

“Foodplate” web application for healthy and environmentally-friendly eating

Final scenario report

Foodweb project



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Table of contents

1. Introduction.....	5
2. Materials and methods	7
2.1. Basic meal set	8
2.2. Methods and data for the “Foodplate” web application	8
2.3. Improvement scenarios.....	12
3. Analysis of the basic meal set.....	13
3.1. Energy and nutritional value	13
3.2. Environmental impacts.....	20
3.2.1. CO ₂ – the carbon footprint	20
3.2.2. Eutrophication impact (PO ₄) on the Baltic Sea.....	22
3.2.3. Ecotoxicity (MCPA eq)	24
3.2.4. Weighted environmental impact.....	26
3.3. Toxic exposure.....	28
3.3.1. Contaminants	28
3.3.2. Human exposure index (HEI)	33
4. Scenarios for food consumption	34
4.1. The overall impact factors of basic meals	34
4.2. Overall impact factors of the modified meals.....	36
5. Scenario for some hazardous compounds for the Baltic Sea	41
6. Conclusions.....	47
7. Appendix 1: Examples of the basic meals of the “Footplate” web-application	49
8. References	53

1. Introduction

Food production and consumption are major contributors to anthropogenic greenhouse gas emissions, which are the major cause of climate change¹. The environmental and ecological impacts of food production are becoming more important for consumers when making dietary choices. Consumers want to learn more about the environmental aspects of food production and consumption, but understanding the information related to food, health, nutrition, and food safety is difficult and making good food choices represents a challenge².

On a global basis the agriculture sector is one of the biggest contributors to climate change and food is associated with 19–29 % of greenhouse gas emissions³. According to FAO's 2014 report⁴, emissions from agriculture, forestry and fisheries have nearly doubled over the past fifty years and could increase by an additional 30 % by 2050 unless greater efforts are made to reduce them. According to the report, the greenhouse gas intensity values of the commodity products were ranked from highest to lowest as follows: beef, pork, eggs, rice, milk, and cereals. The greatest environmental load of agriculture comes from the meat production sector. The production of livestock accounts for 30 % of land use globally and 70 % of all agricultural land. Livestock production generates nearly a fifth of the world's greenhouse gases — more than does transportation⁵.

In Finland, the food chain is responsible for a significant amount of greenhouse gas emissions: 7 % of all carbon dioxide emissions, 43 % of methane emissions, 50 % of nitrous oxide emissions, 12 % of perfluorocarbon gas emissions and 69 % of ammonia emissions. The food chain is therefore estimated to contribute 14 % to Finland's impact on climate change. Using the lunch plate approach, a single lunch portion was estimated to contribute 2–12 % of a typical Finnish consumer's daily impact on climate change. One day's food consumption could account for 15–20 % of a consumer's total daily climate change impact⁶.

Eutrophication, nutrient pollution in water, is a global problem that has grown exponentially during the past 50 years. According to the European Environment Agency, the main source of nitrogen pollutants is run-off from agricultural land, whereas most phosphorus pollution comes from households and industry⁷. In Finland, most of the nitrogen and phosphate load in the Baltic Sea is caused by primary production. Eutrophication mainly results from animal feed production, which occupies more than half of the arable land area in the Baltic Sea region. A particular problem related to increasing sensitivity of the Baltic Sea to eutrophication is a tendency for the development of toxic cyanobacteria blooms, which can have effects on the entire food chain^{8,9}.

In addition to eutrophication, the Baltic Sea has also been exposed to extensive use of chemicals from the very beginning of the industrialization era, and it has one of the longest histories of contamination in the world¹⁰. For these reasons, the Baltic Sea has been referred to as one of the world's most polluted seas. Emissions of hazardous compounds originate from a variety of sources, including industries, households, agriculture and various additional diffuse sources. Long term emissions from construction materials, and consumer products with an extremely long life cycle, have been noticed recently. From these sources, hazardous compounds are discharged into the aquatic environment via different pathways such as urban runoff, treated effluents and atmospheric deposition¹⁰. Many "legacy" contaminants still exist in the Baltic environment due to their substantial historical use and extreme persistence (e.g. Weber et al. 2008¹¹). Once generated, they can persist in soils, sediments and waste depositories for periods extending from decades to centuries. Transport mechanisms, such as discharge and evaporation from land areas as well as

transport from contaminated soils and sediments, result in long residence times before entering the Baltic food chain.

Food choice can dramatically reduce greenhouse gas emissions³ and nutrient load of the Baltic Sea. Climate-friendly eating (reduction in meat and dairy consumption in favour of vegetables, fruit and cereals) is healthier. Westhoek et al. 2014 reported that halving the consumption of meat, dairy products and eggs in the European Union would achieve a 40 % reduction in nitrogen emissions, 25–40 % reduction in greenhouse gas emissions and 23 % per capita reduced use of cropland for food production. In addition, the dietary changes would also lower health risks¹². In Finland, the agricultural nutrient load could be reduced by 7 % by changing eating habits towards a healthier direction simply by following the official food recommendations¹⁴. According to Korkala et al. 2014¹³, increasing awareness of climate change could lead to increased consumption of climate-friendly food, reduction in greenhouse gas emissions, and thus climate change mitigation.

“The Baltic Environment, Food and Health: from Habits to Awareness – FOODWEB” project focused on public awareness about the links between food quality and its origin, focusing on the Baltic Sea and its surroundings. The cultivation of food for humans and its related production activities might cause negative impacts on the Baltic Sea. In addition, aquatic food products from the Baltic Sea may cause problems to humans as a result of toxins in the marine environment. This is a circular problem in the Baltic ecosystem¹⁴. One of the main goals of the FOODWEB project was to produce a web application “Foodplate” (<http://foodweb.ut.ee/foodplate/>) to aid estimation of food (i.e. lunch) choices while getting feedback on energy content, nutritional quality, environmental impacts and possible contaminant exposure. The aim is to compile an ideal lunch plate with the right energy content and nutritional balance, low environmental impact and low human exposure to contaminants.

The goal of this study was to test the effectiveness of the “Foodplate” application on consumers’ selection of healthy and environmentally friendly meals. The basic meal set was generated according to Finnish consumption statistics and nutritional, environmental and toxicity values of the meals were calculated using the “Foodplate” application. The results were evaluated based on the literature. The objectives were to improve further the nutritional and environmental quality of meals by increasing consumers’ selection of healthy and sustainable meal components. Three different scenarios were developed to study how slight changes in the raw material compositions of meals affect the nutritional quality, environmental impact and toxic exposure.

