BMJ Global Health

Estimated health benefits, costs and cost-effectiveness of eliminating industrial trans-fatty acids in Nigeria: cost-effectiveness analysis

Matti Marklund ,[1,2,3,4] Leopold N Aminde ,[5] Mary Njeri Wanjau,[5] Boni M Ale,[6,7] Adedayo E Ojo,[6,8] Clementina E Okoro,[9] Abimbola Adegboye,[10] Liping Huang,[2] J Lennert Veerman ,[5] Jason HY Wu,[2,11] Mark D Huffman,[2,12] Dike B Ojji[6,13]

To cite: Marklund M, Aminde LN, Wanjau MN, *et al*. Estimated health benefits, costs and cost-effectiveness of eliminating industrial trans-fatty acids in Nigeria: cost-effectiveness analysis. *BMJ Glob Health* 2024;**9**:e014294. doi:10.1136/bmjgh-2023-014294

Handling editor Lei Si

► Additional supplemental material is published online only. To view, please visit the journal online (https://doi.org/10.1136/bmjgh-2023-014294).

MDH and DBO are joint senior authors.

Received 19 October 2023
Accepted 14 March 2024

For numbered affiliations see end of article.

Correspondence to
Dr Matti Marklund;
matti.marklund@pubcare.uu.se

ABSTRACT

Introduction Nigeria is committed to reducing industrial *trans*-fatty acids (iTFA) from the food supply, but the potential health gains, costs and cost-effectiveness are unknown.

Methods The effect on ischaemic heart disease (IHD) burden, costs and cost-effectiveness of a mandatory iTFA limit (≤2% of all fats) for foods in Nigeria were estimated using Markov cohort models. Data on demographics, IHD epidemiology and *trans*-fatty acid intake were derived from the 2019 Global Burden of Disease Study. Avoided IHD events and deaths; health-adjusted life years (HALYs) gained; and healthcare, policy implementation and net costs were estimated over 10 years and the population's lifetime. Incremental cost-effectiveness ratios using net costs and HALYs gained (both discounted at 3%) were used to assess cost-effectiveness.

Results Over the first 10 years, a mandatory iTFA limit (assumed to eliminate iTFA intake) was estimated to prevent 9996 (95% uncertainty interval: 8870 to 11 118) IHD deaths and 66 569 (58 862 to 74 083) IHD events, and to save US$90 million (78 to 102) in healthcare costs. The corresponding lifetime estimates were 259 934 (228 736 to 290 191), 479 308 (95% UI 420 472 to 538 177) and 518 (450 to 587). Policy implementation costs were estimated at US$17 million (11 to 23) over the first 10 years, and US$26 million USD (19 to 33) over the population's lifetime. The intervention was estimated to be cost-saving, and findings were robust across several deterministic sensitivity analyses.

Conclusion Our findings support mandating a limit of iTFAs as a cost-saving strategy to reduce the IHD burden in Nigeria.

WHAT IS ALREADY KNOWN ON THIS TOPIC

⇒ High intake of trans-fatty acids is a recognised risk factor for ischaemic heart disease, leading to the implementation of policies worldwide to eliminate industrial trans-fats.

⇒ In 2023, Nigeria, Africa's most populous nation, regulated to restrict industrial trans-fatty acids in food, but so far, the regulation has not been implemented.

WHAT THIS STUDY ADDS

⇒ This study provides quantitative estimates of the cost-effectiveness and potential impact of this policy in Nigeria, indicating it could prevent about 10 000 ischaemic heart disease deaths after a decade, with healthcare cost-savings were estimated to outweigh implementation costs.

⇒ These findings, alongside previous analyses in high-income nations, suggest that eliminating industrial trans-fats can be a cost-effective or even cost-saving strategy for reducing ischaemic heart disease globally.

HOW THIS STUDY MIGHT AFFECT RESEARCH, PRACTICE OR POLICY

⇒ The study provides crucial data for Nigerian policymakers and those in other low-income and middle-income countries considering trans-fatty acid regulations.

⇒ It underscores the potential benefits of such policies in terms of public health and healthcare cost-savings, supporting their implementation and the fight against ischaemic heart disease across various economic development stages and continents.

INTRODUCTION

In Nigeria and other African countries, the burden of ischaemic heart disease (IHD) is increasing rapidly and in 2019, around 70 000 deaths in Nigeria were attributed to IHD.[1] Diet plays a key role in the development of IHD, and a high intake of *trans*-fatty acids is a well-established dietary risk factor for IHD.

Trans-fatty acids are a group of unsaturated fatty acids with one or more double bonds in the *trans* configuration, making the carbon chain straighter compared with *cis*-fatty acids. This structure allows the *trans*-fatty acid molecules to pack more densely and thereby increases their melting point, making them solid at room temperature, in contrast to their

cis-counterparts. High intake of *trans*-fatty acids is known to cause atherosclerosis,[2] and every 2% increase in total energy intake from *trans*-fatty acids is associated with a 23% higher risk of incident IHD.[3] Although *trans*-fatty acids occur naturally at low levels in meat and milk from ruminants, the predominant source in many countries is industrially made partially hydrogenated vegetable oils (PHVO) in processed foods.[4]

The WHO recommends limiting *trans*-fatty acid intake to <1% energy (%E).[5] In order to help countries to implement successful strategies to eliminate industrially derived *trans*-fatty acids (iTFA) from the food supply, WHO has developed the REPLACE package which includes six strategic action areas: (1) review dietary sources of iTFA and the landscape for required policy change; (2) promote the replacement of iTFA with healthier oils and fats; (3) legislate or enact regulatory actions to eliminate iTFA; (4) assess and monitor *trans*-fatty acid content in the food supply and changes in trans-fatty acid consumption in the population; (5) create awareness of the negative health impact of *trans*-fatty acids among policy-makers, producers, suppliers and the public; and (6) enforce compliance with policies and regulations.[6] An increasing number of countries have implemented strategies to reduce iTFA in the food supply.[7 8] Such policies can range from voluntary reformulation, mandatory labelling, to banning iTFA or PHVO entirely.[9] The global progress in limiting iTFA through policy is monitored by the WHO.[10] Although several African countries (including Nigeria) have expressed commitment to reduce iTFA from the food supply, before 2023, only South Africa had implemented a best-practice policy (ie, mandatory limit of iTFA ≤2% of all fats) as defined by the WHO in the African continent.[10]

In April 2023, Nigeria passed regulations stating that 'Fats, oils and foods containing fats and oils intended for human consumption of which the content of trans-fat exceeds 2 g per 100 g of fat or oil are prohibited in Nigeria'. Quantitative estimates of the potential health and economic impact of such regulation could aid its implementation in Nigeria and may also guide policy-makers in other low-income and middle-income countries, in Africa and elsewhere. Thus, we conducted a modelling study to estimate the cost-effectiveness of a mandatory limit on iTFA content (≤2% of all fats) in the Nigerian food supply, considering policy costs, IHD burden and healthcare expenditures. We hypothesised that a limit of iTFA in the food supply would be a cost-effective strategy to reduce the IHD burden in Nigeria.

METHODS

Study design

Using a multiple cohort proportional multistate life table (Markov) model, we estimated the impact on health outcomes and related costs of an iTFA limit (≤2% of all fats) for the Nigerian food supply. This limit was expected to cover all foods and ingredients containing iTFA. The modelling framework, which has been employed to evaluate similar policies for Australia and Kenya,[11 12] estimated IHD-related outcomes and total healthcare costs resulting from the intervention, where the life table method transmits changes in iTFA intake to IHD-related morbidity and mortality in the modelled population. In this study, we modelled the adult Nigerian population (≥20 years) in 5-year female and male cohorts, where each cohort was simulated until all individuals died or reached 100 years of age. We compared all outcomes estimated for a reference population with a stable *trans*-fatty acid intake comparable to the intake of the Nigerian population before the intervention, and an intervention population with identical characteristics but lower *trans*-fatty acid intake due to the elimination of iTFA from the food supply. The difference between the reference and intervention populations was calculated for IHD incidence and deaths, life years and health-adjusted life years (HALYs). Results were reported for time horizons of 5 years, 10 years and the population lifespan (ie, the time from policy implementation until all individuals died or reached 100 years of age). In this study, we used an extended healthcare perspective to include implementation costs for government and industry, which are directly related to the intervention. We inflated costs and HALYs to 2019 values and used a 3% discount rate in the main analysis, as recommended by the first and second Panels on Cost-Effectiveness in Health and Medicine.[13 14] Key inputs and assumptions are presented in table 1, whereas the Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) checklist and the original study proposal and analytical plan are available in online supplemental appendices 1-2. While the present study shares the same framework and methodology as our recent cost-effectiveness analysis of an iTFA policy in Kenya,[12] there are important differences in how key inputs were derived, particularly in terms of costs, as described below.

Data sources

From the 2019 Global Burden of Disease (GBD) study, we derived the mean and SD of baseline *trans*-fatty acid intake, expressed as energy percentage (%E), separately for n=30 specific age-sex groups (online supplemental table S1). We modelled the effect of a mandatory limit of iTFA to ≤2% in all fats, oils and foods. Similar to our previous cost-effectiveness analysis of a comparable policy in Kenya,[12] we assumed that the policy would virtually eliminate intake of total *trans*-fatty acids in all age-sex groups (ie, postintervention mean intake=0%E) in the primary analysis, as the mandatory limit has been effective in eliminating iTFA from the food supply in other countries (eg, Denmark[15]), and the intake of naturally occurring *trans*-fatty acids (ie, from meat and dairy from ruminant animals) is likely negligible in Nigeria (table 1).[16 17]

Estimates of population size and overall mortality rate, as well as IHD-specific estimates of incidence, prevalence,

Table 1 Key input data and assumptions

Input	Stratification	Values	Source	Note
Preintervention TFA intake, E%	Age, sex	Online supplemental table S1	2019 Global Burden of Disease (GBD) study	For each model iteration, random draws from age-sex-specific lognormal TFA distributions were made.
Postintervention TFA intake, E%	n/a	0 (primary analysis) Mean ± SD: 0.1±0.01 (sensitivity analysis)	2018 Global Dietary Database (estimates of dairy intake)	Given the minimal intake of naturally occurring trans-fatty acids (eg, from dairy) compared to countries like Australia, UK and Denmark, the intervention was assumed to virtually eliminate trans-fatty intake in Nigeria. However, we explored the impact of a low but existing TFA intake post intervention in a sensitivity analysis.
Theoretical minimum risk distribution of TFA intake, E%	n/a	0	Marklund *et al,* Plos Med 2020	The theoretical minimum risk distribution of TFA intake was assumed to equal the intake of natural occurring TFA.
Population size	Age, sex	Online supplemental table S2	2019 Global Burden of Disease (GBD) study	
Mortality rate	Age, sex	Online supplemental table S2	2019 Global Burden of Disease (GBD) study	
IHD incidence, prevalence and case fatality rates	Age, sex	Online supplemental table S3	2019 Global Burden of Disease (GBD) study	
Disability weights	Age, sex	Online supplemental tables S4 and S5	2019 Global Burden of Disease (GBD) study	
Healthcare costs	Age, sex	Online supplemental table S6	Rosendaal *et al*, PLOS ONE 2016.	We used cost estimates of acute care after an IHD event per patient (ie, incident IHD costs) and costs of follow-up care after an IHD event per patient per year (ie, prevalent IHD costs) from Rosendaal *et al*[20] and estimates of total health expenditure from the Nigerian National Health Accounts for 2017 report.[22] In the absence of a Nigerian source, we derived age and sex distributions of total health expenditure in Nigeria by assuming the relative expenditure by age and sex from the Kenya Household Health Expenditure and Utilisation Survey, 2013. The total health expenditure was then divided by population numbers in each sex and age-group to derive the per capita expenditure. Non-IHD costs were calculated for each age-sex group, subtracting IHD costs from total healthcare expenditure for that group, and was then divided by the group's population size to estimate per capita non-IHD costs. All healthcare costs were inflated to 2019. For each model iteration, random draws from triangular distributions of IHD costs and normal distributions of non-IHD costs (assuming SD equal to 20% of central estimates) were made.
RR for IHD per 2%E from TFA	Age	Online supplemental table S7	Afshin *et al*, Lancet 2019	For each model iteration, random draws from age-specific lognormal RR distributions were made.
Government policy implementation costs	n/a	Online supplemental table S8	NAFDAC estimates	The following costs were considered: national legislation costs; costs for NAFDAC (ie, work force expenses, enlightenment activities, enforcement activities, workshops activities, monitoring, and other activities including research); FMoH costs for legislation; SON costs for revising food standard regulations; and CPC costs for enlightenment activities. For each model iteration, random draws from normal distributions of implementation costs were made, assuming SD equal to 20% of central estimates.

