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# Introduction:

Since 1991, research has demonstrated the link between high intake of industrially produced trans-fatty acids (iTFA) and a variety of non-communicable diseases (NCDs), including coronary heart disease (CHD). Pakistan’s trans-fat intake is estimated to be the 2nd highest in the WHO-EMRO region after Egypt and over 12% of deaths from CHD in Pakistan are attributable to high intake of trans fats. (IHME 2019) The World Health Organization (WHO) recommends limiting trans fat intake to 1% of total energy intake and has called for the global elimination of iTFA from the food supply by 2023. (WHO, 2017) The WHO’s REPLACE framework outlines a number of steps to remove and replace trans-fats from country diets, among them being a ban on and replacement of Partially-Hydrogenated Oils in the food supply and a limit of 2% industrially-produced TFA in all food products. Pakistan’s National Action Plan for TFA elimination also proposes a PHO ban and 2% TFA limit in line with WHO’s REPLACE framework. (Amjad and Khattak, 2020) However, concerns about the costs of replacement, raised in particular by industry actors, have hindered policy movement towards iTFA elimination in Pakistan. This study aims to address those concerns by undertaking a cost effectiveness analysis of TFA replacement policies.

# Study objectives:

The objective of this study was to examine whether TFA elimination and replacement policies are beneficial in terms of health and economic outcomes in Pakistan. This was done by assessing the potential health and economic benefits of TFA elimination and replacement policies from 2022-2026 and comparing them with the industrial cost of replacement technologies. The related supplementary objectives were to estimate current health and economic cost of high TFA intake in diets and estimate future effect of averted premature mortality due to TFA elimination and replacement in Pakistan.

# Methodology

## Research design

In this paper, we developed a comparative risk assessment model (the TFA Macrosimulation Model - TFAMM) developed by Dr. Eduardo Nilson[[1]](#footnote-1) and applied this tool to estimate the potential reductions in CVD mortality gained from the compared scenarios of TFA reduction/elimination, using Pakistan as a case study. The TFA macrosimulation model estimates the change in the annual number of CVD deaths between baseline with current TFA consumption levels and alternate or counterfactual scenarios, which, in this case, was defined as the elimination of industrially produced TFA from the food supply chain in Pakistan. The model incorporates additional outputs beyond impact of TFA elimination on Deaths Prevented or Postponed, such as Years of Life Lost, Years of Productive Life Lost, and other economic impacts of premature deaths. (Nilson et al, 2022)

## Estimating TFA consumption:

There is an absence of population-level consumption surveys measuring TFA intake in Pakistan, due to which production data on PHOs in Pakistan was used to estimate TFA intake levels. PHO production data for Pakistan was obtained from the PHO and Non-PHO based Oils and Fats Market: Global Industry Analysis 2013-2017 and Forecast 2018-2026, produced in 2018 by Persistence Market Research for EMRO for the WHO Eastern Mediterranean Region. (Persistence Market Research 2018) The market data includes information on global, regional, and national PHO and non-PHO based oils and details on the market value, volume, and application (use). PHO is used in foods like bakery products, dairy and ice cream, chocolate and confectionery, breads, and cereals. National data on PHO use in foods can be used to estimate per capita percentage of total energy intake attributed to TFA, considering the population in the year of analysis and the estimated energy intake in the population according to dietary surveys or national food acquisition data.

## TFA comparative risk assessment macrosimulation model:

The TFA comparative risk assessment macrosimulation model estimates the potential ischemic heart disease (IHD) mortality reduction if trans-fat intake was reduced in diets. The primary outcome measure of this methodology is the total number of deaths prevented or postponed (DPP) that can be attributed to the reduction in TFA intake. It is defined as the difference between the number of expected deaths in the year of analysis (age- and sex-specific IHD mortality) and the expected deaths if trans-fat intake was reduced in the diet of a specific population. Additional outcome measures used are Years of Life Lost (YLL), and Years of Productive Life Lost (YPLL).

