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REVIEW

# WHO Scientific Update on *trans* fatty acids: summary and conclusions

R Uauy[1,2], A Aro[3], R Clarke[4], R Ghafoorunissa[5], M L'Abbé[6], D Mozaffarian[7,8,9], M Skeaff[10], S Stender[11] and M Tavella[12]

[1]*Department of Public Health Nutrition, Instituto de Nutricion y Tecnologia de los Alimentos, University of Chile, Santiago, Chile;* [2]*Department of Epidemiology and Public Health, London School of Hygiene and Tropical Medicine, London, UK;* [3]*Department of Health and Functional Capacity, National Public Health Institute (KTL), Helsinki, Finland;* [4]*Clinical Trial Service Unit, University of Oxford, Oxford, UK;* [5]*Department of Biochemistry, National Institute of Nutrition, Hyderabad, India;* [6]*Bureau of Nutritional Sciences, Health Products and Food Branch, Health Canada, Ottawa, Ontario, Canada;* [7]*Division of Cardiovascular Medicine, Brigham and Women's Hospital, Harvard Medical School, Boston, MA, USA;* [8]*Department of Epidemiology, Harvard School of Public Health, Boston, MA, USA;* [9]*Department of Nutrition, Harvard School of Public Health, Boston, MA, USA;* [10]*Department of Human Nutrition, University of Otago, Dunedin, New Zealand;* [11]*Department of Clinical Biochemistry, Gentofte University Hospital, Hellerup, Denmark and* [12]*Program for the Prevention of Infarcts in Argentina (PROPIA), Department of Medicine, Faculty of Medicine La Plata National University, La Plata, Argentina*

The purpose of the WHO scientific review on *trans* fatty acids (TFAs) was to examine the evidence generated since the 1993 Joint FAO/WHO Expert Consultation on Fats and Oils in Human Nutrition, and to inform member countries on the health consequences of TFAs consumption that have emerged since the last report was released. The new information was deemed sufficient to recommend the need to significantly reduce or to virtually eliminate industrially produced TFA from the food supply in agreement with the implementation of the 2004 WHO Global Strategy on Diet, Physical Activity and Health. This goal has been accomplished in some countries and cities, by the virtual elimination of partially hydrogenated vegetable oils in the human food supply, replacing them with healthy *cis*-unsaturated fatty acids. The document provides the evidence base to promote discussion between the international scientific community related to nutrition and health as well as between agriculturalists, food producers, relevant health professionals, national and international food regulatory agencies, civil society and the private sector to achieve the stated goal.
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## Introduction

The WHO Scientific Update considered new evidence on the health consequences that have emerged on *trans* fatty acids (TFAs) since the last Joint FAO/WHO Expert Consultation on Fats and Oils in Human Nutrition was held in 1993 (FAO, 1994) and the Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases (WHO, 2003; Nishida *et al*., 2004). The new data considered by the group was deemed sufficient to support recommendations, leading to a significant reduction or virtual elimination of industrially produced TFA for the implementation of the Global Strategy on Diet, Physical Activity and Health (WHO, 2004). The Scientific Update enabled a number of conclusions to be drawn and to establish recommendations for the elimination of industrially produced TFA from the food supply. This Scientific Update applied similar criteria to those used by the 2002 WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Diseases (WHO, 2003) and the Joint FAO/WHO Scientific Update on carbohydrates in human nutrition (Nishida and Martinez Nocito, 2007) to describe the strength of evidence and to draw conclusions from the scientific review of the totality of the evidence, including both randomized controlled studies in humans and observational studies involving long-term follow-up of cohorts and experimental animal and laboratory studies when no other data were available. The aim of the present report is to provide a summary of the

Correspondence: Professor R Uauy, Instituto de Nutricion y Tecnologia de los Alimentos, University of Chile, Casilla 138-11, Santiago, Chile.
E-mail: Ricardo.uauy@lsthm.ac.uk or ruauy@inta.cl

scientific reviews of the evidence prepared by the experts and the conclusions of the discussions of this expert group prepared in response to the updated evidence presented at the meeting in Geneva on 29–30 October 2007. This Scientific Update represents the collective view of the participating experts, acting in their own personal capacity.

