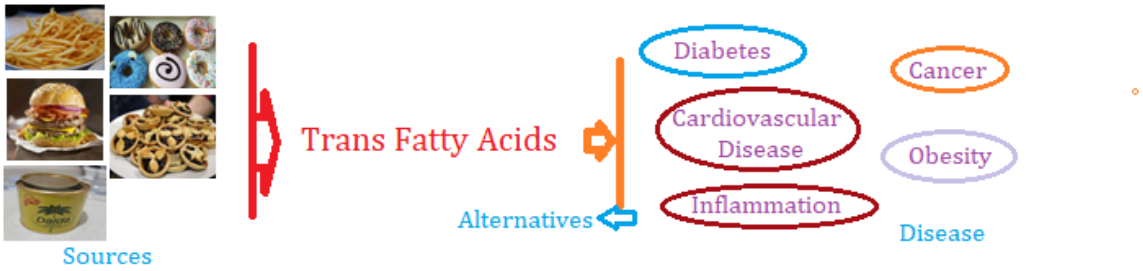
ABSTRACT



Trans fatty acids finds extensive usage in the food industry. The vegetable ghee or Vanaspati obtained from partial hydrogenation of vegetable oil is primary source of trans fats. The trans fats are also naturally found in small amounts in dairy and meat products. The trans fats possess selected good functional properties like higher melting point and longer shelf life, but their use has been associated with a number of health issues like cardiovascular diseases, inflammation, diabetes, cancer, obesity, and allergy. Other adverse effects include increase in the total and LDL cholesterol and decrease HDL cholesterol values which further aggravates atherosclerosis. Several efforts have been initiated at national and international level to reduce the consumption of trans fats. In the Indian scenario, a multisectoral proactive approach at the production and consumer level is required to eliminate trans fats from the food supply.

Keywords: trans fatty acids, cholesterol, atherosclerosis, inflammation, diabetes, vanaspati

INTRODUCTION

Fat is an essential nutrient that contributes about 20-30% of our daily energy requirement. Fats may be saturated, monosaturated or polyunsaturated depending upon the all single C-C bond, one C-C double bond or multiple double bond in the fatty chains of the fats. It is essential to balance the different types of fat to manage inflammation and maintain healthy lipid profile. Fatty acids are constituents of fats, and in unsatured fatty acids (having double bonds in the chain) there could be a cis or trans configuration at the double bonds (Figure 1). Cis form has hydrogens on the same side of double bonds, whereas in trans form, the hydrogens are placed on the opposite side. Trans fats may be defined as 'geometric isomers of monounsaturated and polyunsaturated fatty acids that have at least one carbon-carbon double bond with hydrogen present on opposite sides of the double bond'.[1]

Due to the presence of hydrogen on the same side in Cis configuration, the fatty acid molecule has a tendency to bend. Also, the increased number of double bonds will lead to the presence of more bends. This further enables the fatty acids to remain loosely packed and increase the fluidity of the membrane. On the other hand, trans fats having hydrogens on the opposite sides leads to straightening of the molecule, compact packing, and decreases the fluidity of the membrane.[2] Trans fatty acids (TFA) are present naturally in limited amounts in meat and dairy products.[3] Conjugated linoleic acid (CLA) is an example of natural TFA. It consists of two double bonds; one is present in the cis configuration, and another is present in the trans configuration. Many trans fats are formed during the making of vegetable/vanaspati ghee by the

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partial hydrogenation of vegetable oil. The amount of TFA produced depends on factors like time, catalyst, temperature, hydrogen, and type of oil used.[4] In partial hydrogenation, 30 to 60 % of bonds are transformed into trans form. In this way, healthy unsaturated oils are converted to harmful trans fats.[5] Processed products contribute significantly to trans fats in the diet in comparison to naturally occurring trans fats from animal sources. Trans fats are widely used commercially in deep frying due to its properties like longer shelf life and more stability. Another reason for being extensively used in frying is their property to pack compactly. This affects their physicochemical properties such as melting point; for example, elaidic acid, a TFA, has a much higher melting point as compared to oleic acid. Pastries, cakes, potato chips, cookies are significant sources of TFA.

More than two-thirds of deaths and global disability worldwide is due to the presence of non-communicable diseases.[6] Too much consumption of processed food products rich in sugar, salt, saturated fats, and trans fats indicates an unhealthy eating pattern. Many studies have suggested that consumption of trans fats leads to more incidence of heart diseases.[78,9,10] The review of the literature indicates that industrially produced trans fatty acids are more harmful compared to ruminant-produced trans fatty acids.[11] From these reports, it can be inferred that trans fats possess negligible nutritional value; instead, they produce more adverse symptoms in the body. Thus, it necessitates the removal or reduction of TFA from the processed foods by introducing strict regulations and also by creating public awareness regarding the harmful effects of TFA by the health and nutrition experts. At present almost all countries are trying to achieve the WHO's target of reducing overall mortality from non -communicable diseases by 25% by 2025.[12]

This review is a deliberation to identify the sources of trans fats and their harmful effects and explore how to remove or reduce TFA in our diet.