2. Materials and methods

We used the data and the assessment methods of the web application “Foodplate” (<http://foodweb.ut.ee/foodplate/>) to analyse the effects of food choice on health and the environment. Nutritional quality, environmental impact and toxic exposure were studied in a set of meals composed of different raw material components included in the “Foodplate” database, so that each meal was distinct. We then investigated the meal data as well as the data on the raw material components in order to examine possibilities for consumers to decide which food to eat, which to approach with caution and which to avoid, and to what extent, when seeking improvements in these goal properties of their diets. Other environmental and economic properties of the diets, such as food expenditure and other environmental impacts etc. were not considered.

We analysed dependencies among nutritional quality, environmental impacts and toxic exposure in the basic meal set, and produced estimates on how relatively slight modifications in the raw material compositions would affect the level of the three goal properties in the basic meal set. To generate the estimates we employed a scenario method for three improvement goals, namely:

- 1) to reduce the climate change impact (carbon footprint),
- 2) to increase the nutritional quality, and
- 3) to reduce toxic exposure of the diet.

For each goal a modification strategy for the raw material compositions of the basic meals was developed based on the dependencies established among the goal properties within the basic set, as well as the intensities of raw materials to increase each property calculated from the raw material data of the “Foodplate” model. Each strategy was relative and general in nature, so that they could be easily applied to all meals in the basic meal set.

For each improvement scenario we computed the effects of the modification on the actual goal property in the meal set, as well as the consequential effects on the other two goal properties. In addition to the improvement scenarios, the future trends of occurrences and possible impacts of selected hazardous compounds were evaluated based on the literature. In this part only contaminants that can end up in the environment through human activities were considered. Natural contaminants, such as nitrates, glycoalkaloids and mycotoxins, as well as contaminants formed during food production and processing, were not assessed, nor were the residues of plant protection agents, which were excluded due to insufficient information.

2.1. Basic meal set

To generate the basic meal set we used ready-made meals and modified them to match the averages of two weeks per capita consumption for the raw materials computed from the Finnish agricultural statistics for 2002 and 2011¹⁵, as well as from the results of a study on food consumption in 2007¹⁶. The consumption data for 2002 and 2011 were based on Tike's agricultural statistics (Balance sheet for food commodities, consumption of food commodities per capita, 1990–2013, and the data for 2007 on The National FINDIET Surveys conducted by The National Institute for Health and Welfare (THL). The recipes for the ready-made meals (Appendix 1) were written by The Martha Organisation (Martat) in 2013, published in 'The environment on a platter' brochure¹⁷.

These recipes, which are also the basis of the ready-made meals in the "Foodplate" tool, are all adjusted to one third of the daily energy and nutrients needs given in the Finnish Nutrition Recommendations of 2005¹⁸, taking into account the intake of energy, and fat (25–40 %), protein (10–20 %) and carbohydrates (45–60 %) in relation to the total energy intake of the meal. Thus, each meal represents a nutritional whole.

Accordingly, we composed three meals for each day in each two-week period for each reference year, resulting in a total of 126 meals with distinct compositions. Finally, we harmonised all meals for energy to meet one third of the daily energy requirement of an average 35 year old woman with a bodyweight of 63 kg and a medium level of activity. Harmonisation was achieved by changing all raw materials of each meal relatively equally so that the energy content remained constant at about 3067 kJ per meal (732 cal/meal).

The data were analysed using Statistica StatSoft software.

2.2. Methods and data for the "Foodplate" web application

The environmental impact, contaminant exposure and nutritional quality of different food plates were examined using the "Foodplate" web application. The use and background of the "Foodplate" application is described in the background paper: Web application "Foodplate – how to make reasonable choices?"¹⁹, which provides an overview of the data and methods used in the tool. In the following we discuss further the overview for the essential methods and data used to compute the energy intake, nutritional quality, environmental impact and toxic exposure, which are the main outputs of the "Foodplate" tool.

Energy intake values are based on Finnish Nutrition Recommendations 2005¹⁸ and they follow the recommendations for the Nordic countries. The total energy of the food items selected for the plate is shown relative to the recommended energy intake.

Nutritional quality shows the nutrient balance of proteins, carbohydrates, fats, sugars, salts, vitamins, minerals and microelements in the food. The nutritional data are from Fineli[®] – Finnish Food Composition Database maintained by the National Institute for Health and Welfare²⁰. The database consists of over 3700 foods and 55 nutrient factors. Nutrient values are average concentrations in Finnish foods.

We used the method developed for the “Foodplate” tool to compute the indicator values for nutritional quality. The method works on a meal basis in two phases. In the first phase intake scores are calculated for each of the nutrients taken into account in the model. Score function utilizes the data for absolute minimum intake ($I_{a,min}$), recommended minimum intake ($I_{r,min}$), recommended maximum intake ($I_{r,max}$), and absolute maximum intake ($I_{a,max}$). The “Foodplate” model includes these data for every nutrient for various consumer groups. The data were collected mainly from the Finnish food recommendations (2005), and supplemented with data from the literature and experts, accordingly. In the case that a nutrient was given only as the recommended maximum intake ($I_{r,max}$) in the literature, then zero was assigned for the recommended minimum intake ($I_{r,min}$), and the absolute minimum intake ($I_{a,min}$) was set to -1. Intake scores are then computed so that when total intake of a nutrient (I) is 1) lower than $I_{a,min}$ then the intake score is zero, 2) between $I_{a,min}$ and $I_{r,min}$ then the score is $(I - I_{a,min}) / (I_{r,min} - I_{a,min})$, 3) between $I_{r,min}$ and $I_{r,max}$ then the score is 1, and 4) between $I_{r,max}$ and $I_{a,max}$ then the score is $(I_{a,max} - I) / (I_{a,max} - I_{r,max})$, and 5) greater than $I_{a,max}$ then the score is zero. Figure 1 shows the intake score functions for sodium and fibre as an example.

