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Invited Review

Trans Fats: A Review of Their Sources, Consumption, Health Implications, International and National Policies and Regulations

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ABSTRACT

Trans fatty acids (TFA) are formed when unsaturated fatty acids undergo hydrogenation. Many studies have confirmed the association between TFA intake and disease incidence. Data on TFA intake are limited or not available for many countries in developing regions including the Middle East.

Objectives: This review aimed to evaluate the main sources of TFA and its association with disease risk, and to review global and national policies and regulations to eliminate TFA from food products.

Methods: This is a narrative literature review that provides an updated summary of current data on dietary TFA diversity in its sources and consumption, health Implications, and policies and regulations across nations, particularly in Jordan.

Conclusion: In response to growing evidence linking intake of TFA to heart disease, the World Health Organization (WHO) has launched an action package to provide strategic guidance for the global elimination of industrially-produced TFA by 2023. Several countries have imposed voluntary or mandatory measures to minimize the content of TFA in their food supply. The available data in Jordan indicates that TFA in the food supply and its intake are above the WHO limits. Currently, there are no policies specific to noncompliance with TFA regulations in Jordan.

Keywords: Trans fatty acids (TFA), "partially hydrogenate oil" (PHOs), coronary heart disease (CHD), lipid profile, nutrition food labeling, policies and regulations.

INTRODUCTION

Trans fatty acids are commercially produced when unsaturated fatty acids undergo hydrogenation. This process of fat refinement involves the addition of hydrogen molecules to oils to increase their melting point and therefore, improve their physical and functional properties, stability, and utility (Cameron-Smith & Sinclair, 2006, Fernandez-San Juan, 2009). Several studies have reported that TFA is similar in conformation and behavior to saturated fatty acids (Fernandez-San Juan, 2009, Institute of Food Science and Technology Trust Fund (IFST), 2007, Lichtenstein, 2000).TFA content of foods is variable in processed foods, in hydrogenated oils, and smaller amounts, in meats and milk products (Fernandez-San Juan, 2009, Innis *et al*., 1999, and Ratnayake *et al*., 2009). Mashal *et al*. (2012 a) have established the first reference database for TFA composition of locally produced and imported food supply in Jordan and demonstrated a wide variability of TFA content.

It has been reported that partially hydrogenated oils might contain 30-50% TFAs, resulting in significant TFA intake in many populations (Mozaffarian *et al*., 2007). Data on TFA intake are limited or not available for many countries in less developed regions such as Asia, Africa, and the Middle East (Wanders *et al*., 2017). Based on a systematic review on TFA consumption patterns in 29 countries during the years 1995 through 2017 reported that the majority of countries showed a mean TFA intake below the World Health Organization (WHO) recommendations (< 1% of total energy). However, the previous study also indicated that TFA intake from animal sources was higher than that from industrial TFA sources (Wanders *et al.,* 2017).

Many studies have previously shown that dietary TFA intake is associated with health problems such as breast cancer, poor growth, and development (Innis *et al*., 1999, Stender and Dyerberg, 2004). Many studies have also shown that TFA intake is associated with an increased risk of coronary heart disease(CHD) (Fernandez-San Juan, 2009, Lichtenstein, 2000, Mozaffarian *et al*., 2007). The WHO estimates that 500,000 deaths of people from cardiovascular disease each year are attributed to the high intake of TFA (WHO, 2018 a). TFA affects the functions of the cell membrane, and as consequence, it decreases the cell sensitivity to insulin and thus, increases the risk of developing T2DM (Risérus, 2006). However, data from the prospective Nurses' Health Study indicated that there is a possible reduction of the chance of developing type 2 diabetes mellitus (T2DM) by 40% when the TFA percentage is reduced to 2% of total daily energy intake (Bendsen et al., 2011).

Based on an extensive body of epidemiological and experimental evidence relating to the health implications of TFA intake, the Joint WHO/Food and Agriculture Organization (FAO) Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases recommended that the mean dietary intake of TFA from hydrogenated oils and fats should be limited to less than 1% of energy intake (Skeaff, 2009).

Data regarding TFAs intake and its association with CHD in developing countries are relatively scarce (Mozaffarian *et al*., 2006). Like any developing country, Jordan experienced trends toward urbanization that are accompanied by changes in the lifestyle of individuals. In Jordan, the prevalence of CVD accounts for 37% of the annual deaths (WHO, 2018b). In response to growing evidence linking intake of TFA to coronary heart disease, most food manufacturers and retailers have largely removed TFA from their products. The global agreement is growing for the total elimination of industrial TFA from food products as they are known to have deleterious health effects on various body systems (Costa *et al*., 2016). Many developed nations such as Denmark have eliminated the use of industrially produced TFA from the food supply. Bans on industrial *TFA* have not yet been instituted in all countries, particularly in Jordan. The present review is outlined to summarize the sources of TFA, particularly in Jordan, its health implications, the global strategies to limit its exposure, and the current Jordanian regulations as well.