The experts included Antti Aro, Robert Clarke, Rasheed Ghafoorunissa, Mary L'Abbé (Rapporteur), Dariush Mozaffarian, C Murray Skeaff, Steen Stender, Marcelo Tavella and Ricardo Uauy (Chairman), who were selected on the basis of their scientific background and geographic representation. The Secretariat members included Denis Aitken, Timothy Armstrong, Vanessa Candeias, Chizuru Nishida, Christophe Roy, Jorgen Schlundt and Jonathan Siekmann and Frank Martinez Nocito who served as a temporary advisor. FAO, represented by Gina Kennedy, also participated in the meeting.

## Health effects of *trans* fatty acids

The Joint WHO/FAO Expert Consultation on Diet, Nutrition and the Prevention of Chronic Disease (WHO, 2003; Nishida *et al*., 2004) confirmed that dietary TFAs have adverse effects on blood lipoprotein profiles and coronary heart disease (CHD) risk impacting individuals and populations. The adverse effects on CHD are mediated by increases in plasma concentrations of low-density lipoprotein cholesterol (LDL-C) and lipoprotein(a) (Lp(a)), and reductions in high-density lipoprotein cholesterol (HDL-C), promotion of inflammation and endothelial dysfunction, and possible effects on coagulation, insulin resistance and displacement of essential fatty acids from membranes, affecting prostanoid-related functions and possibly other key membrane-related functions. The current body of evidence further indicates that TFA enhances multiple cardiovascular risk factors and increases CHD-related events.

As part of this WHO Scientific Update on TFA, the evidence for effects of TFA consumption on CHD was reviewed (Mozaffarian *et al*., 2009). Controlled trials and observational studies provide concordant evidence that consumption of TFA from partially hydrogenated oils adversely affects several cardiovascular risk factors and contributes significantly to an increased risk of CHD events. Despite the inherent differences in chemical structure, limited evidence indicates that industrial and ruminant TFAs may have similar effects on serum lipoproteins when ruminant TFA are consumed in sufficient quantities (much higher than seen with usual dietary intakes) in experimental studies. TFAs increase the ratio of serum levels of total/HDL-C, the best single lipid predictor of CHD risk, and therefore intakes of TFA should be avoided. Although ruminant TFAs cannot be removed entirely from the diet, their intake is low enough in most populations that they do not constitute a significant risk factor for CHD. Because TFAs produced by partial hydrogenation are not normally present naturally in foods and have no known health benefits, the group considered them as industrial additives; as such, food services, restaurants, and food and cooking fat manufacturers should avoid their use as well (Mozaffarian *et al*., 2009).

As reviewed by L'Abbe *et al*. (2009), the experience from Denmark indicates that it is possible to largely eliminate industrial TFAs in foods, whereas experiences from Canada and New York City indicate that focused efforts can also bring about reductions. Experiences from Argentina and India also illustrate successes and serve to demonstrate the variety of approaches that have been or can be used to remove TFA. Attention should also be given to possible health effects of TFAs created during other industrial processes, such as light deodorization of marine oils and prolonged deep-frying. The removal of partially hydrogenated vegetable oil (PHVO), a main source of TFAs in processed foods, would result in substantial health benefits, with the greatest advantage obtained when TFAs are replaced by oils rich in polyunsaturated fatty acids (PUFAs) and/or monounsaturated fatty acids (MUFAs) (Mozaffarian and Clarke, 2009). Significant benefits would be expected based on both effects on cardiovascular risk factors in controlled trials and observed relationships with clinical CHD events.

Industrial TFA consumption is believed to increase cardiovascular risk in multiple ways. The effects consistently observed in both randomized controlled trials and observational epidemiological studies include changes in lipoproteins, increased LDL-C and Lp(a), reduced HDL-C and an increased total/HDL-C ratio; proinflammatory effects and endothelial dysfunction, assessed by both circulating markers and functional measures. Each of these effects is most prominent when contrasted with the effect of *cis*-unsaturated fats (PUFA or MUFA) replacement; the adverse effects of TFA on the total/HDL-C ratio and endothelial dysfunction have also been documented relative to saturated fatty acid (SFA) replacement. Controlled trials and observational studies suggest that high intakes of TFAs may worsen insulin resistance, particularly among susceptible individuals such as those with visceral adiposity, preexisting insulin resistance or lower physical activity; further studies are needed to confirm possible effects on weight gain and on diabetes incidence in normal individuals (Mozaffarian *et al*., 2009). Together these findings suggest that, among dietary fats, TFA consumption induces characteristic cardiovascular and metabolic effects (Mozaffarian and Willett, 2007), aggravating multiple related interlinked pathways that appear linked to the insulin resistance syndrome. Long-term effects of habitual TFA consumption on clinical outcomes have not been assessed under fully controlled dietary conditions in humans; ethical limitations make it unlikely that such trials could ever be performed.