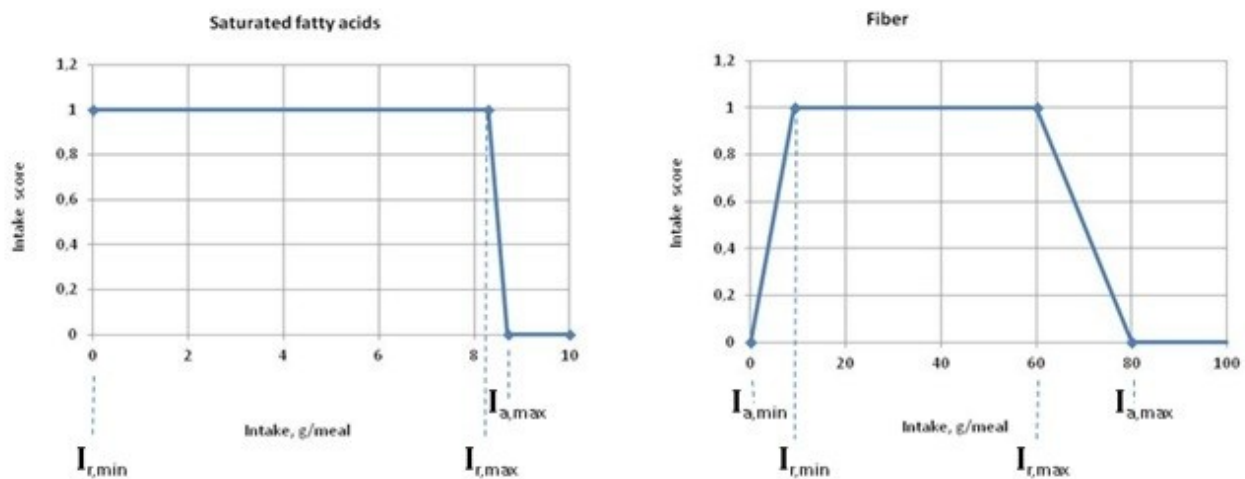


Figure 1. Intake score functions for saturated fatty acids and fibre.

In the second phase, weighted intake scores for different nutrients are summed to get the indicator for the total nutrient quality of the meal. The weight given for a nutrient describes its relative importance for the nutritional quality. In the “Foodplate” model the weights are nutrient-specific constants, i.e. the same for all meals and consumer groups. Weights given for the nutrients are shown in Figure 2.

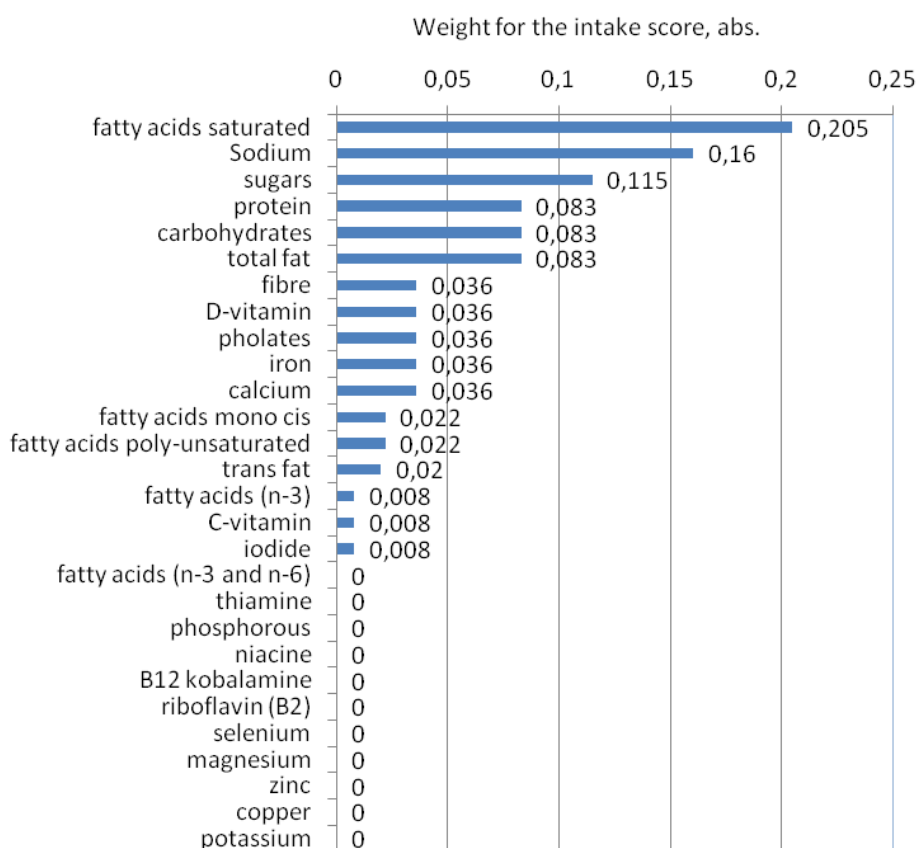


Figure 2. Weights given for the intake scores of nutrients in the “Foodplate” model.

Environmental impact indicates the impact of food production on the environment. The value is normalised and calculated as the weighted average of three factors (weighting in parentheses): CO₂ equivalent (carbon footprint) (61 %), eutrophication impact (PO₄ equivalent) on the Baltic Sea (28 %) and crop protection agents (CPA) (MCPA equivalent) applied by farming (11 %). CO₂ eq and PO₄ eq values per kg of food raw material are from LCA (lifecyle analysis) calculations made by MTT Agrifood Research Finland. Normalisation values used are 0.986 kg (CO₂ eq), 11.35 g (PO₄ eq) and 0.4847 kg (MCPA eq), and are produced by The Finnish Environment Institute (SYKE).

MCPA eq values were calculated with characterisation factors derived from the environmental impact assessment model USEtox^{TM21}. In USEtoxTM, the compound-specific characterisation factor represents the compound's potency to induce potential ecotoxic damage on aquatic organisms. The usage data for crop protection agents (CPA) were obtained from ProAgria Agricultural Plot Database (Pro Agria Lohkotietopankki) developed by the Association of ProAgria Centres. Each CPA used was converted to kg MCPA, the most commonly used crop protection agent, using the equation:

$$\text{For active ingredient } X, \text{ MCPA equivalent} = c(X) / c(\text{MCPA})$$

Where $c(X)$ is the ecotoxic value (USEtoxTM) of ingredient X and $c(\text{MCPA})$ that of MCPA, respectively.

Toxic exposure data were collected from European Food Safety Authority (EFSA) data and national contaminant data sources of the Finnish Food Safety Authority (EVIRA). The data indicate whether, and at which level, the food plate or individual food items contain certain contaminants. Contaminants taken into account in the calculation are dioxins, polychlorinated biphenyls, furans, benzo(a)pyrene, acrylamide, mercury, cadmium, lead, arsenic, organotins, perfluorooctane sulphonate (PFOS), perfluorooctanoic acid (PFOA), nitrates and the toxins aflatoxin, ochratoxin, deoxynivalenol and T2-HT2.

We used the method of the “Foodplate” model to compute the toxic exposure indicator. The method comprises two phases. In the first phase, concentrations of contaminants in each food raw material are converted into body weight (BW) units (kg BW/kg raw material) by dividing them by the TWI (Tolerable Weekly Intake) value. Human Exposure Index (HEI), which represents the joint exposure, is calculated as an average of the BW values of the contaminants multiplied by $N^{0.5}$, where N is the count of contaminants (19). In the second phase, the toxic exposure indicator is computed by multiplying the body weight values of the contaminants by the intake quantity for each raw material, and then summing the results by contaminants over the raw materials to obtain the total exposure for the meal.