SOURCES OF TRANS FATTY ACIDS

Most natural unsaturated fatty acids in foods exist in the cis-isomer form. Trans fatty acids (TFA) are stereo-isomers of the naturally occurring cis-linoleic acid (Fernandez-San Juan, 2009, Lichtenstein, 2000). TFA are commercially produced when unsaturated fatty acids undergo hydrogenation. This process involves the addition of hydrogen molecules to oils resulting in “partially hydrogenated” oil (PHOs) to increase their melting point and therefore, improve their stability and utility (Nishida and Uauy, 2009). The main dietary sources of TFA are summarized in Table 1. (Zupanič *et al*, 2021; Thompson *et al*., 2011; Bhardwaj *et al*., 2011).

Table 1. Main Dietary Sources of Trans Fatty Acids

Source	Description
Partial catalytic hydrogenation of oils	The process is often used industrially with the intent of producing a product that is more solid or stable at room temperature than the original oil.
Biotransformation by bacteria in the stomach of ruminant animals.	It results in the natural presence of TFA in milk, milk products, and meat from these animals.
Heat treatment of oil	Heat treatment of oil, such as commercial refinement of cooking (e.g. deep frying) at high temperatures.

The isomerization process also occurs in the rumen of cattle resulting in low levels of TFA in beef and dairy products (Mozaffarian *et al*., 2006). The extent of hydrogenation is determined by the unsaturated fatty acid content of the oil and the desired stability and physical properties of the end product (Innis *et al*., 1999). However, hydrogenation also removes the essential unsaturated fatty acids [(α-linolenic acid (18:3n-3) and linoleic acid (18:2n-6)) (Innis and King, 1999)] because they tend to oxidize with prolonged storage or with exposure to high temperatures (Ascherio *et al*., 1999, and Wagner *et al*., 2008). TFA content of foods is variable in processed foods, in hydrogenated oils, and smaller amounts, in meats and milk products. The number of trans fatty acids in PHOs may reach 60%, with different isoforms of trans-octadecenoic acid (trans 18:1) accounting for 80–90% of the total trans fatty acid content (Oteng and Kersten, 2020). The primary sources of industrially produced TFAs are (PHOs), which had been broadly used in margarine, shortenings, baked goods, and processed, frozen, and fried foods (Chaoyang Li *et al*., 2021).

The amount of TFA in food products was estimated all over Europe; the highest amounts were found in frying fat, French fries, and popcorn. Additionally, various types of cakes, cookies, biscuits, and Danish pastries have high values of TFA (Leth *et al*., 2006). On the other hand, the major food sources of TFA in the US were baked foods (37% TFA), deep-fried foods (36%), snack chips (35%), and margarine (11-49%) (Feldman et al., 1996). In Iran and Turkey, similar TFA content in food products ranged between 2% and 5% of total fat. In contrast, the TFA content of food products ranged between 2% to 50% in Kazakhstan, Kyrgyzstan, Armenia, Georgia, Serbia, Slovenia, and Croatia (Steen Stender, 2020). Recent data analysis of TFA content in the national food supply in Thailand reported that bakery products containing partially hydrogenated oils (PHOs) are the major sources of TFA in Thailand (Chavasit et al., 2020).

ESTABLISHMENT OF TRANS FATTY ACIDS SOURCES IN JORDAN

Mashal *et al.,* (2012 a) have established the first reference database for TFA composition of locally produced and imported food supply in Jordan and demonstrated a wide variability of TFA content among food groups and within a food category as well. Data has illustrated that the average TFA levels in food groups in Jordan varied from 2.46 ± 0.97g/100g fat to high up to 5.6 ± 4.9 g/100g fat (Mashal *et al*., 2012 a). Further, the highest level of TFA was contributed by fast food, Arabic sweets, and dairy products (Figure 1). Among milk and dairy products, the TFA content of the traditional foods in this food group such as Jameed and Arabic cheese was up to ~ 5 % (Mashal *et al*., 2012 a).

Among the imported food items, the levels of TFA (g/100 g fat) in five popcorn items ranged approximately from 2% to over 40% as compared to 1.26% in a locally produced popcorn representing differences from 0.04 g to 5.9 g of trans fatty acid per 100 g popcorn. Surprisingly, the variability in TFA content was less pronounced among 14 locally produced chip-snacks which ranged from 1.16 - 1.55% as compared to 1.11 - 3.95% among 12 imported chips items (Mashal *et al.,* 2012 a).

The previous study has also demonstrated considerable variations in TFA content among selected foods within a product category in locally produced food items. For instance, the TFA content ranged from 1.54 - 7.23%/100 g fat in a locally produced fast food item such as falafel as presented in Figure 2. The amount of TFA (g/100 g fat) in 4 Arabic sweet (baklava) items and 4 samples of sweet biscuits/cakes varied considerably as shown in Figures 2. However, it is believed that the quantity of TFA isomers formed after heat application depends on the amount of heat, the duration of heat exposure, and the product itself (Menaa *et al*., 2013).

Overall, the variability in TFA content within a product category would affect the estimates of the levels of TFA dietary intake. Innis *et al*. (1999) stated that the validity of the TFA content of foods could result in misclassification of TFA intake. Therefore, accurate and updated food composition tables with values for specific foods, by brand or by the fats and oils in a product must be made available (Innis *et al*., 1999).

Unfortunately, food composition tables that provide the TFA composition of foods to evaluate TFA dietary intake are limited. Although few countries such as the United States, Germany, and the United Kingdom have a food composition database that includes the TFA composition of foods in their database, the capacity of these databases to show brand new TFA composition of the food items is uncertain (Skeaff, 2009).