## Model parameters and data sources:

The TFA macrosimulation model was parametrized or populated using three types of relevant baseline data for the population over 25 years of age, including the context-specific and age- and sex-specific distribution of:

i. The number of people living in the population;

ii. Dietary risk factors (TFA intake and total energy in the diet);

iii. The annual number of deaths, YLLs and YLDs from IHD included in the model.

Sources for the data used include the most recent and available population data from the Pakistan Bureau of Statistics, Economic Survey of Pakistan data for energy intake, market research data for PHO use for food production (food and beverage industries, commercial and household) that capture the distribution of the TFA exposure, and published meta-analyses of prospective epidemiological studies/cohort studies that estimate relative risks associated with TFA intake and cardiovascular disease mortality. (Zhu Y, Bo Y, Liu Y, 2019) Together, these data points reflect the baseline situation of the TFA macrosimulation model.

The per capita consumption of TFA (g/day) was derived from PHO market research data for Pakistan, in which the amount for annual volume of PHO used in the food chain and for household consumption (in tons) was converted into annual per capita PHO consumption in g/year by using population data from the Bureau of Statistics. Daily TFA intake was then calculated through the maximum, minimum and average levels of TFA in PHOs in Pakistan as estimated in the literature. (Tarar 2020; Iqbal 2014) TFA as a percentage of energy intake was estimated through calculating average per capita TFA intake (in baseline and intervention scenarios) as a proportion of total per capita energy intake (Economic Survey of Pakistan, 2022).

Table 1 Sources of data

|  |  |
| --- | --- |
| Data | Source |
| IHD deaths, years of life lost, years lived with disability, from high TFA intake in Pakistan | Global Burden of Disease database  Institute of Health Metrics and Evaluation (2019) |
| Annual PHO volumes for Pakistan | PHO and Non-PHO based Oils and Fats Market: Global Industry Analysis 2013-2017 and Forecast 2018-2026, Persistence Market Research (2018) |
| Relative Risk (RR) of TFA intake for cardiovascular disease | Meta-analyses of cohort studies (Zhu, Bo and Liu 2019) |
| Energy intake per capita | Economic Survey of Pakistan |
| TFA levels in PHO/Vanaspati ghee in Pakistan | Iqbal, Perwaiz (2014)  Tarar, Omer (2020) |
| Labour force participation rates | Pakistan Labor Force Survey (Pakistan Bureau of Statistics) |
| TFA replacement costs for industry | Mapping of Industrially-produced Trans Fatty Acids in Pakistan. GAIN (2020) |
| GDP per capita | Economic Survey of Pakistan |
| Pakistan population estimates and trends | Pakistan Bureau of Statistics, Macrotrends (future projections) |

## Barendregt’s continuous distribution shift method

As applied in Marklund, Veerman and Wu (2020), Barendregt’s continuous distribution shift Potential Impact Fraction (PIF) method (Barendregt and Veerman 2010) was used for the statistical analysis. The PIF is estimated through the following formula:



where the PIFas is the potential impact fraction for age group a and sex s for TFA elimination intervention; RRa(x) is the relative risk of CVD as a function of high TFA intake; Pas(x) is the reference TFA intake distribution at current levels; and P’as(x) is the intervention TFA intake distribution following enactment of limits. (Marklund, Veerman and Wu, 2020)

## Estimating health impact of TFA elimination:

The PIF was used to calculate the effect on IHD mortality due to the reduction in TFA intake via the following equation:

M’ = M (1 - PIF)

Where M is the deaths due to TFA intake in the reference population, M’ is the deaths in the TFA replacement intervention population and PIF is the potential impact fraction. The estimated incidence rates were used in life tables to calculate reference and intervention IHD prevalence and mortality. (Ibid)

## Estimating cost of premature deaths:

The estimated Years of Life Lost (YLL), which are part of the estimates for DALYs (Disability Adjusted Life Years), were calculated by multiplying the number of deaths averted at each age group by the number of years of life remaining up to life expectancy.

The Years of Productive Life Lost (YPLL) were estimated through the Human Capital Approach, which calculates the present value of potential time in the workforce (the measure of productivity) using country-specific data for multiple years. (Rumisha et al, 2020) The YPLL was calculated by multiplying the YLL from age 25 to the retirement age by the average national income (GDP per capita) and the labor force participation estimates (for men and women, segregated by age groups).