2.3. Improvement scenarios

With the help of scenarios we studied how slight changes in the raw material compositions would affect the nutritional quality, environmental impact, and toxic exposure of meals. The changes should not essentially change the character of the meals, the diversity of food, or the energies of the meals. Hence, three scenarios were developed, each for a different specific goal, as described below.

Scenario 1. Reducing the climate change impact (carbon footprint) of meals

The goal for this scenario was to reduce the carbon footprints of meals. The strategy was to reduce the amounts of animal protein raw materials and increase the amounts of vegetables, carbohydrate raw materials and fish, while keeping the amounts of other raw materials unchanged. Reduction was by 15 % and the increase by a factor corresponding to the energy increase needed collectively to compensate for the energy decrease resulting from the reduction.

The strategy was justified by the CO₂ eq intensities. In the “Foodplate” database the average intensity was 0.78 g CO₂ eq/kJ for protein and milk protein raw materials of the basic meal set, and for vegetables, carbohydrate raw materials and fish 0.16 g CO₂ eq/kJ, respectively.

Scenario 2. Increasing the nutritional value of meals

The goal for the scenario was to increase the nutritional value of meals. The strategy used was to reduce the amounts of raw selected materials containing saturated fats, salt and sugar and to increase the amounts of other raw materials. Reduction was by 25 % and the increase by a factor corresponding to the energy increase needed collectively to compensate for the energy decrease due to the reduction.

The strategy was justified by the intensities of saturated fats, salt and sugar. Thus, 13 milk products were chosen for saturated fatty acid reduction, salt and four sodium-containing raw materials for sodium reduction, and sugar and five sugar-containing raw materials for sugar reduction. The selected products were all on the top of the intensity ranking in their reduction group.

Scenario 3. Decreasing the toxic exposure of meals

The goal for the scenario was to reduce toxic exposure of meals. The strategy was to reduce the amounts of raw materials with high toxic values, and to increase the amounts of other raw materials. Reduction was by 15 % and the increase by a factor corresponding to the energy increase needed collectively to compensate for the energy decrease due to the reduction.

The strategy was justified by the intensities of human exposure index (HEI). Thus, 12 raw materials were chosen for HEI reduction, including two fish raw materials, coffee, tea and salt, as well as mushrooms and six green salads and herbs, including spinach and lettuce. All selected raw materials were on the top of the HEI intensity ranking in the “Foodplate” database.

3. Analysis of the basic meal set

3.1. Energy and nutritional value

One of the most important factors affecting the health, environment and possible intake of hazardous compounds is **portion size**. Large portions of food can contribute to excess energy intake and health problems, including greater obesity²². Excessively large portions of food can also increase the intake of harmful compounds. When eating two servings of the food, the amount of calories, nutrients, and toxic compounds also doubles.

Excess energy intake also has an increasing environmental effect. Large portion sizes may lead to large quantities of food waste. Results of a Finnish food waste study, Foodspill 1, showed that one person produces an average of 23 kg of food waste annually. Households throw away a total of 120–160 million kilos of edible food per year. This corresponds to about one percent of Finland's greenhouse gas emissions²³.

Energy dense foods are high in fat and/or sugar. On the other hand, energy dilute foods are high in fibre and water, such as fruit, legumes, vegetables and whole grain cereals²⁴. Most energy intensive foods in this study were based on the amount of consumption of French fries, potato crisps, pork, broad bean, rainbow trout, flavoured yogurt, rice, spelt, and beef. Both health-promoting items and nutritionally poor options were found among these choices. Therefore, it is possible to make healthy food choices and select low energy-dense foods of high nutritional value (Figure 3). Furthermore, the amount of food consumed is important. Oils and fats are the most energy intensive foods in a diet, but a low consumption increases the nutritional quality in the total diet.

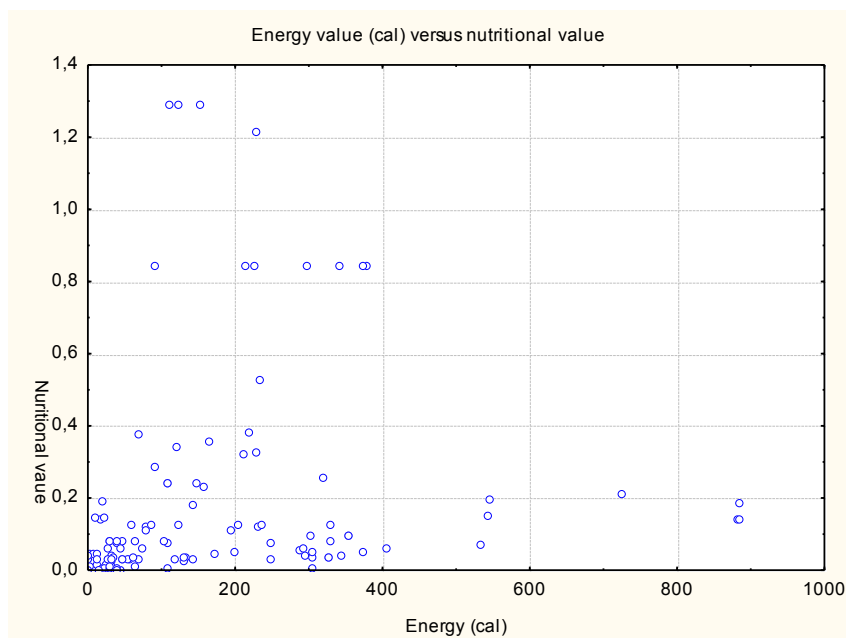


Figure 3. The amount of energy compared with nutritional value. Energy and nutritional values are expressed on a raw-material basis (100 g).

The adverse dietary changes include shifts in the structure of the diet towards a higher energy density diet with a greater role for fat and added sugars in foods, greater saturated fat intake (mostly from animal sources), reduced intakes of complex carbohydrates and dietary fibre, and reduced fruit and vegetable

intakes²⁵. The **quantity and quality of fat** in our diets can affect the development of several health conditions related to diabetes, including obesity, insulin resistance, and cardiovascular disease. Vegetable oil and soft margarine are healthier fat types than butter. Finnish and Nordic Nutrition Recommendations advocate reducing total fat and saturated fatty acids and increasing unsaturated fatty acids in a person's diet²⁶. According to the recommendations, the total amount of fat intake should be a minimum of 2/3 vegetable fat and a maximum of 1/3 animal fat. Daily energy intake should consist of 25 % to 35 % fat. The average Finnish diet includes more saturated fat and less unsaturated fat than recommended. In the "Foodplate" application, the selected fat quality changes the nutritional quality markedly. The use of animal fat is also seen as an increased environmental impact (Figure 4).