Continued

Table 1 Continued

Input	Stratification	Values	Source	Note
Industry reformulation	n/a	Online supplemental table S8	Marklund *et al*, Plos Med, 2020	Reformulation costs were calculated using equivalent USD costs from UK estimates (25 000 GBP per product)[5] multiplied by the number of products in the Nigerian food supply potentially containing industrial TFA (primary model: n=331; sensitivity analysis: n=662). Annual cost to industry equaling 1% of the initial reformulation cost was assumed. For each model iteration, random draws from normal distributions of initial and annual reformulation costs were made, assuming SD equal to 20% of central estimates.

Table created by the authors.
CPC, Consumer Protection Commission; E%, energy percentage; FMoH, Federal Ministry of Health; GBP, British pound; IHD, ischaemic heart disease; n/a, not available/applicable; NAFDAC, National Agency for Food and Drug Administration and Control; RR, relative risk; SON, Standard Organisation of Nigeria; TFA, trans-fatty acid; USD, United States dollar.

mortality and years lived with disability were obtained from the GBD 2019 study (online supplemental appendix and online supplemental appendix and tables S2-S5).[18] We used the DisMod II software[19] to obtain estimates of case fatality rates for IHD, and we calculated IHD disability weights to be used for the estimation of HALYs (online supplemental appendix and tables S3-S5).[12]

We derived estimates of the cost of incident IHD and prevalent IHD from a study by Rosendaal *et al*,[20] and as previously described,[12] estimated total, IHD-related and non-IHD-related health expenditure stratified by age and sex (online supplemental appendix and table S6).[12] To estimate government policy implementation costs, local experts including clinicians, academics and Ministry of Health and National Agency for Food and Drug Administration and Control (NAFDAC) staff were contacted to determine the cost components and estimates that would be required to implement a mandatory limit of iTFA among foods in Nigeria (online supplemental appendix). The government costs included: legislation costs (ie, preparing the law at the Federal Ministry of Health and passing the bill at the National Assembly); NAFDAC costs which included human resources (workforce per geopolitical region, media and enlightenment activities, enforcement and monitoring, other activities, eg, research); Standard Organization of Nigeria costs for revising food standard regulations; and Consumer Protection Commission costs for consumer information campaigns. These cost estimates were derived from the cost of similar activities carried out in previous years, with information sourced from the Finance and Accounts departments of the various relevant ministries, departments, and agencies (MDAs). We used an activity-based budgeting system as our costing framework. This costing framework is normally adopted by all MDAs in developing their annual work plan. It highlights the activities to be carried out and costs them using prevailing market prices. The legislative cost was equivalent to the cost for the various agencies.

We estimated industry costs for reformulation as previously described,[11 12] based on our recent food supply analysis, where we identified 310 packaged food products potentially containing iTFA in the Nigerian supermarkets (online supplemental appendix).[21] All costs were inflated to 2019 values using World Bank consumer price indices for Nigeria.[22]

Statistical analysis

Estimation of health benefits and cost-effectiveness

To estimate the proportional change in IHD incidence due to the elimination of iTFAs, we used the reference and intervention *trans*-fatty acid intakes and the relative risk of IHD per %E of *trans*-fatty acid intake to calculate the potential impact fraction (PIF),[11 12] according to Barendregt's continuous 'distribution shift' PIF method (online supplemental appendix and table S7).[23] The PIF was used to calculate the effect on IHD incidence due to the reduction in trans-fatty acid intake (online supplemental

appendix), and the estimated incidence rates were used in the disease Markov model to calculate reference and intervention IHD prevalence and mortality. The changes in IHD mortality rate are then entered into the lifetable to alter the overall mortality rates and recalculate the life years. To account for time spent in suboptimal health due to IHD and any other conditions present, we calculated HALYs using estimates derived from prevalence and years lived with disability from IHD and other causes. One HALY thus represents the equivalent of a year in perfect health. HALYs gained were calculated as the difference in HALYs between the reference and intervention populations. Changes in healthcare expenditures were estimated both for IHD-related healthcare and total healthcare. The change in IHD-related healthcare expenditure was based on the predicted reduction in IHD mortality and morbidity. Overall healthcare costs in added years of life were also included.[24] Impact on health outcomes (ie, HALYs gained and averted or postponed IHD events and deaths) and healthcare cost-savings were estimated over the total population and separately for women and men.

Net costs included policy costs and healthcare costs (including costs unrelated to IHD) and were used to calculate the incremental cost-effectiveness ratios (ICERs), defined as the difference in net costs of the intervention compared with current practice, divided by the difference in HALYs. We used the Nigeria-specific cost-effectiveness threshold described by Pichon-Riviere *et al*,[25] which defines a cost-effective intervention as ICER <US$374 per HALY gained. A negative net cost indicated a cost-saving intervention. The costs were estimated in US dollars and converted to local currency (Naira, ₦) using the average exchange rate of 1 July 2019 (US$1= ₦358).

Uncertainty and sensitivity analysis

As previously described,[11 12] we quantified the parameter uncertainty around the modelled estimates in Monte Carlo simulations (n=2000). For each iteration, a draw was made from the distributions of *trans*-fatty acid intake, relative risks, healthcare costs and policy implementation costs. The point estimate and 95% uncertainty intervals (UI) were defined as the mean and 2.5th–97.5th percentiles, respectively, of the distribution of the intervention effects (eg, HALYs gained) estimated across all 2000 iterations using the Ersatz V.1.35 software. Similarly, Monte Carlo simulations (n=2000) of policy implementation costs were conducted in RStudio V.1.1.423. For each simulation (n=2000), we calculated ICER and return on government investment (defined as healthcare cost-savings divided by government implementation costs). The net costs and ICERs of all simulations were used to estimate the probability of the policy being cost-saving and cost-effective.

Similar to our previous cost-effectiveness analysis of an iTFA policy in Kenya, we used univariate sensitivity analyses to explore the impact of variation in discount rates (0% and 6%), *trans*-fatty acid intake and policy implementation costs (table 1). We also evaluated the impact of 50% lower or higher mean and SD of preintervention intakes. To test the effect of a potentially greater prevalence of iTFA among Nigerian foods (eg, due to iTFA-containing foods not being included in the large nutrition composition database from which the estimate of iTFA-containing foods was based on), the number of products potentially containing iTFA was assumed to be twice as many as identified in the database.[21] Experience of iTFA regulations in Denmark has suggested negligible reformulation costs[26] and reformulation can be considered to be a part of the natural life cycle of a product.[27] Thus, we conducted a sensitivity analysis assuming no industry costs. We also evaluated the impact of 50% greater monitoring costs compared with our primary model.

To evaluate the potential impact of partial elimination of iTFA in the Nigerian food supply (eg, due to suboptimal compliance to the mandatory iTFA limits), we conducted a threshold analysis to estimate the HALYs gained, the net cost, and the ICER in scenarios with gradually greater reductions in iTFA intake (from 0.05%E to 0.20%E lower intake compared with the base population).

Patient and public involvement

No patients were involved in setting the research question or the outcome measures, nor were they involved in developing plans for design or implementation of the study. No patients were asked to advise on interpretation or writing up of results. An author reflexivity statement is available as an online online supplemental appendix.

RESULTS

Health impact

In the first 10 years, a mandatory limit of iTFA content in the Nigerian food supply was estimated to avert or postpone ~67 000 incident IHD events and ~10 000 IHD deaths, compared with a base case scenario maintaining current intake of *trans*-fatty acids (table 2). Around 480 000 IHD events and ~260 000 IHD deaths could be averted over the population's lifetime. The intervention could generate some 25 000 HALYs over the first 10 years, and ~760 000 HALYs over the population's lifetime. The estimated deaths and incidences averted and HALYs gained were evenly distributed among men and women (figure 1), especially for the lifetime horizon.

Economic impact and cost-effectiveness

The reduced IHD burden was estimated to generate ~US$90 million (~₦12 billion) in total healthcare cost-savings in the first 10 years and ~US$520 million (~₦185 billion) over the population lifetime (table 2). The lifetime healthcare costs savings specific to IHD were estimated to be ~US$750 million (~₦270 billion). The greatest total healthcare cost-savings were attributed to men, among which 65% of the estimated population's lifetime cost-savings accrued.

The implementation of the mandatory limit was estimated to cost the Nigerian government ~US$2.0 million (~₦720 million) in the first 10 years, accumulating to

Table 2 Estimated health and health economic effects of a mandatory limit of iTFA content (≤2% of all fats) in the Nigerian food supply, assumed to eliminate TFA intake (ie, postintervention TFA intake = 0%E)

	5 years	10 years	Population lifetime
IHD incidence			
n	−31,018 (−34 571; −27 488)	−66 569 (−74 083; −58 862)	−479 308 (−538 177; −420 472)
%‡	−3.51 (−3.91; −3.14)	−3.42 (−3.81; −3.05)	−2.21 (−2.49; −1.94)
IHD deaths			
n	−2625 (−2914; −2334)	−9996 (−11 118; −8870)	−259 934 (−290 191; −228 736)
%‡	−0.76 (−0.85; −0.68)	−1.32 (−1.47; −1.18)	−2.20 (−2.47; −1.94)
Health-adjusted life years, n§	4515 (3995; 5021)	24 774 (21 888; 27 643)	759 831 (668 211; 851 217)
IHD-related healthcare costs, million USD§	−35.9 (−40.8; −31.3)	−100.6 (−113.3; −87.9)	−749.0 (−843.0; −657.3)
Total healthcare costs, million USD§	−34.0 (−38.8; −29.6)	−89.6 (−101.6; −77.9)	−518.0 (−587.2; −450.4)
Total implementation costs, million USD§	15.6 (9.8; 21.1)	17.2 (11.2; 23.0)	26.2 (19.0; 33.2)
Government implementation costs, million USD§	0.89 (0.80; 0.97)	1.96 (1.81; 2.12)	7.81 (7.54; 8.09)
Industry reformulation costs, million USD§	14.7 (9.0; 20.3)	15.3 (9.3; 21.1)	18.4 (11.2; 25.4)
Net costs, million USD§	−18.5 (−25.7; −11.1)	−72.4 (−85.4; −59.5)	−491.8 (−561.0; −427.0)

Vaues are mean (95% uncertainty interval) derived from n=2,000 Monte Carlo simulations.
†Table created by the authors.
‡Expressed as a percentage of IHD incident events or deaths under the base case scenario.
§Health-adjusted life years and costs were discounted at 3%.
%E, per cent of total energy intake; IHD, ischemic heart disease; iTFA, industrially-derived trans-fatty acids; USD, United States dollar.

~US$7.8 million (~₦2.8 billion) over the population lifetime (table 2 and online supplemental table S8). The cost for industry to reformulate foods containing iTFA was estimated to be ~US$15 million (~₦5.5 billion) in the first 10 years and ~US$18 million (~₦6.4 billion) over the population lifetime (table 2 and online supplemental table S8). Thus, the total implementation costs for the government and industry together were estimated to be ~US$17 million (~₦6.2 billion) in the first 10 years and ~US$26 million (~₦9.4 billion) over the population lifetime (table 2).