## Uncertainty analysis:

A Monte Carlo uncertainty analysis was incorporated in the model to calculate probabilistic 95% uncertainty intervals (95% UI) for all model outputs, based on 5,000 draws from specified probabilistic distributions for the model input variables, using the Erastz add-on for the Barendregt model. (Barendregt 2017) This also allowed the model to incorporate the usual random error (sampling error) in the Relative Risks (RR) and exposure prevalence as well as other potential sources of uncertainty like extrapolation from a source to a target population, because of the assumption of the portability of the RRs from the meta-analyses. In case of the modeling in this study, the final population impact fractions (PIF) are based on the weighted sum of the PAF for each exposure, sex, and age-group strata

## Estimating TFA replacement costs:

The costs of iTFA replacement were estimated in terms of the cost of reformulation of food products containing iTFA in the food supply chain (primarily vanaspati ghee, as identified by recent studies (Rashid, A, Amjad, Nishtar and Nishtar 2020; Tarar et al 2020) on dietary sources of iTFA in the Pakistani food supply). The replacement solutions were identified from the recent study on ‘Replacement solutions for industrial trans-fatty acids by small and medium enterprises’ in Pakistan by the Global Alliance for Improved Nutrition. (GAIN 2019) Costs were estimated for the reformulation solutions of chemical and enzymatic interesterification, as they are identified in the study as having high practical application, with the added advantage of producing high polyunsaturated and monounsaturated content and lower SFA content (compared to other production methods), being easily implementable in existing factories in the country and acceptable to consumers. (Ibid) Replacement cost per annum was estimated in terms of the capital and operational cost of chemical and enzymatic interesterification per ton of production multiplied by the annual estimated domestic production volumes of producers, as per the latest available data (from 2021).

# Assumptions:

It was assumed for the purpose of the analysis that changes between current TFA consumption and after TFA replacement occurs in all individuals by the same amount. Further, TFA intake (% of total energy) was treated as a continuous risk exposure with a log-normal distribution in the population. As the percentage of use of PHO for food production is not available by country, we assume that the proportions estimated by Market Persistence Research (2018) for food production for the entire WHO-EMRO Region will be applicable to Pakistan. It is further assumed that TFA regulations will be implemented and enforced by food authorities and complied with by industry.

# Limitations:

As population-level dietary data on TFA intake levels is not available for Pakistan, hence PHO market volumes had to be relied on to estimate current and future share of TFA in energy intake. Further, the economic impacts of TFA elimination on productivity represents only part of the total outcomes (premature deaths), but other aspects such as treatment costs, presentism and absenteeism are not covered by the model because of lack of data on IHD incidence attributable to TFA. Additionally, the macrosimulation model also does not account for the possible interactions between behavioral risk factors for NCDs and is unable to incorporate the effect of time lag between exposure and disease outcome.