Figure 4. Olive oil is a healthier choice than butter. Olive oil contains only 25 % saturated fat while butter is composed of 57.3 % saturated fat. Olive oil has no cholesterol, while butter contains 0.18 % cholesterol²⁰.

Trans fatty acids (also known as trans fats) are another group of fats that are harmful to health. Trans fatty acids are the sum of all unsaturated fatty acids that contain one or more isolated double bonds in a trans configuration. Functionally, these resemble saturated fats, but have been proven to be more harmful to cardiac health than saturated fats. Trans fatty acids in the diet originate from two sources. The first is from bacterial hydrogenation in the fore stomach of ruminants, which produces trans fatty acids that are found in beef fat, milk and butter. Trans fatty acids are also produced from the hydrogenation of liquid oils (mainly of vegetable origin). However, since the mid-1990s, many countries around the world have started to move away from using partially hydrogenated oils. This led to the production of new margarine varieties that contain less or no trans fat. Hardened vegetable fats, used in dairy cream substitutes, for example, and in baking margarines and vegetable fat ice cream, may contain trans fatty acids²⁷.

The recommended **intake level of salt** is 5 g/day, according to the Finnish Nutrition Recommendations, while according to the Nordic recommendations it is a little higher, 6 g/day. Sodium plays an essential role in the transmission of nerve impulses, and the regulation of osmotic pressure in the body. Sodium is also required for muscle function. Consuming too much salt is associated with adverse health effects and chronic diseases²⁸. If consumers have to choose between two meals, comparing the amount of salt helps them to select the healthier option. The most important dietary sources of salt are bread, cheese, sausages and other meat products, soups and sauces, and prepared and semi-prepared foods. Excessive salt use is seen in the "Foodweb" application immediately as reduced nutritional value (Figure 5).

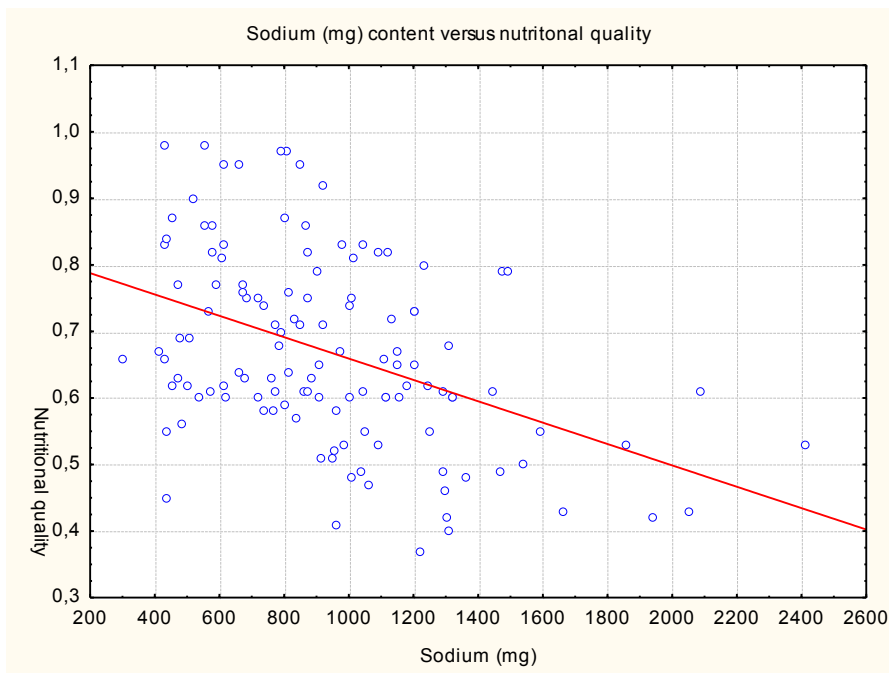


Figure 5. Excess sodium intake reduces the nutritional value of basic meals. The salt content of meals can be calculated multiplying sodium content by 2.5. Sodium content and nutritional quality are expressed on a whole meal basis.

Most countries recommend a limited **sugar intake**. Reduced consumption of beverages and foods with added sugar is especially recommended. According to the Finnish Nutrition Recommendations, less than 10 % of energy intake should be derived from sugar. In addition, Nordic recommendations also favour selecting foods that are low in sugar, and eating refined sugar sparingly, and limiting the frequency of intake of sugary drinks and sweets. High consumption of beverages with added sugars is linked to an increased risk of type-2 diabetes and excess weight gain²⁶. Excess sugar intake is shown in the “Foodplate” application as an increased energy value.

Plant foods such as **vegetables, fruits and berries, nuts and seeds, and whole grain cereals** are a fundamental part of a healthy diet. They are rich in dietary fibre and include plenty of protective nutrients like vitamins, minerals and antioxidants. The new Finnish Nutrition Recommendations (published 2014) recommend the consumption of vegetables, berries and fruits be increased to half a kilo per day instead of the 400 g recommended earlier (2005) and as in the Nordic Nutrition Recommendations²⁹. Finns eat a variety of fruits and vegetables, but insufficient amounts according to the dietary recommendations. However, the consumption of fruits and vegetables has increased markedly during recent years. According to the National FINDIET 2012 Survey, the daily intake of fruits, vegetables, berries and legumes was, on average, over 400 g among women and slightly less than 400 g among men³⁰. According to the Agricultural Statistics for the total consumption of fruits and vegetables per person, the share of citrus fruits was 11 %, other fresh fruits 32 %, fruit preserves and dried fruit 6 %, and fresh vegetables 51 %³³. Lowering the food-based energy density by increasing fruit and/or vegetable intake is associated with significant weight loss. Furthermore, there is strong scientific evidence that natural fibre-rich plant foods contribute to a decreased risk of diseases such as hypertension, cardiovascular diseases, type-2 diabetes, and some forms of cancer^{26,31}.

According to the Finnish Nutrition Recommendations, women should get at least 25 g and men 35 g of **fibre** a day. Finns get too little fibre from the food they eat, on average only 21 g per day. Grain products, especially rye bread, are the most common sources of fibre for Finns. Soluble fibre reduces the cholesterol level in blood, contributes to a healthy digestive system, balances blood sugar, and helps to control weight. Fibre, when regularly eaten, reduces the risk of coronary artery disease and diabetes mellitus type 2. Nutrient fibre also has some cancer-preventing qualities³². Adding ingredients high in dietary fibre to meals is seen as increased nutritional value in the “Foodplate” application (Figure 6).

