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STUDY

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Trans Fatty Acids and Health: A Review of Health Hazards and Existing Legislation

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Executive Summary

Trans fatty acids (TFA) are a type of fat that is found in foodstuff such as commercial baked goods, fried foods, frozen foods, margarines, red meat and dairy products. While TFA are naturally present in dairy and meat, they are also industrially produced used as an ingredient in processed foods. Originally, the industrial production of TFA aimed at lengthening storage times for liquid fats and facilitating their transport, while today they are used to lengthen the shelf-life and enhance the texture of processed foods. There is a considerable body of scientific evidence that associates the ingestion of TFA with disease. In particular, the evidence for TFA as causative factor in cardiovascular disease is strong. For obesity, diabetes, blindness, cancer and other diseases the evidence could be considered suggestive. In view of the strong evidence for a relationship between TFA and cardiovascular disease, it seems prudent that measures be taken to decrease the intake of TFA. Given that such fats are also found in dairy products and red meat, it is neither feasible nor advisable to exclude TFA completely from the diet. As such, restrictions should be limited to industrially produced TFA. Policies that restrict and regulate the intake of TFA have been implemented in some countries. Denmark and Switzerland and some cities and states in the US have adopted regulatory approaches to controlling the presence of TFA in food products. In the Netherlands and the UK, industry has adopted voluntary measures to reduce TFA content or to eliminate TFA from food products. Canada and the US have adopted mandatory labelling requirements to alert consumers to the presence of TFA in food products and to allow them to make choices to control their intake. In drawing conclusions on the success of these measures, it is clear that while voluntary initiatives have reduced average TFA intake, levels remain high in specific types of food products and subgroups of the population still have high intakes of industrial TFA. Similarly while mandatory labelling requirements achieved a certain degree of success in reducing TFA intake, it remains possible to consume levels of TFA higher than the recommended daily allowance when certain meals are selected. In addition, labelling brings up issues related to equity, since the capacity of individuals to interpret labels and make purchasing choices to reduce TFA relates to their socio-economic status, particularly in a context where foods free of industrial TFA may be more expensive. In contrast, the ban on industrial TFA in Denmark has successfully eliminated industrial TFA from all food products, apparently with negligible effects on the economic situation of the food manufacturing and restaurant industry. Based upon the evidence of negative health impacts of industrial TFA and the success of the Danish ban in reducing TFA intake, this study recommends that a ban of industrial TFA be considered at EU level.

1. Introduction

The Committee on Environment, Public Health and Food Safety (ENVI) of the European Parliament has requested a study in order to provide background information to Members of the European Parliament on trans fatty acids (TFA).

In order to provide some context to the discussions, the section below outlines the current *status quo* regarding policy develops for the regulation of TFA in the EU and identifies the need for this study. Section 2 by outlines the chemical composition of *trans* fatty acids (TFA), before providing an overview of the industrial production of TFA and their role and significance in the food market of the European Union (EU). Section 3 identifies the health issues that have been associated with the ingestion of TFA, and assesses the significance of scientific findings to date. In section 4, the study examines existing regulations to control the public ingestion of TFA in EU Member States, namely in Denmark, the Netherlands and the UK. Section 5 then reviews the regulation of TFA outside the EU, in Switzerland and the US. Finally in section 6, conclusions are drawn regarding the impact of different regulatory approaches on the public consumption of TFA and the types of conditions that determine success in reducing intake. Based on these conclusions, a number of recommendations are made concerning possible approaches for the future regulation of TFA in the EU.

1.1. Policy Developments for the Regulation of TFA in the EU

To date, neither the content of TFA in food stuffs nor the specific labelling of foodstuffs as containing TFA are regulated at the EU level. With regards to labelling, while Directive 2000/13/EC[1] on the labelling, presentation and advertising of foodstuffs, as amended by Directive 2003/89/EC[2], requires that the ingredients present in food products be listed on the label, it does not require that the type of fat be specified. The consumer will receive information on the level of fats in the product, without knowing what percentages of those fats are TFA. With regards to possible developments on labelling, the January 2008 proposal of the European Parliament and the Council to the Commission on food information to consumers mentions that TFA content is one thing that "may" be added on the label of the food product (COM 2008/40 final)[3].

Denmark did not consider the current EU regulations to be strict enough to protect human health, given the scientific evidence associating consumption of TFA with health hazards. In 2003, the Danish parliament adopted legislation stipulating that the content of TFA in oils and fats, including emulsions with fat as the continuous phase, which are intended for human consumption either alone or as part of processed foods, shall not exceed 2 grams per 100 grams of oil or fat[4]. This action is discussed in further detail in section 3 below.

[1] Directive 2000/13/EC of the European Parliment and of the Council of 20 March 2000 on the approximation of the laws of the Member States relating to the labelling, presentation and advertising of foodstuffs.
[2] Directive 2003/89/EC of the European Parliment and of the Council of 10 November 2003 amending Directive 2000/13/EC as regards indication of the ingredients present in foodstuffs.
[3] COM 2008/40 final, Proposal for a Regulation of the European Parliament and of the Council on the provision of food information to consumers.
[4] Executive Order No. 160 of 11 March 2003 on the Content of Trans Fatty Acids in Oils and Fats.

In 2005, the European Commission requested that Denmark suspend its regulation of industrial TFA in food, arguing that the restrictions on TFA content in products adversely affected trade within the EU. However, Denmark responded negatively and the case was subsequently dropped.

In response to the regulatory action by Denmark, the European Commission asked the Scientific Panel on Dietetic Products, Nutrition and Allergies of the European Food Safety Authority (EFSA) to undertake a review of the scientific evidence concerning TFA. In response, EFSA issued an Opinion on 8 July 2003[5]. The Opinion recognised that evidence from many human studies clearly demonstrates that an increased dietary intake of TFA results in elevated blood levels of Low Density Lipoprotein cholesterol (LDL – considered as 'bad' cholesterol), thereby increasing the risk of coronary heart disease. However, the opinion went on to conclude that human studies revealed no consistent evidence of any effect of TFAs on blood pressure or on other markers associated with risk of coronary heart disease, such as platelet aggregation or on insulin sensitivity. Epidemiological evidence for a possible relationship of TFA intake with cancer, diabetes or allergy was also perceived as weak or inconsistent. In addition, the panel found that no causal link had been established between TFA consumption by pregnant and breastfeeding mothers and adverse effects on foetal and infant development. Regarding public consumption of TFA, the panel identified different levels of TFA intake across Member States, with the lowest intakes found in the Mediterranean countries.