SOURCES OF TRANS FATTY ACIDS

The primary contributory source of TFA is partially hydrogenated oil (PHO). The trans fat content of PHO can range from 10-60% of the oil; it depends on how the oil is manufactured, average TFA content being around 25-45%.[13] PHO is present in processed foods like fried and baked foods like biscuits, cookies, pies, premixes like a pancake, vanaspati ghee, and margarine. Processed foods have approximately 80 percent share of trans fats in our diet compared to the 20 percent contribution by the natural sources of TFA. The high temperature favours the conversion of the double bond from the original cis configuration into the trans one. There are reports that prove that on heating and frying oil at high temperatures, moderate increases in trans fat concentrations occurs[14,15, 16]. On average, TFA values have been found to rise by 3.67 g/100g on heating and by 3.57 g/100g on frying.[14] No proof indicates the effect of other cooking methods, e.g. baking, boiling, grilling on trans fat concentrations.[17]

On the contrary, it was reported that unhydrogenated oil usage for frying at 160℃, 180℃, or 200℃C for 24 hours does not lead to the significant formation of trans fats.[18] The primary fatty acid, which is formed during the process of vegetable oil solidification is elaidic acid (C18:1, trans-9).[19] However, during frying or baking food in vegetable oils, linoelaidic acid formation occurs (C18:2; trans-9,12).[20] Primary dietary sources of the industrial TFA include margarine (1.2-7.85% TFA content per weight basis), snacks such as biscuit, cakes, and popcorn (5-10%), and frying oils (23-30%).[20]

Reduction in the consumption of processed foods would be an effective way to reduce the intake of TFA. Also, consuming plant oil sources like soybean, safflower, corn, flaxseeds for polyunsaturated fatty acids and olive oil, canola oil, nuts for monosaturated fatty acids are a good alternative for these trans fats. Including fish and shellfish in the diet will provide omega 3 fatty acids.

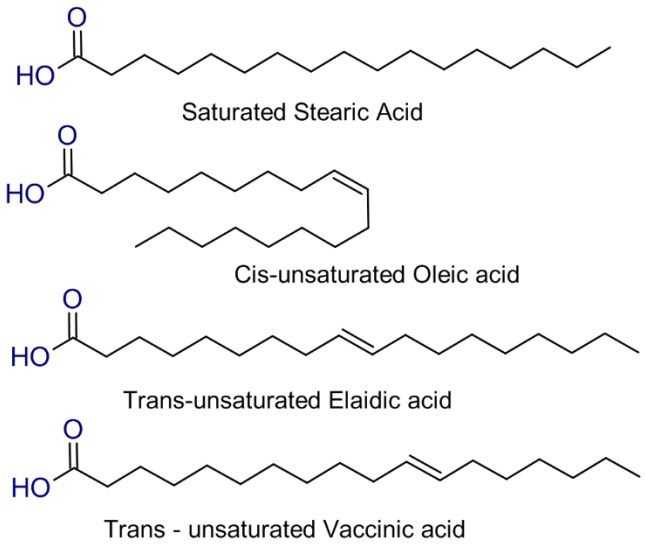

Figure 1: Structure of the geometric isomers of C18 fatty acids

ADVERSE HEALTH IMPACT OF TFA ON HEALTH

Intake of trans fats has been associated with many ailments. They contribute to the development of the following conditions:

Cardiovascular Diseases:

Cholesterol is mainly transported either with low-density lipoprotein (LDL) or high-density lipoprotein (HDL) in the blood. Higher blood levels of LDL- cholesterol correlate with atherosclerotic cardiovascular disease risk.[21,22] TFA has a unique property to increase the total and LDL-cholesterol and decrease HDL-cholesterol values, thus increasing the chances of atherogenicity.[23,24] It was reported that trans fats cause atherogenicity partly due to their ability to reduce LDL particle size. This occurs in a dose-dependent manner.[25] Likewise, it was shown that in hypercholesterolemic women, the adverse lipoprotein profile caused by *trans* fatty acid intake is partly due to higher apoA1 and lower apoB100 catabolism.[26] An independent study with animals found that feeding a diet rich in elaidic acid obtained from partially hydrogenated soybean oil resulted in higher plasma values of total cholesterol, LDL cholesterol, and triglycerides than a diet rich in polyunsaturated fatty acids.[27] Though the exact mechanism is still not precise, it is proposed that TFA might affect membrane structure, which further influences the enzymatic