The differential effects of specific TFAs based on carbon chain length or *trans* isomer bond(s) position are less well established. Too few studies have evaluated partially hydrogenated fish oils to draw strong conclusions on the difference between 18-carbon as compared to 20- or 22-carbon isomers on CHD risk. Performing controlled trials comparing 18:2 against 18:3, TFA isomers are limited by the relatively lower concentrations of these isomers in partially hydrogenated oils. In observational studies utilizing biomarkers of TFA consumption, both 18:1 and 18:2 isomers appear to contribute to risk of CHD; conversely, most studies did not detect any effect of 16:1 TFA. The available data also suggest that *trans*-18:2 isomers may be more strongly associated with CHD risk than *trans*-18:1 isomers, but the current evidence on this is limited and precludes definitive conclusions. This distinction has potential implications as some processes, such as light hydrogenation or deodorization, may create proportionally more 18:2 *trans* isomers and thus could have greater effects than would be expected based on content of total TFA alone (Mozaffarian *et al*., 2009).

Experimental studies of ruminant *trans* fats are limited by difficulty in distinguishing effects of changes in TFA from changes in other fats in ruminant products; the few small trials reported to date provide inconclusive evidence on whether the effects of ruminant TFA are different from industrial TFA. However, evidence from observational studies in which estimated TFA consumption from industrial and ruminant sources of TFA has been distinguished and from studies in which specific TFAs have been measured utilizing biomarkers generally do not support an adverse effect of ruminant TFA, in the low amounts usually consumed, on risk of CHD. Whether very high intakes of ruminant TFA could affect CHD risk is unresolved, but because consumption levels are low this does not appear to be critical in practice.

## CHD effects of replacing PHVO with other fats/oils

A growing number of food manufacturers, restaurants and government agencies have implemented or are considering voluntary, labeling initiatives or regulatory efforts to reduce the content of industrial TFA in foods. On the basis of changes in blood lipids, for example, the ratio of total/HDL-C in short-term randomized controlled trials and on associations of habitual TFA consumption with disease outcomes in prospective cohort studies, the estimated effects on CHD risk of replacing TFA with equivalent calories from carbohydrate or *cis*-unsaturated fats were previously estimated. However, in practice, TFAs in foods cannot be specifically fully replaced on a 1:1 basis by other nutrients. Rather, PHVO or other fats/oil sources that contain TFAs must be removed and replaced with alternative fats or oils. A variety of alternatives to PHVO include different combinations of SFA, PUFA and MUFA, for example, vegetable oils, tropical oils, lard or butter (Mozaffarian and Clarke, 2009).

The predicted effects on CHD risk of replacing different PHVO formulations with alternative fats and oils were calculated (Mozaffarian and Clarke, 2009). To provide the more robust and reliable estimates of the importance of TFA for CHD risk, they performed two quantitative estimates: the first based on the effects of dietary fats (TFA, SFA, MUFA and PUFA) on blood lipids, lipoproteins and C-reactive protein (CRP) obtained from randomized controlled trials, and the second based on the relationship of habitual consumption of dietary fats with CHD events based on data from prospective observational studies.

To establish the quantitative effects of TFA consumption, as a replacement for other fats, on blood lipids, apolipoproteins and Lp(a), Mozaffarian and Clarke (2009) performed a meta-analysis of 13 randomized controlled dietary trials. This demonstrated clear effects of TFA, in comparison with SFA, MUFA or PUFA, on blood lipid concentrations, ApoB, ApoA-I and Lp(a). Notable effects of TFA included an increase in the total/HDL-C ratio and ApoB levels, particularly versus MUFA or PUFA but also versus SFA; lower HDL-C and ApoA-I and an increase in Lp(a). The effects on ApoB and ApoA-I were only partly attenuated ($\sim$50%) after adjustment for changes in the total/HDL-C ratio, indicating that TFA consumption independently affects both blood lipid concentrations and apolipoprotein levels. A separate meta-analysis of prospective cohort studies evaluating habitual TFA consumption and CHD events demonstrated that a 2% higher energy intake from TFA, as an isocaloric replacement for carbohydrate, was associated with 24% higher CHD risk (Mozaffarian and Clarke, 2009).