EFSA concluded that recent dietary surveys indicated that TFA intake had decreased in a number of EU countries, mainly due to the reformulation of food products. In addition, the average intake of TFA in European diets was described as generally more than 10-fold lower than those of saturated fatty acids. The potential of TFA to significantly increase cardiovascular risk was therefore assessed as being much lower than that of saturated fatty acids, which are currently consumed in excess of dietary recommendations in many Member States. Finally, the panel highlighted that there is currently no method of analysis applicable to a wide range of foods which can distinguish between TFAs naturally present in foods (e.g. dairy and red meat) and those formed during the industrial processing of hydrogenated oils.

More recently, pressure for action to regulate TFA at the EU level has come both from Members of the European Parliament and from the European public. In April 2007, four Members of the European Parliament presented a declaration calling for more restrictive regulation of TFA in the EU[6]. The declaration stated that diseases of the heart and circulatory system account for 1.9 million deaths in the EU per year. It highlighted the association between consumption of TFA and coronary heart disease and suggested the replacement of TFA with alternatives. The declaration applauded Denmark's initiative to reduce the amount of TFA in food products and encouraged the Commission and Council to introduce a mandatory labelling system and public awareness campaigns. In addition, the group called for necessary measures towards the elimination of TFA from food products (Higgins *et al.*, 2007).

In terms of public action, in 2008 Mayor Dr Ilija Batljan of the Swedish city of Nynäshamn collected signatures to a list of demands entitled "No to Trans Fats" that were then sent to the European Commission[7]. The demands were that as of 1 June 2009:

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[5] EFSA, Opinion of the Scientific Panel on Dietetic Products, Nutrition and Allergies on a request from the Commission related to the presence of trans fatty acids in foods and the effect on human health of the consumption of trans fatty acids (Request N° EFSA-Q-2003-022) adopted on 8 July 2004.
[6] Declaration 0009/2007 by MEPs Jim Higgins, Dan Jørgensen, John Bowis and Linda McAvan.
[7] See: http://www.nynashamn.se/sagnejtilltransfetter/nototransfats.4.3ac848b61190b6fbab38000555.html

1. TFA must be listed on food labels, on a separate line immediately under the line for the declaration of saturated fatty acids; and
2. the content of TFA in the oils and fats, including emulsions with fat as the continuous phase, which, either alone or as part of processed foods, are intended for human consumption or must be assumed to be intended for human consumption, shall not exceed 2 grams per 100 grams of oil or fat.

As such, the Swedish citizens demanded a ban of TFA equivalent to that enacted in Denmark.

1.2. The Need for this Study

The effects of TFA on health have become subject to considerable public attention, with several EU Member States having taken steps to reduce the consumption of TFA. Since ESFA delivered its 2003 Opinion reviewing the scientific evidence of health effect associated with TFA as potentially hazardous to health, further evidence has emerged and it is important that this evidence is reviewed and communicated to the legislators. In addition, it is important that legislators approach the topic with an understanding of the regulatory tools that have already been employed to address TFA in foodstuffs, both within and outside the EU. This study serves to provide this information and to deliver recommendations on the kind of measured and practical policy approach that could best serve the interests of public health in the EU.

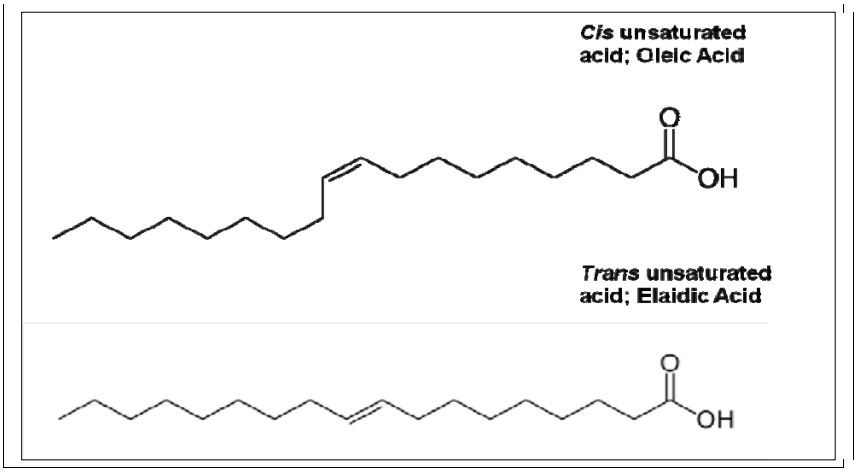
2. Trans Fats in Food and on the Market

This section provides background information on the physical characteristics of TFA and identifies the main dietary sources through which TFA may be ingested. It goes on to discuss the reasons why TFA are included in food products.

2.1. Fatty Acids and Trans Fatty Acids

Fatty acids are composed of carbon, hydrogen and oxygen. If the fatty acids have a relationship between carbon and hydrogen implying that not all atomic bonds are saturated (i.e. more hydrogen could be bound to the carbon), the fatty acid contains one or more double bond between carbon atoms and is called unsaturated. Such a fatty acid is less stable and fat containing such fatty acids is more fluid. Examples of fats with many unsaturated fatty acids are the vegetable oils, such as olive and sunflower oils. These naturally occurring unsaturated fatty acids have a configuration know as a *cis* configuration, with hydrogen atoms on the same side of the double bonds of the carbon chain. Due to the direction of the unsaturated double bonds, the fatty acids are not straight but appear bent in a molecular model (see figure 1 below). Fats with more saturated fatty acids that do not carry double bonds are more rigid, examples being the animal fats, such as butter and lard.

Figure 1: Chemical structure of the *cis* unsaturated fatty acid oleic acid (large component of olive oil) and the *trans* unsaturated fatty acid elaidic acid which often occurs in partially hydrogenated vegetable oils. These fatty acids have different arrangement of the double bond but are otherwise chemically identical. Source: Wikimedia Commons



TFA are a particular type of unsaturated fat that are naturally occurring in animal fats. TFA are also generated during the cooking process, and are industrially produced through a process know as hardening. The industrial hardening process for the production of TFA was developed in 1911 in response to problems related to the transport and storage of liquid fats containing unsaturated fatty acids, such as vegetable oils. The process is based on the hydrogenation of saturated fats (i.e. the addition of hydrogen atoms) and results in liquid oils being transformed into solid fats like margarine. However, the saturation process of the fatty acids is not complete, leading to partially hydrogenated fatty acids called TFA. As shown in figure 1, TFA have a straight structure with at least one double bond with hydrogen atoms on different sides of the chain, hence the term *trans* ("across" in Latin). The hardening process (the partial hydrogenation) may lead to up to 45% of the fatty acids being in the *trans* form.