pathways that may cause sudden death. It was reported that trans fats had a cholesterol enhancing effect by reducing the concentration of intracellular free cholesterol.[28] Both TFA and saturated fats have been said to have similar effects in increasing LDL values in the blood, but TFA also decreased HDL, thus increased the total cholesterol to HDL ratio.[29] A 2 % absolute increase in energy intake from trans fats has been associated with a 23% increase in cardiovascular risk.[30] Trans fats also cause endothelial dysfunction and it may represent an important mediating pathway between the trans fats consumption and coronary heart disease occurance.[8] Also, trans fats lead to the thickening and hardening of arteries as they cause systemic inflammation by increasing C-reactive protein (CRP) levels.[31,32] As the structure of trans fatty acids is somewhat similar to linoleic acid, thus there is possibility of interference with its important biological functions. They impair the metabolism of linoleic acid by hindering the activity of Δ6 and Δ5 desaturases, thus decreaseing the amount of arachidonic acid available (Δ6 and Δ5 desaturases are required for the synthesis of highly unsaturated fatty acids such as eicosopentaenoic and docosahexaenoic acids). In this way they interefere with ecosanoids production from essential fatty acid precurcursors.[33]

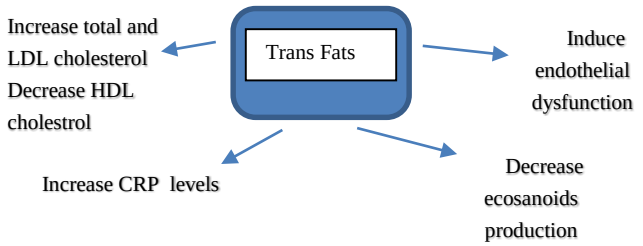

Figure 2. Possible effects of trans fats as casuative factors of cardivascular diseases

Trans fat intake from ruminant sources is approximately 0.5% of the energy intake. The role of these trans fatty acids in causing cardiovascular disease is irrelevant as their intake is so low.Consumers who take low fat dairy products will eventually reduce their intake of ruminant trans fatty acids.[34] However, when taken as a supplement, CLA dose may be up to 6g/day and it has an unfavourable impact on lipid profile like other trans fats. Some studies indicate that when the level of consumption of natural trans fats and industrially produced TFA are the same, they impact lipoproteins. It can be inferred that there exists a positive relationship between the intake of *trans* fatty acids and the risk of cardiovascular disease due to the adverse effect of *trans* fatty acids on the overall lipoprotein profile, especially plasma LDL cholesterol. Studies have indicated that replacement of trans fats with PUFA or MUFA can significantly lead to reduction of total cholesterol, low-density lipoprotein cholesterol, and triglycerides.[35]

Inflammation

Inflammation is an important aspect of innate immunity which helps to defend the host against infections. It is observed that initial acute phase of inflammation is followed by recovery in which there is activation of the system that opposes the inflammatory signals, remove the dead tissues and accelerate the repair process. But in chronic illnesses this self limiting mechanism is lost, thus contributing to pathology of the disease due to inflammation.[36]

Inflammation is a symptom of many chronic degenerative diseases that includes atherosclerosis.[37] In addition to being caused by an unhealthy lipid profile, atherosclerosis is an inflammatory disease predominated by the deposition of macrophage foam cells along the vascular wall, thus initiating the secretion of several inflammatory mediators, which further leads to the recruitment of other cells of the immunity system.[38] Randomized studies support atherogenesis due to consumption of trans fats can be attributed to their pro-inflammatory effects.[39,,40] Also, compared to saturated fatty acids, trans fatty acids induced more intestinal inflammation that resulted in significantly impaired glucose tolerance with increased hepatic fat accumulation and progression of liver fibrosis.[40] The increased TFAs consumption has been linked with the higher circulating concentration of inflammatory markers in the blood. The underlying cellular and molecular mechanisms, how the TFAs consumption influences the inflammatory response, is still not well established. There are some biological mechanisms where trans fatty acids have been found to increase systemicinflammation. Trans fatty acids are incorporated into endothelial cell membranes, which has several cell cell-specific pathways leading to inflammation.[41] Trans fatty acids also influence inflammatory pathways via their effects on macrophage membrane phospholipids and signaling pathways.[42] Also trans isomers of oleic and linoleic acids were related to higher inflammatory marker concentration. Trans fatty acids are more closely associated with systemic inflammation in patients with chronic heart disease.[31]

In the recent studies it is reported that diet rich in trans fatty acids relatively decrease in amount of phylum *Bacteroidetes*, together with an increase in the phylum *Proteobacteria* and the family *Desulfovibrionaceae*, a gram-negative sulfate-reducing bacteria.[43,44] Increase in *Desulfovibrionaceae* and excessive production of hydrgen sulfide contribute to inflammation-related bowel diseases.Hydrogen sulfide also enhances the breakdown of the mucus barrier thereby leading to an increase in permeability of the mucus membrane.[45] Due to rupture of mucus barrier, toxins and bacteria come in close proximity to the colonic epithelium, thus causing inflammation-related bowel disease.[46]

