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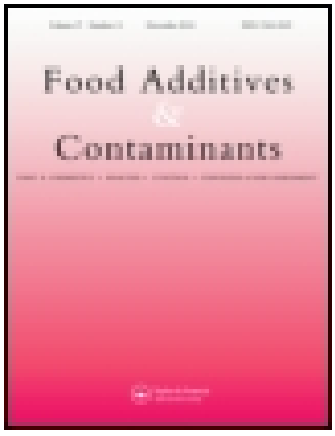

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Modelling consumer intakes of vegetable oils and fats

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Modelling consumer intakes of vegetable oils and fats

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Vegetable oils and fats make up a significant part of the energy intake in typical European diets. However, their use as ingredients in a diverse range of different foods means that their consumption is often hidden, especially when oils and fats are used for cooking. As a result, there are no reliable estimates of the consumption of different vegetable oils and fats in the diet of European consumers for use in, for example, nutritional assessments or chemical risk assessments. We have developed an innovative model to estimate the consumption of vegetable oils and fats by European Union consumers using the European Union consumption databases and elements of probabilistic modelling. A key feature of the approach is the assessment of uncertainty in the modelling assumptions that can be used to build user confidence and to guide future development.

Keywords: dietary exposure modelling; EFSA database; intake modelling; probabilistic modelling; vegetable fats; vegetable oils

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Introduction

Substances other than fatty acids can arise in vegetable fats and oils from a number of sources, including natural constituents, food additives, contaminants or processing byproducts. Such substances can be naturally occurring such as major nutrients including fat-soluble vitamins, micronutrients such as polyphenols, allergens, lipophilic chemicals that may be concentrated in oils and fats, or materials arising from contamination. Examples of specific substances reported to occur in certain vegetable oils and fats include vitamin E (Maras et al. 2004), hydroxytyrosol (Miró-Casas et al. 2003), polycyclic aromatic hydrocarbons (EFSA 2008), and 3-monochloropropane-1,2-diol esters (EFSA 2013). The types and amounts of substances can vary considerably between oil sources (e.g. soybean, sunflower seed, etc.) and their subsequent history. It is therefore necessary to discriminate between vegetable oils and fats derived from different plant products to produce reliable estimates of consumers' exposure to such substances. Therefore, the development of a robust dietary exposure model was needed to enable fats and oils consumption to be more accurately assessed in European Union member states.

There is limited information available about the amounts of different types of vegetable fats and oils in the diet. National dietary surveys typically estimate the total fat intake and intakes of different fatty acid groups (e.g. polyunsaturated fats, saturated fats, etc.), but no further breakdown between vegetable fat sources is usually provided. Furthermore, consumption of vegetable oils and fats is not always well recorded in food consumption surveys because a proportion can be incorporated into other foods in the form of ingredients or oils and fats used for cooking. Also, the treatment of oils and fats in composite foods is not consistent across dietary surveys. It is possible to estimate per capita vegetable oil consumption on the basis of import–export data by removing an estimated amount of the oil used for technical purposes (e.g. biodiesel) and animal feed. Nevertheless, the estimated consumption obtained is uncertain and does not give any indication about the differences in consumption by age or by high and low consumers. As a way to overcome this, estimated intakes of polyunsaturated fatty acids (PUFAs) have been proposed as a marker for the presence of vegetable fats in diets. Vegetable fats are higher than animal fats in their PUFA content and tend to be the main source of PUFAs in human diets.

In the approach described here, the EFSA Comprehensive National Food Consumption database was used as the basis for modelling food consumption (EFSA 2011a). This was combined with European Union-wide information on the levels of PUFAs in foods to estimate PUFA intakes. These in turn have been combined with the proportions of PUFA in specific vegetable oil types and the relative food utilisation of different vegetable oils based on oil trade statistics to estimate intakes of different vegetable oils and fats by European consumers on a country-by-country basis.

The result is a consumer exposure model for substances associated with vegetable fats and oils. If the concentrations of a substance in various vegetable oil and fat types are known,

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these can be entered into the model and the potential intakes of European consumers will be estimated based on the data and probabilistic model described below in the next section. Until now, it has been difficult to discriminate between animal- and vegetable-derived fats and oils and potential exposures to substances associated with them. Furthermore, it has not been possible to link exposures to levels of substances in particular oil types. The problem has been compounded by the limited amounts of national food consumption data and the problems associated with estimating high level exposures when there are simultaneous routes of exposure. The proposed model overcomes all these shortcomings and is provided in the in the Supplemental data online in a readily useable form.