2.2. Dietary Sources of Trans Fatty Acids

The presence of TFA in foodstuff depends on whether the ingredients include industrially produced TFA, as well as the origin of the fat and whether the foodstuff is fried. The majority of the TFA in our diet are industrially produced and typically found in commercially produced foodstuffs, such as baked goods and fried foods. A list of the types of products that commonly contain industrially produced TFA is provided in table 1 below. The level of industrial TFA in food products varies considerable across countries and brands. According to survey results published in 2006, industrial TFA content in KFC servings varied from less than 1g in Germany to 24g in Hungary. Looking at results from Europe, the same study found fat levels of industrial TFA of about 10% in frying oils and 40-50% in popcorn (Stender, Dyerberg and Astrup, 2006).

Table 1: Examples of processed foods that contain large amounts of TFA

Spreads	margarine, shortening
Packaged Foods	cake mixes
Fast Food	Pommes Frites, chicken, anything deep-fried
Meat	sausages, meat products
Frozen Food	pies, waffles, pizzas, breaded fish sticks
Commercially Baked Goods	biscuits, cakes, doughnuts, pastries

Whilst there is little doubt that industrially processed TFA is the largest dietary source of TFA, there are other sources. Natural TFA constitute up to 5% of the total fat in beef fat and milk from ruminant animals like cows, sheep and goats, since TFA are formed by bacterial processes in the gut of ruminants.

In addition, TFA can be formed during heating of unsaturated fatty acids. Thus, frying foods in vegetable oils can lead to the formation of TFA even if no such fatty acids are introduced into the oil prior to cooking. Typically 0.2-1% of total fat may be converted to TFA when using vegetable oils for deep frying over long periods (Health Canada, 2006).

Table 2 provides data on the contribution of selected food groups to the intake of TFA in the diet of population groups in 11 EU Member States, taken from the TRANSFAIR study published in 1999. As shown by the data in the table, the sources of TFA vary considerable across Member States. Nevertheless, it is possible to identify baked goods, meats and dairy products as key dietary sources of TFA in all 11 Member States.

In Western Europe, the average intake of TFA has decreased over the last decade. Nevertheless, a recent study found that in many countries it remains possible to consumer more than 20g of industrial TFA in a one-meal menu consisting of some popular foods. The study argued that subgroups of the populations may therefore consume more than 5g of industrial TFA per day (Stender, Astrup and Dyerberg, 2008.

Table 2: Contributions (%) of selected food groups to the total intake of TFA in the diet of population groups in European countries

	Belgium	Finland	France	Germany	Greece	Italy	Netherlands	Protugal	Spain	Sweden	UK
Milk and Milk Products (ice – cream included)	5.6	20.7	8.7	8.2	13.1	16.1	5.4	14.0	23.8	18.3	11.0
Cheese	10.6	8.4	16.8	14.0	24.0	33.8	8.4	16.3	7.5	14.2	7.8
Eggs	0.2	<0.1	1.6	0.8	0.1	0.7	0.2	0.3	0.6	1.0	0.9
Meat, Meat Products	20.7	4.8	11.4	5.3	14.6	13.4	12.3	26.2	29.8	10.1	10.33
Fish	1.0	2.2	0.8	0.9	2.4	0.1	0.1	3.3	0.5	0.9	0.6
Butter	6.2	10.2	35.4	49.6	0.4	12.1	2.9	9.0	1.4	8.2	5.9
Oils and Fats	18.0	37.6	3.7	12.2	0.4	6.9	33.0	10.0	9.0	1.2	35.3
Biscuits, buns, cakes, fruit, pies etc.	13.5	6.6	14.6	7.5	15.7	14.5	13.0	12.7	13.3	20.6	16.5
Pizza, meat pies, vegetable pies, etc.	0.7	1.8	*	*	14.1	0.6	0.1	*	0.7	2.2	3.5
Other grains and grain products	3.4	0.0	0.3	<0.1	5.9	0.2	1.6	1.8	10.0	3.9	0.5
Seeds, kernels nuts	0.1	*	0.2	0.0	2.5	*	*	*	0.0	*	0.0
Chocoltae, candy bars & confectionary	12.6	2.9	2.3	0.2	0.6	<0.1	12.5	5.8	0.7	13.7	4.5
Industrial meals, restaurant foods	<0.1	1.5	2.7	<0.1	4.1	<0.1	0.5	*	*	*	0.5
Miscellaneous	0.6	0.6	0.0	0.8	0.2	*	0.1	0.0	*	0.7	0.4

* No information available

Source: Hushof *et al.* , 1999

2.3. The Rationale for using Trans Fatty Acids in Food Products

TFA have been taken up by the commercial food industry as an ingredient that can reduce costs and increase the attractiveness of food products to consumers. TFA have replaced solid animal fats (butter and lard) in the fast food sector, snack foods, fried foods and baked goods, allowing people following vegetarian, vegan, kosher or halal diets to consume the goods. Commercial bakeries rely on TFA to give an enhanced texture to baked goods, whereby the fat takes on a semi-solid status at room temperature. They are also cheaper than other naturally occurring semi-solid oils that could perform the same function, such as palm oil. TFA are more resistant to oxidation at room temperature and as such enhance shelf-life and reduce refrigeration requirements, so reducing cost. This same property allows TFA to be reused for longer in deep frying making them a cheaper option for fast food restaurants, although non-hydrogenated oils have recently become available with even longer lifespans for deep frying.

TFA were developed in response to limited facilities for refrigeration during storage and transport of food products. However, these limitations no longer apply and the continued use of TFA produces marginal economic savings in comparison to using other sources of fats in food production. There is an ongoing process of reducing and/or eliminating TFA in response to public awareness of the health risks of TFA, mandatory labelling of the TFA content, and restrictions on the TFA content in foodstuffs. A number of alternatives to fats containing TFA exist, but it is beyond the scope of this study to provide full details of available alternatives and the associated production techniques.

It is important to consider the fact that in responding to policy pressure to reduce TFA content, the food industry may replace TFA with fats high in saturated fats, which also have negative impacts on health. As such, there is a need for collaboration between the food industry and health and nutrition professionals in the development and implementation of alternative food production techniques (Eckel, 2007).