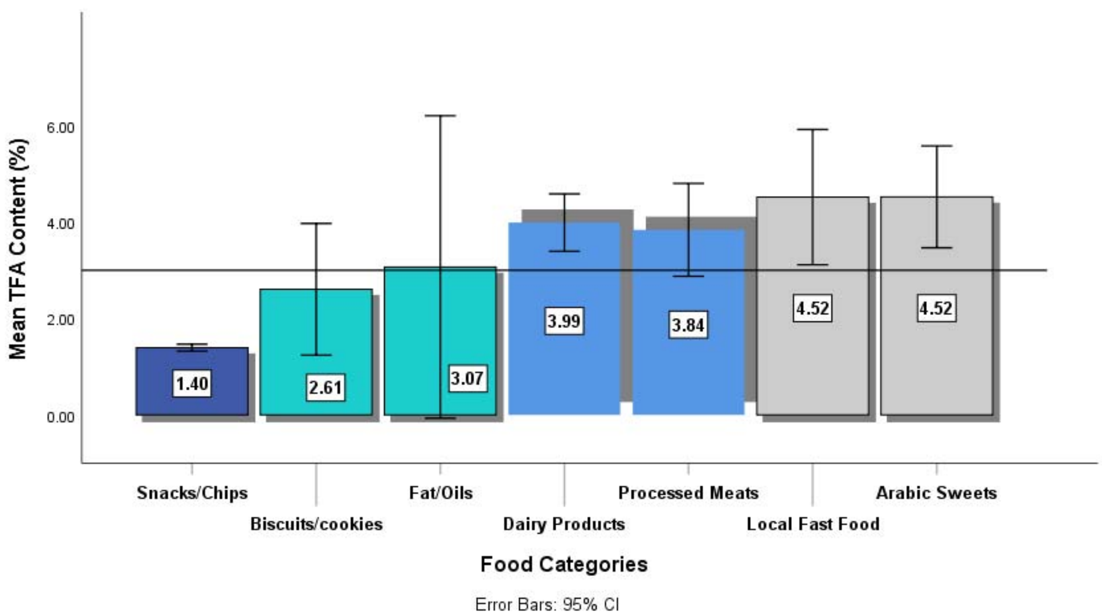

Figure 1. Trans Fatty Acid Content in Selected Jordanian Food Groups

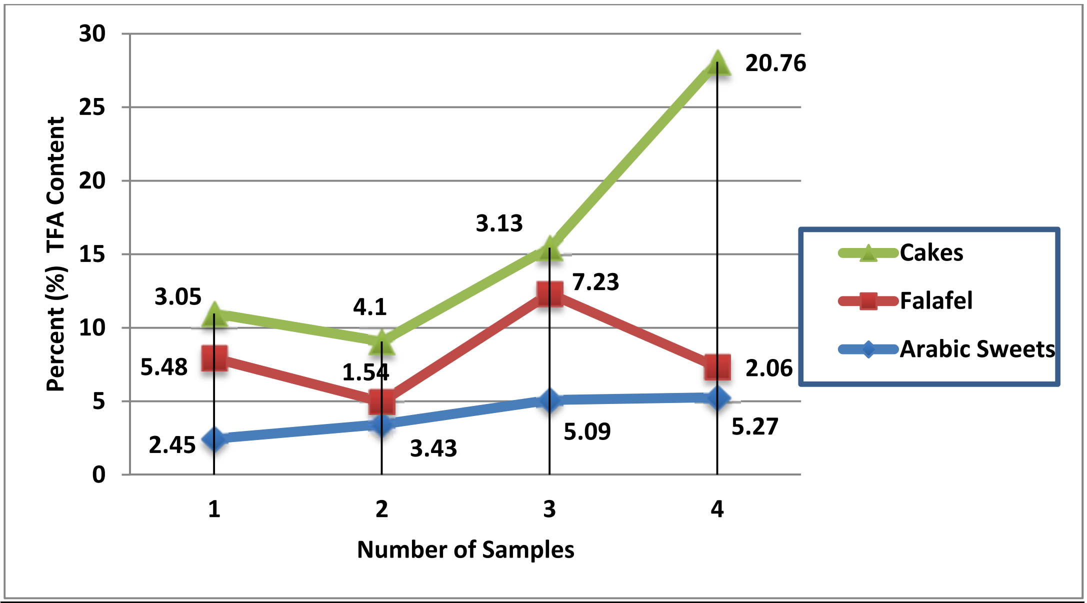

Figure 2. Variability in Trans Fatty Acid Content in Selected Jordanian Food Products

CONSUMPTION OF TRANS FATTY ACIDS

Worldwide, diverse levels of TFAs have been reported because of different dietary habits, varying quantities of TFA in food products, and methods used to estimate its consumption (Craig-Schmidt, 2006). For instance, Allison et al. (1999) estimated the mean level of TFA intakes among a representative sample of the US population, using dietary recall or records and the most updated food composition databases. The results suggested that the US population intake of TFA was 5.3g per day and 2.6% of their total energy and 7.4% of their fat energy. Moreover, results have shown that about 20-25% of TFA intake was from naturally occurring sources, therefore, dieticians would be advised to consider it when planning a diet for individuals.