Results of calculations predicting changes in CHD risk indicated that replacement of PHVO (having 20, 35 or 45% TFA) providing 7.5% total energy with any of the alternative fats/oils would lower CHD risk, though the magnitude of the predicted benefits varied. For a 20% TFA PHVO, replacement with butter would have minimal effects on CHD risk, whereas replacement with vegetable oils would lower risk by $\sim$10%. For PHVO with 35 or 45% TFA, any of the alternative fats/oil, including butter, lard, palm oil or vegetable oils, would lower risk by 12–20%, with larger benefits coming from vegetable oils compared with animal fats.

A comparison of these results—the estimates based on documented effects on cardiovascular risk factors in controlled trials versus observed associations between dietary intakes and CHD events in cohort studies—serve to derive important conclusions relevant to quantitating the risk from TFA consumption (Mozaffarian and Clarke, 2009). First, for the replacement of PHVO with butter, lard or palm oil, the predicted effects based on risk factor changes obtained from short-term randomized trials were qualitatively and quantitatively similar to those derived from observed associations obtained from observational cohort studies of long-term differences in diet. The effects of TFA on risk factor levels consistently accounted for most (65–80%) of the differences in CHD risk reduction predicted by the observational studies, suggesting that most of the observed effects may be explained by effects on total/HDL-C ratio, ApoB, ApoA-I, Lp(a) and CRP.

Conversely, for the replacement of PHVO with different vegetable oils, the predicted effects on CHD based on risk factor changes from trial data accounted for only ~50% of the estimated effects derived from observed associations in cohort studies. This could be due to either underestimation of benefits based on risk factor changes in trials or overestimation of benefits based on CHD incidence from cohort studies. Because the estimates of CHD benefits of vegetable oils calculated only from changes in selected risk factors (total/HDL-C ratio, ApoB, ApoA-I, Lp(a) and CRP) may not account for other benefits (for example, on insulin sensitivity or endothelial function), the magnitude of benefits calculated from the cohort studies may be closer to the true effects (Mozaffarian and Clarke, 2009). The analysis identified several strengths and potential limitations of the approach taken in these estimations (for additional details see Mozaffarian and Clarke, 2009). However, these analyses of data suggest that when removing PHVO from foods, manufacturers and restaurants should take advantage of the expense and effort of food reformulation to maximize the overall healthiness of the foods by using *cis*-unsaturated fats for replacement.

The discussion by the experts on the merits and limitations of the analysis presented by Mozaffarian and Clarke (2009) centered on its usefulness as a risk assessment and management tool. The group considered that the suggested approach was extremely useful provided there was information on the energy from industrial TFA being consumed by a given individual or population and on the proportion of TFA in the PHVO being consumed. The overall approach is clearly useful to assess risk management options based on the prediction of potential effectiveness of the PHVO replacement by the specific oil/fat sources based on the health benefit to be derived. The absolute effects on risk will depend on the contribution of PHVO-derived energy being replaced. In addition, as the average TFA content of PHVO changes, so will the relative benefits in terms of the various replacement fat or oils. This is of relevance in the choice of alternative fats and oils used to replace PHVO; for example, the replacement of PHVO with butter might be beneficial for PHVO with higher content (35–45%) of TFA but neutral for PHVO with lower content (<20%) of TFA. Unfortunately, for most countries the quality of data on TFA content of PHVO and the %E from industrially derived TFA consumed is insufficient if available at all. Nevertheless, these data indicate, based on the currently available evidence, the best estimates of effects of replacing PHVO with different fats or oils, with direct implications for product reformulation by manufacturers and restaurants.

Another critical element of the Mozaffarian and Clarke's (2009) proposal was selection of indicators to define CHD risk reduction because the choice of lipoprotein outcome as affected by the replacement fat is highly relevant to the final conclusions. Total/HDL-C ratio and the ApoB/ApoA-I, rather than solely LDL-C, were chosen as two of the criteria by which the predicted risk can be estimated. On the other hand, if the analysis were to be based exclusively on the changes in LDL-C as the only factor to define risk reduction, the effect of replacement of PHVO with animal fats and tropical oils would appear considerably less beneficial, particularly if the PHVO has the lower TFA relative content (tropical oils and animal fats rich in lauric and palmitic acid raise both LDL-C and HDL-C in comparison to TFAs that raise LDL but lower HDL). Some of the experts believed that the latter approach would be supported by the evidence from drug trials of statins in which the absolute reduction in CHD risk is largely determined by lowering of LDL-C; however, others believed that such extrapolation of the results of controlled trials of statin therapy to potential effects of dietary interventions could not be justified. However, the group in examining both alternatives agreed with the proposed model based on both HDL and LDL effects highlighting the need for close monitoring of both the fatty acid composition of the oils sources to be used in replacement but also the biological impact in terms of lipoprotein levels and actual risk reduction within the specific populations being intervened.