3. Health Hazards Associated with Trans Fatty Acids

Fats are found in all human tissues and are important components of our daily food. The active components of fats are fatty acids, and these have a number of important physiological roles, including the formation of biologically active signalling substances in the body. Other fatty acids are broken down in the body and are used as constituent parts in cell membranes or are stored as an energy reserve in the fat cells of adipose tissue. Fatty acids may originate from the diet or from biosynthesis in the body. Some of the fatty acids are called essential fatty acids, as they cannot be formed in the body and are precursors for substances which regulate inflammation and blood coagulation. Essential fatty acids must be obtained through the diet in order for an individual to be healthy, and as such it is important that the human diet include sources of fat. It is therefore critical that the scientific basis for regulating the type of fat that we consume be based on rigorous scientific evidence of associations between specific types of fat and disease, and that policy measure target specific types of fat.

There is no physiological requirement for TFA in our diet (Institute of Medicine, 2002). Despite the fact that TFA has been industrially produced and added to commercially food products for over a century, the possibility that they may have adverse health effects was not considered until the last couple of decades. During this period, researchers have investigated associations between TFA and the risk of a number of chronic diseases. Emerging from this body of evidence have come claims that TFA may contribute to cardiovascular disease, cancer, neurological disorders, blindness, diabetes, obesity, liver disease, and infertility, and have adverse effects on infant development.

Table 3: Average daily intake of TFA in 12 EU Member States, data from 1996

Country	Age	TFA % of energy intake	Grams of TFA per day
Netherlands	19-64	1.6	4.3
Belgium	18-63	1.4	4.1
UK	0-75+	1.3	2.8
Denmark	19-64	1.0	2.6
Sweden	19-64	1.1	2.6
France	19-64	1.2	2.3
Germany	16-64	0.8	2.2
Finland	25-64	0.9	2.1
Spain	0-70+	0.7	2.1
Italy	1-80	0.5	1.6
Portugal	38	0.6	1.6
Greece	23-64	0.6	1.4

Source: Stender, S. and Dyerberg, J., 2003, *The influence of trans fatty acids on health*, fourth edition, Danish Nutrition Council, Denmark

The 2006 report of Canada's Trans Fat Task Force, which had the mandate of providing substantiated recommendations to Health Canada on TFA, reviewed existing evidence and found that metabolic and epidemiological studies consistently show that TFA are more harmful than any other type of fat (Health Canada, 2006). Indeed, available evidence prompted the World Health Organization in 2003 to advise that the intake of TFA be limited to less than 1% of overall energy intake as a key measure in reducing the incidence of chronic disease (WHO, 2003, pp. 56). Table 2 above provides data from a 1996 study on the average daily intake of TFA in 12 EU Member States.

In the following sections we will briefly examine the basis for these health claims.

3.1. Cardiovascular Disease

In their Opinion of 2004, EFSA concluded that TFA might be associated with an increased risk for heart disease. Since then, further evidence has been presented and the epidemiologic evidence for a link between TFA intake and the risk for heart disease must now be considered strong.

A 2006 review of epidemiological and experimental studies investigating links between TFA and cardiovascular disease found convincing evidence that TFA contributes to an increased risk for developing cardiovascular diseases by affecting blood lipid levels, as well as through other mechanisms The review concluded that a 2% increase in the energy intake from TFA was associated with a 23% increase in the incidence of coronary heart disease. The authors noted that the adverse effects of TFA were seen even when daily intake was really low, only 3% of total daily energy intake (20-60 calories), about 2-7 g for a person consuming 2000 calories (8.37 mJ) per day (Mozaffarian *et al.*, 2006).

Several cohort studies, including the Nurses' Health Study (Willett, 1993), have shown that TFA from partially hydrogenated vegetable oils is most strongly correlated to the risk of coronary heart disease. In addition, a direct epidemiological link between TFA and the risk of heart disease has been found in three ongoing major prospective studies, whereby 150,000 subjects have been followed for 6-14 years (International Union of Food Science and Technology, 2007). A 2008 study, found a daily intake of 5g of primarily industrial TFA to be associated with a 29% increased risk of coronary heart disease (Stender, Astrup and Dyerberg, 2008).

There are a number of specific mechanisms through which TFA increase the risk of cardiovascular disease. The most important mechanistic effect identified to date is their effect on the plasma lipoprotein profile. TFA serve to make the plasma lipoprotein profile more harmful, by increasing the levels of harmful low-density-lipid cholesterol in the blood serum, and simultaneously decreasing levels of protective high-density-lipid cholesterol (Sundram *et al.*, 2003). Elevated low-density-lipid cholesterol has been causally linked to coronary heart disease. In addition, an elevated intake of TFA leads to larger vascular wall thickness with narrowing of the blood vessel.

Increased TFA intake is also associated with elevated levels of inflammatory markers such as tumour necrosis factor (TNF), interleukin-6 (IL-6), and C-reactive protein (CRP). Inflammation is associated with an increased risk of cardiovascular disease. Interestingly, the effect of TFA on these factors is greater with higher body-mass-index in women, suggesting that pro-inflammatory effects may be mediated by effects on adipose tissue. Lowering TFA intake would therefore improve sub-clinical inflammation and contribute to decreased risk for heart disease and other chronic diseases attributed to inflammation.

In addition, higher TFA intake is associated with a number of other changes that have been linked to heart disease. The mechanisms underlying these changes are not completely understood. However, it is feasible that TFA may act in similar ways as other fatty acids; by altering function of specific membrane receptors, affecting signalling pathways in the cells, and affecting gene expression. The associations between TFA and obesity and diabetes are discussed below. Both of these health problems are considered major risk factors in the development of cardio-vascular disease.

On the basis of this evidence, academics have suggested that guidelines be developed for removing TFA from the diet, thereby decreasing the risk for heart disease (Booker and Mann, 2008). In considering possible guidelines for action to reducing the intake of TFA, it is important to distinguish between naturally-occurring TFA and industrially-produced TFA and their associated health impacts. The TRANSFACT study, the results of which were published in 2008, investigated whether industrial or natural TFA have similar negative influences on blood lipids. The adverse effect of industrially-produced TFA on blood lipids was again clearly demonstrated, with consumption of TFA from industrial sources resulting in elevated levels of serum low-density-lipid cholesterol, a blood lipid associated with cardiovascular disease. In contrast, results revealed that consumption of moderate amounts of natural TFA do not alter the risk of cardiovascular disease (Chardigny *et al.*, 2008). A review of epidemiological studies conducted by Mozaffarian *et al.* supports the conclusion that natural TFA at levels found in regular diets do not contribute to elevated risk of cardiovascular disease (Mozaffarian *et al.*, 2006).

3.2. Obesity

Evidence to date suggests that that TFA plays a role in obesity development through multiple mechanisms. However, the evidence is still not strong enough for a firm conclusion on causality.

