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Posted Date: 1 June 2023

doi: 10.20944/preprints202306.0023.v1

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Assessment of Trans Fatty Acid Levels in Popular Edible Oils and Fried Foods: Implications for Public Health in Tanzania

Fredirick Mashili [1,2,*], Hassan J Rusobya [3] Juliana S Masaulwa [4,] Cleopatra J Shonyella [5,] Kaushik L Ramaiya [6] and Walter C Willet [7]

[1] Department of Physiology, School of Biomedical Sciences, Muhimbili University of Health, and Allied Sciences (MUHAS), Dar es Salaam, Tanzania, fredirick@gmail.com.
[2] East African Centre of Excellence in Cardiovascular Sciences, Muhimbili University of Health, and Allied Sciences (MUHAS), Dar es Salaam, Tanzania, fredirick@gmail.com
[3] Department of Epidemiology, School of Public Health and Social Sciences, Muhimbili University of Health, and Allied Sciences (MUHAS), Dar es Salaam, Tanzania, hassanrusobya@gmail.com
[4] Department of Education, St Joseph College of Engineering and Technology, Tanzania, masaulwajuliana@gmail.com
[5] Department of Pharmacognosy, School of Pharmacy, Muhimbili University of Health, and Allied Sciences (MUHAS), Dar es Salaam, Tanzania, patracj87@gmail.com
[6] Tanzania Non communicable disease alliance, Dar es salaam, Tanzania, ceo@hc.shm.or.tz,
[7] Department of Nutrition, Harvard T.H. Chan School of Public Health, Boston, MA, USA, wwillett@hsph.harvard.edu,
* Correspondence: fredirick@gmail.com; Tel. +255752255949

Abstract: Trans fatty acids (TFA) are a concern for public health due to their negative impact on cardiovascular health. This study aimed to assess the levels of TFA and other fatty acids in popular edible oils and fried foods commonly consumed in Tanzania. A total of 57 samples from 38 brands of edible oils and 20 samples of fried street foods and fast foods were collected in Dar es Salaam, Tanzania. Capillary gas chromatography was used to determine TFA levels, while nutritional labeling and other fatty acid classes were also evaluated. Among the analyzed edible oils, 21% exceeded the recommended TFA levels, primarily found in popular brands of margarine, industrially refined sunflower oils, animal butter, and peanut butter. Only two food items surpassed the 2% TFA limit, but a majority of the foods had high levels of saturated fatty acids and a fatty acid profile similar to palm oil. Additionally, only 22% of the edible oils provided TFA content information. These findings indicate the persistence of TFA levels beyond recommended limits and inadequate TFA nutritional labeling in Tanzanian food products. Urgent interventions are necessary to reduce TFA levels and improve nutritional labeling practices to safeguard public health.

Keywords: Trans Fatty Acids; edible oils; cardiovascular health; fried foods; nutritional labeling; public health; fatty acid profile; Recommended limits

1. Introduction

The ongoing nutrition transition in most low- and middle-income countries (LMICs) is characterized by a shift towards the consumption of energy-dense foods that are low in nutritional value [1]. In Tanzania, this transition is partly explained by a change from the consumption of traditional homemade meals to the consumption of purchased meals that are often baked or fried, and containing large quantities of fats [2]. Due to high fat content, these meals are likely high in trans fatty acids. Additionally, the mass production and availability of oils and fat-based products, along with the introduction of industrial processing, have likely increased the consumption of unhealthy trans-fatty acids (TFA) in the country [3].

 doi:10.20944/preprints202306.0023.v1

Trans Fatty Acids (TFA) are unsaturated fatty acids with at least one double bond in the trans configuration [4]. These fatty acids are primarily found in industrially produced partially hydrogenated oils (PHOs) used in food processing and are commonly referred to as industrial produced trans fatty acids (iTFA) [4]. Evidence from epidemiological studies has demonstrated that dietary intake of TFA is positively associated with an increased risk of cardiovascular disease (CVD) [5,6]. Additionally, consumption of TFA has been linked to increased inflammation, impaired endothelial function, and adverse lipid profiles [5,6]. The adverse health effects of TFA have prompted public health authorities worldwide to regulate and monitor the intake of iTFA in food products.

In response to the harmful effects of TFA, different countries have adopted various approaches to control the amount and intake of TFA in food products. These approaches include limiting the amount of TFA, mandatory labeling of TFA in packaged food, or a total ban of PHO [7]. Despite the implementation of these measures, studies conducted in different parts of the world have reported high levels of TFA in edible oils/fats and a variety of food products [8,9]. In Europe, despite the implementation of good practice policies to regulate levels of TFA by some countries, higher levels of TFA were still detected in a variety of food products [8,9]. Similarly, in New Zealand and the USA, certain food products including pastry-based foods and margarine still contained higher levels of TFA[10,11]. Put together, these findings underscore the need for continuous monitoring of TFA in food products.

Despite known health consequences of TFA, and the progress made by western countries in eliminating TFA from the global food supply, data on the levels of TFA in African foods are still limited. Furthermore, there is a lack of information on TFA levels in Tanzania, where both the industrial processing and consumption of oils/fats have tremendously increased over the past decades. This increase is in parallel with the increasing prevalence and incidence of major non-communicable diseases (NCDs) in the country [12,13]. The World Health Organization (WHO) has planned to eliminate iTFA by the year 2023[7]. However, until recent, studies that assessed levels of TFA in Tanzanian foods were lacking. For that reason, data on which to base the adoption of good practice policy for the elimination of iTFA from the Tanzanian food supply is very limited. To date, levels of TFA in Tanzania have only been assessed once, and that assessment involved already used edible oils [14]. To address this gap, this study aimed to adopt a WHO standardized protocol to assess levels of TFA in popular edible oils and fried foods in Tanzania [7,15,16]. This information will provide valuable insights into the levels of TFA in Tanzania's food supply, enabling public health authorities to develop and implement effective policies for reducing the intake of TFA and preventing NCDs.

2. Materials and Methods

In this study, we utilized the sampling protocols jointly developed by WHO and Resolve to save lives for rapid assessment of trans-fatty acids (TFA) in edible oils and foods [17,18] (Figure 1). These protocols are part of the WHO REPLACE package [7]. We made slight modifications to the protocol to fit our study setting and budget.