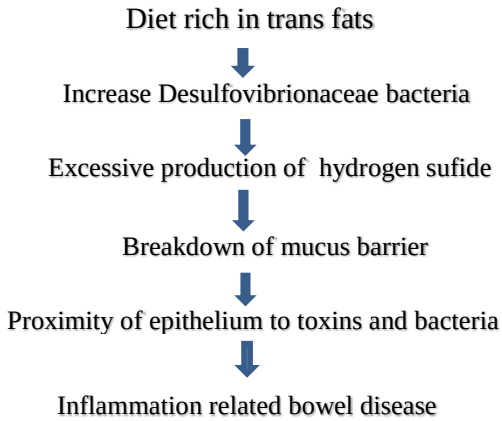

Figure 3 Mechanism of causing inflammation by trans fats

Diabetes

These days diabetes mellitus type II is on the rise globally.[47] Most of the processed foods rich in trans fats also have a high concentration of refined carbohydrates, which exacerbate the state of insulin resistance. Furthermore, high fructose corn syrup in trans fat-rich snack promotes lipogenesis, thereby increasing serum triglycerides. It was reported that trans fats and dietary cholesterol alone are not sufficient to cause diabetes, but being responsible for insulin resistance may increase the possibility of developing diabetes.[48] Research studies carried out at the National Institute of Nutrition showed TFA up to 3% of the energy intake increased insulin resistance. Also, trans fats resulted in significantly impaired glucose tolerance with increased hepatic fat accumulation and progression of liver fibrosis.[39,49] As trans fats contribute to insulin resistance, they increase the risk of developing type 2 diabetes. [31] It was found that intake of trans-fatty acids caused dysbiosis and associated immune changes in the intestine, that significantly aggravated metabolic diseases such as diabetes.[44] Studies further reported that TFA has an impact on the cardio-metabolic imprint, which leads to the development of insulin resistance and also metabolic-syndrome pathways.[8] Consumption of high trans fatty acids in daily diet during pregnancy led to disturbance in glucose metabolism and increase in risk of gestational diabetes in the second half of pregnancy.[50]

On the contrary some studies have found no association between consumption of trans fatty acids and type 2 diabetes. Consumption of ruminant and industrially produced trans fats for four weeks did not alter peripheral insulin sensitivity in insulin resistant women.[51] Also role of trans-palmitoleic acid in prevention of type 2 diabetes was reported.[52] The protective role of trans-palmitoleic could corelate to its ability to mimic cis-palmitoleic acid which is reported to be protective against diabetes in animals.[53]

Adverse effect on pregnancy

Nutrition during intrauterine have an impact on foetal development and has long-term consequences. TFA ingested by the mother interferes with converting essential fatty acids belonging to the n-3 and n-6 families into their long-chain polyunsaturated fatty acid. Arachidonic acid (20:4, n6) and docosahexaenoic acid (22:6, n3) are formed in the liver from dietary essential fatty acids and are crucial for foetal development; they have a role in vision and central nervous system.[54,55] This conversion takes place through delta 6 and delta 5- desaturase reactions. In animal experiments, it has been demonstrated that TFAs have the ability to reduce the activity of delta 6-desaturase.[56] This decreased activity may be the causative factor that leads to the development of insulin resistance.[57] Trans fats can cross the placenta, and high levels of these fatty acids during pregnancy have been linked with low birth weight.[58,59] TFA also harms new born nutrition during lactation. Trans fats impair lipid metabolism in the mammary gland, thus alters the composition of milk.[60] Trans fats appear to decrease the pregnancy period if the amount of TFA in the foetus blood is higher. Also, a high intake of TFA is associated with more chances of pre-eclampsia.[61,62] Early life exposure to trans fatty acids can increase the risk of developing chronic metabolism related diseases in the adulthood.[63]