Model development

The overall approach to developing this model can be summarised in five steps:

Step 1. Identify food categories containing vegetable oil and fats. For that purpose, the EFSA Comprehensive National Food Consumption Database was analysed.
Step 2. Identify typical PUFA content for each food category. National food composition data provide typical PUFA levels for the different food groups listed in the EFSA Comprehensive National Food Consumption Database.
Step 3. Calculate the dietary intake of PUFA using a probabilistic model.
Step 4. Calculate the relative amounts of different oil and fats in the diets of different countries using trade statistics.
Step 5. Combine the dietary intake of PUFA, the PUFA level in each oil and fat and the percentages of different oils and fats in the diet to calculate the dietary intake of each vegetable oil and fat.

EFSA comprehensive national food consumption database (Step 1)

In order to select the food categories consumed in Europe containing vegetable oils and fats, the EFSA Comprehensive National Food Consumption Database was assessed. The database was compiled using the national dietary survey data of 22 European Union member states, a total of 32 dietary surveys and over 66 000 individuals. The information from the different national dietary surveys was standardised by assigning foods to one of around 160 food groups (described as 'FoodExL2'), each of which is assigned to one of 20 broader categories ('FoodExL1'). The database contains food consumption data for each country for a range of age groups (infants, toddlers, children, adolescents, adults and the elderly), for intakes between the 5th and 99th percentiles. Data are presented as total consumption in g day^{-1} and, by taking into account the body weight of the participants in the survey, in g kg^{-1} body weight day^{-1}. Consumption data are also presented for consumers alone alongside data for the entire population.

For some food categories in the EFSA database, no consumption data were reported in some countries and zero consumption was applied for the entire population. Such values reflect the use of different food coding systems in different countries and the different treatments of composite foods. This represents a potential source of uncertainty in the model and will be discussed below.

All FoodExL2 categories listed in the database were reviewed, and any foods likely to contain vegetable oils and fats (either endogenous, as direct ingredients, or introduced during cooking) were noted. Consumption data for these categories were extracted on a g day^{-1} and on a g kg^{-1} bw day^{-1} basis, following the guidance from EFSA on the use of the EFSA Comprehensive European Food Consumption Database in Exposure Assessment (EFSA 2011b). The categories extracted from the database are summarised in Table 1 with an example of Danish adult food consumption data. Having established the consumption of foods containing vegetable oils and fats, it was then necessary to know the PUFA content of these food categories per amount of food eaten.

Identification of typical PUFA content for FoodExL2 category foods (Step 2)

Typical PUFA contents for foods in each of the 22 food categories identified as potentially containing vegetable oils or fats were derived from European food composition databases. The EuroFIR system (European Food Information Resource) database of food composition resources (EuroFIR 2014) was used to identify European national food composition databases that contained data on the PUFA content of a range of individual food items, were available for download and covered all European Union regions. PUFA data sources included the Czech Republic (Centrem pro databázi složení potravin ČR 2014), Denmark (National Food Institute 2009), France (AFSSA 2012), Finland (National Institute for Health and Welfare 2013), Spain (BEDCA 2010) and the UK (Department of Health 2011).

Each of the food descriptions in the databases (or which there are over 9000) was matched to one of the FoodExL2 codes for foods containing vegetable oils and fats. The datasets were then combined to determine the number of foods, average PUFA content and standard deviation (SD) for each of the 22 FoodExL2 codes used in the model (see the 'PUFA Food' table in the Supplemental data online).

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Table 1. FoodEx Categories used in model and example of food consumption data – for Danish adults (g day^{-1}).