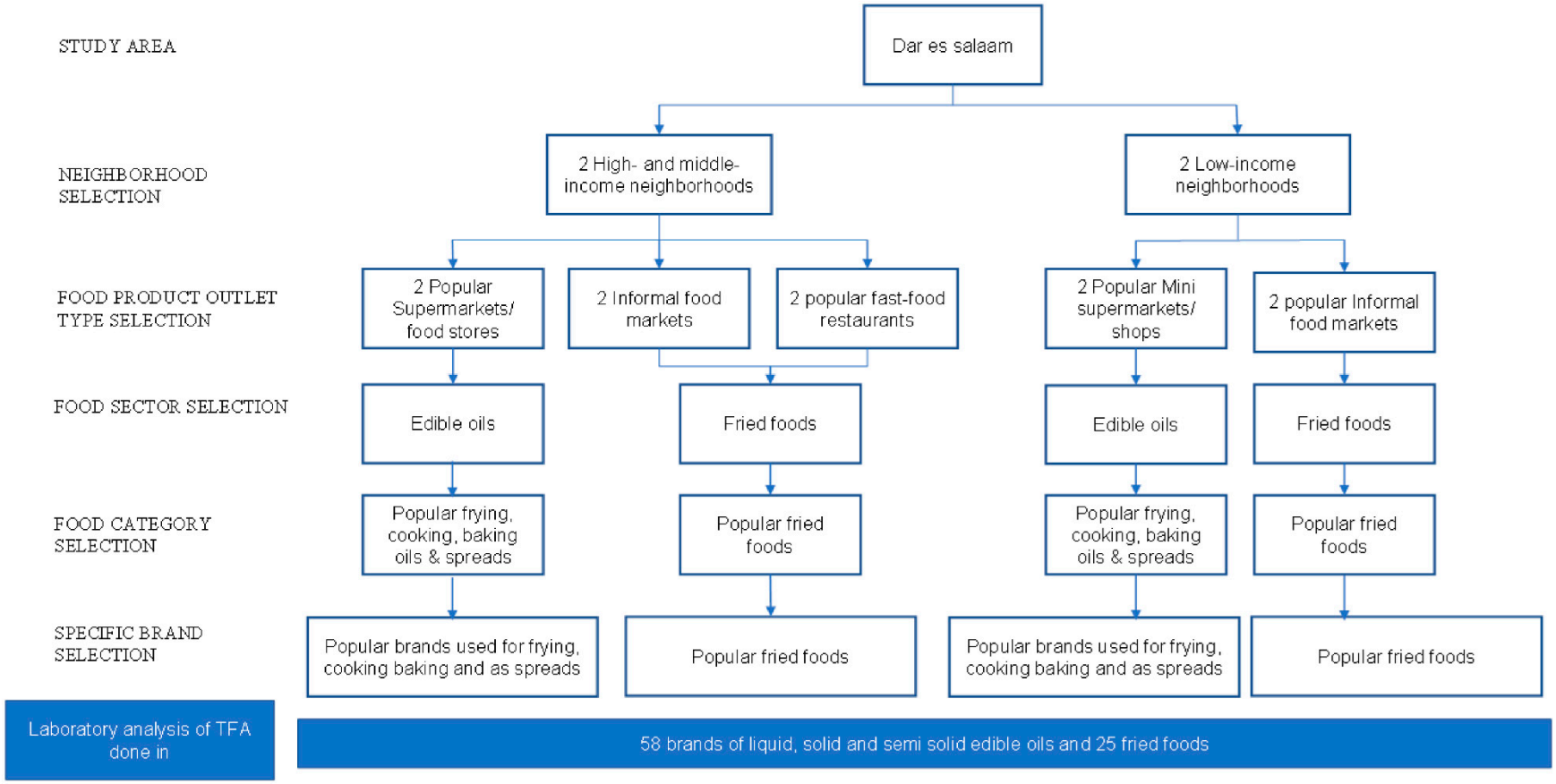

Figure 1. Sampling protocol for rapid assessment of trans fatty acids in edible oils and foods.

doi:10.20944/preprints202306.0023.v1

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Study Design

A cross-sectional study design conducted between the year 2020 and 2022.

Study setting

This cross-sectional study was conducted in food stores (including supermarkets), informal food market areas and in fast food restaurants located in selected neighborhoods in Dar es Salaam, Tanzania. Dar es salaam is the largest city in the country and has a high consumption and production of cooking oil/fat.

Data collection

Data collection involved several stages/procedures as described in the sampling protocols for rapid assessment of TFA in edible oils and foods, which are modules in the WHO REPLACE package[7]. These stages include selection of neighborhoods, selection of food outlet types, selection of specific food outlets, selection of food sectors, selection of food categories, selection of food/edible oil item and brands and finally sample collection, storage, and shipping.

1. *Neighborhoods' Selection*

The study area was Dar es Salaam, and all neighborhoods within the city were identified, categorized and selected based on the sampling protocols for rapid assessment of TFA in edible oils and foods, described in the WHO REPLACE package[7]. Except for a purposeful inclusion of neighborhoods with informal food markets, all other procedures were in accordance with the REPLACE package protocols. Two neighborhoods from each of the two social economic status groups (SES) (High/middle and low SES neighborhoods) were visited for sample collection.

2. *Food Outlet Type Selection*

For edible oils and fats, popular supermarkets and shops selling edible oils/fats in the selected neighborhoods were selected. For street foods, popular informal markets where street foods are sold were selected from the selected neighborhoods.

3. *Specific Food Outlet Selection*

Criteria described in the REPLACE package protocols were used to identify popular supermarkets/shops/grocery stores and informal food markets that are commonly visited in the four selected neighborhoods. For fast foods, three popular outlets were selected since fast food outlets are usually located in high and middle SES areas.