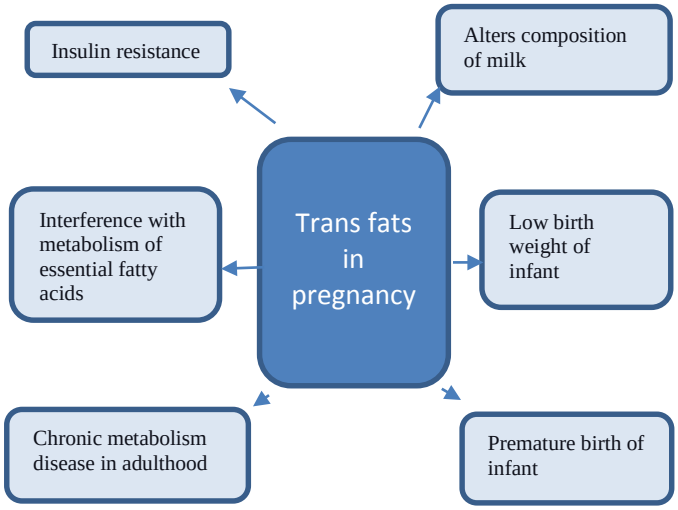

Figure 4 Adverse effects of trans fats during pregnancy

Cancer

Cancer is a broad term which involve rapid or irregular growth of cells leading to formation of tumor in any part of the body. Several types of cancer have been reported namely brain, colon, breast,pancreas, prostate, ovary cancer etc. Different causative factors are responsible for different types of cancer.[64, 65,66] Some reported cancer cases are associated with life styles while some owe their origin to genetic mutation or microbial infestation.

The correlation between the intake of trans fats and the occurrence of cancer is poorly understood. Some studies have repoted positive association between total trans fats intake and prostate and colorectal cancer. in experimental and human studies.[67,68] Trans fats increase radical activity, which results in oxidative stress. When oxidative stress outbalances the body's antioxidant defence mechanism, it interferes with the cell growth mechanism of the body. Reactive oxygen species are linked with DNA mutations that trigger cancer. Trans fats seem to be associated with the development of cancer as they cause inflammation and oxidative stress. There is sufficient evidence to support that chronic inflammation can be a causative factor of cancer.[69] In some studies pro-tumoral effects of elaidic acid, a major trans fatty acid have been reported.[70,71] Eladic acid is a long chain fatty acid having 18 carbon chains in trans configuration. It is structural isomer of oleic acid. Higher levels of circulating industrial trans fat elaidic acid may be linked with more chances of ovarian cancer.[72]

The role of trans fats as causative factors in breast cancer is not clear. Some studies found a significant dose-dependent risk between trans fats intake and cancer, while others did not. Dietary intake and serum levels of TFA and the risk of breast cancer have been studied, and it was found that the findings were inconsistent. TFA is involved in breast carcinogenesis as they exacerbate the inflammatory response. TFA is associated with raised markers of inflammation in the plasma[32].In another study on analysis of blood serum of women, it was revealed that the incidence of breast cancer increased with increased TFA levels, which was the result of increased processed food consumption. The report indicated that

women having raised serum values of TFA have twice the risk of having breast cancer when compared with women having low values.[49] Studies have reported a positive association of saturated fatty acids (SFA) and TFA with the incidence of breast cancer risk among women having excess weight.[73,74] Studies found that in post-menopausal women, serum levels of trans fats were correlated with the risk of breast cancer.[74,75]

Obesity

Obesity, as assessed by high body mass index (BMI), has become a significant health concern globally. It has been associated with increased rates of cardiovascular disease, type 2 diabetes, and hypertension. Obesity enhances the inflammatory progression in the body that gradually affects the functions of the testes, epididymis, and male accessory glands.[76] This may result in male infertility.[77] Not much data is available regarding the correlation between obesity and the consumption of trans fats. Moreover, conflicting results are reported about the role of TFA in causing obesity. Some studies have reported trans fats to inhibit lipid synthesis and deposition.[78] While some studies reported no change in body weight on consuming a diet having TFAs.[51,79] On the other hand it was found that the trans fats intake caused a four-fold greater gain in body weight despite being fed an individualized weight maintenance diet. The trans fats present in the diet seemed to result in increase intra-abdominal fat deposited by 30% for every cubic centimeter of fat gained. Also, the increase in intra-abdominal fat was significantly linked with insulin resistance.Consumption of a diet rich in trans fats increased visceral adipose tissue and caused high post - prandial hyperinsulinemia.[80] Trans fatty acids are also reported to promote lipotoxicity in several target organs. [81] Consumption of dietary trans fats was associated with higher body mass index(BMI) in adult male and Each additional 2.5 grams of trans fats taken daily was linked with BMI increment of one point.[82]

Allergy

An allergy may be defined as an abnormal immune response, and it has diverse symptoms. It was found in children in the age group 13-14 years, consumption of trans fats increases the risk of asthma, allergic conjunctivitis, allergic cold, and eczema.[83] Likewise, a positive correlation between intake of butter and incidence of asthma in children was reported.[84] A positive association between the consumption of margarine and eczema was found.[85]

Some other health risks caused by Trans Fatty Acids

It has been reported adverse health impact of trans fats goes beyond the effects mentioned above. Some more adverse effects have been reported due to the consumption of trans fats.