The challenge to agriculturists and food producers by TFA replacement is to examine the issue in a comprehensive way starting from the breeding of oil seeds, through to the production of edible fats and oils, food processing and final consumption, considering the impact of the changes on human health, on the environment and on the availability of replacement fats and oils in a particular region. The ultimate goal of TFA elimination is to maximize the benefits, minimizing risk for human health and the environment in a cost-effective way. The actual choices of fats and oils used in many countries will be restricted by availability, actual costs of the replacement alternatives and their capacity to innovate.

## Feasibility of recommending replacement fats

The 2002 Joint WHO/FAO Expert Consultation on Diet, Nutrition, and the Prevention of Chronic Diseases recommended that mean population intake of TFA, for example, hydrogenated oils and fats, should be less than 1% of daily energy intake. This figures correspond to at most 2% of total fat (WHO, 2003). Although this recommendation was based on an extensive body of epidemiological and experimental evidence concerning the health effects of TFAs, the evidence upon which to judge the feasibility of recommending particular replacement or alternative fats is not as accessible or of similar quality (Skeaff, 2009). The use of PHVO containing TFA is widespread in the global food supply as ingredients in manufactured foods, in foods prepared in the food service industry and as cooking fats in the home in lower income countries. Although there is limited information about the distribution of TFA intakes in most countries, it is likely that many subgroups within the population, particularly those who use PHVO for cooking or consume a high proportion of industrially processed foods or restaurant foods, would have mean TFA intakes considerably higher than the population mean. Thus, evaluation of mean population intakes is insufficient; the distribution of those at higher risk should also be evaluated.

Present knowledge on TFA intakes in most countries is not robust because it is often obtained from pragmatic dietary assessment surveys that do not rely on nutrient composition databases with complete TFA data. The transition phase in implementing governmental and/or industry-led initiatives to reduce TFA in the diet offers an excellent opportunity to develop or to strengthen existing nutrient and fatty acid food composition databases. The monitoring of TFA reduction or elimination policies should consist of systematic sampling and analysis of foods likely to contain PHVO and analysis of the saturated fat content of reformulated foods once TFAs have been removed. Furthermore, biomarkers should be used to assess TFA exposures in representative samples of the population. Monitoring is not only for the purpose of assessing changes in TFA intakes but also to assess the fatty acids that replace them. The effort to monitor the impact of regulatory and nonregulatory initiatives on TFA intakes should be commensurate with the degree of effort their introduction has required (Skeaff, 2009).

Currently, there is an insufficient world supply of high *cis*-unsaturated, zero TFA replacement fats and oils to meet the demand if all PHVO were to be removed from the global food supply over a short period of time. Substitute vegetable oils with zero or low TFA and high *cis*-unsaturated fatty acid can replace PHVO and maintain food product quality. There is a clear need to alert oil seed producers and agriculturists that there will likely be a need for an increased supply of substitute oils and that this represents an opportunity to expand or develop new oil seed varieties. International efforts to reduce the use of PHVO by the agriculture and food industry will need to be coordinated with supplies of appropriate alternative oils to avoid a decrease in TFA intake accompanied by a larger increase in SFAs, which would reduce the potential health gain derived from the reformulation of manufactured foods containing TFA.

The introduction of regulations to remove TFA from the food supply will require coordination with the food industry to increase the availability of cost-effective zero-TFA fats or oils that are higher in *cis*-unsaturated fatty acids and lower in SFAs (Skeaff, 2009). Considering all upfront costs are in product reformulation, the food industry should consider all elements of fat content, not just TFA, to create an overall healthier product. Regulatory measures to reduce TFA in the food supply should ideally be accompanied by efforts to monitor intake of TFA as well as intakes of other fatty acids likely to be used as substitutes. Removing industrially produced TFA requires the replacement of PHVO with alternative fats, preferably vegetable oils high in *cis*-unsaturated fats rather than with fats and oils that are high in saturated fat. However, in the case of PHVO with very high TFA content, even replacement with saturated fat oils may convey some benefit. It is widely held that the easiest substitutions are to use tropical oils such as palm, palm kernel or coconut oils. Supply of these oils is abundant, the price is low, the food industry has long used them and their physical and sensory properties produce foods with favorable characteristics. However, replacing TFAs with vegetable oils high in PUFA and MUFA is the preferred option for health benefits. As TFAs are industrially made and not intrinsic to the food supply, there is no harm in removing them from the food supply, that is, eliminating use of TFA-containing PHVO should be considered as hazard removal, in line with risk management models used to address many other food safety issues.