4. *Food Sector Selection*

We assessed trans-fat content in popular edible oils/fats and fried street and fast foods. Various edible oils and fats are used for baking, frying, cooking, and spreads. Therefore, edible oils could represent the trans-fat content of a wide variety of foods that are consumed in Dar es Salaam. Street foods (from street food vendors) are also commonly consumed in Tanzania and were another food sector included in the sampling. In addition, consumption of food from fast food restaurants is rapidly increasing. Commonly consumed fast foods were sampled and profiled for trans-fat.

5. *Food Categories Selection*

Based on review of both published and grey literature supplemented by the Tanzania food composition tables[19], oils/fats that are commonly used for baking, frying and as spreads are potentially high in trans-fat. All the available brands of potentially partially hydrogenated oils (PHO) (margarine and cooking fat) and all the edible oils/fats that were mentioned as popular, were included. These were purchased from selected outlets and processed for trans-fat assessment. For margarine and the top three popular oils, one sample was purchased from each of the supermarkets/stores in both the SES neighborhood categories (four samples for each brand). Fried

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foods from street food vendors and formal fast-food restaurants are also potentially high in fats and trans-fat. We selected fried foods that are commonly used as breakfast and lunch from informal markets (street foods) and popular fried fast foods from fast-food restaurants.

6. *Food Item and Brand Selection*

To select appropriate brands of edible oils/fats for each category from outlets (supermarkets/shops/grocery stores), we reviewed sales information and interviewed owners, managers/employees of respective outlets. This was important to ensure appropriate selection of brands/items that are commonly purchased for each of the three edible oils/fats categories (frying, cooking, baking and spreads).

7. *Sample Collection, Storage and Shipping*

Sample collection, storage and shipping procedures were designed and implemented following the Sampling Protocol for Rapid Assessment of trans-Fatty Acids in edible oils and foods[17,18]. The protocol was strictly adhered to throughout the study to ensure consistency and reliability of the data obtained. Field researchers were trained on the sampling procedures and quality control measures prior to the commencement of the study.

A. Collection of Fats and Oils:

Different categories and brands of edible oils/fats were collected/purchased from supermarkets/shops. From each outlet, a minimum of three different brands of consumer-sized oils/fats packages were collected/purchased for each edible oil/fat category (frying, baking, cooking and spreads). Additionally, at least one brand that is potentially low in TFA (liquid vegetable oils) was collected from each outlet, based on results from interviews conducted at the food stores. This was important to identify edible oils/fats that can be used as healthy alternatives.

The purchased items were processed, packaged, labeled, and stored according to the procedures described in the sampling protocols for rapid assessment of TFA in edible oils and foods [17,18].

B. Collection of Fried Foods from Street Vendors and Fast-food Outlets:

To maximize the possibility of sampling foods that are potentially higher in iTFA with limited resources, sampling was limited to fried foods. Three fried items/foods commonly used for breakfast and three for lunch were collected/purchased from street food vendors and fast-food joints. To identify commonly purchased street foods, a short survey was conducted using a modified version of the sample questionnaire for food sampling at informal food markets, from the REPLACE package[7]. For fast foods, outlet managers were interviewed, and sales records were reviewed to confirm the foods that were commonly purchased from selected fast-food outlets.

Due to limited resources, the three items for a single category (breakfast or lunch) were collected from the same vendor. However, to account for possible variabilities within vendors, a single item/food (likely French fries/chips) was collected from 5 different vendors. Items from the two targeted categories (breakfast and lunch) were collected from two different vendors who happen to be using different edible oils. This approach allowed for a targeted, but a more complete analysis of TFA within a narrow food category, with a limited budget.

From each outlet, three 100 g portions of food samples for each of the two subcategories (breakfast and lunch) were collected. The same procedures were followed for selected fast-food outlets.

In summary, sample collection, storage and shipping procedures were implemented with strict adherence to the Sampling Protocol for Rapid Assessment of trans-Fatty Acids in edible oils and foods. The procedures ensured the collection of a representative sample of different categories and brands of edible oils/fats, and a targeted but complete analysis of TFA within a narrow food category, with a limited budget. The collected samples were properly labelled, stored, and transported to the laboratory for analysis.

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8. *Sample collection and preparation*

Samples were collected in triplicate and packaged in sterile containers. The samples were then transported to the laboratory for analysis.

9. *Laboratory analysis*

The analysis of trans fatty acids (TFAs) was conducted using gas chromatography with flame ionization detector (GC-FID) with a 100-meter GC column. Due to the unavailability of a laboratory with the required capabilities in Tanzania and nearby countries, the samples were shipped to the laboratory at the Harvard T.H. Chan School of Public Health (HSPH) in Boston, USA. The selection of the HSPH laboratory was based on the guidance on selection of appropriate laboratory to conduct analysis of food samples present in the WHO, REPLACE package. Before the analysis, the laboratory at HSPH was inspected by a consultant to ensure it met the WHO standards.

10. *Data analysis*

Descriptive statistics were used to present the fatty acid profile data. Frequency distribution tables and charts, including bar and pie charts, were used to present the different fatty acid content of different foods and oils/fats. Mean, modes, and proportion were used to compare the TFA content of different oils/fats and foods.

11. *Data management and ethical considerations*

Unique identification (code) was assigned to each sample, which was linked to the edible oils/fats and foods database for ease of identification. The codes were placed on the samples that were shipped to the US for laboratory analysis to ensure that those conducting the analysis were blinded to the type and brands of edible oil and foods, thereby controlling for analysis bias. The coding also ensured data security and confidentiality before official dissemination.

Ethical review was sought from the National Institute of Medical Research (NIMR) since the study involved the collection of food samples from various markets and supermarkets. The study involved minimal human contact, and all interviewed volunteers signed informed consent forms after agreeing to participate in the surveys. All necessary authorities were consulted, and necessary procedures were followed accordingly.

3. Results

3.1. Popular (mostly purchased) edible oils.

From the 4 food stores that were visited, 38 different brands of edible oils (including 8 brands of peanut and 1 brand of cashew butter) were identified as popular (mostly purchased), and used for cooking, frying, baking and as spreads. Based on front and back-of-pack nutritional labelling, supplemented by information collected from respective company websites, 9 (24%) of the brands were liquid palm oil, 5 (13%) sunflower oil, 2 (5%) coconut milk/powder, 1 (3%) olive oil, 1 (3%) blended oil, 8 peanut butter (24%), 4 (10%) animal butter, 1 (3%) cashew nut butter, 4 (10%) margarines and 2 (5%) cooking fats (Figure 2A). All the margarine and cooking fats contained palm oil.