Alzheimer's Disease: Intake of trans fats is associated with the development of Alzheimer's disease.[86] It is reported that trans fats impair memory and learning in animal experiments. Also, inflammation was produced in the brain around the hippocampus, responsible for memory and learning. Studies indicate relationships between trans fat intake and risk of cognitive problems.[87] Findings suggest that higher serum elaidic acid is a risk factor for the initiation of dementia in the later life.[88] People having higher levels of trans fats in their blood had 50% to 75% more chances to develop Alzheimer's disease.[89]

Diminished memory: Consumption of dietary trans fats is linked to a decline in word memory in adults less than 45 years of age.[90]

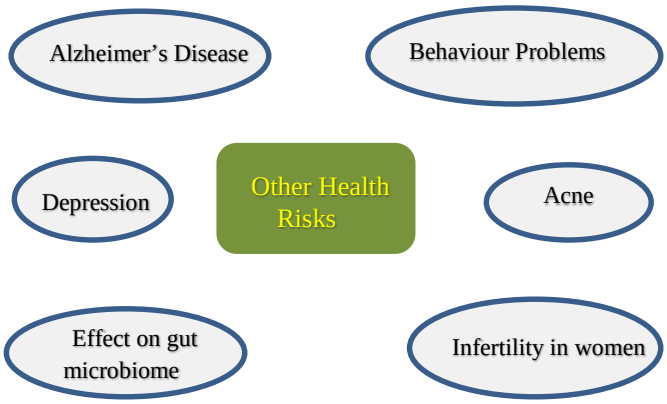

Figure 5 Other health risks caused by trans fatty acids

Behaviour irritability and aggression: Strong correlation between dietary trans fats and self-reported aggression in behaviour has been seen though no causality has been found in these cases.[91]

Acne: In a study, it was found that trans fatty acids along with a diet rich in saturated fats, carbohydrates having a high glycaemic index, dairy products promote acne while diet having an ample amount of omega-3 fatty acids reduce acne.[92]

Major Depressive order: By analysing the diet of 12,059 people for six years, those with a higher amount of trans fats had more chances of depression than those who did not have trans fats. The mechanism involved for this reason could be the substitution of docosahexaenoic acid by trans fats in the orbitofrontal cortex (OFC).[93] On post mortem, it was observed that suicidal brains had less DHA in the OFC. The OFC is the centre for controlling reward and empathy and regulates the limbic system.[94]

Infertility in women: In a study, a slight increase in energy intake from trans fats compared to carbohydrates was linked with a greater risk of ovulatory.[95]

Effect on gut microbiome: The human gut contains a large number of microorganisms or microbiota. These play important role in maintenance of good health. A study revealed that naturally and industrially produced trans fatty acids might exert distinct effects on the gut microbiome.[96] The consumption of industrially produced trans fatty acids resulted in significant dysbiosis of gut microbiota which led to the development of chronic diseases.[97,98]

Measuring trans fat content of foods

Measuring trans fat amounts in foods requires understanding how trans fats are entering the food supply chain. All potential sources of trans fats, such as fats, packed foods, street, and restaurant foods, should be taken as samples and analysed for trans fat contents and records to be maintained. Nutrition label data should also be reviewed for TFA and SFA content and the database to be updated.

REPLACE TRANS FATS- A STRATEGY PROPOSED BY WHO

In May 2018, the World Health Organization (WHO) announced the elimination of industrially-produced TFA by 2023 globally and also released the REPLACE as an action framework. This framework serves as a roadmap for countries to work to eliminate industrially-produced TFA from the food supply. The six REPLACE modules will provide a step-by-step guide for the implementation of REPLACE by governments. Elimination of industrially-produced TFA entirely from the food supply is an essential priority identified by the World Health Organization (WHO) in 2019-2023. The main aim is to eliminate trans fats by 2023, globally. It includes six areas of action.

Re (Review):

It is about reviewing dietary sources of industrially-produced trans fats and reviewing what policy changes can be done. All primary sources of TFA in the diet have to be identified, along with foods that are low in TFA but are consumed in large amounts. Also, government bodies with jurisdiction need to be recognized at national and local levels.

P (Promote):

It is about promoting the replacement of industrially-produced trans fats with healthier alternatives. WHO guidelines suggest using PUFA or MUFA as a replacement for TFA. It also includes removing subsidies on partially hydrogenated vegetable oils and tropical oils, which are high in saturated fats, ensuring nutrition labelling, and the mandatory nutrient declaration.

L (Legislate):

Regulatory action includes the elimination of industrially-produced TFA. To eliminate them, an effort is required to prohibit or limit TFA content to no more than 2 grams per 100 gram of total fat in all foods.

A (Assess):

It includes an assessment of TFA levels in the food supply. Develop a system to monitor TFA and SFA in main food categories like frying oils, packaged baked goods, and food analyses. Fatty acids which replace TFA also to be assessed and changes produced over time recorded.