The implementation of a mandatory limit of iTFA content in Nigerian foods was estimated to be a net cost saving, with ~US$72 million (~₦26 billion) saved in the first 10 years, and ~US$490 million (~₦176 billion) over the population lifetime (table 2). The return of government investment (defined as healthcare cost-savings divided by government implementation costs) was estimated to US$46 (95% UI 39 to 53) per USD invested in the first 10 years, and US$66 (58 to 75) per USD invested over the population lifetime.

Sensitivity analyses

The probability of the intervention to be cost-saving within the first 10 years was ≥99.9% in all sensitivity analyses (figure 2, online supplemental figure S1 and table S9), except when only a 0.05%E reduction in trans-fatty intake was assumed (probability of being cost saving: 43%; probability of being cost-effective: 64%). Also in the shorter time horizon (ie, 5 years), most sensitivity analyses suggested a high probability (≥70%) of being cost-saving (online supplemental figure S1), with the only exception being in scenarios with the smallest intake reduction (ie, ≤0.10%E). Over the population lifetime, all sensitivity analyses suggested the intervention had a 100% probability of being cost-saving, except when assuming a 0% discount rate. In this specific sensitivity analysis, with no discounting, the increased overall healthcare costs due to improved survival caused a positive net cost compared with the base population. Nevertheless, the intervention was estimated to have a 100% probability of being cost-effective (figure 2, online supplemental table S9). While assumptions regarding discount rates had the greatest impact over the population life time, assumptions regarding preintervention and postintervention intakes of *trans*-fatty acids and reformulation costs had the greatest impact on HALYs and/or net costs in the shorter time horizons (ie, ≤10 years). Alternative assumptions regarding policy implementation costs for the

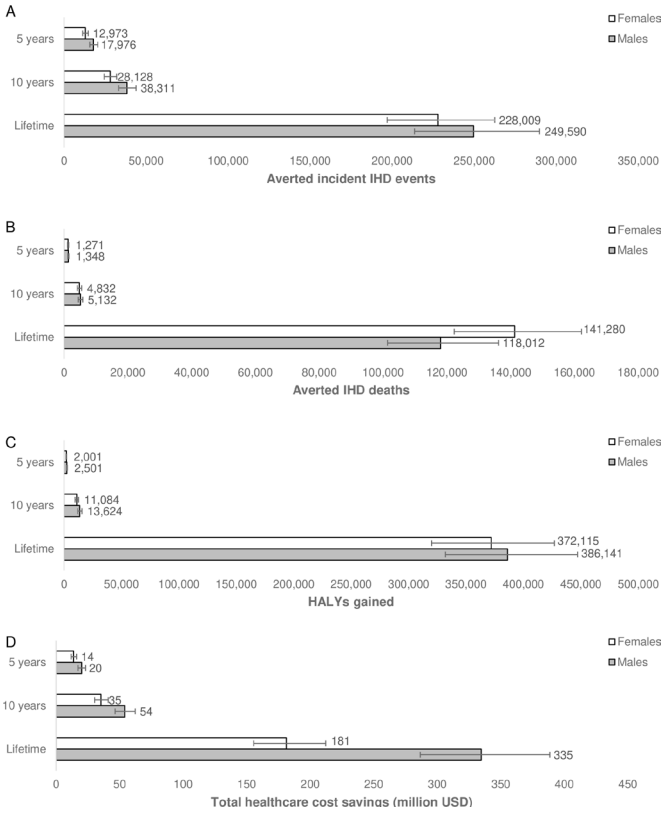

Figure 1 Sex-specific estimates of averted ischaemic heart disease (IHD) events (A), averted IHD deaths (B), health-adjusted life years (HALYs) gained (C) and total healthcare cost-savings (D) after 5 years, 10 years and over the population lifetime. Data labels indicate mean of n=2000 simulations and error bars represent 95% uncertainty intervals. Figure created by the authors.

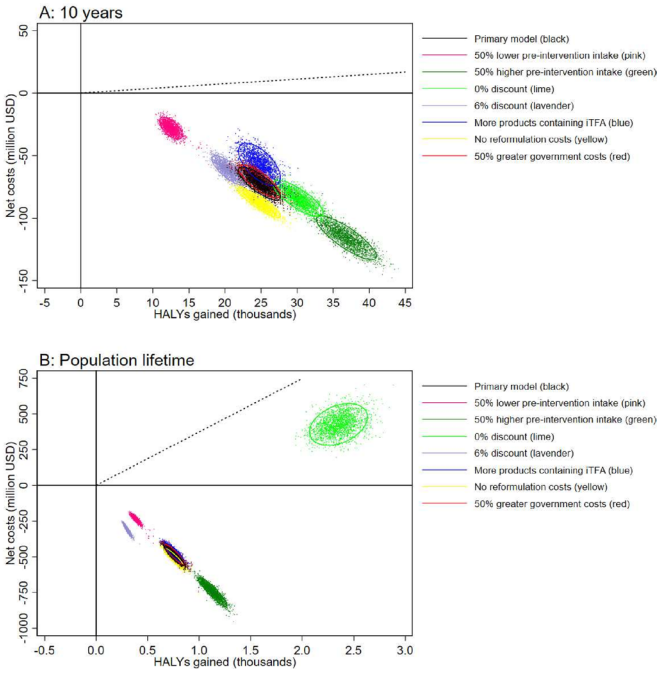

Figure 2 Net costs and health-adjusted life years (HALY) gained during the first 5 years (A) and over the population lifetime (B) estimated in the primary model and in deterministic sensitivity analyses related to preintervention trans-fatty acid intake, discount rate and implementation costs. The dotted line indicates the cost-effectiveness threshold for Nigeria (ie, US$374 per HALY gained). Figure created by the authors. iTFA, industrially derived trans-fatty acids.

government had minimal impact on model estimates regardless of time horizon.

DISCUSSION

In this cost-effectiveness study, we estimated that a mandatory limit of iTFA (≤2% of total fat) in the Nigerian food supply would be a cost-saving intervention, compared with a scenario with no policy action to remove iTFA from foods. The intervention was estimated to prevent or postpone ~10 000 deaths and ~67 000 incident IHD events in the adult population over the first 10 years, and around ~260 000 IHD deaths and ~480 000 incident IHD events could be prevented over the population's lifetime. The intervention was estimated to be cost-saving regardless of the time horizon evaluated.

Removing iTFA from the Nigerian food supply through a mandatory limit could lead to reductions in IHD burden and healthcare costs. The predicted costs for policy implementation (for both government and industry) were greatly outweighed by the estimated healthcare cost-savings already at 5 years after implementation. Even when considering total healthcare costs, which include additional costs for non-IHD related healthcare in a population where more individuals reach old age due to a lower IHD burden, the net cost-savings were substantial. The reduced spending on IHD care could potentially allow further action to help eliminate any remaining iTFA in the informal food sector (eg, subsidising iTFA-free oils and fats to street vendors). The WHO REPLACE package highlights the importance to support food manufacturers and vendors in the replacement of iTFA-containing fats.[6] In our assessment of products with potentially iTFA-containing ingredients (eg, partially hydrogenated oils) in Nigerian supermarkets,[21] most such products (218/310, 70%) came from outside of Nigeria (unpublished data). However, iTFA-containing ingredients may be used in Nigerian restaurant and street foods. Substantial amounts of elaidic acid (a major iTFA) have been reported in unbranded oils used in the preparation of suya, a popular Nigerian street food,[28] and there are concerns that street foods could be a significant contributor to *trans*-fatty acid intake in low-income and middle-income countries.[29] While prolonged or repeated heating of cooking oils at high temperatures may result in formation of trans-fats, common cooking practices rarely use such high temperatures.[30] An alternative source of *trans*-fatty acids is the refinement process of cooking oils, especially deodorisation, which can generate substantial amounts of trans-fat isomers.[31] Apart from intervention

targeting iTFA, cost-savings on IHD care from the policy could also allow the allocation of funds to other preventive public health campaigns, thereby further increasing the potential health gains from the modelled iTFA policy.

Altering inputs and assumptions in a series of sensitivity analyses did not substantially change the findings suggesting that the intervention could be a cost-saving strategy to prevent IHD mortality and morbidity in Nigeria. Importantly, even if the policy would not result in the complete elimination of *trans*-fatty acid intake in Nigeria (eg, due to incomplete removal of iTFA from foods in Nigeria), the policy was still estimated to be a cost-saving or very cost-effective strategy to generate substantive health gains.

Interestingly, the intervention was estimated to be overall cost-saving, although the estimated mean *trans*-fatty acid intake before the intervention (ie, 0.25–0.31%E) is considerably lower compared with populations in previous cost-effectiveness analyses of policies targeting iTFA in Europe and Australia (ie, ≥0.59%E).[11 27 32] Furthermore, even when healthcare cost-savings were disregarded, the intervention in Nigeria was still estimated to be cost-effective after 5 years.

A systematic review of policies aiming to lower *trans*-fatty acid intake suggested that bans of partially hydrogenated oils or mandatory iTFA limits (as modelled here) would outperform less stringent policies (eg, voluntary limits or mandatory labelling).[9] This study expands this previous evidence by indicating that in Africa's most populous nation, Nigeria, a lower-middle income country with low estimated *trans*-fatty acid intake, a mandatory limit of iTFA in foods, oils and fats could even generate net cost-savings. Such findings support national initiatives in Nigeria as well as WHO's global call to eliminate iTFA from food supplies as a public health 'best-buy'.[8] With the REPLACE technical package, WHO provides guidance to countries for multiple strategies to be considered together in order to reduce or eliminate iTFA intake.[6] For example, even if partially hydrogenated oils are banned, mandatory labelling of TFA content in foods is still recommended. Elimination of iTFA from the national food supply has proven feasible in high-income countries like Denmark and the USA,[33 34] and an increasing number of middle-income countries have implemented WHO best-buy policies (eg, Brazil, India and Peru). In addition to government policy efforts to eliminate iTFA from foods, leading global food companies have pledged to remove iTFA from their products, which further supports the feasibility of iTFA elimination from foods.[35] However, such voluntary actions by the food industry have often only led to a partial reduction of iTFA.[36] Thus, government legislation to limit the use or completely ban iTFA-containing ingredients, with monitoring of compliance and enforcement mechanisms, will likely be needed to ensure elimination of iTFA from the food supply. By passing regulations to limit iTFA, Nigeria recently became the second country in Africa (after South Africa) with a best practice *trans*-fatty acid policy, as defined by WHO.[10] The findings of our study may aid the implementation of the regulation in Nigeria and, perhaps more importantly, they can provide guidance and motivation to policy-makers considering similar policies for low-income and middle-income countries in Africa and globally.

We recently conducted a similar cost-effectiveness analysis of a mandatory iTFA limit in Kenya.[12] Due to substantial dissimilarities in data inputs (eg, demographics and cost inputs), the magnitude of estimated health and economic impacts varied considerably between the studies. Nevertheless, a mandatory iTFA limit in foods, fats and oils was estimated to generate substantial net cost-savings while markedly reducing the IHD burden in both countries. In Kenya, the probability of the policy being cost-saving was ≥99.6% across all sensitivity analyses and regardless of time horizon.

Our study has several strengths. To identify products potentially containing iTFA in the Nigerian food supply, we used a country-specific and contemporary database of packaged foods in Nigeria.[21] We derived the relative risk estimates of *trans*-fatty acid intake with incident IHD from a large meta-analysis of prospective studies directly linking consumption of *trans*-fatty acid to incidence of IHD, thereby taking into consideration not only effects mediated by blood lipids but also other potential pathways through which *trans*-fatty acid intake can impact IHD, for example, inflammation.[37] Total healthcare costs included both costs related to IHD care and other healthcare, thereby accounting for potential additional costs resulting from a population where more individuals reach old age due to a reduced IHD burden. We estimated health impact and healthcare cost-savings stratified by sex.