FoodExL1 name	FoodExL2 name	Mean	SD	P5	P10	Median	P95	P97.5	P99
Grains and grain-based products	Fine bakery wares	9.7	14.9	0.0	0.0	2.4	37.1	47.9	65.7
Starchy roots and tubers	Potatoes and potatoes products	109.8	83.9	6.4	22.5	91.1	269.0	327.6	387.6
Meat and meat products	Meat and meat products (unspecified)								
	Livestock meat	80.0	47.7	19.8	29.1	71.5	168.1	200.2	235.9
	Poultry	25.4	26.0	0.0	0.0	20.1	75.5	88.3	114.3
	Edible offal, farmed animals	0.8	5.5	0.0	0.0	0.0	0.0	15.2	23.6
	Preserved meat	7.4	5.8	0.5	1.3	6.3	18.1	22.0	27.1
	Sausages	15.8	22.4	0.0	0.0	6.3	60.3	79.4	94.3
Fish and other seafood	Fish and other seafood (unspecified)								
	Fish meat	15.3	17.0	0.0	0.0	10.3	48.0	59.6	73.6
	Fish products								
Animal and vegetable fats and oils	Animal/vegetable fats and oils (unspecified)								
	Vegetable fat	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0
	Vegetable oil	0.8	1.4	0.0	0.0	0.2	3.2	4.5	6.4
	Fats of mixed origin								
	Margarine and similar products	14.5	8.7	4.4	5.6	12.8	30.6	36.4	43.7
Herbs, spices and condiments	Dressing	5.0	5.9	0.0	0.0	3.2	16.5	20.8	25.8
Composite food	Composite food (unspecified)								
	Cereal-based dishes								
	Rice-based meals								
	Meat-based meals								
	Fish and seafood based meals								
	Egg-based meal (e.g., omelette)								
	Prepared salads								
Snacks, desserts, etc.	Snack food	3.1	7.6	0.0	0.0	0.0	17.1	25.5	34.3
	Ices and desserts	7.2	12.2	0.0	0.0	0.0	28.6	42.9	50.0

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In the case of animal-derived products such as fish, meat and poultry, there can be significant endogenous PUFA levels in addition to those coming from cooking with vegetable oils and fats (Wood et al. 2008). It was therefore necessary to develop a method for separating endogenous PUFA from those added from vegetable sources during cooking. The UK food composition database (Food Standards Agency 2010) provides some useful data on PUFAs in raw animal products as well as in cooked animal products as eaten. The differences between the two values for the FoodExL2 categories for meat and fish products and fish meat and fish-based dishes were used to derive corrections factors (3.2% for meat and meat products, poultry, offal, fish and fish products, and 5.5% for cooked dishes) so that only vegetable oils and fats added during cooking were considered in the model. The correction factors applied are provided in the 'PUFA Food' table in the Supplemental data online. For certain categories such as snack foods, and ices and desserts, it was not possible to separate animal- and vegetable-derived PUFAs, and it was assumed that they were all derived from vegetable oils and fats. This may lead to overestimation of consumption, which will be discussed below.

The PUFA content of foods will not be constant since it depends on the amount of fat used in preparation and on the types of vegetable oils and fat used. The PUFA content of similar foods may also differ between countries because of differences in national food preparation practices and uses of different types of vegetable oil and fats. There are also differences between national databases in the ways that composite foods are treated. The variation in PUFA content in foods in the PUFA database is characterised by an SD for each FoodExL2 category. These are given in the 'PUFA Food' table in the Supplemental data online. These values can be used in specifying a probability distribution of PUFA concentration for input into the probabilistic model.

Calculation of the dietary intake of PUFA (Step 3)

A PUFA intake database is created by merging the food consumption data (Step 1) and PUFA concentration data (Step 2). Using a Monte Carlo sampling strategy, the different distributions of food consumption from the EFSA database were combined with the associated PUFA content. This probabilistic model takes the variability in food consumption into account alongside the variability of PUFA content in different foods. This is important because the SDs of PUFA contents were relatively high. However, the data were found to be generally skewed to lower values (e.g., see Figure 1 for PUFA levels in fine bakery wares). It is therefore appropriate to model

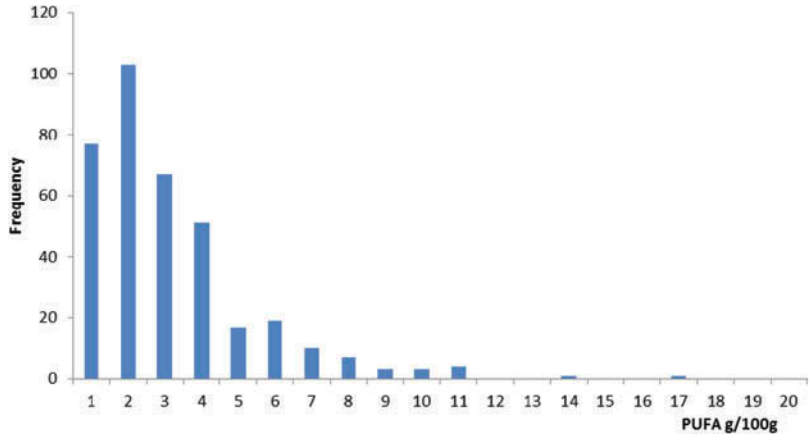

Figure 1. Distribution of PUFA levels in fine bakery wares.