In North America, daily intakes have been estimated to be 3–4 g/person using a food frequency questionnaire and greater than 10 g/person in human milk (Craig-Schmidt, 2006).

TFA content of northern European diets is traditionally greater than that in Mediterranean countries as the predominant vegetable oil is olive oil. in Europe, TFA intake range from the lowest estimates reported in Italy, Portugal, Greece, and Spain (1.4–2.1 g/day) to the highest estimates in Germany, Finland, Denmark, Sweden, France, the United Kingdom, Belgium, Norway, The Netherlands, and Iceland (2.1–5.4 g/day) (Craig-Schmidt, 2006). However, TFA intake is ranked the second-highest after that in Egypt in the Eastern Mediterranean Region (EMR). The average TFAs intake in EMR countries exceeds the global average value (Jawaldeh and Al-Jawaldeh, 2018). The pattern of TFA intake in developing countries of Asia, Africa, and the Middle East is unclear due to limited available data (Chopra *et al.*, 2021).

In China, a multi-center study that covers nine provinces among populations aged ≥ 3 was conducted to collect data on food consumption from 1991 to 2011. The intake of TFA in Chinese populations during the 20-year follow-up period had increased but remained at a level that is relatively lower than that recommended by the WHO (from 0.25 g/d (0.11%

for E%) to 0.53 g/d(0.24% for E%)) (Jiang et al., 2020). Several studies have reported a decrease in TFA consumption during the last decades due to active public campaigns as well as voluntary or mandatory measures of TFA elimination. At present, about one-third of the population worldwide in 28 countries is safe from the TFA health risks; but more than two-thirds of the population is still at risk as policies are not implemented to eliminate trans fat (Chopra *et al*., 2021).

CONSUMPTION OF TRANS FATTY ACIDS IN JORDAN

Jordan is particularly a high consumer of TFAs; among the countries of WHO's EMR, TFA consumption in Jordan was ranked higher than the WHO limit (Jawaldeh and Al-Jawaldeh, 2018). A case-control study that involved 100 patients known to have CHD of either sex and 91 healthy controls of age ≤ 60 years was conducted to investigate the association between dietary intake of TFA and CHD risk. Mean daily dietary intake of %TFA was significantly higher in cases (0.78 ± 0.55) as compared to controls (0.62 ± 0.28, p=0.01).

A more recent study was conducted in 2017 to examine the associations between dietary intake of TFA and adiposity in a group of 100 obese and overweight school children and 100 healthy controls aged 6-10 years in Al-Karak, Jordan. The mean % of TFA was 2.38±1.52% (of total energy) for all the participants, which is above the WHO recommended TFA intake (< 1% of total energy). The highest contribution of TFA from dietary food sources was from the Chocolate cupcake and French fries in this particular sample of Jordanian children (Al-Jarajreh and Mashal, 2017). These studies provide baseline data on the dietary exposure of TFA among Jordanian adults and children. However, surveys on TFA consumption at a population-level level in Jordan are lacking. Considering WHO recommendations on TFA elimination, a comprehensive representative evaluation of TFA consumption in Jordan is critical to creating baseline reference data for which monitoring progress can be achieved.

HEALTH IMPLICATIONS OF TRANS FATTY ACIDS CONSUMPTION

Chronic non-communicable diseases

According to a systematic analysis that included 266 country-specific nutrition surveys, almost 75% of all deaths worldwide are attributable to non-communicable chronic diseases including cardiovascular diseases, type 2 diabetes, obesity, and cancers, with the greatest frequency and burdens in low and middle-income countries as compared to high-income countries (Micha *et al*., 2014). Cardiovascular disease (CVD) constitutes the leading cause of death globally, accounting for 32% of mortality. In Jordan, the prevalence of CVD accounts for 37% of the annual deaths (WHO, 2018 b). Unlike other dietary fats, TFA is not essential or beneficial to human health and in fact, its consumption can lead to elevated frequency of certain non-communicable diseases (Menaa *et al*., 2013). The WHO reported that high exposure to dietary TFA is responsible for more than 500,000 deaths of people from cardiovascular disease each year around the world (WHO, 2018 a). Most interests in the health impact of TFA was focused on chronic heart diseases (CHD) (Downs *et al*., 2012; Bassett *et al.,* 2016), but now it is clear that they can influence a range of other non-communicable diseases, including type 2 diabetes (T2DM) through increasing insulin resistance, and some inflammatory diseases such as arthritis and several types of cancer (Thompson *et al*., 2011; Costa *et al*., 2016).

Many studies have been conducted to investigate the possible adverse effects of TFA on CHD risk, breast cancer, and growth and development. Several studies have shown that TFA intake is associated with an increased risk of CHD. Generally, most of these assertions were based on the following: the changes induced in plasma lipid profile; the relation between adipose tissue composition and TFA dietary intake (Garland *et al*., 1998); and the effects of TFA on calcium influx human arterial cells (Kummerow *et al*., 1999). Ascherio *et al*. (1999) summarized the results of several randomized studies that investigated the effects of a high TFA diet or saturated fatty acids diet on the ratio of low-density lipoprotein(LDL)/high-density lipoprotein (HDL) cholesterol. It has been found that the effect of TFA on the LDL/HDL cholesterol ratio was significantly greater than that of saturated fatty acid in each of the six studies. Moreover, the best-fit regression line indicates that the ratio of LDL/HDL cholesterol would increase by 0.1 units with an absolute increase of 2% in TFA intake. A 1-unit increase is associated with a 53% increase in the risk of CHD.