We acknowledge that our study has limitations. In the absence of nationally representative estimates of *trans*-fatty acid intake in Nigeria, we used age-specific and sex-specific intake estimates from the GBD 2019 study derived through imputation using a spatiotemporal Gaussian regression method, which uses dietary data and PHVO sales as inputs.[38] We did not consider any potential ongoing voluntary reformulation to reduce iTFA in Nigeria's food supply, as there is little evidence to suggest such secular trends. For example, trans-fatty acid intake estimates from GBD and hydrogenated vegetable oil sales data from Euromonitor show no meaningful changes in recent years.[1 39] In addition, even in a sensitivity analysis assuming 50% lower baseline intake (compared with the main analysis), the policy was estimated to be cost-saving. Thus, it is very likely that the policy would also be cost-saving even with some ongoing trends of reduced iTFA intake due to voluntary reformulation. We used estimates of industry costs from the UK, reported nearly 20 years ago, and may thus not be fully representative of the potential reformulation costs required to comply with the modelled policy. Furthermore, our estimation of potentially iTFA-containing products requiring reformulation did not include foods or ingredients not available

in supermarkets. However, even when assuming doubled reformulation costs in a sensitivity analysis, the policy was likely to be cost-saving or at least very cost-effective already after 5 years. In the absence of a recent costs-of-illness study for Nigeria, we used IHD costs from a rural area with rather uncertain estimates (likely lower compared with urban areas), assuming a triangular distribution. Thus, the estimates may not fully represent national IHD costs, but are more likely underestimated than overestimated. Thus, we may underestimate the healthcare cost-savings of our preventive intervention, while overestimating the healthcare costs in added years of life, as these are calculated by subtracting the IHD costs from overall healthcare expenditure. We are thus erring on the side of caution; higher estimates of IHD care costs would not alter the conclusion that an iTFA limit is highly likely to be cost-saving. We evaluated the cost-effectiveness from an extended healthcare perspective, including healthcare costs both IHD-specific and non-IHD costs, as well as policy implementation costs for the government and the food industry. Thus, the societal savings from the intervention are likely to be substantially underestimated, given that we did not consider indirect costs (eg, productivity loss due to absenteeism or disability). Due to the scarceness of data (eg, on *trans*-fatty acid intake or IHD burden), we were able to stratify our analyses on sex, but not on socioeconomic status or urban versus rural residency. Previous analyses from the UK and Australia have indicated that elimination of iTFA from the food supply could reduce social-economic and urban–rural inequalities in IHD disease burden.[11 27] The potential impact of such inequalities in Nigeria is unclear. Like previous cost-effectiveness analyses of iTFA-targeting policies, we used risk estimates of change in trans-fatty acid against the overall diet rather than specific substitution with other fat classes. If iTFAs were systematically replaced by saturated fatty acids, the impact of the mandatory limit could be lower than estimated here. However, a systematic review of iTFA policies suggests no overall increase in saturated fatty acid content among foods reduced in iTFA content.[40]

Conclusion

Compared with a base scenario with sustained intake of *trans*-fatty acid at current levels, a mandatory limit of iTFAs was estimated to be a cost-saving strategy to avert hundreds of thousands of IHD events and premature deaths in Nigeria. Our findings support the recently passed regulation to reduce iTFA content in the Nigerian food supply.

Author affiliations
[1]Department of Public Health and Caring Sciences, Uppsala University, Uppsala, Sweden
[2]Food Policy, The George Institute for Global Health, Newtown, New South Wales, Australia
[3]Department of Epidemiology, Johns Hopkins Bloomberg School of Public Health, Baltimore, Maryland, USA
[4]Welch Center for Prevention, Epidemiology, and Clinical Research, Johns Hopkins University, Baltimore, Maryland, USA
[5]School of Medicine and Dentistry, Griffith University, Gold Coast, Queensland, Australia
[6]Cardiovascular Research Unit, University of Abuja Teaching Hospital, Gwagwalada, Abuja, Nigeria
[7]Holo Healthcare, Nairobi, Kenya
[8]Department of Epidemiology and Global Health, University Medical Centre Utrecht, Utrecht, Netherlands
[9]Federal Capital Territory Primary Health Care Board, Abuja, Nigeria
[10]National Agency for Food and Drug Administration and Control, Abuja, Federal Capital Territory, Nigeria
[11]School of Public Health and Community Medicine, University of New South Wales, Sydney, New South Wales, Australia
[12]Washington University in St Louis, St Louis, St Louis, USA
[13]Department of Internal Medicine, Faculty of Clinical Sciences, University of Abuja, Abuja, Federal Capital Territory, Nigeria

X Matti Marklund @MarklundMatti, Leopold N Aminde @LN_Aminde and J Lennert Veerman @lennertveerman

Contributors MM, LNA, JLV, JHYW, MDH and DO conceptualised and designed the study. MDH and DO acquired funding. MM, LNA, MNW, BMA, AEO, LH, AA and DO collected input data. MM, LNA, MNW, BMA, AEO, CEO, JLV, JHYW, MDH and DO reviewed and interpreted results. MM conducted formal analysis, prepared the first draft of the manuscript, had final responsibility for the decision to submit for publication, and is responsible for the overall content as guarantor. All authors contributed to the interpretation of results, drafting and editing the manuscript, reviewed the final version of the manuscript and approved the submission for publication.

Funding This study was funded by the National Heart, Lung, and Blood Institute (UG3HL152381) and Northwestern University (grant number: N/A).

Competing interests All authors have completed the ICMJE uniform disclosure form and declare the following: MM report grant support from Resolve to Save Lives and the World Health Organization; and travel support from the Nordic Dairy Congress 2022; all outside of the present work. MDH has received travel support from the American Heart Association and World Heart Federation. MDH has an appointment at The George Institute for Global Health, which has a patent, license and has received investment funding with intent to commercialise fixed-dose combination therapy through its social enterprise business, George Medicines. MDH has pending patents for heart failure polypills.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Ethics approval Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

Data availability statement Data are available upon reasonable request. All data relevant to the study are included in the article or uploaded as supplementary information. All data relevant to the study are included in the article or uploaded as supplmentary information. Original data are available on request.

ORCID iDs
Matti Marklund http://orcid.org/0000-0002-3320-796X

Leopold N Aminde http://orcid.org/0000-0003-2787-7518
J Lennert Veerman http://orcid.org/0000-0002-3206-8232

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Online supplemental material

Appendix

Study proposal and analytical plan

Title: Estimated health benefits, costs, and cost-effectiveness of policies to reduce the intake of industrial trans-fatty acids in Nigeria

Background: A high intake of trans fatty acids (TFAs) is a well-known dietary risk factor of ischemic heart disease (IHD). TFA causes cardiometabolic dysfunction,[1] and a meta-analysis of prospective studies reported that for every 2% of total energy from TFAs, IHD risk increased by 23%.[2] TFAs occur naturally at low levels in meat and milk from ruminants, but in most countries intakes are predominantly driven by the use of partially hydrogenated vegetable oils in a variety of foods such as packaged processed products and street foods. [3]

Given the adverse effects of TFAs, the World Health Organization (WHO) recommends limiting TFA intake to <1 percent of energy (%E) and countries have implemented strategies to reduce industrially derived TFA (iTFA) in the food supply[4,5]. These policies range from voluntary reformulation, mandatory labeling, through to banning partially hydrogenated vegetable oils entirely. For example, iTFA content in foods must be ≤2% of total fat in Denmark[6] and in 2015, the US Food and Drug Administration determined that partially hydrogenated oils are no longer considered generally recognized as safe for use in human food, essentially eliminating its use.[7] However, in many other countries policies to reduce iTFA have been limited or are completely lacking.

While removal of iTFA from the food supply is expected to have the greatest impact in places where intake is high, we recently estimated that a ban of iTFA even in Australia (a country with relatively low iTFA) would be cost-saving or highly cost-effective and could likely help reduce health disparities. [8] Similar cost-effectiveness analyses for low- and middle-income countries (LMIC) are scarce, although the findings could help inform policy makers in resource-limited settings on the overall health and economic impact of removing iTFA from the food supply.

The 2019 Nigerian National Multisectoral Action Plan for the Prevention and Control of Noncommunicable Diseases includes a high-level political commitment to eliminate artificial trans fatty acids (TFA) through

reformulation, fiscal policies, food labelling changes, and agricultural policies. In 2020, the Nigerian Agency for Food and Drug Administration and Control (NAFDAC) created a draft policy to limit TFA to <2% of fat content in all food products, which aligns with the WHO REPLACE package. However, the potential health impact, costs and the cost-effectiveness of TFA elimination in Nigeria are unknown.

Aims and Objectives: To estimate the health impact, costs, and cost-effectiveness of a mandatory TFA limit in the Nigerian food supply. The specific aims include to:

1. Develop a Markov-cohort model framework to estimate the IHD burden in Nigeria for:
    a. a base case scenario under current TFA intake
    b. alternative scenarios with policies to reduce TFA intake
2. Estimate the direct healthcare cost (IHD-related and total) under both scenarios.
3. Estimate the implementation cost of each policy.
4. Estimate cost-effectiveness, compared to the base case scenario, of the policies, based on net costs and potential health gains.

Expected outcomes: The findings from this study may help to motivate policy makers and the public health community to further commit to and invest into policies related to reducing TFA intake for heart disease prevention. The expected outcomes include:

- Averted IHD deaths, number of IHD events, health-adjusted life-years (HALYs), and healthcare savings (total and IHD-related) from reduced TFA intake.
- Policy costs (could include e.g., legislation, monitoring, and reformulation costs).
- Incremental cost-effectiveness ratio (ICER).

Policy scenario: A limit of iTFA content (≤2%E of all fats) in the Nigerian food supply. The limit would target both packaged foods and foods purchased at restaurants or from street vendors

Model and analysis: A multiple cohort proportional multistate life table (Markov) framework will be developed to estimate the potential impact of reduced iTFA intake on IHD mortality and morbidity as well as HALYs and direct healthcare (IHD-related and total) costs (**Figure 1**). We will incorporate data on TFA intake, IHD burden (e.g., incidence, prevalence, case fatality, disability weights), and all-cause mortality, from country- or region-specific sources or the Global Burden of Disease study (**Table 1**). The effects of TFA intake on IHD risk will be derived from previous meta-analyses of observational studies. Direct IHD-related and total healthcare costs including hospital services, out-of-hospital medical services, pharmaceuticals, and health professionals will be based on best available evidence from national or global data sources and literature. Cost-effectiveness will be evaluated from an extended healthcare perspective (incorporating policy and direct healthcare costs) over 10 years and over the population lifetime.[7] The incremental cost-effectiveness ratio (ICER) will be calculated by dividing the incremental net cost (i.e., policy costs minus healthcare cost savings) by the incremental HALYs gained. Cost-saving will be defined as having a negative incremental net cost and we will use WHO benchmarks and country-specific willingness to pay thresholds for defining cost-effectiveness. We will present estimated health gains separately and jointly for men and women. The parameter uncertainty around the modelled estimates will be quantified using Monte Carlo simulations, with random draws made for each iteration from the distributions of model inputs (e.g., TFA intake, policy effect, relative risks, and costs). Deterministic sensitivity analyses will be conducted to explore the impact of variations in data inputs and model assumption (e.g., counterfactual TFA intake, policy implementation costs, and discount rate).

Health outcomes

We used data from the GBD 2019 study to estimate baseline incidence, prevalence, and mortality rates for IHD in Nigeria.[9] Using multiple data sources, the GBD study provides a systematic analysis of the burden of disease in 204 countries and territories. A complete list of data sources is available through the GBD 2019 data input sources.[10] Furthermore, we used the DisMod II software[11] to obtain estimates of case fatality rates for IHD, as these are seldom reported in the literature. Using data on incidence, prevalence, mortality, and population numbers for Nigeria, DisMod II generates estimates of IHD case fatality rates. The software uses

a set of differential equations that leverage the causal relation in a typical disease process to estimate absent epidemiological parameters while maintaining stability in the overall disease epidemiology.[11] These analyses were conducted by sex and five-year age groups.