Following major changes in our nutritional patterns in the late twentieth century, we ingest more energy and sugar rich foods, as well as more fast-food meals. Fast food from many major restaurant chains contains high levels of TFA, which may be responsible for producing abdominal obesity. The Nurse's Health study discussed above also demonstrated that an increase in TFA consumption is associated with an increase in body weight (Willett, 1993). In addition, post-partum weight gain in mothers is associated with TFA intake (Oken *et al.*, 2007). Fat intake also influences early development and, to avoid obesity and other co-morbidities at young age, it is vital to maintain an age-appropriate energy intake with low levels of TFA.

As discussed above, TFA may contribute to inflammatory cellular processes. Today increasing evidence suggests that inflammation is a central feature in the onset of mechanisms that stimulate the development of obesity.

3.3. Diabetes

TFA have metabolic effects that are similar to several features of the metabolic syndrome considered a pre-stage to diabetes. As discussed above, TFAs influence systemic inflammation, which might partly account for the relations between TFAs and diabetes. A recent investigation found ingestion of TFA to be positively associated with markers of systemic inflammation in women (Mozaffarian *et al.*, 2006). Conversely, results from another recent study suggested that single TFA isomers do not affect either inflammatory markers or immune function in human subjects (Kuhnt et al. 2007).

The Nurse's Health Study observed an association between TFA intake and the risk of developing type 2 diabetes, with a strong association for obese women (Hu *et al.*, 2001). Other studies have not been able to demonstrate a similar relationship.

Although there are a number of studies that demonstrate a positive association between the consumption of TFA and an increased risk of diabetes, inconclusive results from some studies investigating the specific mechanisms by which TFA contribute to diabetes suggest that it is too early to conclude that TFA is a causative agent.

3.4. Cancer

In industrialized countries, up to 30% of cancers are related to dietary factors, making dietary factors second only to tobacco as a preventable cause of cancer (Doll and Peto, 1996). Strong evidence suggests that overweight and obesity contribute to an increased risk of developing several types of cancers, such as cancers of the oespohagus, colo-rectum, breast in post-menopausal women, endometrium, and kidney (WHO, 2003). However, there is still insufficient scientific evidence to directly link consumption of TFA to an increase risk of developing cancer.

3.5. Neurological Disorders

Despite known associations between diabetes, obesity and cognitive decline, current scientific evidence is inconclusive regarding a direct causal role for TFA in the development of neurological disorders.

Both prospective epidemiologic and animal studies have suggested that intake of dietary fat is associated with neurodegenerative disease and it is known that people with a diet high in saturated and TFA exhibit a faster rate of cognitive decline (Parrott and Greenwood, 2007 and Guyonnet *et* al., 2007). Furthermore, the development of Alzheimer's disease has also been associated with a high intake of both saturated fat and TFA (Morris, 2003).

Obesity and diabetes are linked to high blood glucose and high insulin, recently discovered risk factors for dementia. However, a high intake of TFA has not been specifically associated with an increased risk of dementia.

3.6. Blindness

Impaired sight resulting from an accumulation of lipids in the retinal pigment epithelium is associated with normal aging. Although the origin of these lipids is still being actively investigated, TFA that originate exclusively from the diet have been detected in orbital fat and may participate in the progression of age-related maculopathies (University of Illinois Eye and Ear Infirmary, 2008).

While a few studies have addressed the issue of TFA in promoting blindness, it remains too early to make a firm conclusion regarding the negative effect of TFA on the retina.

3.7. Liver Disease

While it is known that TFA have a negative effect on liver function, available scientific knowledge regarding TFA and liver disease is limited and does not allow firm conclusions at this point.

What is known is that the liver metabolises TFA differently to other fats. In studies on rats, TFA have been found to interfere with the normal function of enzymes in the liver that serve to convert essential fatty acids to arachidonic acid and prostaglandin (Mahfouz, 1981). Theses metabolite are needed for normal cell function.

3.8. Infertility

Very few studies have addressed this issue to date, and further investigation is required before conclusive evidence can be presented.

An increased risk of infertility due to suppressed ovulation is associated with a TFA consumption of 2% of the total energy intake. Therefore, a "fertility diet" of low TFA may improve fertility in otherwise healthy women. It could be suggested that the majority of infertility cases due to ovulation disorders may be preventable through dietary modifications (Chavarro *et al.*, 2007).

3.9. Foetal and Infant Development

A number of studies have investigated the relationship between maternal intake of TFA and the health of foetuses and nursing infants, with concerns focussing on the capacity of TFA to interfere with the metabolism of essential fatty acids.

Dalainas suggested that a high intake of industrially produced TFA during pregnancy may negatively influence infant development (Dalainas, 2008). On the other hand, a recent study focusing on diabetes found that the amount of maternal TFA intake in early pregnancy is not linked to gestational diabetes mellitus (Radesky, *et al.*, 2008).

It is known that TFA pass from the mother into the breast milk, with the amount of TFA in infant blood serum fluctuating in response to intake. In Spain and France, where fluid vegetable oils may dominate, 1-2% of the fat in breast milk is TFA. In Germany and Canada where solid fat is more common, about 4-7% TFA is found in the milk. The presence of TFA in human milk is a concern due to potential adverse effects on both development and growth of the newborn child, since TFA interfere with essential fatty acid metabolism (Innis, 2006).

4. Regulation of Trans Fats in EU Countries

With regards to regulatory action to control TFA in the EU, mechanisms that have been employed to date include an effective ban of industrially produced TFA in food products in Denmark, voluntary reductions in the UK and increasing consumer awareness in the Netherlands. Each of these strategies is considered in turn below.

4.1. The Danish Ban

In March 2003, Denmark became the first country to introduce legislation regulating the content of TFA in food products[8]. The legislation prohibits the use in foods destined for human consumption of fats and oils containing more than 2% of industrially produced TFA. The restriction is put on the ingredients rather than the final product, leading to lower concentrations of TFA in the final product.

The requirements were phased in, whereby although as from 1 June 2003, oils and fats were limited to less than 2% TFA, oils and fats used in processed foods were permitted to contain up to 5% TFA from 1 June to 31 December 2003. From 1 January 2004, the limit of less than 2% TFA content was applied to all oils and fats. Given the occurrence of natural TFA, these limits serve to virtually eliminate industrial TFA in Danish food products and restaurant food.

In 2006, Leth *et al.* published their investigations of 148 samples of food products available in ordinary grocery stores in Denmark. The results concluded that "the TFA content has been reduced or removed from the products with high TFA content originally, like French fries, microwave popcorn and various bakery products, so IP (industrially produced)-TFA are now without any significance for the intake of TFA in Denmark" (Leth *et al.*, 2006).