## Approaches to removing *trans* fatty acids from the food supply

In assessing the approaches to reduce or remove TFA from the food supply in industrialized and developing countries, the experts considered a number of successful public health initiatives adopted by government agencies and public health organizations in some cases with the collaboration of the food industry. The examples of past and current initiatives reviewed were from Denmark, Canada, United States (New York City), Argentina and India. These include nutrition recommendations about TFAs and the selection of healthy fats, awareness programs through nutrition and health claims on the adverse effects of TFAs, voluntary or mandatory labeling of the *trans* content of foods, voluntary or legislated programs to encourage industry to reformulate food products in an effort to remove TFA, promoting the reduction of TFAs through health and agricultural policies that also support the production of healthy alternatives, and mandatory regulation of food standards to remove or reduce TFA content (L'Abbé *et al*., 2009).

The public health initiatives implemented in Denmark to eliminate the consumption of TFA appeared to provide a model for other countries worldwide, as it involved a multisectoral approach supported by widespread media and political involvement. Their efforts involved a solid science base of population intake patterns, risk assessment of exposure to TFA and economic considerations, which lead to risk management policies that received wide-based political support from both the community and the government. The results were closely monitored and disseminated widely both in the scientific literature and in the lay press. The driving force in the process to virtually eliminate the consumption of industrially produced TFA in Danish foods was the Danish Nutrition Council. In the neighboring Nordic countries a different approach was chosen. Self-regulation by industry has resulted in markedly reduced intakes of TFA from PHVO. Total TFA intakes have been reduced to 0.5–0.8% of energy intake in Finland and Norway despite not having taken up legislation similar to that of Denmark, as ongoing reduction in the TFA content of the frying oil used by European fast food chains may have been triggered by the Danish example.

Since the late 1970s, Canadian scientists have raised concerns about the detrimental effects of rising TFA levels in the diet, first focusing on margarines and subsequently these warnings led to national recommendations. This focus on TFA led to the development of a number of fat spreads with low TFA specifically targeted to health-conscious consumers. However, the use of PHVOs continued to increase in other categories of processed foods. The estimated TFA intakes placed Canadians among those populations with the highest exposure to TFAs in the world during the mid-1990s. In recognition of these concerns and various local and international initiatives, Canada became the first country to require that TFA levels be included in the mandatory nutrition label on prepackaged foods. Currently available evidence from Canada demonstrates that the TFA reduction strategy is having the desired effect.

Further actions that affect food services and restaurants have been taken by Canada at the municipal and provincial level as well as by the United States at the state and city level. These include a variety of measures to reduce and/or to eliminate industrially derived TFAs in foods, for example, bans on foods containing high levels of TFA from school cafeterias, hospitals, day-care centers and other institutions under local jurisdiction. The example of New York City is one of best known because it has been widely disseminated by mass communication media (including TV and newspapers). As one of the first cities to limit *trans* fats on a wide scale, the New York City Board of Health on 5 December 2006 approved an amendment to their Health Code to phase out artificial *trans* fat in all New York City restaurants and other food service establishments. This was planned as a two-stage process; in the first stage, by 1 July 2007, all restaurants had to ensure that all oils, shortening and margarines containing industrially derived *trans* fat used for frying or for spreads had less than 0.5 g of *trans* fat per serving; by 1 July 2008, all foods sold in restaurants would be required to have less than 0.5 g of *trans* fat per serving if they contain any industrially derived *trans* fat. The New York City Department of Health and Mental Hygiene has prepared a number of information materials to assist restaurants in reformulating products and to comply with the new regulations. Although the amendments to phase out *trans* fats from restaurants and other food service establishments in New York City are still underway and an evaluation of the results and impact of the New York City amendments has yet to be published, New York City Department of Health staff plan to publish this in the near future (L'Abbé *et al*., 2009).