Disability weights (DW) indicate the average loss of quality of life due to a disease condition.[12] We calculated DW by dividing the number of IHD-specific years lived with disability (YLD) by the number of people living with IHD for each age/sex group. These DWs were adjusted for the disability due to other health conditions in each age group, given that the starting point for calculating YLDs was less than full health. We inflated by '1-pYLD /n', whereby pYLD stands for the total YLD for all diseases except IHD, and n is the population size. This calculation is done to derive DWs at the cause level (e.g., IHD) instead of sequela level (e.g., myocardial infarction (MI), chronic IHD, angina, asymptomatic IHD following MI, acute MI) as reported in the GBD study.[9] We base our calculations on the GBD methods for estimating YLDs as the disease prevalence multiplied by disability weights.[12] These DWs are used in the calculation of health-adjusted life years.

Healthcare costs

A review of the literature was conducted to determine total health expenditure and the healthcare costs associated with IHD in Nigeria. Our model includes costs of incident IHD and costs for prevalent IHD. We used estimates from a study by Rosendaal et al.,[13] that included data from a micro-costing study at a public primary care facility[14] on the costs of hypertension and cardiovascular disease prevention care according to international guidelines. This was further informed by additional data on resource utilization from the University of Ilorin Teaching Hospital.[13] Using a healthcare provider perspective, the authors estimated the costs of acute care after an IHD event per patient (i.e., incident IHD costs) and costs of follow-up care after an IHD event per patient per year (i.e., prevalent IHD costs). The cost estimates included consultation fees, diagnostic tests, hospital bed-days, medication as well as overheads. These IHD costs were estimated in 2012 USD, which we inflated to 2019 values using World Bank consumer price indices for Nigeria .[15]

Estimates of total health expenditure were obtained from the Nigerian National Health Accounts for 2017 report.[16] Due to data limitations for Nigeria, we used data from the Kenyan 2013 Household Health Expenditure and Utilization Survey[17] to derive age and sex distributions of total health expenditure in Nigeria. The total health expenditure was then divided by population numbers in each sex and age-group to derive the

per capita expenditure. Our model accounts for healthcare costs that may arise from other conditions that result from keeping people alive due to the intervention. To estimate these unrelated/ non-IHD costs, we subtract the IHD costs from the total health expenditure for each sex and age-group. Total health expenditure estimates were inflated from 2017 to 2019 (model base year) using World Bank consumer price indices for Nigeria.[15]

Estimating government costs for policy implementation

Government costs for policy implementation were elicited by a group of experts who are tenured staff of National Agency for Food Drug and Administration Control (NAFDAC) which comprised a Food Safety Specialist and Risk Analyst, two Economists with one being a Chartered Accountant and two Biostaticians. The team collected data from the Federal Executive and National Assembly as these bodies were identified to be involved in public health policy formulation, laws enactment, standards elaboration and regulations development. Data was also collected from the Ministries of Health, Industries, Trade and Investment, and from National Agency for Food and Drug Administration and Control NAFDAC, Standards Organisation of Nigeria SON involved in food safety, public health. The sources of data were from the libraries and websites for annual work plans, work activities, and the outcomes of these agencies and departments. Other sources of data were from planned budgets and records of expenditure and procurement from these agencies and departments. Responsible officers were also engaged to draw a correlation between the sourced figures and their pronouncements.

Estimating industry costs for policy implementation

As previously described, we identified 310 food products potentially containing iTFA in the Nigeria food supply.[18] Of these 310 products, n=64 (20.6%) were manufactured in Nigeria, n=218 (70.3%) were produced abroad, and n=28 (9.0%) did not contain information of country of origin. Due to paucity of reliable Nigerian data on industry reformulation costs, our calculations were based on evidence from the United Kingdom.[19] We estimated initial reformulation costs (i.e., additional costs to reformulate and repackage, including loss through disuse of existing packaging, products outside of natural product cycles) in the first year by calculating the corresponding USD costs from the UK estimates (£25,000 per product) multiplied by the number of products in the Nigerian food supply potentially containing iTFA. Furthermore, we assumed an ongoing

annual industry cost equivalent to 1% of the initial reformulation cost to conservatively account for increased industry costs for using alternative ingredients, which is consistent with previous studies.[19,20]

All government and industry costs were inflated to 2019 values using the World Bank consumer price indices for Nigeria.[15]

Estimation of policy effect on disease incidence

To estimate the proportional change in IHD incidence due to the elimination of iTFAs, we used the reference and intervention *trans*-fatty acid intakes and the relative risk of IHD per %E of *trans*-fatty acid intake to calculate the potential impact fraction, according to Barendregt's continuous 'distribution shift' potential impact fraction method (Annexure 2). [21]

$$\text{PIF}_{as} = \frac{\int_{x=0}^{m} RR_a(x)P_{as}(x)dx - \int_{x=0}^{m} RR_a(x)P'_{as}(x)dx}{\int_{x=0}^{m} RR_a(x)P_{as}(x)dx} \qquad \text{Eq. 1}$$

Here, the PIF_{as} is the potential impact fraction for age group a and sex s, $RR_a(x)$ is the relative risk for age group a as a function of the exposure x (i.e., *trans*-fatty acid intake), $P_{as}(x)$ is the reference *trans*-fatty acid intake distribution of age group a and sex s, and $P'_{as}(x)$ is the intervention *trans*-fatty acid intake distribution for the same age-sex group. For the primary model, where we assumed that the policy would virtually eliminate intake of *trans*-fatty acids, a simplification of the PIF equation (i.e., a population attributable fraction equation) was used (Equation 2).

$$\text{PIF}_{as} = \frac{\int_{x=0}^{m} RR_a(x)P_{as}(x)dx - 1}{\int_{x=0}^{m} RR_a(x)P_{as}(x)dx} \qquad \text{Eq. 2}$$

The PIF was used to calculate the effect on IHD incidence due to the reduction in *trans*-fatty acid intake (Equation 3).

$$I' = I(1 - PIF) \qquad \text{Eq. 3}$$

Here, I is the IHD incidence in the reference population, I' is the IHD incidence in the intervention population, and PIF is the potential impact fraction.

Table S1. Baseline (pre-policy) in intake of total TFA by age and sex.[1]

		Pre-policy intake (%E)	
Sex	**Age (years)**	**Mean**	**SD**
Women	20-24	n/a[2]	n/a[2]
	25-29	0.25 (0.17; 0.35)	0.14 (0.09; 0.20)
	30-34	0.25 (0.17; 0.36)	0.14 (0.09; 0.20)
	35-39	0.25 (0.18; 0.35)	0.14 (0.09; 0.19)
	40-44	0.26 (0.17; 0.36)	0.14 (0.09; 0.20)
	45-49	0.26 (0.18; 0.37)	0.14 (0.10; 0.20)
	50-54	0.27 (0.19; 0.37)	0.14 (0.10; 0.20)
	55-59	0.27 (0.19; 0.39)	0.15 (0.10; 0.22)
	60-64	0.28 (0.20; 0.39)	0.15 (0.11; 0.21)
	65-69	0.28 (0.20; 0.40)	0.15 (0.11; 0.22)
	70-74	0.29 (0.20; 0.40)	0.16 (0.11; 0.22)
	75-79	0.30 (0.21; 0.42)	0.16 (0.11; 0.23)
	80-84	0.31 (0.21; 0.43)	0.17 (0.11; 0.24)
	85-89	0.30 (0.21; 0.41)	0.17 (0.11; 0.23)
	90-94	0.31 (0.21; 0.42)	0.17 (0.11; 0.24)
	95+	0.31 (0.21; 0.43)	0.17 (0.11; 0.24)
Men	20-24	n/a[2]	n/a[2]
	25-29	0.25 (0.17; 0.35)	0.14 (0.09; 0.19)
	30-34	0.25 (0.17; 0.36)	0.14 (0.09; 0.20)
	35-39	0.26 (0.18; 0.35)	0.14 (0.10; 0.19)
	40-44	0.26 (0.18; 0.36)	0.14 (0.10; 0.20)
	45-49	0.26 (0.18; 0.37)	0.14 (0.10; 0.20)
	50-54	0.27 (0.19; 0.37)	0.14 (0.10; 0.20)
	55-59	0.27 (0.19; 0.38)	0.15 (0.10; 0.21)
	60-64	0.28 (0.19; 0.38)	0.15 (0.10; 0.21)
	65-69	0.28 (0.19; 0.39)	0.16 (0.10; 0.22)
	70-74	0.29 (0.20; 0.41)	0.16 (0.11; 0.23)
	75-79	0.30 (0.21; 0.42)	0.16 (0.11; 0.23)
	80-84	0.31 (0.21; 0.43)	0.17 (0.11; 0.24)
	85-89	0.31 (0.21; 0.43)	0.17 (0.11; 0.24)
	90-94	0.31 (0.22; 0.43)	0.17 (0.12; 0.24)
	95+	0.30 (0.21; 0.42)	0.17 (0.11; 0.23)

%E, percentage of energy intake; n/a, SD, standard deviation.

[1]in the absence of national data on trans-fatty acid intake in Nigeria, we utilized estimates from the Global Burden of Disease study,[22] provided by the Institute for Health Metrics and Evaluation (IHME). A spatio-temporal Gaussian process regression framework using data from 24-h recalls, food frequency questionnaires, and sales data of partially hydrogenated vegetable oils from Euromonitor, were used to generate country-, year-, age- and sex-specific estimates of trans-fatty acids

[2]Estimates for ages 20-24 years not available, thus estimates for ages 25-29 years used for both age groups.

Table S2. Population size and mortality rate, by sex and age.

	Population size (1000s)		Mortality rate (per 1000)	
Age	**Women**	**Men**	**Women**	**Men**
20	2235.0	1989.1	1.2	1.5
21	2161.9	1903.9	1.2	1.5
22	2092.5	1824.5	1.2	1.5
23	2027.8	1751.4	1.2	1.5
24	1955.0	1676.4	1.2	1.5
25	1873.6	1598.1	1.7	2.0
26	1794.6	1528.5	1.7	2.0
27	1717.8	1466.5	1.7	2.0
28	1644.4	1412.5	1.7	2.0
29	1577.0	1362.2	1.7	2.0
30	1512.2	1313.5	2.5	2.7
31	1455.2	1267.0	2.5	2.7
32	1405.5	1224.1	2.5	2.7
33	1361.5	1184.9	2.5	2.7
34	1311.7	1146.1	2.5	2.7
35	1256.0	1107.6	3.3	3.9
36	1205.2	1072.2	3.3	3.9
37	1159.3	1039.8	3.3	3.9
38	1117.7	1010.0	3.3	3.9
39	1076.3	980.2	3.3	3.9
40	1035.1	950.1	4.3	5.5
41	996.1	919.4	4.3	5.5
42	960.2	888.9	4.3	5.5
43	927.4	858.8	4.3	5.5
44	895.2	829.8	4.3	5.5
45	864.3	802.2	5.7	7.3
46	835.7	772.7	5.7	7.3
47	809.7	741.5	5.7	7.3
48	786.6	708.5	5.7	7.3
49	763.4	674.9	5.7	7.3
50	739.6	640.1	7.8	10.1
51	709.5	605.2	7.8	10.1
52	675.7	571.7	7.8	10.1
53	639.5	539.2	7.8	10.1
54	610.1	504.6	7.8	10.1
55	587.5	469.3	10.9	14.2
56	563.2	439.7	10.9	14.2
57	534.9	413.1	10.9	14.2
58	503.3	389.2	10.9	14.2
59	472.2	365.2	10.9	14.2
60	441.8	341.5	16.9	21.4
61	408.8	319.2	16.9	21.4
62	374.3	298.4	16.9	21.4
63	339.5	278.8	16.9	21.4
64	308.2	258.5	16.9	21.4
65	280.1	238.1	25.6	31.6
66	257.8	221.8	25.6	31.6
67	240.1	208.9	25.6	31.6
68	222.1	198.7	25.6	31.6
69	246.6	210.2	25.6	31.6
70	163.1	162.8	43.1	49.2
71	159.6	159.8	43.1	49.2
72	148.8	151.4	43.1	49.2
73	121.9	134.5	43.1	49.2
74	109.9	122.8	43.1	49.2
75	144.7	133.0	67.5	74.2
76	131.8	122.4	67.5	74.2
77	118.9	110.9	67.5	74.2
78	93.0	94.9	67.5	74.2
79	86.0	87.4	67.5	74.2

80	75.8	77.7	103.7	111.6
81	65.9	68.6	103.7	111.6
82	56.6	60.0	103.7	111.6
83	47.8	50.9	103.7	111.6
84	40.9	44.0	103.7	111.6
85	34.9	37.5	140.1	157.9
86	29.9	31.6	140.1	157.9
87	25.5	26.4	140.1	157.9
88	19.8	23.3	140.1	157.9
89	16.8	18.7	140.1	157.9
90	14.1	14.6	199.8	227.5
91	11.6	11.2	199.8	227.5
92	9.5	8.4	199.8	227.5
93	8.7	5.6	199.8	227.5
94	6.8	4.0	199.8	227.5
95	3.6	2.5	303.8	334.9
96	3.0	1.8	303.8	334.9
97	2.5	1.3	303.8	334.9
98	2.1	0.9	303.8	334.9
99	1.7	0.7	303.8	334.9
100+	5.1	1.4	-[1]	-[1]

[1]Model simulations terminated when all individuals were dead or had reached the age 100 years.