C (Create):

Creating awareness regarding the negative health impact of trans fats among varied groups like policymakers, producers, suppliers, and the public can motivate reformulate food products.

E (Enforce):

For significant and sustained implementation, enforcement is required. Develop a compliance monitoring system. For the coming years, WHO recommends that countries should focus on developing and implementing the best-practice policies to set TFA limits or ban PHO. Governments are expected to invest in monitoring mechanisms to measure TFA amounts in foods, such as laboratories. Also, WHO has advocated for regional or subregional regulations to expand the benefits of TFA policies. WHO will give its support to countries working to eliminate TFA by extending technical support for building regulatory capacities to speed up best-practice policy development, their implementation, and further enforcement in countries. WHO expects food and beverage set up to implement their commitments to remove industrially produced TFA from their products. WHO also expects oils and fats suppliers to come forward to remove industrially produced TFA from their products, which they are selling globally.

TRANS FATS IN INDIAN SCENARIO

At present, India faces the double burden of malnutrition because of chronic energy deficiency, which includes low intakes of nutrients, including *n*−3 PUFAs, and also increased cases of diet-related chronic diseases. In the past few years, India has experienced fast economic growth, which further led to changes in nutrition and health profile[99]. There has been an increase in diet-related non-communicable disease (NCD) involving all socio-economic sections of the society.[100] There have been rapid dietary patterns like increased use of oils, eggs, and meat in urban and rural communities. Consumption of processed foods rich in sugar and fat and sweetened beverages has increased.[101] Also, the preference for outside foods is increased. It has been observed that Indian snacks, which are sold as a packaged products or as street foods, contain an excessive amount of trans fats. Vanaspati, a rich source of TFA, is widely used to prepare processed, ready-to-eat foods, sweet and savoury items, and premixes to make the food products tastier and increase their shelf life. Even at home, vanaspati used as a frying medium is loaded with many trans fats. The majority of homemakers are aware of the harmful health effects of these sources of trans fats. They use it to prepare daily items like parathas, pooris, bakery items, and sweets. Also, the same oil is being used again and again. Street vendors use them because of their low cost as most consumers prefer products with low prices. Trans fatty acids in commonly consumed Indian foods are shown in Table 1.

Table 1. Trans fat in commonly consumed Indian foods (g/100g) Source ref [102].

S No	Food Item	Energy (calories)	Fat (gm)	Total trans fats(gm)	TFA as Fat %	TFA en%
1	Barfi	409.0	19.7	8.4	42.5	18.4
2	Sweet biscuit	349.0	10.2	4.8	47.1	12.4
3	Pinni	492	17.4	0.3	1.9	0.6
4	Jalebi	494	34.8	17.7	50.8	32.2
5	Potato Kachori	603	10.5	5.6	53.0	30.3
6	Paapri	444	19.5	10.2	52.2	20.6
7	Mathri	495	30.8	16.3	53.0	29.7
8	Samosa	256	13.0	3.3	25.4	11.6

The high intake of TFA is part of many dietary and other lifestyle patterns leading to the present-day high incidence of diet-related chronic diseases in India. As a vast population of India is predisposed to insulin resistance, and there is a high incidence of diabetes, and coronary heart disease, the reduction of trans fats from partially hydrogenated oils and foods taken in India need to be

monitored for health benefits. Elimination of trans fats can effectively improve health conditions of the people.[7]

Food Safety and Standards Authority of India (FSSAI), the highest food regulatory body in India, has taken the initiative to reduce the consumption of trans fatty acids. As per the regulations of 2011, FSSAI prescribed that trans fat content shall not be more than 5 % in the products like vanaspati, industrial margarine, bakery shortening. There should be a declaration regarding the quantity of trans fats on the label. A product can be claimed as trans-fats-free if it contains less than 0.2 g per 100g or 100 ml of food. Also, FSSAI has a plan to eliminate trans fats from the food supply chain by 2022. To accomplish this aim, FSSAI has initiated several programs in this direction. It includes sensitization of the baking industry as they make extensive use of trans fats due to their long shelf life. To provide them with alternative inter esterified fats (IEF), enzymatically produced fats are suggested though their safety must be established before use.