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the PUFA contents by a log-normal distribution, which avoids excessive overestimation of PUFA intake. Using such a distribution is common in consumption modelling (McNamara et al. 2003; van der Voet et al. 2007), but it is not the only plausible choice and this additional uncertainty will be discussed below.

We sampled at random from the probability distributions of food consumption data for each food and from the distribution of PUFA concentrations for that food. Multiplying these together creates an estimate of PUFA intake from each food. These are summed to provide an estimate of the total PUFA intake for each individual. This creates one value in the distribution of total PUFA intake and so the process is repeated many thousands of times to populate a theoretical distribution of PUFA intakes for a given country and age group. Daily dietary consumption of PUFA for different intake levels (mean, median and percentiles) can then be calculated for this distribution. The dietary intake of PUFA was calculated both on a total basis (g day^{-1}) and on a body weight basis (g kg^{-1} bw day^{-1}) using the relevant data from the EFSA Comprehensive National Food Consumption Database in each case. The resulting PUFA intake for each age group by country are provided in the 'Toddlers', 'Children', 'Adolescents', 'Adults' and 'Elderly' tables and summarised in the 'PUFA Intakes' table in the in the Supplemental data online. A more detailed description of the PUFA intake model is given in Appendix 1 also in the Supplementary data online.

Calculation of the relative amounts of the different vegetable oils and fats used in the diet of different countries in the EU-27 (step 4)

The data on fat intake, and PUFA intake, as derived from the EFSA database in combination with the national food composition databases explained in Steps 1–3, do not specify the specific types of vegetable oils and fats that are included in the country diet. The aim of the model is to give intake estimates for different oil and fat types which may be useful for both safety and nutritional reasons.

In order to arrive at a set of more accurate data on the distribution of the various vegetable oils and fats, the EUROSTAT database (EUROSTAT 2014) was used as a starting point. This database records the import and export of the different refined oil and fats in each of the EU-27 member states. This database also distinguishes between technical use and non-technical use (food and feed).

Tropical oils and fats (palm oil, palm kernel oil, coconut oil)

For tropical oils and fats, there is no local production in Europe. Therefore, the EUROSTAT data for import and export directly provide the volumes of oil and fat used in the EU-27 member states for 'edible use' (i.e. food plus feed). Using experience in the sector, the federation representing the vegetable oil and protein meal industry in Europe (FEDIOL) estimated the use of these tropical fats for feed, based on EUROSTAT official data (EUROSTAT 2014) and expert knowledge, to determine the use for food in European Union countries.

Some product types contain a significant amount of tropical fats. These products are also imported and exported between the various EU-27 countries. This means that the local consumption of oil and fats is distorted if there is no correction made for the import and export of finished goods containing vegetable oils and fats. The EUROSTAT database does provide such import and export data. However, only if the composition of these products is known (fat level, composition) can a correction actually be made. For the category 'margarines and fat spreads', the association representing the oils and fats

industry in the Netherlands (MVO) provided data on the average composition of these products.

Based on internal statistics of the various subtypes of margarines and spreads, and their individual composition, the level of palm oil-based components was calculated to be 40% on average. With expert input from the International Margarine Association of the Countries of Europe, the same number was derived for all European Union countries. It was therefore decided to correct the data on local consumption of palm oil only for the import and export of margarines, spreads and shortenings ('margarine and fat spreads') arriving at the best estimated numbers for the local consumption of tropical oil and fats. Note that it was not deemed possible to conduct a further refinement taking into account other food products containing fats due to the diversity of their composition.

Other oil and fats (sunflower oil, rapeseed oil, soybean oil, maize germ oil, groundnut oil and olive oil)

For sunflower oil, rapeseed oil, soybean oil, maize germ oil and groundnut oil, 'local production' derived from EUROSTAT imports and exports data and FEDIOL statistics (FEDIOL, 2015). This time the total import and export data for both 'technical' and 'non-technical' applications were used in combination with the data reflecting total local production.