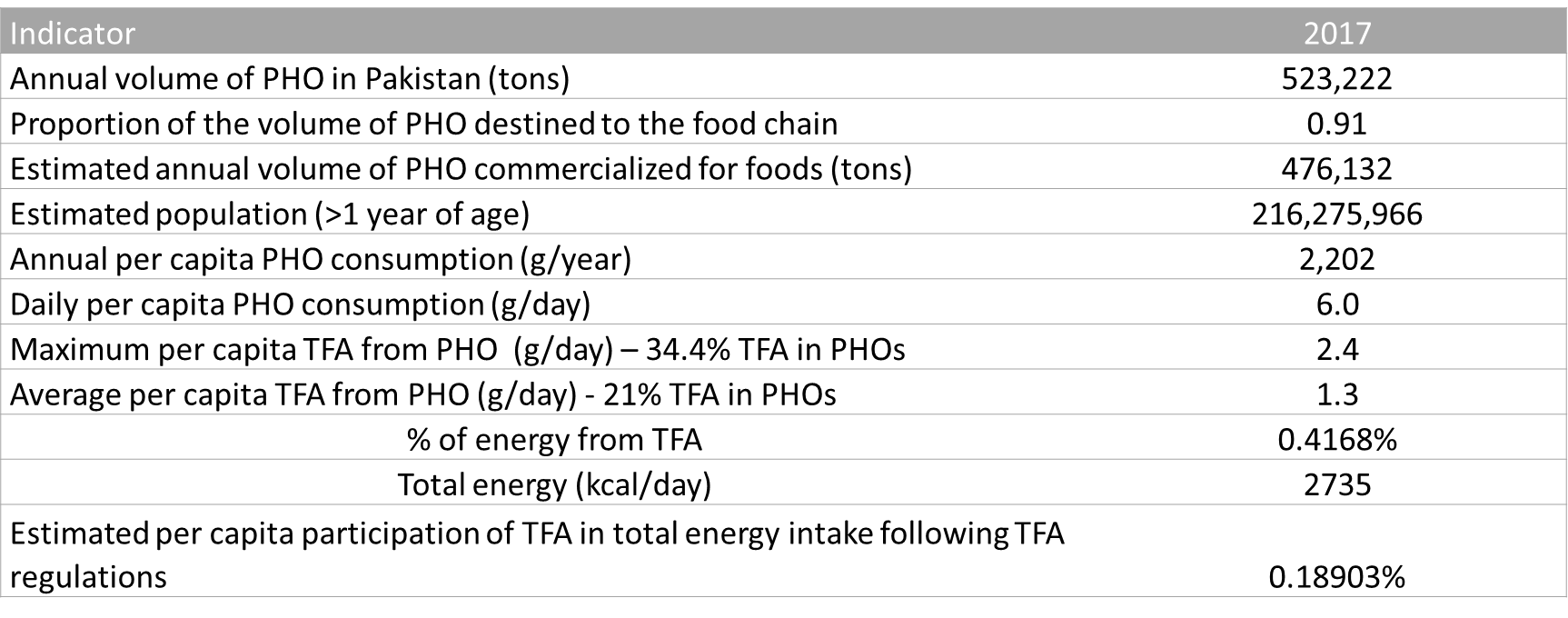
# Results:

## Health and productivity benefits of TFA replacement:

Existing estimates of deaths and YLLs due to trans fat in Pakistan, from the IHME’s Global Burden of Disease database show that 17,445 deaths and 556,851 YLLs from ischemic heart disease (IHD) in 2019 were attributable to trans fat.

In 2017 (the year for which latest PHO volumes for Pakistan are available), the average per capita use of PHO in Pakistan was estimated at 6 g/day, with a maximum per capita TFA intake of 2.4g/day and an average per capita TFA intake of 1.3g/day. The average percentage of energy from TFA is estimated at 0.42% of an estimated 2,735 kcal/day. It is estimated that with a policy of TFA replacement, the estimated per capita participation of TFA in energy intake for the same year would fall to 0.19%.

Table 2 Results: TFA and PHO use and estimates of per capita TFA intake in Pakistan (2017)



It is further estimated that, from 2023-2026, approximately 45,379 deaths attributable to trans fat could be prevented or postponed, which correspond to preventing or postponing 1,004,106 Years of Life Lost. The prevention or postponement of premature deaths, which have a significant impact on workforce productivity, correspond to US$ 1.34 billion in savings to the economy from prevented premature deaths.

Table 3 Estimated averted mortality due to trans fat replacement in Pakistan by age and gender (2023-2026)

|  |  |  |  |
| --- | --- | --- | --- |
| Age | Male | Female | Total |
| 25-29 years | 683 | 290 | 973 |
| 30-34 years | 1115 | 540 | 1655 |
| 35-39 years | 1541 | 930 | 2471 |
| 40-44 years | 1983 | 1203 | 3186 |
| 45-49 years | 2489 | 1436 | 3926 |
| 50-54 years | 2489 | 1436 | 3926 |
| 55-59 years | 3477 | 1664 | 5141 |
| 60-64 years | 3458 | 1805 | 5264 |
| 65-69 years | 2878 | 1841 | 4718 |
| 70-74 years | 2631 | 1673 | 4304 |
| 75-79 years | 2105 | 1575 | 3679 |
| 80-84 years | 1744 | 4391 | 6134 |
| All ages | 26593 | 18785 | 45379 |