Though the Indian government has published regulations regarding limitations of trans fats in the food supply, a proactive approach is necessary to ensure the desired effect as per rules. People, especially the low-income group, consume snacks and sweets with high trans fat values much above the dietary recommendations. Looking at the size and diversity of the Indian population, nutrition labelling alone will be ineffective. In such a scenario, a multisectoral policy approach with coordinated action at various levels like production, manufacturing, and consumer are required. Cohesive action by the Ministries and apex regulatory bodies is needed to improve the quality of the food supply.[103]

Policies should be made to address the elimination or reduction of industrially-produced trans fats; where possible, blends of natural vegetable oils, especially indigenous oils having additional health benefits, should be used. The government should also specify lower limits for TFA and SFA values in vegetable oil, refined oils, and processed food products; processed foods should have labels giving the amounts of TFA and SFA separately, and restaurants should declare using ‘partially hydrogenated oils’ in their served preparations. Consumer awareness should be made regarding the adverse health impact of TFA and the requirement to reduce the TFA content of foods. The food industry should replace hydrogenation technology with newer technologies that produce zero *trans* fats with the required functional properties for various food applications. More research is needed to develop bakery shortenings at a low price. Trans fat-free frying oils are required, along with investment in the production of healthier oil options. Manufacturers and food vendors also need economic support so that they produce products using more beneficial oils. Policies formulated for improving the quality of fat consumed should also aim to improve the overall diet quality of the population at large.

Countries who have successfully eliminated trans fats

Over the past 30 years, Denmark has been monitoring the amount of trans fats in food and now has achieved virtual elimination of industrially produced TFA[104]. Countries like Australia, Austria, Finland, Iceland, Norway, Poland, and Sweden have average national trans fats intake below 1% of the total energy consumed.

How to reduce TFA in the food supply

- Replacement of natural plant oils for vanaspati: India ranks at the fourth position in oilseed production globally after the USA, China, and Brazil and contributes about 10% of the world oilseeds production. We can consider using healthier oil options such as canola oil, sunflower oil, and olive oil. PHO replacements should have a minimum in SFA and high in PUFA, including both omega-3 and omega-6 fatty acids.
- Nuts and fish having a high amount of unsaturated omega-3 fatty acids are good choices of healthy fats.[64] Include a diet rich in fruits and green leafy vegetables daily.[73] Also, have proper proportions of whole grains and low-fat dairy products. Limit the consumption of red meat and sugary foods and beverages.[101],[37]
- As frying is related to TFA formation, deep-fried food products are likely to be high in TFA. Adoption of other cooking methods can reduce TFA formation in these items.
- Reuse of the oil for frying is a common practice commercially as well as at the household level. Hydrogenated vegetable oils that are normally used for frying are already high in TFA content, which would further increase more on repeated frying . Hence reuse of cooking oil should not be done.
- Consumer education is a crucial step to avoid TFA rich food items. Media can also help spread awareness about the harmful effects of trans fats consumption. Laws should be formulated by the Government for mandatory labelling regarding information of TFA and SFA content on vanaspati oil, edible oil, and other oil products. Information given on the food label should be read correctly, and the product having trans fats should be avoided.
- Reformulation of food products can be done to reduce TFA content in the products. It should consider the cost-benefit analysis also. During product reformulation and TFA removal, healthy fats and oils should be used for favourable health consequences.[105]
- Functional properties of substitutes should resemble their partially hydrogenated counterparts to minimize costs, reformulation time, and research and development efforts. It would benefit the smaller local food industries.
- Fat interesterification can also be done. In interesterified fat, the fatty acids are shifted from one triglyceride molecule to another. In the interesterification of vegetable oil, an unsaturated fatty acid, for example, oleic acid at the middle position of a glycerol molecule, can be replaced by a saturated fatty acid, for instance, stearic acid, with the help of an enzyme. The majority of studies did not report that inter esterification of dietary fats leads to any negative impact on lipoprotein profile. However, it requires more intensive studies to see the effect of interesterified fat as inflammatory indicators.
- Genetically modified fatty acids: Fatty acids with desired characteristics can be obtained using genetic engineering. Afterward, these fatty acids can be used in food products' reformulations to reduce TFA levels.
- More Investment in research is required by both governments and the private sector to increase oilseeds production, which is currently being produced, but their production is suboptimal. Initiatives should be taken to breed and produce more new varieties of oilseeds, serving as replacement oils. These varieties

could be designed to withstand the harsh climatic conditions which many countries can face, give higher yields, have better fatty acid profiles, like high oleic acid in sunflower oil. Besides, the research could help develop varieties that are profitable for use in different processing applications.

CONCLUSION

Trans fats have long been used in food products due to their beneficial effects, like cost-effectiveness, longer shelf life, and higher melting point. But they have posed a threat to many health aspects like coronary heart diseases, foetal development, cancer allergies, etc. All-trans fats cannot be banned as some of these are obtained from natural resources such as meat and dairy. Some strategies can be developed to ban industrially-produced trans fats. Consumers should be guided to recognize the sources of TFA and avoid these products. Restaurants, food vendors, and food manufactures should use alternative fats in the production of food products. National government agencies should enforce legislation to reduce the use of trans fats. Also, more research is required to develop new trans fat-free products. It should be ensured that the new product does not have a detrimental effect on health. The introduction of these food regulations to eliminate TFA from food supply will require proper coordination with industry, agriculture, and food manufacturers to increase the supply and cost-effectiveness of the proposed intervention.

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