The intake of industrially produced TFA is negatively associated with the blood lipid profile. TFA intake can also stimulate inflammatory responses and increase mortality, particularly from CHD (Zupanič *et al*, 2021). However, the effects of ruminant-derived TFA and industrially produced TFA on CHD were initially considered to be similar (Mozaffarian *et al.,* 2009). Recently, a meta-analysis of data from clinical trials relating ruminant *TFA* to the risk of cardiovascular diseases revealed that the current ruminant *TFA intake was not associated with increased* **cardiovascular risk markers including** the ratio of total cholesterol to LDL cholesterol and the ratio of LDL cholesterol to HDL cholesterol (Gayet-Boyer *et al*., 2014).

Overall, although many studies have suggested an association between TFA intake and CHD incidence, they are limited in some respects. Several stu estimates of TFA intake were based on old or incomplete databases. Further, studies that provide evidence of a correlation between TFA intake and CHD have used a food frequency questionnaire (FFQ) for TFA estimates. This method may provide estimates of questionable validity as compared to food records or recalls (Allison *et al*., 1999). Innis *et al*. (1999) stated that the validity of TFA content of foods could result in misclassification of TFA intake, hence, weakening the relative risk (RR) estimates of CHD. However, many researchers highlighted the significance and the need for stating the amount of TFA content on food labels (Holub *et al*., 1999, Ascherio *et al.,* 1999). A considerable body of scientific evidence on the associated adverse health effects of TFA intake has led the Food and Drug Administration (FDA) in 2006 to require that the amount of TFA be included in the nutrition fact panel (Remig *et al*., 2010).

Mazidi *et al*. (2018) examined the link between liver tests, fatty liver index (FLI), and plasma TFAs; and evaluated the impact of adiposity on this link as well. The study involved 4,252 participants from the National Health and Nutrition Examination Survey (NHANES). The authors suggested a direct significant association between plasma TFAs, liver tests, and FLI; with a strong impact of body mass index (BMI) on the link between FLI and plasma TFA. The authors recommended that high consumption of TFA should be avoided in order tody minimize cardio-metabolic risk.

The association between TFA intake and increased risk of breast cancer has not been supported by many studies (Holmes *et al*., 1999; Michels *et al*., 2021). Dhaka *et al*. (2011) reported that women with elevated serum TFA levels have double the risk of developing breast cancer as compared to women with lower levels. Recently, a systematic review that included 46 observational studies relating TFA intake to any cancer risk showed that high consumption of TFA was associated with an increased risk of prostate and colorectal cancer (Michels *et al*., 2021).

The Jordan case

A case-control study that involved 100 patients known to have CHD of either sex and 91 healthy controls of age ≤ 60 years was conducted to investigate the association between dietary intake of TFA and CHD risk. The results of the study were consistent with previous findings. Trans fatty acid intake was highly significantly independently associated with an increased risk of CHD. The risk of CHD for daily intake of TFA was increased by 2.4 (95% CI: 1.1-4.9, p= 0.01) fold in cases as compared to controls. However, controlling for age, the multiplicative effect of TFA intake in the presence of selected conventional predictors on CHD risk was increased by 5.2 (95% CI: 1.1-26.9, p=0.4) in cases as compared to controls (Mashal *et al*., 2012 b).

In a study that involved a group of 100 obese and overweight school children and 100 healthy controls aged 6-

10 years in Al-Karak, Jordan relating serum and dietary intake of TFA to adiposity, significant positive associations were found between serum TFA levels and both insulin resistance (β=0.74) and adiposity (β=4.38; $P < 0.05$). Serum TFA levels [OR: 5.5 (1.7 – 17.1), $P < 0.05$] were significantly positively independently associated with increased risk of obesity in obese children as compared to controls (Al-Jarajreh and Mashal, 2017). These results provide baseline data on the dietary exposure of TFA among Jordanian children and highlight the critical need for taking actions toward reducing TFA in the food supply and informing consumers about TFA health risks.

Pregnancy and lactation

There is evidence that TFA would interfere with essential fatty acids metabolism (n-3, n-6) and thus adversely affect fetal growth and development. TFA present in breast milk is entirely derived from the maternal diet (Holub, B, 1999). Some studies have reported an inverse relationship between TFA concentrations in infants' tissue and growth measurements. However, the effects of milk trans, n-6, and n-3 fatty acids in breastfed infants are still unclear (Innis and King, 1999). Innis and King (1999) investigated the relations between trans and cis USFA in breast milk and plasma of breast-fed infants. There were comparable concentrations of TFA in the diet of the Canadian mothers, breast milk, and breastfed infants' plasma. TFA levels were inversely related to the levels of n-6 and n-3 in milk ($P < 0.05$). The percentage of TFA in milk was 7.1±0.32%. TFA represented 7.7% of maternal total fat intake and 2.5% of their total energy. The major food sources of TFA in the maternal diet were bakery products, snacks, and fast food. Holub (1999) reported that one of the richest dietary sources of TFA in the North American food supply in breast milk. Moreover, baby cereals and biscuits analyses indicated that up to 23% and 37%, respectively, of fat in these products was TFA. Hence, the author suggested that mandatory labeling of TFA food content if required by the FDA could dramatically reduce infants' exposure to TFA. Kummerow *et al*. (1999) suggested that nursing mothers would be recommended to avoid high TFA intakes and to increase their dietary Mg intake. It was reported that a high intake of TFA is associated with an increased risk of preeclampsia. Red cell TFA levels were approximately 30% higher in women with preeclampsia than women without the disorder (Dhaka *et al*., 2011).