To arrive at a split between food, feed and technical use, FEDIOL prepared the 'Industry best estimate split-end-use' for each oil and fat, using its experience and knowledge from the feed, the technical and the biodiesel sector. However, as no data were available on this split on a country-by-country basis, the food consumption percentage was calculated for the total EU-27 situation and applied to each individual country arriving at the consumption of the other vegetable oils and fats per country.

Finally, for the local consumption of olive oil, the production data on a country-by-country basis of the International Olive Oil Council were used (International Olive Oil Council 2014).

Oil and fat consumption profile per country

Using the total weight of oils and fats of each type consumed in each of the EU-27 countries, the final relative contribution of each oil and fat to the total per country was calculated. By combining these data with the typical fatty acid profile per oil and fat and the PUFA intake as calculated from Steps 1 to 3, the model calculates the consumption of each oil and fat, in each country on a per day basis. An overall table combining both tropical oils and fats and other oils and fats is available in the 'Veg Oil Supply' table in the Supplemental data online.

Combining the dietary intake of PUFA, PUFA level in each oil and fat and percentage different oils and fats in the diet to calculate the dietary intake (Step 5)

The model can provide PUFA intake data related to vegetable oils and fats for different countries, age groups and intake levels (Steps 1–3). Knowledge of the PUFA content of different oils and fats and the proportion of each oil and fat in the diet can be used to convert this to estimates of oils and fat intake. To reach this, the proportion of each oil and fat in the diet (see 'Veg Oil Supply' in the Supplemental data online) and the amount of PUFA in each oil and fat (see 'PUFA Oils' in the Supplemental data online) were combined to calculate the percentage contribution of each oil and fat to the total PUFA intake. This relative proportion to the total PUFA intake was then combined with the total PUFA intake in g day^{-1} or g kg^{-1} bw day^{-1} (see 'PUFA Oils' in the Supplemental data online) and the PUFA content of each oil and fat to give the intake of each type of oil and fat, per country, per age group. An example of PUFA intakes for Danish adults is given in Appendix 1 in the Supplemental data online.

Results and discussion

Following all these steps, it was crucial to verify the model output. This was done by comparing the estimates of PUFA intake generated by the model with estimates available in the published literature. Estimated intakes of PUFAs were available for adults and children from studies in France, Denmark (Pedersen et al. 2010), Finland (Pietinen et al. 2010), Hungary, Germany (Mensink et al. 2007), Sweden (Becker & Pearson 2000; Enghardt Barbieri et al. 2007), the Netherlands (Van Rossum et al. 2011), and the UK (Department of Health 2011) and on the basis of 24-h recall surveys in Spain, Italy, France, Germany, the Netherlands, the UK, Denmark and Norway (Linseisen et al. 2009). Across all the published surveys, average PUFA intakes for adult men and women ranged from 7 to 21 g day^{-1} and high level intakes up to 32 g day^{-1}. For children intakes ranged from 6 to 11 g day^{-1} with high intakes ranging up to 27 g day^{-1}. PUFA intakes generated by the FEDIOL model are summarised in Table 2. Overall the model produces estimates of PUFA intake that are similar to those published for adults and for children, with averages being slightly lower whilst the upper range of high level intakes (95th percentile) being slightly higher. A direct correspondence between surveys is not expected because differences in methodology between the published surveys and between the surveys incorporated into the EFSA Comprehensive Food Consumption Database make the results incompatible.

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Table 2. PUFA intakes developed and used in model.

	Mean (g day^{-1})[a]	P95 (g day^{-1})[a]
Toddlers	2.5–7.9	6.6–19.4
Children	3.6–14.6	8.2–31.7
Adolescents	5.4–17.9	11.7–37.4
Adults	5.7–17.5	13.0–37.7
Elderly	5.9–16.6	13.9–37.6
Very elderly	6.5–14.1	15.5–31.5

Note: [a]Range: lowest–highest value reported in each country.

Uncertainty analysis

The exposure modelling approach adopted in this study was subject to many of the uncertainties that may arise when undertaking exposure analyses. The Scientific Committee of the EFSA has provided comprehensive guidance on the evaluation of uncertainties in dietary exposure assessment and the structure of their recommendations is followed in this article (EFSA 2006). In addition, recommendations in the WHO/IPCS report on characterising and communicating uncertainty in exposure assessment have been taken into consideration (WHO 2008).