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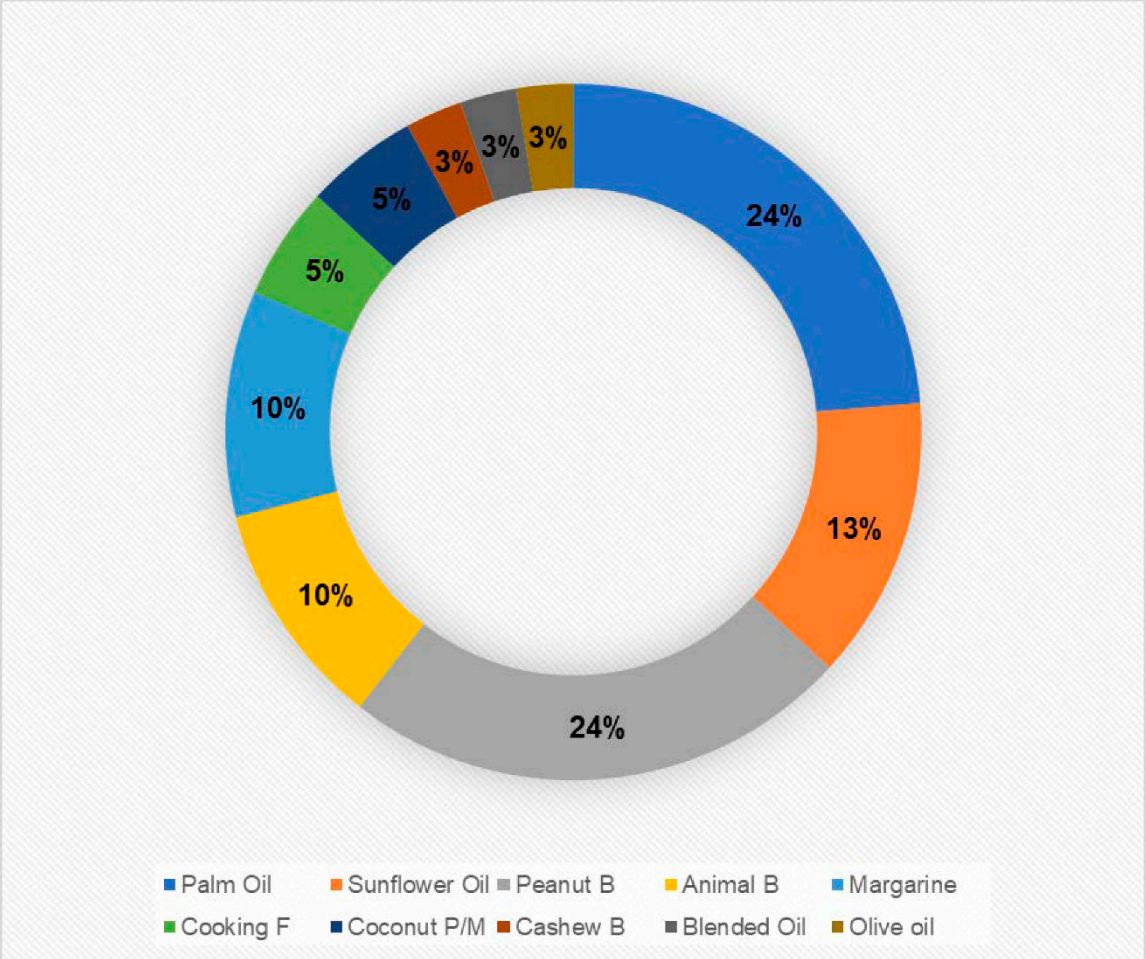
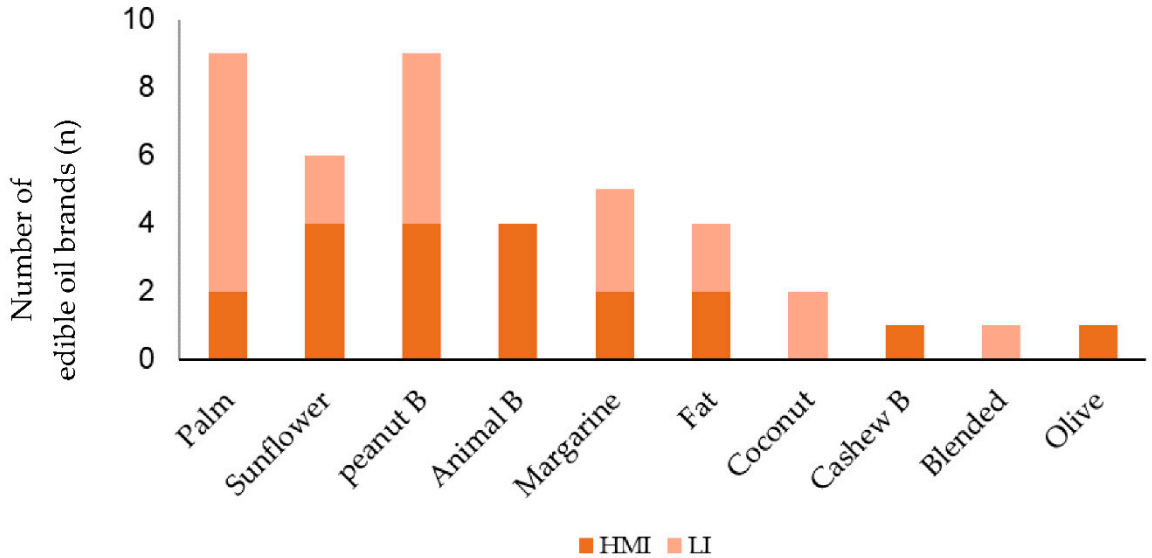


Edible oils that are mostly purchased from popular supermarkets/shops that are in selected high/middle- and low-income neighborhoods in Dar es salaam.