In 1990, the Program for the Prevention of Infarcts in Argentina (PROPIA) was created, supported by La Plata National University, the Buenos Aires Scientific Investigations Commission and the Buenos Aires Health Ministry. Results from baseline evaluations conducted in Balcarce city showed that almost all foods contained high levels of TFAs and ω-3 fatty acids were practically absent in the local diet. This investigation was the starting point for the planning of intervention strategies necessary to modify the situation observed in Balcarce city. Successful collaboration with the suppliers of fats and oils and the food industry from 2001 served to secure a stable supply of replacement fats and oils; product reformulation was actively encouraged by providing a tax bonus to those companies that met the suggested WHO limit of less than 1% of energy from TFA in specific food products. These actions served to facilitate government efforts in establishing public policies to promote healthier choices in diet and physical activity in line with the WHO Global Strategy to prevent nutrition related chronic disease. The systematic mass media dissemination of the *trans* fat reduction program served as a strong incentive because it created a demand for *trans*-free products that translated into a commercial advantage. In addition, the Mercosur (the South American Common Market integrated by Argentina, Brazil, Paraguay and Uruguay) agreed in July 2007 on a regulation that all foods must include information on its *trans* content. As a result of this successful experience, in 2005 the regional UNU network of Latin American institutions part of the United Nations University Food and Nutrition Program asked PROPIA to lead an applied research program to evaluate the health impact of interventions addressed at improving the quality of the fat supply carried out in the Latin America (Uruguay, Chile, Mexico and several Central American countries).

Today, India faces the double burden of malnutrition due to chronic energy deficiency (associated with low intakes of nutrients including $n-3$ PUFAs) and also rising prevalence of diet-related chronic diseases. A wide range of oilseeds occupy a prominent place in the national food economy of India, second only to cereals. Vanaspati, a PHVO that contains TFA, is widely used in the preparation of commercially fried, processed, ready-to-eat and street foods, and for the preparation of Indian snacks, sweets and savory items, frozen foods, packaged and premixed foods. The high intake of TFA may be part of several changes in dietary and other lifestyle patterns contributing to the present day high prevalence of diet-related chronic diseases in India. Because a large proportion of the Indian population is predisposed to insulin resistance and there is a high prevalence of diabetes and CHD, the reduction of TFA from partially hydrogenated oils and foods consumed in India needs to be actively pursued on grounds of the projected health benefits.

The analysis of the case of India suggests some recommendations can be of relevance to other developing countries facing a similar situation. Considerations to take into account in policies to address the reduction and/or elimination of industrially derived TFA, including the food processing industry, should use blends of natural vegetable oils that furnish higher stability to products wherever feasible, especially indigenous oils with potentially additional health benefits; the government should consider specifying achievable lower limits for TFA and SFA content in vegetable oil products, refined oils and processed foods; labels on processed foods should provide the content of TFA and SFA separately and state the optimal recommended ranges based on local conditions and options within the socioeconomic reality of the country; restaurants should disclose the use of 'partially hydrogenated oils' in served preparations; consumer awareness should be heighten through food-based dietary guidelines regarding the negative health impact of TFA and the need to reduce TFA content of foods; and the food industry should replace hydrogenation technology with newer technologies that produce zero *trans* fats with desired functionality for various food applications.

Overall a multisectoral and proactive approach is required to successfully reduce or remove industrially produced TFAs from the food supply. In the example of the edible oil and food industries support, investment and incentives to develop, establish and operate new technologies will be needed.

## Conclusions

The current growing body of evidence from controlled trials and observational studies indicates that TFA consumption from partially hydrogenated oils adversely affects multiple cardiovascular risk factors and contributes significantly to increased risk of CHD events. Although ruminant TFAs cannot be removed entirely from the diet, their intake is low in most populations and to date there is no conclusive evidence supporting an association with CHD risks in the amounts usually consumed. In contrast, TFA produced by partial hydrogenation of fats and oils should be considered industrial food additives having no demonstrable health benefits and clear risks to human health. The WHO Scientific Update on TFA concludes that restaurants and food manufacturers should avoid using industrially derived TFA in food products and that governments should take steps to support alternative fats or oils for TFA replacement The evidence on the effects of TFA and disease outcomes strongly supports the need to remove PHVO from the human food supply. The result would be a substantial health gain for the population at large, with greatest health benefits obtained when replacement oils are rich in $n-3$ and $n-6$ PUFA and in MUFA. Additionally, controlled studies and observational studies suggest that TFA may worsen insulin resistance, particularly among predisposed individuals with risk factors, for example, preexisting insulin resistance, visceral adiposity or lower physical activity. Further studies are needed to confirm the apparent effects of TFA on weight gain and diabetes incidence in humans.