In addition, food producers have developed new methods of production without increasing prices or reducing variability in products on the Danish market. While continuing to sell foods with high levels of industrial TFA in other countries, the major multinational fast food chains successfully reduced the amounts of TFA sold in foods in Denmark to within the legal requirements. The regulation has been implemented without noticeable effect on the availability, price or quality of foods that previously contained high amounts of industrially produced TFA (Stender, Dyerberg and Astrup, 2006).

With regards to knock-on effects on the consumption of other fats, the elimination of TFA from margarines was not accompanied by an increase in saturated fats, but rather with an increase in monosaturated fats.

The legislation can therefore be judged as having achieved its goal and has made Denmark the only country in which it is possible to eat far less than 1g of industrially produced TFA on a daily basis, even with a diet that includes prepared foods (Stender *et al.*, 2006).

It is important to note that concerns about TFA had been voiced in Denmark for tens years prior to legislative action being taken. A 1994 report of the Danish Nutritional Council dealt specifically with TFA (Stender and Dyerberg, 1994), and following its publication margarine producers in Denmark took steps to reduce TFA content in their products. This voluntary initiative contributed to a fall in the Danish average daily consumption of TFA from 2.5g per day per person to 1-2g.

[8] Executive Order No. 160 of 11 March 2003 on the Content of Trans Fatty Acids in Oils and Fats

The decision of the Danish Government in 2003 to phase-out the use of industrially produced TFA responded to the fact that certain population groups were still consuming well above average daily intakes of industrial TFA, due to their consumption of fast food, French fries, and processed snack foods. This resulted partly from high TFA in imported products and partly from the fact that baked goods and margarines still contained high levels of TFA, despite the technical potential to reduce the TFA content (Danish Nutritional Council, 2003).

In terms of international recognition of the Danish legislation, at their session of 29 October 2008 in Helsinki, the Nordic Council, a transnational parliament for Denmark, Finland, Iceland, Norway and Sweden, recommended that other Nordic countries follow Denmark's example. They called on the Governments of the Nordic countries to put pressure on the EU to adopt similar legislation.

4.2. Voluntary Approaches in the UK

In the UK, industry has responded to increasing public awareness of TFA by voluntarily reducing the levels of TFA in food products.

Discussion was catalysed in 1994, when the Food Standards Agency published their results of a consumer survey regarding public preferences for the better labelling of products containing TFA (Food Standards Agency, 1994). Amongst other things, respondents identified labelling of different types of fats in food products, including TFA, as a priority. Population intakes of TFA have since fallen and are now at 1.2% of energy on average, well below the recommended 2% of total energy set by the Department of Health in 1991 (Henderson *et al.*, 2003). However, this average may not reflect differences in TFA daily intake between social groups with different consumption patterns.

In 2006, Clarke and Lewington published a study in the British Medical Journal that pointed to clear evidence of TFA as a causal agent in cardio-vascular disease. Noting that the TFA content of randomly selected food products varied substantially, they went on to stress that consumers require information in order to allow them to make informed choices. As such, Clarke and Lewington supported mandatory labelling of the TFA content of food products in order to enable consumers to make healthier choices and reduce their risk of cardio-vascular disease. Regarding the EU policy process, the authors claimed that the UK Food Standards Agency supported the revision of Directive 2003/89/EC that governs the content and format of nutrition labels on foods marketed in the EU to include TFA (Clarke and Lewington, 2006).

As a result of the increasing public pressure, in 2007 members of the British Retail Consortium, namely Asda, Boots, Co-op, Iceland, Marks and Spencer, Sainsbury's, Tesco and Waitrose, announced that they intended to voluntarily cease adding TFA to their own-brand products (BBC, 2007). According to the British Retail Consortium, approximately 5,000 products would be affected by the decision.

In 2007, the Food Standards Agency released a press release stating that voluntary measures to reduce TFA in food had already resulted in safe levels of consumer intake. The press release stated that average dietary TFA intakes in the had UK fallen to 1% of food energy, half the daily intake recommended by the Scientific Advisory Committee on Nutrition. These estimates were based on data on levels of TFA in processed foods that were supplied by the food industry. They announced their intention to recommend to the UK Health Ministers that voluntary measures were successful and that mandatory measures were not necessary (Food Standards Agency, 2007). The Board of the Food Safety Agency has subsequently advised the Department of Health to maintain its successful voluntary approach to the regulation of TFA in food.

4.3. Voluntary Approaches in the Netherlands

In the Netherlands, industry responded early to public awareness of the negative health impacts of TFA by voluntarily reducing TFA content in food products. In the early 1990s, the large Anglo-Dutch food producer, Unilever, decided to eliminate TFA from its products. The decision was triggered by media events and was in line with the company´s policy to "know their products" and also "apply that knowledge". Other producers followed Unilever´s example, and by 1996 it was reported that Dutch margarines contained only trace amounts of TFA (Korver and Katan, 2006). In a prospective population-based study, Oomen *et al*. found that the average TFA intake had decreased from 4.3 to 1.9 % of energy from 1985 to 1995.

In 2002, the Health Council of the Netherlands published a report reviewing the impact of reductions in TFA intake on a limited target group and making further recommendations. The report stated that the reduction in TFA intake from 1987/88-1997/98 will account for a reduction in the incidence of cardiovascular disease in the order of 5% (9,000 cases) among men and 4% (2,000 cases) among women over the coming forty years. These projections relate only to the target age group, individuals of 19-35 with lower educational qualifications. For the population as a whole, the overall health effect may be extrapolated. The report claimed that a reduction in intake of TFA to a maximum of 0.8% of total energy would reduce the incidence of such diseases by 4%.

In terms of recommendations for future action, the report stated that the food industry should be encouraged to undertake a further reduction in the quantity of TFA in the diet to the level found in nature itself.

With regards to legislation, the report called for regulations to ensure that TFA content is clearly labelled, and stated that the EU should consider the imposition of a maximum permissible content of TFA in industrially processed edible vegetable oils and fats (Health Council of the Netherlands, 2002).

5. Case Studies on the Regulation of Trans Fatty Acids in non-EU Member States

A number of countries outside of the EU have taken action to reduce the daily intake of TFA of their citizens. Canada, US, Brazil, Argentina, Uruguay and Paraguay have all chosen to make the labelling of TFA content in food products mandatory. In contrast, Switzerland, the State of New York, and South Korea have chosen to restrict the level of TFA that can be included in food products. This section draws on case studies of action in Switzerland, the US and Canada to provide details of the rationale behind actions and the mechanisms employed. It concludes with a brief overview of an international labelling initiative voluntarily undertaken by industry.