Table 4 Estimated savings in losses of productivity due to TFA replacement in Pakistan (2023-2026)

|  |  |  |  |
| --- | --- | --- | --- |
| Age | Male | Female | Total |
| 25-29 years | 77,279,668 | 8,086,427 | 85,366,095 |
| 30-34 years | 111,292,070 | 8,927,222 | 120,219,292 |
| 35-39 years | 147,563,084 | 13,917,934 | 161,481,018 |
| 40-44 years | 172,015,055 | 18,182,289 | 190,197,344 |
| 45-49 years | 194,383,185 | 24,474,233 | 218,857,418 |
| 50-54 years | 224,391,433 | 29,590,030 | 253,981,462 |
| 55-59 years | 153,665,495 | 14,672,941 | 168,338,436 |
| 60-64 years | 126,742,124 | 15,439,118 | 142,181,242 |
| All ages | 1,207,332,114 | 133,290,193 | 1,340,622,307 |

Table 5: Savings in productivity losses due to trans fat elimination by age group in Pakistan from 2023-2026 (Males)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Age** | **2023** | **2024** | **2025** | **2026** |
| 25-29 years | 17,511,122 | 18,673,134 | 19,900,089 | 21,195,323 |
| 30-34 years | 25,601,866 | 27,033,016 | 28,537,694 | 30,119,494 |
| 35-39 years | 33,452,001 | 35,661,313 | 37,993,846 | 40,455,924 |
| 40-44 years | 39,362,816 | 41,706,092 | 44,173,849 | 46,772,298 |
| 45-49 years | 44,640,273 | 47,187,943 | 49,868,002 | 52,686,966 |
| 50-54 years | 51,399,989 | 54,424,119 | 57,607,939 | 60,959,386 |
| 55-59 years | 34,960,634 | 37,182,235 | 39,525,627 | 41,996,999 |
| 60-64 years | 28,881,851 | 30,684,795 | 32,585,764 | 34,589,714 |
|  | 275,810,553 | 292,552,647 | 310,192,810 | 328,776,103 |

Table 6: Savings in productivity losses due to trans fat elimination by age group in Pakistan from 2023 to 2026 (Females)

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| **Age** | **2023** | **2024** | **2025** | **2026** |
| 25-29 years | 1,849,159 | 1,960,129 | 2,077,017 | 2,200,121 |
| 30-34 years | 2,000,457 | 2,148,834 | 2,305,880 | 2,472,052 |
| 35-39 years | 3,166,339 | 3,367,649 | 3,579,999 | 3,803,947 |
| 40-44 years | 4,164,732 | 4,409,886 | 4,667,988 | 4,939,683 |
| 45-49 years | 5,515,464 | 5,902,572 | 6,311,824 | 6,744,373 |
| 50-54 years | 6,695,935 | 7,146,542 | 7,622,485 | 8,125,068 |
| 55-59 years | 3,321,074 | 3,544,057 | 3,779,566 | 4,028,244 |
| 60-64 years | 3,527,850 | 3,741,414 | 3,966,418 | 4,203,437 |
|  | 30,241,009 | 32,221,083 | 34,311,177 | 36,516,925 |

## Cost of industrial replacement of TFA:

According to estimates by GAIN (2019), the unit cost (operational plus capital) of vanaspati ghee production through chemical interesterification comes to US$ 42/ton at 1kg/ton catalyst usage and US$ 36/ton at 0.5 kg/ton catalyst usage, while the unit cost (operational plus capital) of vanaspati ghee production through enzymatic interesterification comes to US$ 47/ton at 0.5kg/ton catalyst usage and US$ 38/ton at 0.3 kg/ton catalyst usage. (GAIN 2019)