(**A**)



Mostly purchased edible oils in high/middle income (HMI) and low income (LI) neighborhoods in Dar es salaam.

(**B**)

Figure 2. Popular (mostly purchased and consumed) edible oils from 4 selected food stores in Dar es salaam. (**A**). Proportion of popular (mostly purchased) edible oils per type of edible oil. (**B**). Distribution of popular (mostly purchased) edible oils according to neighborhoods (High/middle and Low income).

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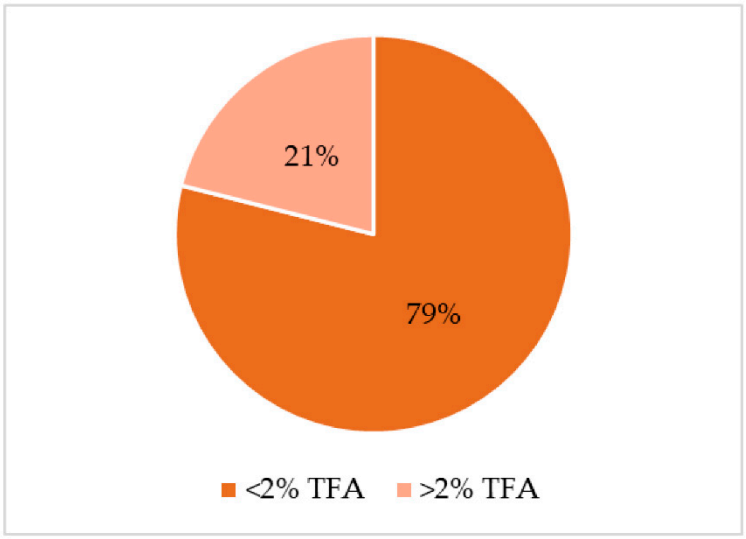
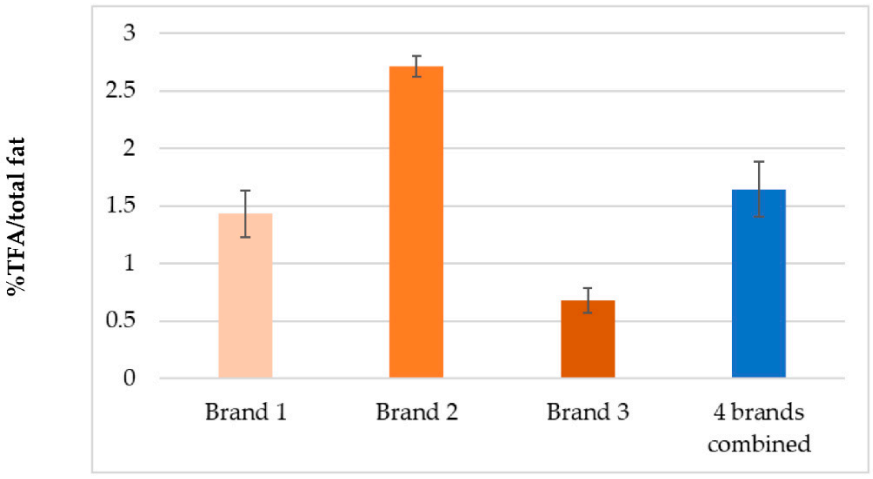
Of the 2 mostly purchased types of liquid oils (palm and sunflower), we noted a difference in the pattern of purchase between the 2 neighborhoods categories visited (high/mid and low income). Palm and sunflower were the mostly purchased liquid oils from the food stores located in low (7 brands of palm oil vs 2 brands of sunflower oils) and high/middle income (4 brands of sunflower oil vs 2 brands of palm oil) neighborhoods respectively. In addition, based on our surveys, animal butter (4 brands) and olive oils (1 brand) were exclusively popular from stores located only in high/middle income neighborhoods (supermarkets), and coconut powder/milk (2 brands) were popularly purchased from stores located in low-income neighborhoods (Figure 2).

3.1.1. Levels of trans fatty acids in popular edible oils

Chemical analysis of TFA was done in 57 edible oil products (37 brands). Since margarines are likely to have high levels of TFA due to partial hydrogenation during their processing, TFA was measured in 4 different products for each of the top 3 popular brands of margarine. Additionally, given their potential as healthy replacement alternatives, TFA was also measured in 4 different products for each of the top 3 popular brands of sunflower oil. Regardless of brand, 12 out of all 57 edible oils (21%), had TFA levels that exceeded 2% (Figure 3A).



(**A**)



Average levels of TFA in each of the 3 top brands of margarine (n=4/brand) and in 4 brands of margarine combined (n=17). For brand 4, only 1 product was analyzed for TFA.

(**B**)

Figure 3. Levels of trans fatty acids in popular edible oils. A. Proportion of edible oil products (regardless of brands and type of oils) exceeding the WHO recommended TFA Levels. B. Average

 doi:10.20944/preprints202306.0023.v1

TFA levels in individual top 3 popular brands of margarines and in all 4 brands of margarines available in Dar es salaam.

For margarines (partially hydrogenated oils (PHO)), 4 products per brand (top 3 brands) were analyzed for TFA. Average TFA levels exceeded the WHO limit in 1 out of top 3 brands of margarines (33%), with TFA levels ranging from 0.7% to 2.7%. Put together, average TFA in all the margarines that were analyzed (4 brands) was 1.8% (Figure 3B).

3.1.2. Edible oils/fats and foods exceeding the WHO recommended levels of trans fatty acids (TFA)

Considering individual brands of edible oils and foods, put together, a total of 10 products exceeded the WHO recommended levels of TFA. These included all 4 brands of animal butter that were analyzed for TFA (100%), 1out of 4 brands of margarines (25%), 2 out of 5 brands of refined sunflower oils (40%), 1 out of 20 fried street foods (5%) and 1 out of 5 fried fast foods (20%). Considering individual brands and food products, the highest level of TFA was found in a brand of animal butter (5.22%), and a brand of sunflower oil represented a product with the lowest levels of TFA (2.08%) among those exceeding the recommended WHO limit (Table 1).

Table 1. Products (brands and food items) exceeding the WHO recommended 2% TFA limit.