Table S3. Estimated rates of IHD incidence and prevalence (per 100K) and IHD case fatality by age and sex.

	Women			Males		
Age	**Incidence (per 100K)**	**Prevalence (per 100K)**	**Case fatality (%)**	**Incidence (per 100K)**	**Prevalence (per 100K)**	**Case fatality (%)**
20	0	20	3.6	10	30	4.0
21	0	20	3.3	10	30	3.8
22	10	30	3.0	10	40	3.6
23	10	30	2.6	10	50	3.3
24	10	40	2.2	10	60	3.0
25	10	40	1.9	20	80	2.7
26	10	50	1.6	20	90	2.4
27	10	70	1.3	20	110	2.2
28	20	80	1.2	30	140	2.0
29	20	90	1.1	30	160	2.0
30	20	110	1.2	40	190	2.0
31	20	130	1.2	40	230	2.0
32	20	150	1.3	40	260	2.1
33	30	180	1.4	50	300	2.1
34	30	200	1.4	50	350	2.2
35	30	230	1.4	60	390	2.2
36	30	260	1.4	60	440	2.3
37	40	290	1.4	70	490	2.3
38	40	320	1.5	70	550	2.4
39	50	360	1.5	80	610	2.4
40	50	400	1.5	90	680	2.4
41	60	450	1.6	100	750	2.5
42	60	500	1.7	110	830	2.5
43	70	560	1.7	120	920	2.5
44	80	620	1.8	140	1,030	2.6
45	90	690	1.9	150	1,140	2.6
46	100	770	2.1	170	1,270	2.6
47	110	860	2.2	190	1,410	2.7
48	120	950	2.4	210	1,570	2.7
49	140	1,050	2.5	230	1,740	2.8
50	150	1,170	2.6	260	1,930	2.8
51	170	1,290	2.7	290	2,140	2.8
52	180	1,430	2.8	320	2,370	2.9
53	200	1,570	2.9	350	2,630	2.9
54	220	1,740	2.9	390	2,910	2.9
55	250	1,920	3.0	430	3,220	2.9
56	270	2,110	3.0	470	3,560	2.9
57	300	2,330	3.1	520	3,940	2.9
58	340	2,570	3.3	580	4,350	3.0
59	370	2,820	3.4	640	4,800	3.0
60	410	3,100	3.6	700	5,290	3.1
61	450	3,400	3.8	770	5,820	3.1
62	500	3,730	4.0	840	6,390	3.2
63	540	4,070	4.2	910	7,010	3.3
64	590	4,430	4.4	990	7,660	3.3
65	640	4,820	4.7	1,060	8,360	3.4
66	690	5,220	4.9	1,140	9,090	3.5
67	750	5,640	5.2	1,230	9,860	3.5
68	810	6,080	5.4	1,320	10,680	3.6
69	880	6,540	5.7	1,410	11,530	3.7
70	950	7,010	6.0	1,520	12,430	3.8
71	1,020	7,510	6.3	1,620	13,360	3.9
72	1,100	8,020	6.7	1,730	14,330	4.0
73	1,190	8,560	7.0	1,860	15,350	4.1
74	1,290	9,100	7.4	1,980	16,400	4.3
75	1,380	9,660	7.8	2,120	17,490	4.4
76	1,480	10,240	8.2	2,250	18,620	4.6
77	1,590	10,810	8.6	2,400	19,780	4.7
78	1,690	11,400	9.1	2,550	20,970	4.9
79	1,800	11,970	9.6	2,700	22,180	5.1
80	1,910	12,540	10.1	2,840	23,410	5.3
81	2,020	13,090	10.7	2,990	24,640	5.5
82	2,120	13,610	11.3	3,120	25,860	5.7
83	2,220	14,090	12.0	3,260	27,070	6.0
84	2,320	14,520	12.7	3,390	28,240	6.3
85	2,420	14,900	13.5	3,510	29,360	6.7
86	2,510	15,200	14.5	3,610	30,400	7.2
87	2,600	15,420	15.5	3,700	31,340	7.7
88	2,690	15,550	16.7	3,790	32,150	8.4
89	2,780	15,580	18.0	3,860	32,810	9.1
90	2,860	15,510	19.4	3,920	33,300	9.9
91	2,930	15,340	20.9	3,970	33,620	10.9
92	3,010	15,070	22.4	4,020	33,750	11.8
93	3,070	14,730	23.9	4,070	33,700	12.7

94	3,130	14,330	25.4	4,120	33,500	13.6
95	3,190	13,890	26.9	4,170	33,150	14.5
96	3,240	13,410	28.4	4,220	32,670	15.4
97	3,280	12,930	29.7	4,260	32,080	16.2
98	3,320	12,450	31.1	4,310	31,410	17.0
99	3,360	11,990	32.4	4,350	30,670	17.8
100+	3,380	11,570	32.9	4,370	29,910	18.1

Table S4. Age- and sex-specific disability weights for IHD, adjusted for disability from other causes.

Disease	**Ischemic heart disease**	
Age/ Sex	**Male**	**Female**
20 to 24	0.022	0.021
25 to 29	0.024	0.021
30 to 34	0.024	0.020
35 to 39	0.025	0.021
40 to 44	0.029	0.023
45 to 49	0.030	0.024
50 to 54	0.029	0.023
55 to 59	0.029	0.023
60 to 64	0.029	0.023
65 to 69	0.029	0.022
70 to 74	0.030	0.023
75 to 79	0.030	0.024
80 to 84	0.030	0.023
85 to 89	0.028	0.021
90 to 94	0.029	0.021
95 plus	0.033	0.027

Table S5. All-cause prevalent years lived with disability (pYLD) rates by sex and single-year age groups.

Age	Male	Female	Age	Male	Female	Age	Male	Female
20	0.07	0.09	**50**	0.13	0.16	**80**	0.28	0.29
21	0.07	0.09	**51**	0.13	0.16	**81**	0.28	0.29
22	0.07	0.09	**52**	0.13	0.16	**82**	0.29	0.30
23	0.07	0.09	**53**	0.14	0.17	**83**	0.29	0.30
24	0.07	0.10	**54**	0.14	0.17	**84**	0.30	0.31
25	0.08	0.10	**55**	0.14	0.17	**85**	0.30	0.31
26	0.08	0.10	**56**	0.15	0.17	**86**	0.31	0.31
27	0.08	0.11	**57**	0.15	0.18	**87**	0.31	0.32
28	0.08	0.11	**58**	0.15	0.18	**88**	0.32	0.32
29	0.08	0.11	**59**	0.16	0.18	**89**	0.32	0.33
30	0.09	0.12	**60**	0.16	0.19	**90**	0.33	0.33
31	0.09	0.12	**61**	0.17	0.19	**91**	0.33	0.33
32	0.09	0.12	**62**	0.17	0.19	**92**	0.33	0.34
33	0.09	0.13	**63**	0.18	0.20	**93**	0.34	0.34
34	0.09	0.13	**64**	0.18	0.20	**94**	0.35	0.35
35	0.09	0.13	**65**	0.19	0.21	**95**	0.35	0.36
36	0.10	0.13	**66**	0.19	0.21	**96**	0.36	0.36
37	0.10	0.14	**67**	0.20	0.22	**97**	0.37	0.37
38	0.10	0.14	**68**	0.20	0.22	**98**	0.37	0.38
39	0.10	0.14	**69**	0.21	0.23	**99**	0.38	0.38
40	0.10	0.15	**70**	0.22	0.24	**100**	0.38	0.38
41	0.11	0.15	**71**	0.22	0.24			
42	0.11	0.15	**72**	0.23	0.25			
43	0.11	0.15	**73**	0.24	0.25			
44	0.11	0.15	**74**	0.24	0.26			
45	0.12	0.15	**75**	0.25	0.26			
46	0.12	0.16	**76**	0.25	0.27			
47	0.12	0.16	**77**	0.26	0.27			
48	0.12	0.16	**78**	0.27	0.28			
49	0.12	0.16	**79**	0.27	0.28			

Years lived with disability (YLDs) and Nigeria population data estimates from the 2019 GBD study used to calculate per person YLD [10].

Table S6. Total, IHD-related, and other healthcare costs per capita, by sex and age.

	Annual pre-intervention healthcare costs per capita, USD					
	Women			Males		
Age (year)	Total	IHD	Non-IHD	Total	IHD	Non-IHD
20	24.8	0.1	24.8	19.8	0.1	19.7
21	24.8	0.1	24.8	19.8	0.1	19.7
22	24.9	0.1	24.8	19.8	0.1	19.7
23	24.9	0.1	24.8	19.9	0.2	19.7
24	24.9	0.1	24.8	19.9	0.2	19.7
25	39.3	0.1	39.2	32.3	0.3	32.0
26	39.3	0.2	39.2	32.3	0.3	32.0
27	39.4	0.2	39.2	32.4	0.4	32.0
28	39.4	0.3	39.2	32.5	0.5	32.0
29	39.5	0.3	39.2	32.5	0.6	32.0
30	39.5	0.4	39.2	32.7	0.7	32.0
31	39.6	0.4	39.2	32.8	0.8	32.0
32	39.7	0.5	39.2	32.9	0.9	32.0
33	39.8	0.6	39.2	33.0	1.0	32.0
34	39.8	0.7	39.2	33.2	1.2	32.0
35	76.1	0.8	75.3	59.1	1.3	57.8
36	76.2	0.9	75.3	59.3	1.5	57.8
37	76.3	1.0	75.3	59.5	1.7	57.8
38	76.4	1.1	75.3	59.7	1.8	57.8
39	76.5	1.2	75.3	59.9	2.1	57.8
40	76.7	1.3	75.3	60.1	2.3	57.8
41	76.8	1.5	75.3	60.3	2.5	57.8
42	77.0	1.7	75.3	60.6	2.8	57.8
43	77.2	1.9	75.3	60.9	3.1	57.8
44	77.4	2.1	75.3	61.3	3.5	57.8
45	166.4	2.3	164.1	132.6	3.8	128.8
46	166.7	2.6	164.1	133.1	4.3	128.8
47	167.0	2.9	164.1	133.5	4.8	128.8
48	167.3	3.2	164.1	134.1	5.3	128.8
49	167.7	3.6	164.1	134.6	5.9	128.8
50	168.0	3.9	164.1	135.3	6.5	128.8
51	168.5	4.4	164.1	136.0	7.2	128.8
52	168.9	4.8	164.1	136.8	8.0	128.8
53	169.4	5.3	164.1	137.7	8.9	128.8
54	170.0	5.9	164.1	138.6	9.8	128.8
55	421.0	6.5	414.6	376.6	10.9	365.7
56	421.7	7.1	414.6	377.7	12.0	365.7
57	422.4	7.9	414.6	379.0	13.3	365.7
58	423.3	8.7	414.6	380.4	14.7	365.7
59	424.1	9.5	414.6	381.9	16.2	365.7
60	425.0	10.5	414.6	383.5	17.8	365.7
61	426.1	11.5	414.6	385.3	19.6	365.7
62	427.2	12.6	414.6	387.2	21.5	365.7
63	428.3	13.8	414.6	389.3	23.6	365.7
64	429.6	15.0	414.6	391.5	25.8	365.7
65	903.0	16.3	886.7	668.5	28.1	640.4
66	904.3	17.7	886.7	671.0	30.5	640.4
67	905.7	19.1	886.7	673.5	33.1	640.4
68	907.2	20.6	886.7	676.3	35.8	640.4
69	908.8	22.1	886.7	679.1	38.6	640.4
70	910.4	23.8	886.7	682.1	41.6	640.4
71	912.1	25.5	886.7	685.2	44.7	640.4
72	913.9	27.2	886.7	688.4	48.0	640.4
73	915.7	29.1	886.7	691.8	51.4	640.4
74	917.6	30.9	886.7	695.3	54.9	640.4
75	919.5	32.9	886.7	699.0	58.6	640.4
76	921.5	34.9	886.7	702.8	62.3	640.4