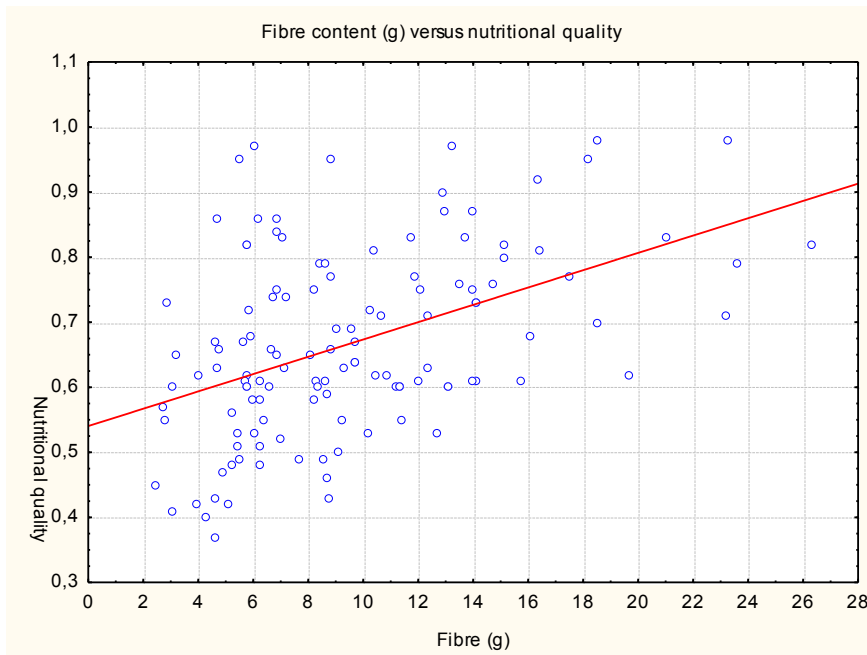


Figure 6. Fibre-rich meals contribute to increased nutritional value of basic meals. Fibre content and nutritional quality are expressed on a whole meal basis.

Foods such as **meat, dairy, and eggs** provide important protein and minerals in the diet. Because meat and dairy are also major contributors of saturated fatty acids, high-fat products should be exchanged for low-fat dairy and low-fat meat alternatives according to the Finnish Nutrition Recommendations of 2007. In the new 2014 recommendations, reducing **meat consumption** is recommended. Finns eat almost 1.5 kg meat a week³³ and that amount is triple the recommendations of the World Cancer Research Fund and the American Institute for Cancer Research. The recommendation to people who eat red meat is to consume less than 500 g a week, and very little if any of it should be processed. Those recommendations stated that meat can be a valuable source of nutrients, in particular protein, iron, zinc, and vitamin B12. The panel emphasised that the overall recommendation is not for diets containing no meat or diets containing no foods of animal origin. The public health goal was for the population average consumption of red meat to be no more than 300 g a week, and, again, very little if any of it processed³⁴. The consumption of red meats (beef, pork and mutton) and especially that of processed meat (such as ham, bacon, sausages, hamburgers, salami, corned beef and canned meat) should be reduced according to the new National 2014 recommendations²⁹. High consumption of processed meat increases the risk of colorectal cancer, type-2 diabetes, obesity, and coronary heart disease. Similar, but weaker, associations have been recorded for red meat. Replacing processed and red meat with vegetarian alternatives (such as pulses), fish, or poultry reduces the risk of diseases²⁹. In the “Foodplate” application, comparing different meals shows that an

increased amount of saturated fatty acid decreases the nutritional value (Figure 7). Also the use of processed meat is seen as a decreased nutritional value (Figure 8).

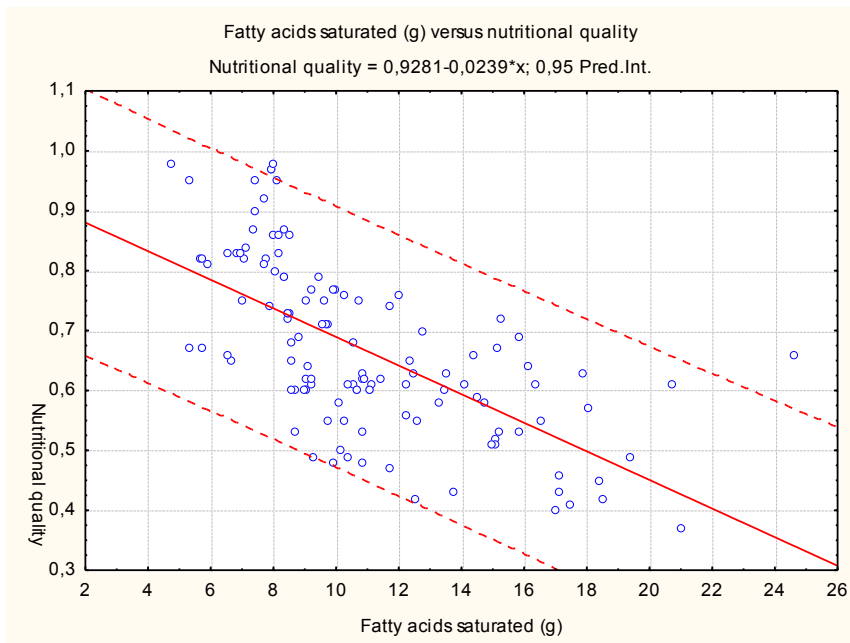


Figure 7. The nutritional quality of analysed basic meals decreased as the amount of saturated fatty acids increased. The values are expressed on a whole meal basis.



Figure 8. Limited processed meat consumption will improve the nutritional quality of a meal.

Milk and dairy products play a key role in the Finnish diet. Milk is an important source of protein, calcium, nutrients and many vitamins. In the past ten years milk consumption has dropped by 25 litres per capita. During recent years the decline has been 1–2 % annually, but consumption of cheese, yoghurt and ice-cream has increased. Cheese consumption was just over 23 kilos per capita in 2013. Per capita consumption of liquid dairy products totalled 180 kilos in 2013. Average per capita milk consumption in Finland in 2013 was slightly over 129 litres. About half of this was low-fat milk, 40 % skimmed milk and 10 % whole milk³³. Finnish nutrition recommendations favour low-fat dairy products. Skimmed milk, low-fat sour milk and water are recommended drinks with meals. Milk and milk products are main sources of calcium. High consumption of low-fat milk products has been associated with reduced risk of hypertension, stroke, and

type-2 diabetes. In Finland, margarines were fortified with vitamins A and D since the 1950s, but this procedure had too little impact on vitamin D intake. Finland began to fortify milk with vitamin D in 2003. Fortifying milk has been an effective way of increasing the population's vitamin D levels¹⁸. In the “Foodplate” model the use of milk as a drink with a meal increased the nutritional quality. It is also possible to select soy or an oat drink in the application as a recommended vegan or lactose-free alternative to dairy milk (Figure 9).