Findings indicate that the replacement of TFAs in PHVO with alternative fats and oils would lower CHD risk through mechanisms beyond changes in blood lipid levels, thus explaining in large part the difference derived from estimates based on controlled dietary interventions focusing mainly on serum cholesterol fractions versus prospective cohort studies having CHD events as the outcome. Health benefits are projected to be greatest for replacement of PHVO with vegetable oils, but even replacement with tropical oils or animal fats would result in benefits, particularly for PHVO having higher (35–45%) levels of TFA as consumed in some developing countries. Thus, the choice of replacement fat/oil for PHVO needs to consider the effect of the replacement oil as well as the level of risk associated with the specific TFA containing sources to be replaced. It is also important to consider environmental sustainability in choosing appropriate replacement fats and oils.

Manufacturers, restaurants and food services should take advantage of making the most of the effort required for food product/preparation reformulations to not only reduce the TFA content but also maximize the overall healthiness of the foods destined for human consumption by increasing the content of *cis*-unsaturated fats. Reformulation should consider in the upfront potential cost–benefit analysis, not only TFA removal but also the favorable health consequences of using the most healthful fats and oils for TFA replacement during product reformulation.

The evidence to assess a specific source of fats/oils as a replacement or alternative to TFAs reflects the complexity of the corresponding scientific evidence. The use of PHVO-containing TFA is widespread in the global food supply as a basic ingredient of manufactured foods and food preparations used and sold by the food service industry. Although there is limited information on the distribution of TFA intakes in most countries, it is likely that many subgroups within the population, particularly those who use PHVO for cooking in the home (common in developing countries) or consume a high proportion of bakery foods or fast-service restaurant foods, have mean TFA intakes considerably higher than the population mean. Removing industrially produced TFA requires the replacement of PHVO with alternative fats, preferably vegetable oils high in *cis*-unsaturated fats. However, in the case of PHVO with very high TFA content, replacement even with fats and oils high in SFAs may convey some, albeit smaller, benefit. The introduction of regulations to remove TFA from the human food supply will require coordination with the food industry and agricultural and food production sectors to increase the supply and to reduce the cost of their substitution by zero TFA, *cis*-unsaturated fat and oil sources that are also low in SFAs; thus, increasing cost effectiveness of the proposed intervention.

The experts acknowledged the need to review the current recommendation that the mean population intake of TFA, that is, partially hydrogenated oils and fats, should be less than 1% of daily energy intake. There is sufficient epidemiological and experimental evidence to support revising this recommendation so that it encompasses the great majority of the population, and not just the population mean, to protect large subgroups from having high intakes. This could be accomplished, and has been in some countries and cities, by the virtual elimination of PHVO in the human food supply. The outcomes of this Scientific Update provide the evidence and scientific bases to promote discussions between the international scientific community related to nutrition and health as well as to agriculture and food production, relevant health professionals, national and international food regulatory agencies, civil society and the private sector to achieve this goal.

## Conflict of interest

During the preparation and peer review of this paper in 2007, the authors and peer-reviewers declared the following interests:

Professor Ricardo Uauy: Scientific Advisor to Unilever and Wyeth (*ad-hoc* basis); Scientific Advisor to Knowles and Bolton, Danone, DSM and Kellogs (*ad-hoc* basis).

Dr Antti Aro: Consultancy with the Scientific Advisory Board, Valio Ltd (current).

Dr Robert Clarke: None declared.

Dr Ghafoorunissa: Chairperson of the Edible Oils and Fats Subcommittee PFA, Central Committee of Foods Standards (Ministry of Health and FW, Government of India) (current); Member of the Nutrition Advisory Council for the Malaysian Palm Oil Promotion Council (2004–2005); Consultant in the area of 'heart health' for Hindustan Unilever Limited (2006–2007); Life Member of the Nutrition Society of India (current).

Dr Mary L'Abbé: None declared.

Dr Dariush Mozaffarian: None declared.

Professor Murray Skeaff: Led a research project that tested the effects of a plant-sterol enriched fat spread on blood cholesterol concentrations; costs of research partially funded by Unilever Research and Development (2003–2004); participated in a subcontract to conduct a randomized controlled trial of a milk product enriched with an antioxidant extract from vegetables, which was partially funded by Fonterra, a milk company in New Zealand (2005–2007). All industry-supported research projects were organized and administered through the University of Otago Research and Enterprise Unit.

Professor Steen Stender: None declared.

Professor Marcelo Tavella: Scientific advice provided to Dow Agrosciences, Argentina (current).

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