77	923.5	36.9	886.7	706.7	66.2	640.4
78	925.6	38.9	886.7	710.7	70.2	640.4
79	927.6	40.9	886.7	714.7	74.3	640.4
80	929.6	42.9	886.7	718.8	78.4	640.4
81	931.5	44.9	886.7	723.0	82.5	640.4
82	933.3	46.7	886.7	727.0	86.6	640.4
83	935.0	48.4	886.7	731.0	90.6	640.4
84	936.6	49.9	886.7	734.9	94.5	640.4
85	937.9	51.3	886.7	738.7	98.2	640.4
86	939.1	52.4	886.7	742.1	101.6	640.4
87	939.9	53.3	886.7	745.2	104.7	640.4
88	940.5	53.9	886.7	747.9	107.4	640.4
89	940.8	54.1	886.7	750.1	109.6	640.4
90	940.7	54.1	886.7	751.7	111.3	640.4
91	940.4	53.7	886.7	752.8	112.4	640.4
92	939.7	53.0	886.7	753.3	112.9	640.4
93	938.7	52.1	886.7	753.3	112.8	640.4
94	937.6	51.0	886.7	752.7	112.3	640.4
95	936.4	49.7	886.7	751.7	111.3	640.4
96	935.0	48.3	886.7	750.4	109.9	640.4
97	933.6	46.9	886.7	748.6	108.2	640.4
98	932.1	45.5	886.7	746.6	106.2	640.4
99	930.8	44.1	886.7	744.4	104.0	640.4
100+	929.5	42.9	886.7	742.1	101.7	640.4

IHD, ischemic heart disease

Table S7. Etiologic effects of Relative risk for IHD per 2%E from TFA.

Age (y)	Relative risk (95% confidence interval)
25-29	1.901 (1.591-2.275)
30-34	1.775 (1.514-2.085)
35-39	1.615 (1.415-1.848)
40-44	1.517 (1.352-1.707)
45-49	1.461 (1.316-1.627)
50-54	1.396 (1.274-1.535)
55-59	1.323 (1.225-1.433)
60-64	1.264 (1.186-1.352)
65-69	1.222 (1.157-1.294)
70-74	1.186 (1.132-1.246)
75-79	1.158 (1.112-1.207)
80-84	1.150 (1.107-1.197)
85-89	1.150 (1.107-1.197)
90-94	1.150 (1.107-1.197)
95+	1.150 (1.107-1.197)

IHD, ischemic heart disease; TFA, trans-fatty acids.

Table S8. Estimated policy costs of a mandatory limit of industrial trans fatty acids in the Nigerian food supply over 5 years, 10 years, and the population lifetime.

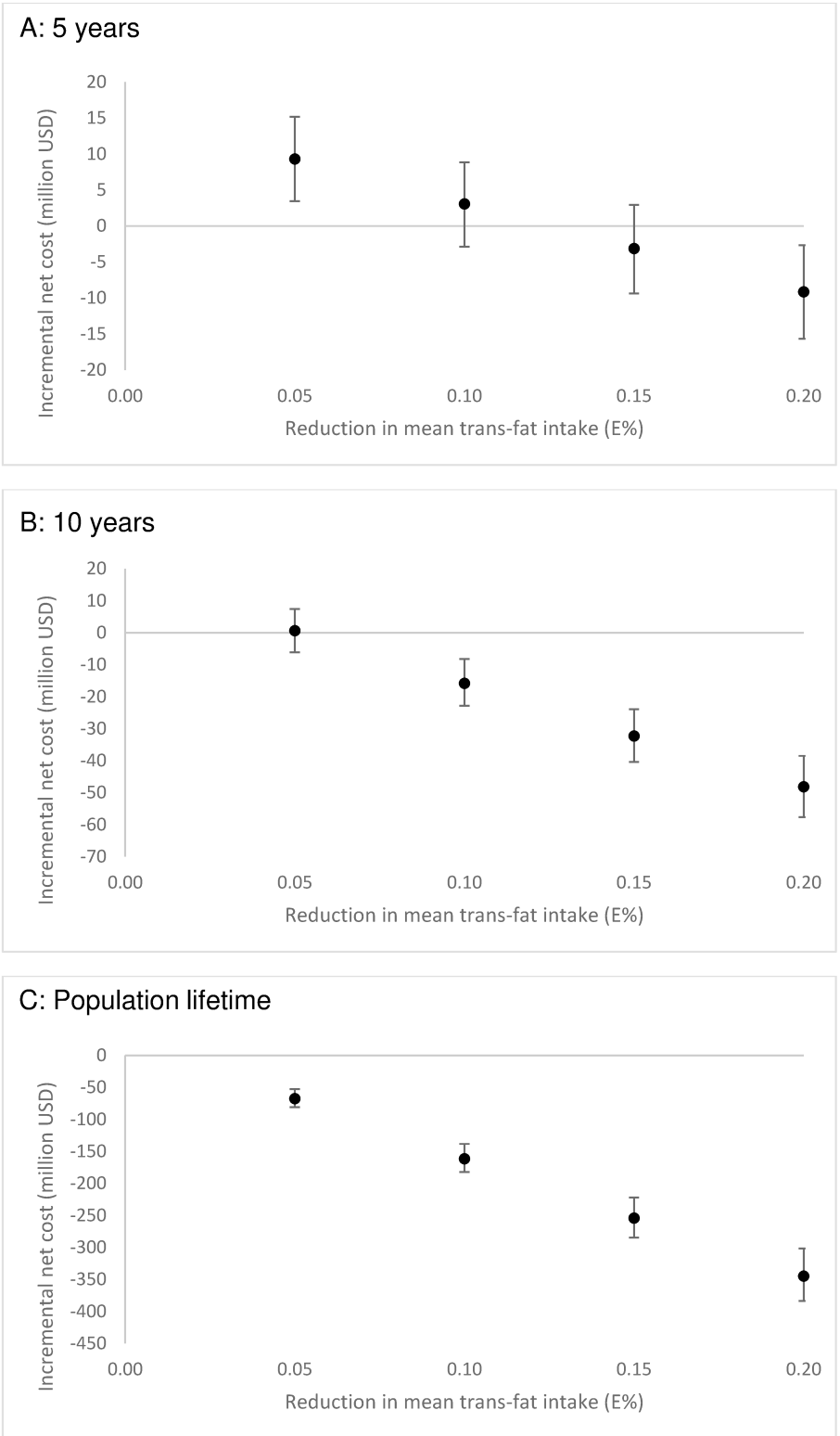
	5 years	**10 years**	**Population lifetime**
Total costs, millions USD	15.6 (9.8; 21.1)	17.2 (11.2; 23.0)	26.2 (19.0; 33.2)
Government costs, thousands USD	885 (795; 974)	1,960 (1,809; 2,120)	7,811 (7,540; 8,087)
National legislation	25 (16; 35)	25 (16; 35)	25 (16; 35)
NAFDAC	736 (654; 814)	1,811 (1,661; 1,963)	7,661 (7,394; 7,926)
Work force expenses	37 (31; 44)	69 (61; 78)	243 (231; 255)
Enlightenment activities	40 (24; 55)	40 (24; 55)	40 (24; 55)
Enforcement activities	309 (254; 366)	576 (500; 652)	2,024 (1,920; 2,134)
Workshops activities	122 (74; 170)	122 (74; 170)	122 (74; 170)
Monitoring	124 (104; 146)	230 (203; 259)	809 (768; 852)
Other activities e.g., research	103 (85; 121)	775 (651; 898)	4,423 (4,176; 4,650)
FMoH (legislation)	71 (44; 100)	71 (44; 100)	71 (44; 100)
SON (revising food standard regulations)	14 (9; 20)	14 (9; 20)	14 (9; 20)
CPC (enlightenment activities)	39 (24; 55)	39 (24; 55)	39 (24; 55)
Industry costs, millions USD	14.7 (9.0; 20.3)	15.3 (9.3; 21.1)	18.4 (11.2; 25.4)

CPC, Consumer Protection Commission; FMoH, Federal Ministry of Health; NAFDAC, National Agency for Food and Drug Administration and Control; SON, Standard Organisation of Nigeria.