Sources of uncertainty

Assessment objectives

The objective of the study was to develop a model for calculating the consumption of vegetable oils and fats by European populations for use in modelling exposures. The primary objectives included the ability to account for differences in occurrence levels between vegetable oil and fat sources and to estimate exposures for each European Union population and age group separately. The objectives have been effectively met within the limitations of the availability of national food consumption data.

Exposure scenarios

The EFSA Comprehensive National Food Consumption Database is based on dietary surveys that are typically of short duration. Therefore, food items consumed infrequently can be missed. However, for chronic exposure over long periods, this would be unlikely to impact the calculated intakes significantly. This is particularly true when assessing a food ingredient consumed as regularly as vegetable oils and fats. Likewise, vegetable oil and fat intakes are unlikely to be significantly influenced by seasonal variation in consumption.

Across the European Union there are significantly different dietary habits between countries. Whilst the EFSA database does not include data from every member state, the countries for which there are data include those located in Scandinavia, Northern Europe, the Mediterranean area and Eastern Europe. Therefore, there is sufficient representation for the model to be considered representative of the European Union as a whole.

Exposure model

The degree of uncertainty associated with the exposure model is determined to a large degree by the level of detailed information available on the consumption of foods containing oil and fats and the application of a realistic PUFA content to each food category. Because food consumption surveys are conducted in different countries using different methodologies, this can lead to inconsistencies. A particular issue is the way in which foods are categorised (coded) during data collection. This applies particularly to composite foods that could be classified according to the food as eaten (e.g. as ‘meat-based meals’) or corresponding to the ingredients (e.g. ‘livestock meat’). Similarly salad dressing may be recorded separately or could be recorded as part of the prepared salad. This results in some food categories having no reported consumption. However, this should be balanced by their inclusion under another reporting category and so the overall effect is expected to be limited.

The model is based on the ability to use summarised data from the EFSA Comprehensive Food Consumption Database in a probabilistic model. This will introduce uncertainties because in order to use Monte Carlo sampling a probability distribution must be assumed. This can be particularly challenging where there are few reported observations so that only data on high percentile consumers are available. This is reflected in some differences between the reported values in the EFSA database and those generated by the FEDIOL model. The probability distributions also reflect an assumption of independence between eating events. Other probabilistic models have attempted to include dependence between quantities of each food type consumed by basing their models on dietary survey data directly (Ferrier et al. 2002; Gibney & van der Voet 2003) or by adding the dependency into their probability distributions (Paulo et al. 2005; Allcroft et al. 2007). In our case, neither solution was available without major assumptions because dependency information is not included in the EFSA Comprehensive Database. Overall, these effects are minor and non-systematic and are considered to have a small effect on the outputs.

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Model inputs

Model inputs refer to the raw data used to support the exposure model. In this case there are four main types of input data:

- Food consumption from EFSA database.
- PUFA content of food sources from national compositional databases.
- PUFA levels in vegetable oils and fats.
- Relative total consumption of each vegetable oil and fat in each country.

The PUFA content of foods derived from vegetable sources corresponding to each food category was based on published data from six European countries. Some adjustment had to be made to exclude PUFAs of animal origin from certain categories such as meat dishes so that only the vegetable oils and fats used to cook the meat were included. This was based on average differences between cooked and uncooked meats. This will have introduced a partial correction but some animal derived PUFAs will have been included, such as dairy fats associated with ice creams and desserts. Since most PUFAs used in the model are derived from vegetable sources the impact of this effect is likely to be minor. The use of only six databases for estimating PUFA content of FoodExL2 food categories introduces some uncertainties because the composition of foods will vary from country to country and the relative proportions of a given type of food making up each category will also vary. However, since detailed information on the composition of foods was not available for all countries contributing to the EFSA Comprehensive Database, it was not possible to avoid this source of uncertainty in the model. Variability in PUFA contents of foods within FoodEx categories was represented by the SD assuming a normal distribution. In reality some foods will fall outside of this range and if a consumer consistently chooses such foods then his or her PUFA intake could be higher or lower than the values represented in this model. However, this is not expected to result in systematic bias.