5.1. The Swiss Ban

On 1 April 2008, a regulation came into force in Switzerland that limits the percentage of TFA in fat and oils from plant sources to 2%[9]. The restriction of the scope to TFA from plant sources derives from the fact that those TFA have been shown to have negative influences on health, whereas similar evidence has not been found for the naturally occurring animal-derived TFA. Food producers have one year to adjust their products according to the new limit.

The decision to regulate TFA in food products emerged from a collaborative discussion between the Federal Health Agency and the ETH Zürich, a technical university. The ETH had delivered a report summarising the situation with regards to TFA in Switzerland and recommending legal limits for TFA content as the most efficient means of promoting a shift away from TFA in the food production industry (Colombani *et al.*, 2007).

Given the recent implementation of the regulation, it is not yet possible to draw any conclusions regarding its success.

5.2. The New York Ban

In December 2006, the New York Board of Health acted to restrict the content of TFA in restaurant foods, with restaurants banned from serving foods with a TFA content that exceeds 0.5 g per serving[10].

The new regulation has been criticised for raising the running costs for restaurant owners, and labelled “unjust” since only restaurants were covered by it, not grocery stores or food producers. It was also argued that large fast food chains were better placed to handle the regulation, compared to small independent restaurant owners (Filosa, 2008).

Despite the critique many cities and one state in the US today have banned TFA, or plan to do so. The list includes not only small cities but also large ones like San Francisco and Chicago. In 2008, California became the first state to ban TFA in restaurants[11] (McGreevy, 2008).

[9] 817.02 *Lebensmittel- und Gebrauchsgegenständeverordnung*
[10] Section 81.08 of the New York City Health Code
[11] Bill AB 97 of the State of California

5.3. Labelling in the US

In 2003, the US Food and Drug Administration issued a regulation requiring manufacturers to list TFA on the Nutrition Facts panel of foods and some dietary supplements[12]. The regulation does not distinguish between natural TFA and industrial TFA, and as such dairy products will be labelled as containing TFA. With this rule, consumers are deemed to have the information that enabled them to lower their consumption of TFA. Food manufacturers were given until 2006 to ensure that TFA content was listed on the label. The Food and Drug Administration estimated that TFA labelling would prevent from 600 to 1,200 cases of coronary heart disease and 250 to 500 deaths each year.

However, TFA levels of less than 0.5 grams per serving can be listed as "0 grams TFA" on the food label in the US. Although this is a small amount, multiple servings can mean that individuals consume significant amounts of TFA without knowledge.

The labelling approach is not supported by the American Public Health Association (APHA), who adopted guidelines entitled "Restricting Trans Fatty Acids in the Food Supply" in 2007. The Guidelines urged federal, state, and local governments to ban and monitor the use of TFA in restaurants, as well as barring the sales and availability of foods containing significant amounts of TFA in public facilities including universities, prisons, and day care facilities (American Public Health Association, 2007).

5.4. Labelling in Canada

In January 2003, Canada was the first country to introduce mandatory labelling of TFA on pre-packaged foods[13]. Under the system, products with less than 0.2 grams of TFA per serving may be labelled as TFA free. While voluntary nutritional labelling had begun in Canada in the late 1980s, it was only after mandatory requirements came into effect that the labels became universal and as such more accessible to consumers.

This action was taken in response to a situation where Canada had one of the world's highest intakes of TFA in the mid 1990s. A Trans Fat Task Force co-chaired by Health Canada and the Heart and Stroke Foundation of Canada reported on progress in a 2006 report, and noted that mandatory labelling combined with heightened consumers awareness had promoted food manufactures to reduce or eliminate TFA for many processed foods (Health Canada, 2006).

At the same time, the task force concluded that TFA levels remained high in a range of baked goods, fast foods and snacks and argued that labelling alone will not result in the reformulation of food products high in TFA as this entails costs for the manufacturers. They found that for certain types of food products, taste and convenience outweigh nutritional characteristics and labelling has little impact on consumer choice. The task force therefore called for a limit of 2% TFA in vegetable oils and margarines, and of 5% in all other foods, estimating that the application of these limits would lead to a reduction in TFA intake of 55%.

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[12] 21 CFR Part 101, Food Labeling; Trans Fatty Acids in Nutrition Labeling; Consumer Research to Consider Nutrient Content and Health Claims and Possible Footnote or Disclosure Statements; Final Rule and Proposed Rule, Federal Register, Vol. 68, No. 133, Friday, July 11, 2003, Rules and Regulations

[13] SOR/2003-11 12 December, 2002, Regulations Amending the Food and Drug Regulations (Nutrition Labelling, Nutrient Content Claims and Health Claims), 2003-01-01, Canada Gazette Part II, Vol. 137, No. 1

Health Canada subsequently announced that it is calling on food manufacturers to voluntarily reduce TFA to the levels recommended by the task force. Should the industry fail to meet these targets in two years through a voluntary approach, Health Canada has indicated that it will impose regulations (CBC News, 2007).

5.5. The Choices Programme

The Choices Programme is an industrial initiative that was launched by the Dutch company Unilever in May 2006. It involves a voluntary labelling scheme that continues to be implemented at the international level. It introduces a simple front-of-pack stamp on food products that pass a set of qualifying criteria based on international dietary guidelines, which include TFA content.

The programme aims to facilitate consumer choice in identifying healthier foods, and to generate an incentive for food manufacturers to improve the nutritional composition of their products (Dötsch-Klerk and Jansen, 2008).

6. Conclusions and Recommendations

There is a significant body of scientific evidence that establishes a causal link between the consumption of TFA and the increased risk of cardiovascular disease. Although causal links have not been proven for other chronic diseases, a number of studies have provided suggestive evidence that merits further investigation. The weight of evidence against TFA as a factor in cardiovascular disease would seem to form a sufficient basis for undertaking measures to reduce the average intake of TFA in order to protect human health. Indeed, it has been estimated that a decrease in TFA intake of 2% of energy intake would reduce cardiovascular disease by 5% or more (Health Canada, 2006) and the elimination of industrial TFA from our diets has been identified as a "low hanging fruit" in the quest for a healthier diet (Stender, Astrup and Dyerberg, 2008).

In addition, the rationale for using TFA in food products is no longer valid, as refrigeration during transport and storage have improved and alternatives exist. As such, today's use of TFA in foods is triggered by only marginal economic benefits to the food manufacturers.