INTERNATIONAL AND NATIONAL POLICIES AND REGULATION

Globally, governments have taken actions to reduce TFAs in the food supply and inform consumers about TFA health risks. These actions include the following policy strategies (NCD Alliance, 2019):

1. Voluntary agreements with industry to reduce or remove TFAs from their products.
2. Requirements for proper food labeling of TF.
3. Limits on TFA content in fats/oils and all foods.
4. Bans on the use of PHOs.

Efforts to minimize the intake of TFA worldwide and the associated risk of CVD have been escalated over the past two decades by the WHO and other organizations as summarized in Table 2. The Joint WHO/FAO Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases recommended that mean population intake of TFA should be less than 1% of daily energy intake which corresponds to 2% of total fat intake (WHO, 2003). On July 9, 2003, the United States (U.S.) Food and Drug Administration (FDA) issued a regulation requiring manufacturers to declare

Table 2. A Review of International Policies to Reduce Trans Fat Consumption:

Authority	Date	Regulations/Policies
Joint WHO/FAO Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases	In 2003	Recommended that mean population intake of TFA should be < 1% of daily energy intake that corresponds to 2% of total fat intake.
U.S. (FDA)	-On July 11, 2003 -Effective on January 1, 2006	Regulations on food labeling require that trans fatty acids be declared in the nutrition label of conventional foods and dietary supplements.
U.S. (FDA)	In November 2013	Made a preliminary determination that partially hydrogenated oils are no longer Generally Recognized as Safe (GRAS) in human food.
U.S. (FDA)	In 2015	A final determination is that Partially Hydrogenated Oils (PHOs) are not Generally Recognized as Safe (GRAS).
WHO	May 2018	WHO Launched the "REPLACE" (review, promote, legislate, assess, create, enforce) action package to provide strategic guidance for all countries to take action toward this goal
WHO	In 2019	The WHO has called for the elimination of industrially-produced TFAs from the global food supply by 2023.
WHO	In May 2019	WHO Released the REPLACE modules and additional resources to facilitate the implementation of the policies and measures at a national level.
WHO	17 November 2020	Announces Certification Programme for Trans Fat Elimination

the amount of TFA in the nutrition fact panel and that to be effective on January 1, 2006. These regulations were based on the consistent results provided by a large number of metabolic studies and recent reports of other government bodies relating TFA intake and its adverse effect on LDL-C levels, which contribute to increased risk of CHD. The FDA is convinced that these regulations provide beneficial nutrition information so that consumers cannot be misled about the negative impact of a specific product on CHD risk, and it would help consumers to maintain healthy dietary habits as well (FDA, 2003). Later in 2007, the WHO undertook a Scientific Update on TFA as part of the implementation of the Global Strategy on Diet, Physical Activity, and Health. A Scientific Update on TFA that was undertaken by the WHO in 2007 concluded that using industrially derived TFA in food products should be avoided by restaurants and food manufacturers and that governments should take steps to support TFA replacement (Uauy *et al*., 2009).

A preliminary determination that partially hydrogenated oils are no longer Generally Recognized as Safe (GRAS) in human food has been made by the FDA in November 2013. Later, the FDA released its final determination that Partially Hydrogenated Oils (PHOs) are not Generally Recognized as Safe (GRAS) (FDA, 2015). Recently, the WHO has launched the "REPLACE" action package to provide strategic guidance for the global elimination of industrially-produced TFA by 2023. The action package provides practical, step-by-step implementation information to support governments to eliminate industrially-produced TFA from their national food supplies by implementing best-practice legal measures. Figure 3 presents the six-step roadmap for countries to implement actions for the elimination of industrially-produced TFAs in foods (WHO, 2019). The WHO Eastern Mediterranean Regional Committee has adopted a regional nutrition strategy in 2019 which aimed to virtually eliminate industrially-produced trans-fatty acids from the food supply. This objective was one of several specific objectives relating to the prevention of overweight/obesity and diet-related NCDs and reducing unhealthy diets (Al-Jawaldeh et al., 2020). Overall, WHO has recently announced a "Certification Program for Trans Fat Elimination". This program aims to recognize countries that have eliminated industrially-produced TFA from their national food supplies (WHO, 2020).