	Product type	Number of products/brand(n)	TFA levels (%)	Remarks
01	A brand of animal butter	1	5.22	High
02	A brand of animal butter	1	3.76	High
03	A brand of animal butter	1	3.70	High
04	A brand of animal butter	1	3.63	High
05	A brand of peanut butter	1	2.04	High
06	A brand of Margarine	4	2.71*	High
07	Fast food sausage	1	2.45	High
08	Street food samosa meat/beef	1	2.07	High
09	A brand of sunflower oil	4	3.45*	High
10	A brand of sunflower oil	4	2.18*	High

* average %TFA of 4 different products of similar brand.

When we compared the fatty acid profile of the 2 fried foods (that exceeded the WHO recommended TFA limit) with that of edible oils commonly used for commercial frying, their profile closely reflected that of palm oil (liquid palm oil, margarine, and cooking fat). Generally, the fatty acid profile of all the analyzed foods closely reflected that of palm oil (Figure 3).

3.1.3. Profile of SFA, MUFA and PUFA in popular (mostly purchased) edible oils.

To identify edible oils that could potentially serve as healthy replacement alternatives, other fatty acids (saturated and unsaturated) were also measured in all the collected samples of mostly purchased brands of edible oils. Coconut milk had the highest proportion (95.22%) of saturated fatty acids (SFA), followed by animal butter (68.53%) and cooking fat (48.4%).

Sunflower oil (24.34% and 50.57%), cashew nut butter (56.59% and 18.04%), peanut butter (43.19% and 30.39%) and olive oil (54.06% and 14.37%) presented higher proportions of mono and polyunsaturated fatty acids (MUFA and PUFA), in varying proportions. In addition, the 3 edible oil categories with high content of unsaturated fatty acids, had their proportions of SFA below 40% (Figure 4).

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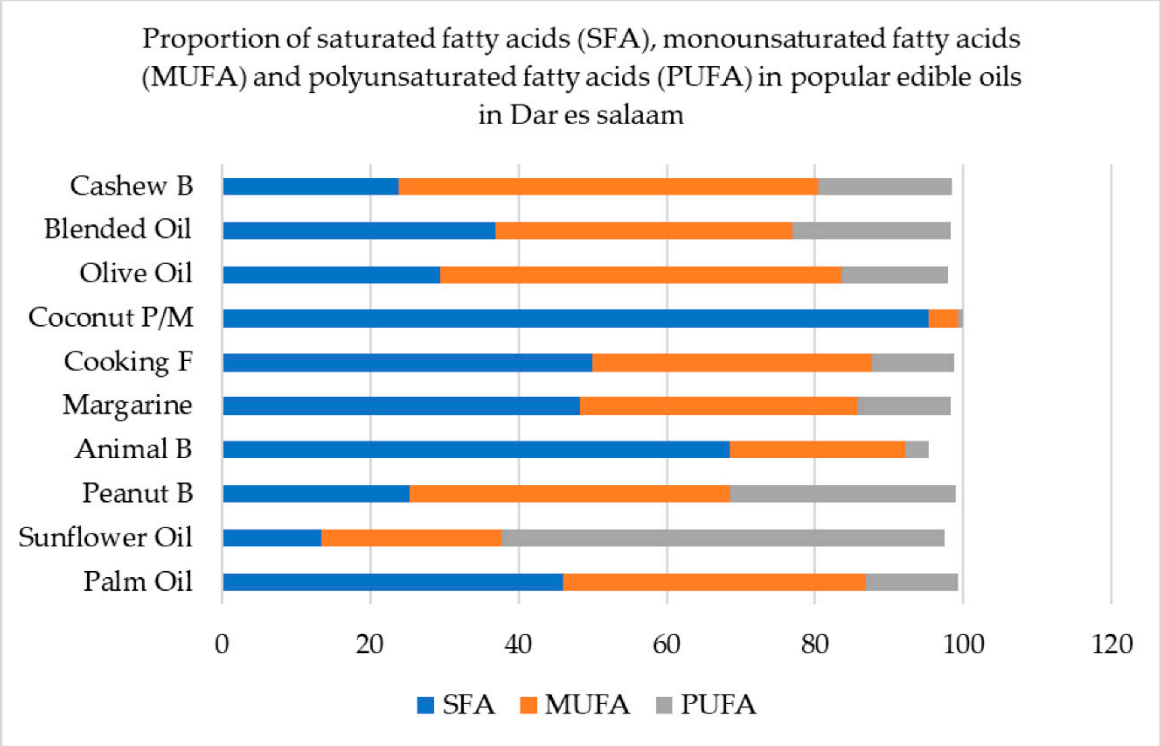

Figure 4. Proportion of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) in popular edible oils in Dar es salaam.

3.1.4. Status of nutrition labelling in popular brands of edible oils

We also evaluated the status of nutrition labelling focusing on fats and fatty acid content of edible oils (Table 2). A check list with four main entries including front-of-pack and back-of-pack labelling for nutrition facts information, as well as health and nutrition claims was created and used to collect information. Generally, essential nutrition fact labelling that included fats (either front or back-of-pack) was present in 27 out of 38 edible oils we evaluated.

Table 2. Status of nutrition labelling in 38 popular brands of edible oils from selected food stores in Dar es salaam.

Products without nutrition fact labelling (n)	Products with nutrition fact information on fats in general (n)	Products with nutrition fact information including *trans-fats* (n)	Products with health claims related to fats (n)	Products with nutrition claim related to fat (n)	Products with *trans-fat* claims (n)
11	27	6	7	20	3

Among those with essential nutrition fact labelling 6 products (22%) had information that included trans fatty acids, mainly as summary fact tables on their back-of-pack. Levels labelled on the product packs, were generally lower than the levels obtained from laboratory analysis (Figure 5). Despite lack of statistical power to run statistical analysis due to a limited sample size, we observed an obvious pattern in deviation from the measured (actual) TFA values. A wider deviation of the measured from the labelled TFA (2.67 vs 1.3, 2.37 vs 0, and 4.38 vs 0) was observed in all the 3 products that contained more than WHO recommended TFA levels (>1.2g TFA/100g of product or >2%TFA/Total fat). For products within the WHO recommended limit, that deviation was narrower (0.31 vs 0.12 and 0.17 vs 0.00). All the 3 edible oils with higher than 2% TFA limit, whose laboratory measured TFA levels widely deviated from those labelled on the products, were popular brands of animal butter.