Figure 9. Skimmed milk and unsweetened soy milk are of similar nutritional quality. However, the environmental impacts of dairy products are higher.

Fish is a recommended food, and consumption of fish should be increased. Fish fat includes numerous long and chained fatty acids with various double bonds, i.e. omega 3 fatty acids, which are not found in other foods. Fish also contains several vitamins and minerals and a lot of protein. Fish is an especially good source of vitamin D (Figure 10). The useful fatty acids contained in fish have been shown to reduce the risk of cardiovascular diseases and to benefit foetal development²⁶.

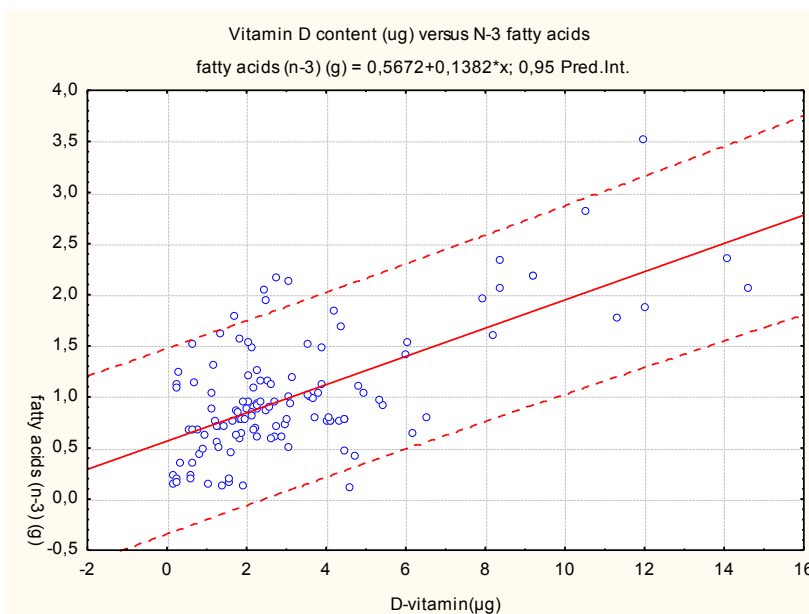


Figure 10. Vitamin D content contributed to the increased fatty acids (n-3) value of basic meals. Fish was the main source of vitamin D and omega 3 fatty acids in basic meals. Fortified milk was also a valuable source of vitamin D. Plant oils are a good source of omega 3 fatty acids. The values are expressed on a whole meal basis.

In Finland, it is recommended to eat fish at least twice a week and to vary fish species in the diet. There is a special recommendation regarding fish consumption because contamination from the Baltic Sea is a problematic issue. Pregnant women in particular are advised to avoid certain fish species, such as pike, and to limit the consumption of large Baltic Sea herring and salmon due to the concentrations of potentially toxic chemical compounds in them³⁵. There are no consistent differences between wild and farmed fish in terms of safety and nutritional value, except for Baltic salmon, according to the EFSA. Frequent consumers of fatty fish coming from the Baltic Sea, i.e. Baltic herring and wild Baltic salmon, are more likely to exceed the PTWI (provisional tolerable weekly intake) for dioxins and dioxin-like PCBs than other consumers of fatty fish. On average, Baltic herring and wild Baltic salmon are respectively 3.5 and 5 times more contaminated with dioxin and dioxin-like PCBs when compared with non-Baltic herring and farmed salmon³⁶.

In the “Foodplate” application the contamination of fish, especially the fish caught from the Baltic Sea, the levels of dioxins, PCB compounds and methyl mercury accumulated result in a high toxic exposure value. On the other hand, the nutritional value of fish dishes is better than for meat-containing meals (Figure 11). Of the selected fish, salmon and rainbow trout have a lower toxic value because these farmed fish are less contaminated than those caught from the wild. Taking into account the current recommendations, it is possible to achieve the nutritional benefits and limit the toxic exposure.

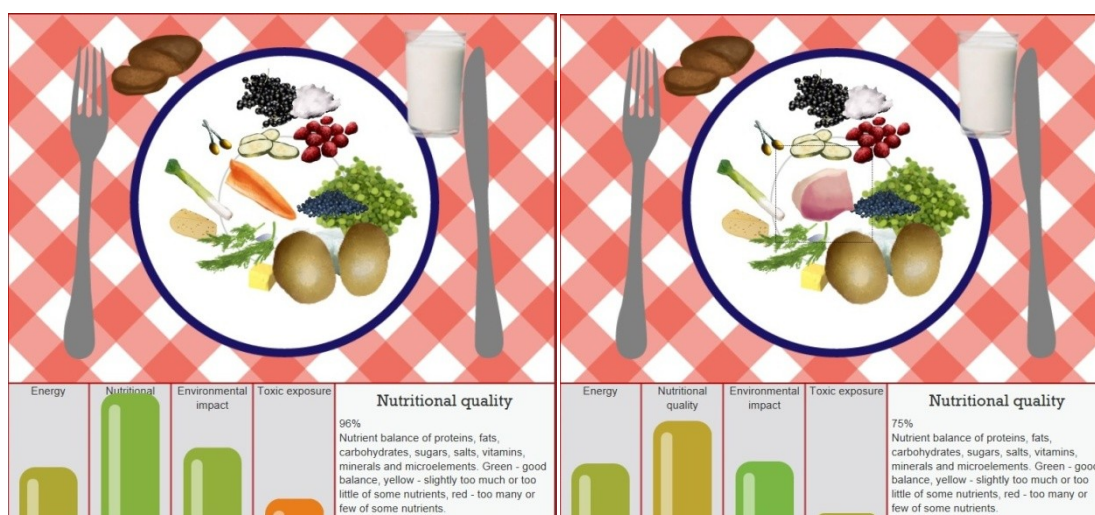


Figure 11. The health benefits of fish are seen in better nutritional value. The same basic meal provides different nutritional values depending on whether the protein source is fish or meat.

Using the “Foodplate” web application, it is possible to select nutritionally balanced meals. Although the application is not very sensitive to changes in nutritional value, it gives a good base from which to design healthy meals based on the Finnish or Nordic Nutrition Recommendations. Saturated fatty acids and the amount of salt and sugar used affect the nutritional quality of meals the most. These factors are also associated with adverse health effects according to nutritional recommendations. In addition, an emphasis on ample intake of fibre-rich foods like fruits and vegetables and whole grain cereals, frequent consumption of fish, and sufficient share of unsaturated fats are highly recommended and are shown in the “Foodplate” application as an increased nutritional value.