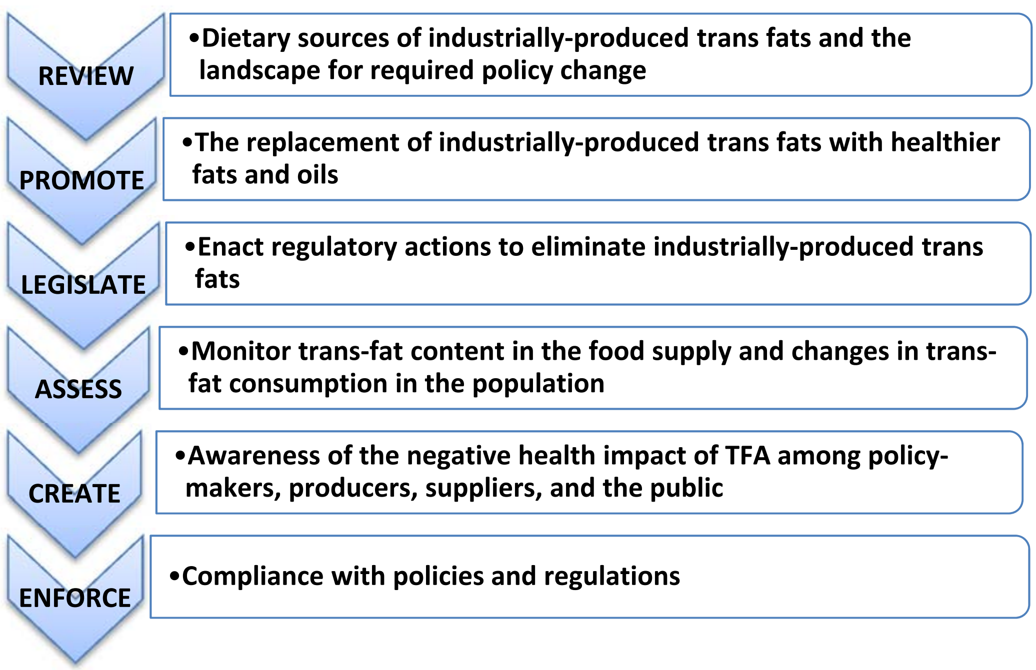

Figure 3: The WHO's REPLACE Action Package: a six-step roadmap for countries to implement actions for the elimination of industrially-produced TFAs in foods.

Different policies and efforts to minimize the global exposure to TFA and the associated health risks have been currently adopted by many countries as shown in Table 3. Denmark was the first country to approve a regulation limiting TFA, in which the policy set a maximum limit of 2 g TFAs per 100 g of total fat in foods in 2004 (Zupaniˇc *et al*., 2021). A similar policy was introduced in 22 other countries, including Switzerland, Austria, Iceland, Hungary, and Norway by the end of 2018 (Zupaniˇc *et al*., 2021). Slovenia enacted a TFA limit of 2 grams per 100 grams of fats and oils and a ban on TFAs was introduced in March 2018 with a transitional period of one year (Zupaniˇc *et al*., 2021; NCD Alliance, 2019). Although South Africa is the only country in Africa to limit TFA of 2 grams per 100 grams of fat or oil in 2011, some challenges in the implementation of the policy may exist, and data on the impact of the regulation is not available (NCD Alliance, 2019). In the United States, several states have introduced partial TFA bans but only in food-service establishments including New York City and California in 2005 and 2008, respectively (Spruk and Kovac Swiss, 2020). Germany, France, and the United Kingdom tend to support the use of voluntary agreements regarding the presence of TFAs in the food supply (Spruk and Kovac Swiss, 2020). Mandatory labeling and limit TFA of 3% on different fats and oils were adopted by India, with continuous efforts to reduce the limit to 2% in all edible oils and fats by 2021 (Chopra *et al*., 2021). Due to the health risks of TFA from PHOs, Thailand endorsed a ban on PHOs in 2018 to stop the production and importation of Western-style foods high in PHOs (NCD Alliance, 2019).

In the Eastern Mediterranean Region, Saudi Arabia is the only country in the region that is considered to have a best practice trans-fatty acid elimination policy in place. (Al-Jawaldeh *et al*., 2020). Saudi Arabia performed both a TFA labeling requirement and a TFA limit of 2 % for fats and oils and 5 % for all other foods in 2015. Saudi Arabia became the second country in the region to limit TFAs through regulation. By December 2018, a ban on PHOs was then performed to align with international best practices (NCD Alliance, 2019). However, only 10 countries in the region had adopted national policies to ban or virtually eliminate industrial TFA in 2019 Some countries including Bahrain, Iran, and Kuwait have had limits on industrially produced TFA but these limits were less restrictive than the recommended best practice policies for trans-fatty acid elimination (Al-Jawaldeh *et al.,* 2020). In Iran, TFA standards were reduced to less than 5% in fats and oils in 2011 and to less than 2% in 2013, with a 2016 compliance deadline (Rashid *et al*., 2020). However, variable regulations are implemented by the key institutions responsible for food safety regulations in Pakistan. These regulations mandate limiting TFA in some food products and banning vanaspati ghee by 2020 in particular (Rashid *et al*., 2020).

Jordan is a middle-income Arabic country that has undergone considerable social developmental changes that have affected the lifestyle and eating patterns of Jordanians. It has been reported that the consumption of fast foods and ready-to-eat processed foods is increasing (Al Hourani, 2011). However, nutritional labeling of TFA is not mandatory and no regulations require that the amount of TFA be included in the nutrition fact panel in Jordan.