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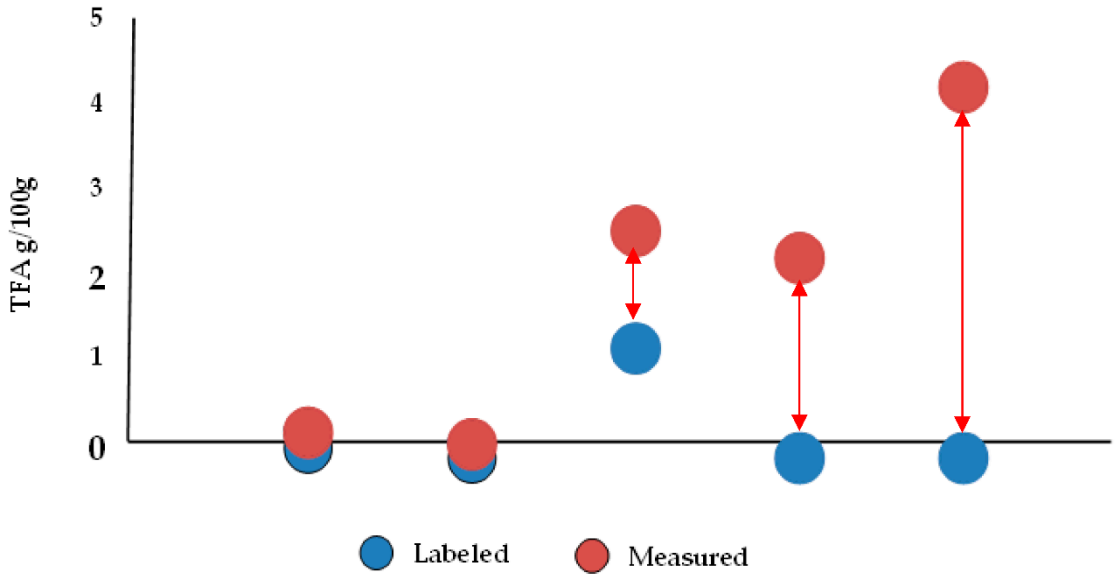

Figure 5. Differences between laboratory measured TFA levels and TFA levels labelled on 5 different brands and types of popular edible oils from selected food stores in Dar es salaam.

4. Discussion

Compelling evidence links excessive intake of trans fatty acids (TFA) to a variety of diseases including cardiovascular conditions. Based on that the world health organization (WHO) has set a target to eliminate industrially produced trans fatty acids (iTFA) from the global food supply by the year 2023[7]. Despite this target, Tanzania still has limited data on which to base the development of good-practice policy to regulate the amount of TFA in food products. Here we report for the first time the TFA status of popular edible oils in Tanzania and provide evidence for the presence of products with more than WHO recommended levels of TFA in the Tanzanian food supply.

Our findings revealed that products with more than the recommended 2% TFA limit are present in Tanzanian food supply. As expected, brands of solid and semi-solid edible oils (margarines, and animal butter), were among the products that exceeded the 2% TFA limit. In addition, high levels of TFA were also found in one brand of peanut butter and two brands of industrially refined sunflower oils. Margarines and cooking fats are made by a chemical process known as hydrogenation, where vegetable oils are converted from their natural liquid state to solid or semi solid fat. During hydrogenation TFA are formed because of partial hydrogenation accounting for the high levels of TFA frequently found in margarines[4].

High levels of TFA in margarines has been a consistent finding in many studies done in previous years. In much older studies from the 80s done in USA, the average TFA in margarines was reported to be 26.8% [20], an amount more than 15 times the average TFA levels of 1.8% in margarines from our study. Following increasing awareness of their detrimental effects on health, countries especially in the western world started to adopt good-practice policies to regulate the amount of TFA. Subsequently, edible oil manufacturers complied with the regulations and reduced the amount of TFA in their products.

Evidence from studies done following the implementation of TFA regulation policies in some countries showed a substantial decrease in the levels of TFA in margarines and other food products[21]. Taking Denmark for example, TFA content in margarines and shortenings steadily declined from about 10g/100g fat in 70s to almost no TFA in margarine in 1999 [22]. In line with that, analysis of brands of margarine in South Africa found that in all the 40 brands of margarines that were analyzed, TFA levels were less than 2% [23]. Interestingly, the TFA assessment of margarines was done before South Africa had implemented any TFA control measure.

To date, Tanzania is yet to adopt any of the WHO recommended good-practice policies for regulation of TFA in food products. However, when compared to studies done elsewhere about a

 doi:10.20944/preprints202306.0023.v1

decade ago, the average TFA levels in margarines reported in the current study, is substantially lower, demonstrating a general decline in the levels of TFA in margarines globally. This implies that the impact of TFA regulations implemented in Europe and other developed countries, might have trickled down and impacted the global food supply. Together, given the free global market, this observation underscores the impact of global policy advocacy campaigns in shaping the global food supply.

As previously reported, all 4 brands of animal butter analyzed for TFA in our study exceeded the recommended 2% TFA limit. Being products from cows, goats or/and sheep, animal butter naturally contains TFA (reviewed in [24]). This TFA is a result of microbial hydrogenation that commonly occur in large intestines of ruminant animals as part of their digestion [24]. Evidence from both experimental and epidemiological studies shows that both naturally occurring and industrially produced TFA can negatively impact cardiovascular health. However, it is argued that excessive consumption of TFA to an extent of negatively affecting health, cannot be caused by the consumption of animal butter[6]. While the consumption of products containing high content of industrially produced TFA has proven adverse effects on cardiovascular health [6], further studies are needed to substantiate the claim that consumption of animal butter is unlikely to result in overconsumption of TFA.