Table 7: Unit costs of industrial replacement of TFA in Pakistan through chemical and enzymatic interesterification

|  |  |  |  |  |
| --- | --- | --- | --- | --- |
| COST | Chemical Interesterification | Chemical Interesterification | Enzymatic Interesterification | Enzymatic Interesterification |
| Catalyst usage kg/ton | 1 | 0.5 | 0.5 | 0.3 |
| Operating Expenditure US$/ton | 27 | 21 | 35 | 24 |
| Capital Expenditure US$/ton  (5-year depreciation) | 15 | 15 | 12 | 14 |
| Total (US$/ton) | 42 | 36 | 47 | 38 |

Based on these unit costs, at 2021 PHO production volume estimates from the PHO industry in Pakistan, the total annual industrial cost for TFA replacement through chemical interesterification is estimated at US$ 14,142,060, while the total annual industrial cost for TFA replacement through enzymatic interesterification is estimated at US$ 14,927,730.

Table 8: Annual cost of TFA industrial replacement options

|  |  |
| --- | --- |
| Replacement options | Costs (at 2021 production estimates) |
| Annual Vanaspati production (tons) | 392,835 |
| Chemical interesterification capital cost (US$/ton) (0.5 kg/ton catalyst usage) | 15 |
| Chemical interesterification operational cost (US$/ton) (0.5 kg/ton catalyst usage) | 21 |
| Chemical interesterification (annual production cost for industry) US$ (capital + operational) | 14,142,060 |
| Enzymatic interesterification capital cost US$/ton (including chromatographic silica) | 14 |
| Enzymatic interesterification operational cost (US$/ton) (0.5 kg/ton catalyst usage) | 24 |
| Enzymatic interesterification (production cost for industry) US$ million (capital + operational) | 14,927,730 |

# Discussion:

As a country with the second highest intake of trans fat in the WHO-EMRO Region, a large number of CVD deaths in Pakistan – 17,455 deaths in 2019 – are attributable to high trans fat intake, which also leads to 556,851 YLLs lost, and annual productivity losses of $459 million owing to premature mortality from CVD. Multiple countries with previously high trans fat consumptions from around the world have acted to remove TFA from their food products through regulatory action and PHO ban. Given that 98% of trans fats consumed in Pakistan are produced in the country, primarily through the vanaspati ghee industry (Tarar, 2020), the simplest policy solution achieve TFA replacement in the food supply is the proposed ban on partially-hydrogenated oils (PHOs) and imposition of a limit of less than 2g pr 100g of TFA in all food products.

This study uses a simple macrosimulation modeling tool to study the impact of a policy to bring about the replacement of TFA in the Pakistan food supply to inform policy decision-making for TFA elimination in alignment with the WHO Replace package. The results demonstrate that industrial replacement of trans fatty acids in the food chain could have significant health benefits, resulting in the prevention or postponement of approximately 10,266 deaths and 243,264 YLLs in 2023, 10,441 deaths and 248,439 YLLs in 2024, 10,623 deaths and 253,614 YLLs in 2025, and 14,080 deaths and 258,788 YLLs in 2026, adding up to 45,380 prevented or postponed deaths and 1,004,016 prevented YLLs due to high trans fat intake.

In addition, the productivity benefits of TFA replacement from avoided premature mortality are also very high, with averted productivity losses of $306 million in 2023, $324 million in 2024, $344 million in 2025, and $365 million in 2026 (leading to a total of $1.34 billion in productivity savings from 2023 to 2026). In comparison, the combined capital plus operational cost of industrially replacing TFA from its sources in the food supply through replacing partial hydrogenation processes with chemical or interesterification is estimated at $14.14 million and $14.93 million per annum for the first year respectively. There is considerable evidence to suggest that the monetized health and economic benefits of TFA replacement far outweigh the private costs to the PHO industry of instituting replacement production processes.

# Conclusion:

Eliminating TFA from the food market in Pakistan by 2023 would be a highly cost-effective policy which could help prevent a substantial number of deaths from CVDs, significantly reduce the health burden from CVD and save hundreds of billions annually in averted productivity losses from premature mortality due to IHD. Banning the production of PHOs and establishing a 2% limit for TFA in all food products could go a long way in ensuring reduction of the country’s cardiovascular and non-communicable disease burden and reducing productivity losses from CVD mortality and morbidity.

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