Table 3. Current Status of TFA Policies in the Elimination of Trans Fatty Acids by Selected Countries

Countries	Regulations/Policies
Chile	- Enacting a TFA labeling regulation in 2006. - TFA limit of 2 % of total fat in all foods, a best practice policy in 2009.

Denmark, Iceland,	- Limits trans fat to 2 % in all Foods
Slovenia	- Limits trans fat to 2 g/100g of fats & oils
Switzerland, Armenia, Russia, Singapore	- Limits trans fat to 2 % in vegetable oils only.
Austria, Hungary	- Limits trans fat to 2 % when the fat content constitutes 20% of the total weight of a food product
South Africa	- Limits trans fat to 2 g/100g of fats & oils
India	- Mandatory labeling - Limit TFA of 3% on different fats and oils
Germany, France, and United Kingdom	- Voluntary agreements regarding the presence of TFAs in the food supply. (Spruk and Kovac Swiss, 2020)
Canada, United States Saudi Arabia, Thailand	- A ban on PHOs
Pakistan	- Mandatory TFA limits for only specific food products.
Jordan	- No implemented Policy to reduce the impact of marketing high saturated fats and TFA foods & beverages. - Other complementary measures in place: - Ban on PHO in dairy products, including imported produce.

Other complementary measures are in place including a ban on PHOs in dairy products, including imported produce as indicated by a recent report (Rashid *et al.,* 2020). Based on the report on the EMRO-Regional workshop on a healthy diet that was held in March 2019 in Lebanon, there are challenges to the elimination of trans-fatty acids from food products in most countries of the Region. The challenges of TFA elimination include the following: (EMRO-WHO, 2019)

1. Unavailability of accurate data and market surveys on TFA content of food products.
2. Data regarding the level of risk exposure to TFA in processed foods among the Region's population, particularly children and adolescents, is minimal.
3. Regional high-quality research on nutrition is lacking and limited funds are available.

In conclusion, low- and middle-income countries bear up to 90 percent of the global CVD burden (NCD Alliance, 2019), which highlights the urge to implement strategies, policies incorporation with food producers and research institutions toward reducing exposure to TFA across the Eastern Mediterranean Region. In this context, a recent review reported that the application of TFA elimination policies over the past 20 years has substantially decreased TFA intake in almost all countries that have applied these policies. About 76% of the countries reported a TFA average intake below the recommended maximum intake of 1% of daily energy intake; this reduction is primarily attributable to a reduction in the use of industrial TFA (Rashid *et al.,* 2020).

Spruk and Kovac. (2020) suggested that banning TFA in Denmark has strong effects on the adolescent obesity rate and is associated with about a 1-percentage point drop in the adolescent obesity rate.

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الدهون المتحولة: مراجعة مصادرها واستهلاكها وآثارها الصحية والسياسات والأنظمة الدولية والوطنية

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الملخص

تتكون الأحماض الدهنية المتحولة عندما تخضع الدهون غير المشبعة لعملية الهدرجة، وأكدت العديد من الدراسات العلاقة بين تناول الدهون المتحولة و خطر الإصابة بالأمراض، والبيانات المتعلقة بالمتناول الغذائي للدهون المتحولة هي محدودة أو غير متوفرة لدى العديد من الدول في المناطق النامية بما فيها الشرق الأوسط.

الاهداف: وهدفت هذه المراجعة إلى تقييم المصادر الرئيسية للدهون المتحولة وعلاقتها بخطر الاصابة بالأمراض، إضافة إلى مراجعة السياسات والتشريعات العالمية والمحلية للتخلص من الدهون المتحولة الموجودة في المنتجات الغذائية.

اساليب البحث: وتعرض هذه المراجعة الأدبية موجزاً عن المعلومات و المستجدات المتعلقة بتنوع نمط الاستهلاك الغذائي للدهون المتحولة و مصادرها الغذائية والمضار الصحية الناتجة عنها، وكذلك السياسات والتشريعات العالمية ولاسيما في الأردن.

الخلاصة: نظراً للأدلة العلمية المتزايدة التي تربط تناول الدهون المتحولة بأمراض القلب واستجابة لها، أطلقت منظمة الصحة العالمية (WHO) حزمة من الإجراءات لتوفير التوجيه الإستراتيجي العالمي للتخلص من الدهون المتحولة و المنتجة صناعياً بحلول عام 2023. وفرضت العديد من البلدان تدابير طوعية أو إلزامية للتقليل من محتوى الدهون المتحولة الصناعية في منتجاتها الغذائية. بناءً على البيانات المتاحة في الأردن والتي تشير إلى أن محتوى المنتجات الغذائية من الدهون المتحولة وكمية استهلاكها يتجاوز الحدود الموصى بها من منظمة الصحة العالمية. في الوقت الحالي، لا توجد سياسات خاصة تتعلق بعدم الالتزام بتطبيق الأنظمة على الاحماض الدهنية المتحولة في الاردن.

الكلمات الدالة: الأحماض الدهنية المتحولة، الزيوت المهدرجة جزئياً، مرض القلب التاجي، مستوى الدهون في الدم، الملصقات الغذائية، السياسات والأنظمة.