Sunflower oil, which is extracted from sunflower, a widely available plant in Tanzania, has a favorable fatty acid composition (less saturated and more unsaturated FA). Because of that, sunflower oil is considered as a potential healthy replacement alternative for Tanzania. Intriguingly, in our study, 2 out of 7 brands of industrially refined sunflower oil exceeded the 2% TFA limit, with one of the brands representing a product with the highest TFA levels (average TFA 3.45% range (1.56%-5.78%)). High TFA levels in sunflower oil has been reported previously from studies done in other parts of the world [25]. Physical refinery processes, whose final stage involve hard heating, introduces TFA in otherwise healthy sunflower oil[25]. In line with our findings the fatty acid profile of sunflower oil is usually characterized by high levels of PUFA, which despite being regarded as healthy FA, are also known to be chemically unstable hence vulnerable to transformation into TFA, by such processes as hard heating[25]. Indeed, information gathered from specific websites of companies that produce the sunflower oil brands found to have more than 2% TFA limit, revealed that the companies employ physical refinery as their process of choice.

Additionally, two fried foods we analyzed for TFA, had levels that exceeded the recommended 2% limit. Sausage purchased from a popular fast-food restaurant and samosa meat/beef from street food vendors represented food products with more than 2% of TFA per 100g of fat. Being of ruminant animal origin, the high levels of TFA in sausage and samosa beef could reflect TFA profile of beef which is known to have high TFA content due to microbial hydrogenation that occur as part of digestion in ruminant animals. Indeed, the abundant trans fatty acid isomer found in both the sausage and samosa beef in our study was elaidic acid. This isomer is known to be in large amounts in food products that originate from ruminant animals (reviewed in [24]).

Furthermore, the 2 food products and all other foods that we analyzed had a fatty acid profile that reflected that of palm oil. Palm oil, either in a liquid or solid form, is a preferred edible oil for commercial frying in Tanzania. Despite its low TFA content, palm oil contains large amounts of saturated fatty acids, a profile that was reflected in all the liquid and solid edible oils originating from palm and all the 25 fried foods that were profiled in our study. Consumption of large quantities of saturated fatty acids are also linked to perturbed cardiovascular health.

The world health organization (WHO) recommends two main approaches as good-practice policies for successful elimination of industrially produced TFA from the global food supply. Countries should either adopt a total ban of partially hydrogenated oils (PHO) and related products or limiting the levels of TFA to 2% TFA per 100 grams of fats in edible oils and packaged foods [7]. The later should be accompanied by a mandatory labelling of TFA on the front or back-of-pack for all packaged food products. The available food labelling regulations in Tanzania do not mandate a direct labelling of TFA in food products[26]. In the current study TFA nutrition fact information

 doi:10.20944/preprints202306.0023.v1

labelling was very limited, and only 21% of products with nutrition fact information had TFA labelling, possibly due to lack of mandatory TFA labelling regulation.

Interestingly, in all the edible oil products with TFA labelling that were analyzed for TFA, levels written on the labels were lower that TFA levels obtained from laboratory results. Additionally, a wider difference between actual and labelled TFA levels was observed in products that had exceeded the 2% TFA limit. Discrepancies between the laboratory measured and labelled TFA content has been reported in several other studies conducted in different parts of the world[27]. Lack of continuous surveillance by regulatory authorities due to either absence of regulatory frameworks or poor policy enforcement likely contribute to such discrepancies.

In conclusion, despite having relatively lower mean TFA content than levels reported elsewhere before the commencement of global TFA campaigns, products exceeding the 2% TFA limit exist in the Tanzanian food supply. Certain brands of margarines, peanut butter and industrially refined (physical refinery) sunflower oils were among the products that exceeded the 2% TFA limit and likely contained industrially produced TFA. High levels of TFA were also found in brands of animal butter, samosa beef and sausage possibly representing naturally occurring TFA. TFA nutrition fact labelling of edible oil products was found to be inadequate and mostly deviated from the values obtained from laboratory analysis.

5. Conclusions

In conclusion, despite having relatively lower mean TFA content than levels reported elsewhere before the commencement of global TFA campaigns, products exceeding the 2% TFA limit exist in the Tanzanian food supply. Certain brands of margarines, peanut butter and industrially refined (physical refinery) sunflower oils were among the products that exceeded the 2% TFA limit and likely contained industrially produced TFA. High levels of TFA were also found in brands of animal butter, samosa beef and sausage possibly representing naturally occurring TFA. TFA nutrition fact labelling of edible oil products was found to be inadequate and mostly deviated from the values obtained from laboratory analysis.

Author Contributions: Fredirick Lazaro Mashili: Conceived and designed the study, led the process of data collection, data management, and analysis, and contributed significantly to the drafting and editing of the manuscript. Hassan Russobya: Played a key role in coordinating and participating in data collection and analysis, and also contributed to the writing of the manuscript. Juliana Masaulwa: Assisted in data analysis and contributed to the writing of the manuscript. Cleopatra Shonyella: Participated in data collection and contributed to the writing of the manuscript. Kaushik Ramaiya: Provided valuable guidance during data collection and contributed to the writing of the manuscript. Walter Willet: Played a pivotal role in conceptualizing the study, led the laboratory analysis of trans fatty acids, and provided essential guidance in writing the manuscript. All authors have read and approved the final manuscript.

Funding: This work was supported by a grant from the LINKS community through a grant funded by Resolve to save lives (RTSL), an initiative of vital strategies. The grant is meant to support a platform that connects people working to improve cardiovascular health around the world.

Institutional Review Board Statement: The study was conducted in accordance with the Declaration of Helsinki, and approved by the Institutional Review Board (or Ethics Committee) of National Institute of Medical Research (protocol code NIMR/HQ/R.8a/Vol IX/3694 approved on 4th of June 2021

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study

Data Availability Statement: All data is available upon request.

Acknowledgments: We express our sincere gratitude to Ms. Lisa Ntui for her unwavering dedication as an administrator throughout the course of this study. Furthermore, we extend our appreciation to all the personnel at the Tanzania Bureau of Standards (TBS), as well as those from the supermarkets, shops, restaurants, and informal markets who aided us in obtaining the information necessary for the successful completion of this study.

Conflicts of Interest: The authors declare no conflict of interest. "The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results".

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