The PUFA levels in vegetable oils and fats are relatively constant and are unlikely to be a significant source of uncertainty. However, the relative consumption of each vegetable oil and fat type in each European Union country is based on trade statistics that record the movement of finished oils and fats between member states only. Home consumption of some oil and fats may be overlooked as well as trade in vegetable oil and fat based products such as baked goods. There are also uncertainties associated with the proportion of oils and fats going to animal feed and that being diverted to produce new energy sources. FEDIOL has taken steps to reduce and remove all of these uncertainties. However, certain doubts remain such as the per capita food palm oil and fat consumption in Ireland and the per capita food sunflower oil and rapeseed oil consumption in Belgium appearing rather high and the per capita consumption in the Netherlands of coconut oil seeming extremely high. These features might be explained by local factors or could be due to oils and fats being re-exported in other food products. It was not possible to obtain data about the split between food, feed and technical use of fats and oils at a national level. Although the vegetable oil industry has applied its best estimate there will be some residual uncertainty and also trends may change with time.

Uncertainty related to oil and fat use and further processing

The model estimates the dietary intake of liquid oils and fats. However, there are insufficient data to be able to account for further processing of liquid oil and fats. For example, liquid palm oil and fat is converted to stearine and blended hardstocks before being used in margarine. Whilst this does not impact on the amount of oil and fat consumed, there would be an impact if assessing intakes of components of the oil and fat which are changed during the processing.

Application of the model

When applying the model, further uncertainties may arise on the way data are gathered. This particularly depends on the availability or not of validated methods to analyse oils and fat samples for chemical constituents.

Overall uncertainty

The verification of model outputs has shown that the model produces estimates of PUFA intake and vegetable oil and fat consumption that are within expected ranges. The model is operating within reasonable bounds of performance given uncertainties associated with the FEDIOL method and with the methods used to estimate PUFA intakes in the literature. The FEDIOL model produced average estimates of PUFA that were slightly lower than estimates from the literature, which is to be expected because the FEDIOL model is predicting PUFA intake from vegetable oils and fats only whereas the literature estimates are predicting PUFA intakes from all sources. However, the FEDIOL model predicts high level intakes that are slightly higher than literature estimates, reflecting a degree of conservatism built into the model.

Uncertainties associated with the model have been tabulated in a qualitative model recommended by the EFSA Scientific Committee (Table 3). Plus and minus

Table 3. Qualitative evaluation of influence of uncertainties on FEDIOL exposure model.

Source of uncertainty	Direction and magnitude[a]
Short-term food consumption surveys	+
Regional variations	–/+
Variation in food coding	–/++
Probabilistic model	–/+
Animal derived PUFAs in model	+
Variations in PUFA levels between countries	–/+
Relative consumption of vegetable oil and fat types in European Union member states	–/++
Overall effect	–/++

Note: [a]+, ++, +++ = uncertainty with the potential to cause small, medium or large overestimation of exposure/risk; and –, –, – = uncertainty with the potential to cause small, medium or large underestimation of exposure/risk (EFSA 2006).

signs are used to indicate the direction and magnitude of sources of uncertainty, with a positive sign indicating greater conservatism in the result. The uncertainty analysis indicates where uncertainties arise and suggests that the model is probably overestimating intakes of PUFA from vegetable oil and fat sources and of vegetable oils and fats overall. However, this small degree of conservatism is acceptable given the uncertainties inherent within the model.

Conclusions

In the absence of reliable dietary intake estimates of vegetable oils and fats, the model described here offers the most robust available estimates of dietary intake of different vegetable oils and fats and the nutrients and other substances associated with them, across different European Union populations. For example, an ILSI-Europe workshop in 2009 noted that in order to make reliable estimates of exposure to 3-MCPD esters from vegetable oils and fats it would be necessary to combine levels in fats in different food categories with the type of fats being used in the food from different regions and the statistics on consumption of different categories of food in different countries (Larsen 2009). Naturally, there are uncertainties with the intake assessment, most notably inconsistencies in dietary survey data incorporated into the EFSA Comprehensive Nutritional Database, inaccuracies in oil and fat trade data relating to finished product trade and the use of generic PUFA levels for different food types. Overall, these uncertainties are considered acceptable and the output of the model as expected compares with both PUFA intake levels published in dietary surveys and per capita oil and fat consumption data based on trade statistics. The uncertainty analysis suggests that if more detailed data on national food consumption patterns were available from the EFSA Comprehensive database then additional refinements could be introduced into the FEDIOL exposure model.

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Supplemental data

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