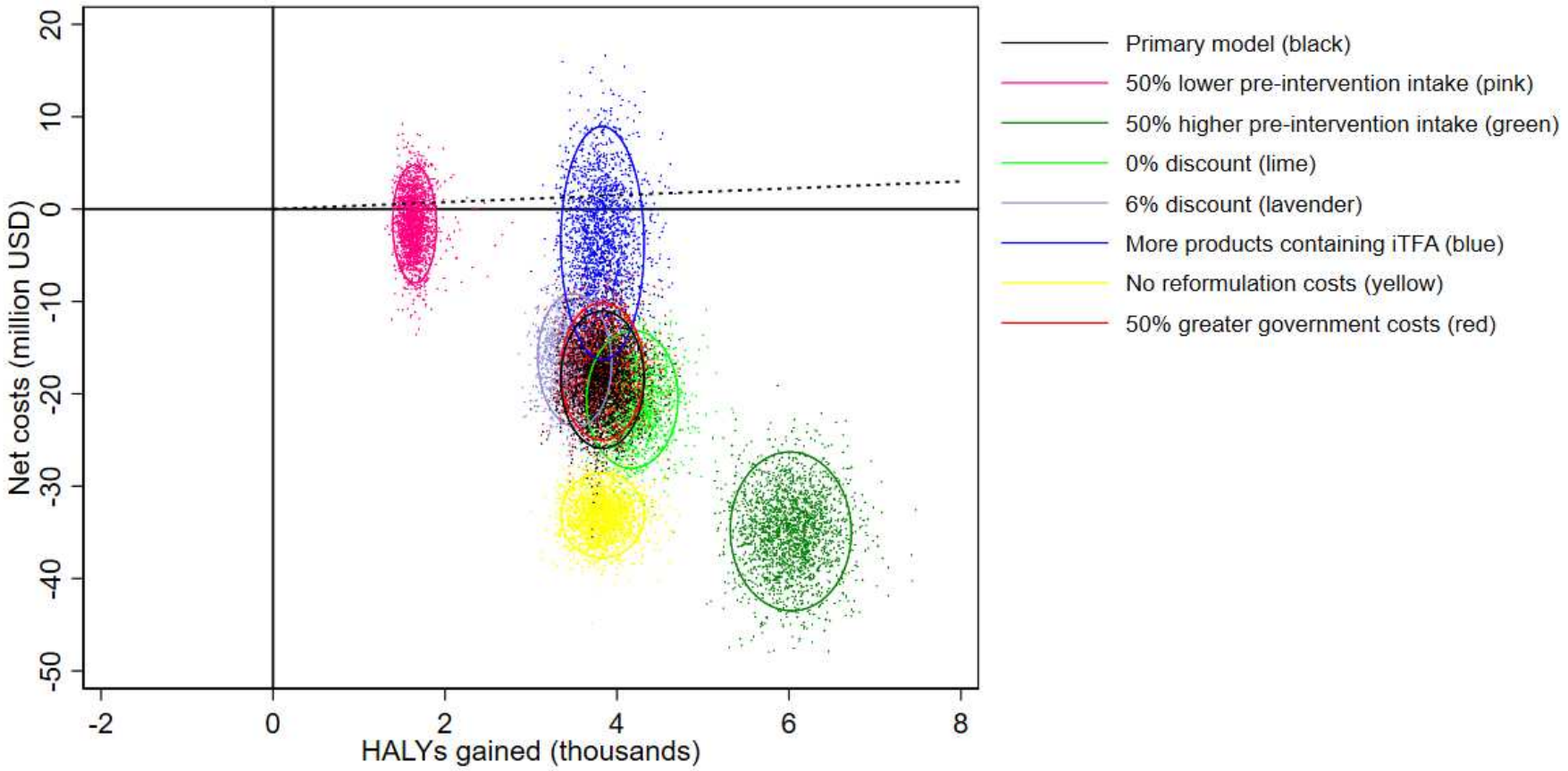
Table S9. Estimated cost-effectiveness of implementing a mandatory limit of iTFA content (≤2% of all fats) in the Nigerian food supply, in main analysis and deterministic sensitivity analyses.

	Main analysis	Lower pre-intervention intake[2]	Higher pre-intervention intake[3]	Intake reduction: 0.05%E	Intake reduction: 0.10%E	Intake reduction: 0.15%E	Intake reduction: 0.20%E	0% discount rate[4]	6% discount rate[5]	More products reformulated[6]	No reformulation costs[7]	50% greater government costs[8]
5 years												
HALYs gained, thousands	4.52 (4.00; 5.02)	2.28 (2.03; 2.57)	6.71 (6.00; 7.45)	0.82 (0.74; 0.91)	1.64 (1.48; 1.81)	2.45 (2.23; 2.69)	3.23 (2.92; 3.54)	4.93 (4.41; 5.49)	4.14 (3.71; 4.61)	4.52 (4.00; 5.02)	4.52 (4.00; 5.02)	4.52 (4.00; 5.02)
Net costs, million USD	-18.5 (-25.7; -11.1)	-1.6 (-8.0; 4.5)	-34.9 (-43.6; -26.6)	9.31 (3.44; 15.18)	3.05 (-2.89; 8.86)	-3.15 (-9.37; 2.94)	-9.14 (-15.65; -2.66)	-20.6 (-28.2; -13.5)	-16.4 (-23.6; -9.4)	-3.7 (-15.7; 8.7)	-33.2 (-37.9; -28.7)	-17.6 (-24.9; -10.3)
ICER, USD per HALY gained	dominant (dominant; dominant)	dominant (dominant; 2,024)	dominant (dominant; dominant)	11,302 (3,991; 19,134)	1,874 (dominant; 5,516)	dominant (dominant; 1,209)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; 1,994)	dominant (dominant; dominant)	dominant (dominant; dominant)
Probabilities												
Cost saving	100%	69.9%	100%	0.2%	15.3%	84.9%	99.8%	100%	100%	71.6%	100%	100%
Cost-effective	100%	78.6%	100%	0.5%	20.9%	90.6%	99.9%	100%	100%	80.4%	100%	100%
10 years												
HALYs gained, thousands	24.8 (21. 9; 27.6)	12.5 (11.1; 14.1)	36.8 (32.9; 40.9)	4.52 (4.05; 4.99)	9.00 (8.12; 9.95)	13.5 (12.2; 14.8)	17.8 (16.0; 19.5)	30.1 (26. 9; 33.6)	20.5 (18.4; 22.9)	24.8 (21. 9; 27.6)	24.8 (21. 9; 27.6)	24.8 (21.9; 27.6)
Net costs, million USD	-72.4 (-85.4; -59.5)	-28.0 (-36.8; -19.9)	-115.7 (-133.6; -99.2)	0.63 (-6.13; 7.38)	-15.91 (-23.61; -8.96)	-32.31 (-40.71; -24.20)	-48.2 (-57.8; -38.7)	-84.3 (-98.8; -71.0)	-61.7 (-73.5; -50.7)	-57.0 (-74.0; -40.6)	-87.7 (-99.6; -76.0)	-70.4 (-83.5; -57.7)
ICER, USD per HALY gained	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	127 (-dominant; 1,682)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)
Probabilities												
Cost saving	100%	100%	100%	42.9%	99.9%	100%	100%	100%	100%	100%	100%	100%
Cost-effective	100%	100%	100%	63.6%	100%	100%	100%	100%	100%	100%	100%	100%
Lifetime												
HALYs gained, thousands	760 (668; 851)	383 (339; 433)	1,131 (1,003; 1,263)	139 (124; 154)	276 (248; 307)	413 (373; 456)	545 (490; 599)	2,353 (2,081; 2,641)	303 (270; 341)	760 (668; 851)	760 (668; 851)	760 (668; 851)
Net costs, million USD	-492 (-561; -427)	-235 (-273; -203)	-744 (-843; -652)	-67.5 (-82.3; -54.1)	-161 (-184; -140)	-254 (-286; -223)	-345 (-388; -306)	427 (290; 568)	-311 (-353; -271)	-473 (-543; -407)	-510 (-579; -443)	-484 (-553; -419)
ICER, USD per HALY gained	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	181 (124; 237)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)	dominant (dominant; dominant)
Probabilities												
Cost saving	100%	100%	100%	99.2%	100%	100%	100%	0%	100%	100%	100%	100%
Cost-effective	100%	100%	100%	99.5%	100%	100%	100%	100%	100%	100%	100%	100%

HALY, health-adjusted life years; ICER, incremental cost-effectiveness ratio; iTFA, industrial trans-fatty acids; USD, United States Dollars. 1Higher post-intervention intake assumed (mean: 0.10%E, SD: 0.01%E). 2Pre-intervention intakes 50% lower compared to main analysis. 3Pre-intervention intakes 50% higher compared to main analysis. 4Assuming 0% discount rate for costs and HALYs. 5Assuming 0% discount rate for costs and HALYs. 6The number of products potentially containing iTFA assumed to be twice as many as in the main analysis. 7Reformulation was considered to be part of the natural life cycle of a product with no additional cost. No additional reformulation costs were assumed. 8Monitoring costs were assumed to be 50% greater compared to the main analysis.



Supplementary figure S1. Net costs estimated in threshold analysis with gradually increasing intervention effects on iTFA intake (0.05-0.20%E reduction from base population intake), evaluated for diverse time horizons: 5 year (A), 10 year (B), and population lifetime (C). Dots indicate mean of n=2,000 Monte Carlo simulations, and the error bars the 95% uncertainty interval (defined as the 2.5th and 97.5th percentiles of model estimates).



Supplementary figure S2. Net costs and health-adjusted life years (HALYs) gained during the first 5 years after policy implementation estimated in the primary model and in deterministic sensitivity analyses. Dotted and dashed black lines indicate thresholds for cost-effective and very cost-effective interventions, respectively.

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CHEERS 2022 Checklist

Topic	No.	Item	Location where item is reported
Title			
	1	Identify the study as an economic evaluation and specify the interventions being compared.	Title/Page 1
Abstract			
	2	Provide a structured summary that highlights context, key methods, results, and alternative analyses.	Abstract/Page 2
Introduction			
Background and objectives	3	Give the context for the study, the study question, and its practical relevance for decision making in policy or practice.	Introduction/Pages 4-5
Methods			
Health economic analysis plan	4	Indicate whether a health economic analysis plan was developed and where available.	Appendix
Study population	5	Describe characteristics of the study population (such as age range, demographics, socioeconomic, or clinical characteristics).	Methods/Page 5
Setting and location	6	Provide relevant contextual information that may influence findings.	Methods/Page 5
Comparators	7	Describe the interventions or strategies being compared and why chosen.	Methods/Page 5
Perspective	8	State the perspective(s) adopted by the study and why chosen.	Methods/Page 6
Time horizon	9	State the time horizon for the study and why appropriate.	Methods/Pages 5-6
Discount rate	10	Report the discount rate(s) and reason chosen.	Methods/Page 6
Selection of outcomes	11	Describe what outcomes were used as the measure(s) of benefit(s) and harm(s).	Methods/Pages 5-6
Measurement of outcomes	12	Describe how outcomes used to capture benefit(s) and harm(s) were measured.	Methods/Pages 7-8
Valuation of outcomes	13	Describe the population and methods used to measure and value outcomes.	Methods/Page 8
Measurement and valuation of resources and costs	14	Describe how costs were valued.	Methods/Pages 6-7
Currency, price date, and conversion	15	Report the dates of the estimated resource quantities and unit costs, plus the currency and year of conversion.	Methods/Page 7
Rationale and description of model	16	If modelling is used, describe in detail and why used. Report if the model is publicly available and where it can be accessed.	Methods/Pages 7-8 and Appendix
Analytics and assumptions	17	Describe any methods for analysing or statistically transforming data, any extrapolation methods, and approaches for validating any model used.	Table 1 and Appendix
Characterising heterogeneity	18	Describe any methods used for estimating how the results of the study vary for subgroups.	Methods/Page 8
Characterising distributional effects	19	Describe how impacts are distributed across different individuals or adjustments made to reflect priority populations.	Methods/Page 8 and Table S7

Topic	No.	Item	Location where item is reported
Characterising uncertainty	20	Describe methods to characterise any sources of uncertainty in the analysis.	Methods/Pages 8-9
Approach to engagement with patients and others affected by the study	21	Describe any approaches to engage patients or service recipients, the general public, communities, or stakeholders (such as clinicians or payers) in the design of the study.	Methods/Page 7
Results			
Study parameters	22	Report all analytic inputs (such as values, ranges, references) including uncertainty or distributional assumptions.	Tables 1 and S1-S8
Summary of main results	23	Report the mean values for the main categories of costs and outcomes of interest and summarise them in the most appropriate overall measure.	Table 2
Effect of uncertainty	24	Describe how uncertainty about analytic judgments, inputs, or projections affect findings. Report the effect of choice of discount rate and time horizon, if applicable.	Tables 2 and S9, Figures 1-2 and S1-2
Effect of engagement with patients and others affected by the study	25	Report on any difference patient/service recipient, general public, community, or stakeholder involvement made to the approach or findings of the study	Tables S9, Figures 2 and S1
Discussion			
Study findings, limitations, generalisability, and current knowledge	26	Report key findings, limitations, ethical or equity considerations not captured, and how these could affect patients, policy, or practice.	Discussion
Other relevant information			
Source of funding	27	Describe how the study was funded and any role of the funder in the identification, design, conduct, and reporting of the analysis	Abstract and Page 16
Conflicts of interest	28	Report authors conflicts of interest according to journal or International Committee of Medical Journal Editors requirements.	Page 16

From: Husereau D, Drummond M, Augustovski F, et al. Consolidated Health Economic Evaluation Reporting Standards 2022 (CHEERS 2022) Explanation and Elaboration: A Report of the ISPOR CHEERS II Good Practices Task Force. Value Health 2022;25. doi:10.1016/j.jval.2021.10.008