It is important to note that natural TFA is present in our foodstuffs at much lower levels than industrially produced TFA, typically less than 5% in dairy products and red meats against up to 45% in a commercially produced food product containing TFA (Canadian Ministry of Public Health, 2006). The broad public health issue would therefore be to concentrate on the intake of industrially produced TFA.

Departing from the premise that industrial TFA intake should be reduced, this final section draws on the various policy options discussed to present some conclusions regarding the success of the different policies. Firstly, the success of voluntary initiatives is compared with that of mandatory regulations. Secondly, the benefits and disadvantages of the two different types of regulations imposed are discussed in turn, namely restrictions on TFA content and of labelling approaches. The section concludes by presenting some clear recommendations for action that could be taken at EU level to reduce the intake of TFA of European citizens.

6.1. Voluntary Initiatives Against Mandatory Regulations

In a number of the countries discussed above and at the international level through the Choices Programme, industry took the initiative to respond to public awareness of the health impacts of TFA by voluntarily reducing TFA content in food products. In all cases, this action resulted in lower average daily intakes of TFA and as such can be deemed successful.

However, the reductions in TFA levels in foodstuffs tended to be focused in the margarine sector, or in specific brands, and were in no cases seen across all TFA containing food products. Indeed, even in countries where the average daily consumption of industrial TFA has fallen considerable it is possible to find very high daily intakes amongst low-income subgroups of the population who may be more likely to consume specific foods, and who already have an increase risk of cardiovascular disease (Stender, Dyerberg and Astrup, 2006). Danish experience demonstrated that it was only after regulations came into effect that industrial TFA were virtually eliminated from the food supply. Health Canada has also recognised the limits of voluntary reductions, even when combined with mandatory labelling requirement, since there are some food products that are not purchased for their nutritional value and as such the manufacturer does not gain a market advantage by making the product healthier.

There is an issue of social equity in the regulation of TFA. Reductions in TFA and associated health claims resulting from voluntary initiatives tend to be found on higher-end products, which are less accessible to price-sensitive consumers (Health Canada, 2006). Mandatory regulations, be they labelling requirements or restrictions on TFA content, ensure that all food products are affected and thus benefit all consumers regardless of their socio-economic status.

In addition, mandatory regulations send a clear signal along the food chain, reduce uncertainty and create a level playing field. It is important that adequate phase-in periods are allowed for the introduction of legal requirements.

6.2. Conclusions on Bans

If the policies are to be judged by their success in reducing TFA intake, the Danish ban has certainly achieved this goal. Importantly, the impacts on the economic situation of the food industry seems negligible, with a rapid adjustment having been made to replace fats with an industrial TFA content of above 2%.

In establishing a ban, decisions must be made regarding the scope of the restriction. Firstly, it must be decided whether to specifically target industrial TFA (as in Denmark), or to set slightly higher limits that accommodate naturally occurring TFA (as recommended by the Trans Fat Task Force in Canada). There are currently no officially accepted analytical methods for distinguishing between the amount of naturally occurring TFA and industrial TFA in food.

A second decision concerns whether to regulate the level of TFA in the ingredient or in the final product. The Danish ban concerns the level of TFA in ingredients of both food products and restaurant food, and as such leads to a lower TFA content in the final product. In contrast, in their recommendations Canada's Trans Fats Task Force argued that it would simplify compliance and enforcement to regulate the total content of TFA in food products, and regulate the TFA content per ingredient for restaurants. The New York State Ban applies specifically to restaurant foods and restricts the intake of TFA to 0.5g per serving.

Given the need to ensure compliance through a credible level of enforcement, the principle seems to be that the restriction should allow enforcement to take place through existing food inspection procedures. With regards to restaurant foods, regulating the TFA content in the ingredients is more practical given difficulties for establishments in analysing their servings on site. In addition, it shifts the burden of responsibility up the food chain and simplifies compliance by reducing the number of actors targeted by the regulation.

6.3. Conclusions on Labelling

The provision of information to the consumer regarding the level of TFA in food, allows the consumer to take decisions when purchasing food and in order to limit their intake of TFA. As such, this course of action leaves industry free to include TFA in their products and replies upon consumers to inform themselves, read the labels on food products and use this information to tailor their consumption habits. In theory, consumer purchasing decisions then send a signal to food producers to reduce TFA levels in their products in order to gain market advantage.

Mandatory labelling requirements for TFA met with some success in Canada, where the food industry responded by reducing TFA content in many, but not all, food products. Prior to introducing mandatory labelling, the Canadian experience showed considerable variation in the voluntary labelling of TFA levels in food products.

In both the US and Canada, a threshold exists below which products can be labelled as TFA-free. The the result of the threshold is that through multiple servings consumers can have an intake of industrial TFA that exceeds the daily recommended intake for TFA, particularly in the US.

The ability to benefit from food labelling by taking appropriate action to protect health depends on our ability to interpret that information and as such raises equity issues. Only those individuals with sufficient education and knowledge will be able to interpret food labels properly. As noted above, foods that are low in TFA tend to cost more, restricting the choice to take action to the wealthier customers. People who do not read labels, including those with lower incomes, lower literacy skills, or immigrants lacking language skills, do not benefit from the information. Low-income groups are already at a higher than average risk of cardiovascular disease (Mackenbach, 2000), and as such are a key target for efforts to reduce TFA intake.

It is therefore clear that in order for labelling to be effective in guiding consumer behaviour, it must be accompanied by a timely awareness raising campaign on fats in general, TFA in particular and on how to read and interpret labels. Finally, the label listing TFA content must be suitable and visible.

In order to generate additional incentives for food manufactures to eliminate TFA from their food products, mandatory labelling requirements can be coupled with incentives. Examples could include support for the development of alternatives, allowing “trans fat free” health claims, and assistance programmes targeted at small and medium-sized enterprises.

Finally, a limitation of product labelling is that it does not capture all food products, since food sold in restaurants is not labelled. This is clearly a weakness of the approach, since the food sold in fast food restaurants is traditionally high in TFA.

6.4. Recommendations for Action at EU Level

Based on the review of policies adopted by different countries to address intake of TFA, it is clear that the most effective approach is to introduce a ban.

This study therefore recommends that a maximum level of 2% TFA in all ingredients intended for human consumption be considered. The rationale for this approach is that it leads to a lower level of TFA in the final product and provides one standard that is applicable to both food products and restaurant food. This level is high enough to allow for the presence of naturally produced TFA in food products. According to the experience from Denmark, this would lead to an average level of 1% TFA in the final food product, and as such would conform to the WHO recommended daily intake of less than 1 % TFA of total daily calories (WHO, 2003).

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