3.2. Environmental impacts

3.2.1. CO₂ – the carbon footprint

The carbon footprint of food indicates the amount of greenhouse gas emissions released into the atmosphere during the production, transport, storage and processing of a product. Carbon dioxide equivalent (CO₂ eq, carbon footprint) describes the potential for global warming of a given amount of a greenhouse gas. The primary greenhouse gases are carbon dioxide CO₂, methane CH₄ and nitrous oxide N₂O.

The amount of greenhouse gases caused by the production of food differs very significantly among food types. As an example, the environmental impact of fruits, berries and vegetables varies greatly depending on how and where they are grown. Vegetables grown on open land have a lower environmental effect than vegetables that are cultivated in greenhouses³⁷. Domestically grown root vegetables have the lowest carbon dioxide emissions per kilo, under 0.4 kg CO₂ eq/kg. Increasing consumption of fruits and vegetables in the diet reduces environmental impact markedly. In addition, seasonal fruits, vegetables and berries are the basis of an environmentally friendly meal.

Potatoes and cereal products (pasta, bread and grains) have a low environmental impact because of their high yield per unit area³⁸. Potatoes in particular have lower greenhouse gas emissions (under 1 kg CO₂ eq/kg). Rice is the only exception, with various research placing its carbon footprint at anywhere from 2.5 to 6 kg CO₂ eq/kg. Rice that is grown in flooded paddies releases about 5–20 % of the total CH₄ emissions from anthropogenic sources and therefore affects the climate more than other cereals and potatoes^{37,39}.

The production of meat has the highest environmental impact of all food items. Animal production accounts for almost a fifth of the world's total greenhouse gas emissions⁴⁰. Cattle and sheep, as ruminants, generate particularly large quantities of greenhouse gases (15–40 kg greenhouse gases/kg meat) because of their digestive systems. Pigs and poultry generate lower emissions (approximately 5 and 2 kg greenhouse gases/kg meat, respectively)³⁷. On the other hand, cattle graze on grass that people cannot eat, and grass binds nutrients in the soil and prevents their runoff into waters. According to Virtanen et al. (2011) livestock contributed to three quarters of Finland's total climate change impact from agriculture. Methane emissions from beef and dairy cattle had the greatest impact on climate change. This means that the most effective way to reduce environmental impacts would be to limit the consumption of meat (Figure 12).

Dairy farming contributes to the emission of greenhouse gases. Although, emissions from milk are less than 2 kg CO₂ eq/kg⁴¹, production of cheese generates a high carbon footprint. Approximately 10 litres of milk are needed to make one kilo of cheese, which increases cheese's carbon footprint by more than 10 kg CO₂ eq/kg. Fats, margarine and rapeseed oil have the lowest environmental impacts, about 1 kg CO₂ eq/kg. The environmental impact of olive oil is less than that of butter, which has a carbon footprint of about 4.8 kg CO₂ eq/kg. Reducing the consumption of dairy products, especially cheese, reduces emission of CO₂.

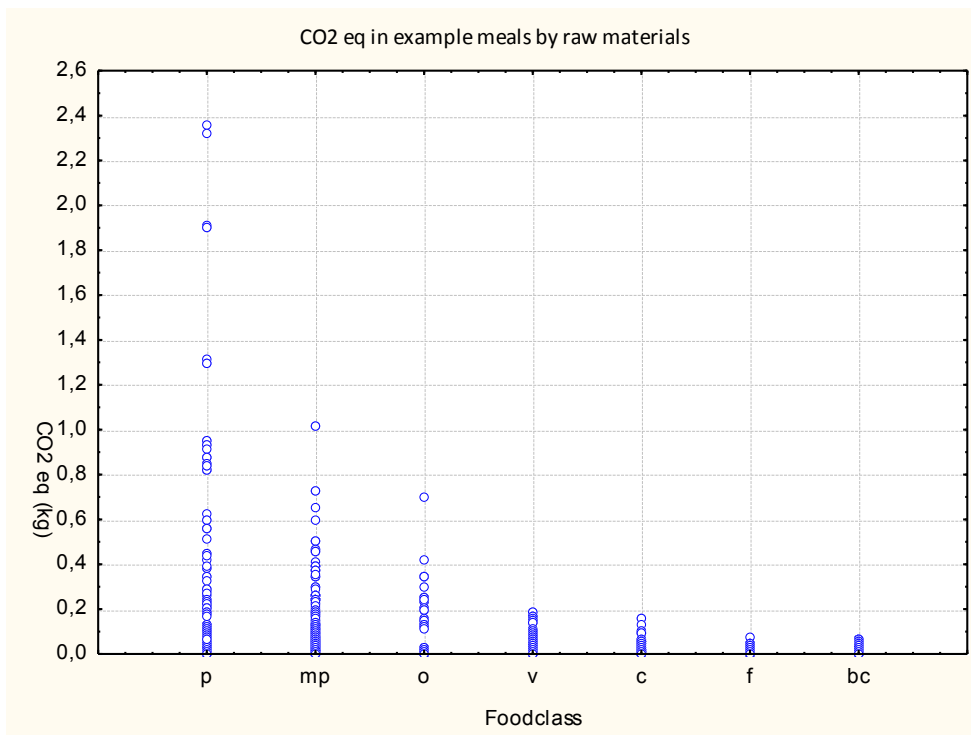


Figure 12. Animal production has the highest carbon footprint of all food items in the basic meals. Increasing consumption of plant-based protein foods such as nuts, seeds, lentils, beans, peas and tofu, could reduce human impact on the environment⁴². Different food plates are expressed in raw food material classes (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates).

Domestic fish is an excellent environmentally friendly choice. The size of the carbon footprint depends on the origin of the fish. Wild fish also do not consume fish feed, so their environmental effects are smaller than those of farmed fish. Pike and Baltic herring, for example, are environmentally friendly choices. Environmental impacts of different fish products might be quite variable. Rainbow trout is economically the most important cultivated fish in Finland and its carbon footprint is lower than that of meat products. Compared with beef, farmed rainbow trout in Finland has one sixth of the carbon footprint. The environmental impact of rainbow trout has fallen by about a fifth over the last ten years. This is mostly the result of a more efficient use of feed⁴³.

The carbon footprints of different food products differ considerably. The animal based products, beef, pork, cheese and butter, are associated with high greenhouse gas emissions. However, high CO₂ emissions for plant-based foods have been reported for products that are produced in heated greenhouses. Hence, increasing the consumption of low carbon footprint food items, potatoes and vegetables, is a practical way to mitigate climate change¹³.

3.2.2. Eutrophication impact (PO₄) on the Baltic Sea

Eutrophication is a state where high nutrient concentrations stimulate the growth of aquatic algae, which leads to imbalance in the ecosystem. Eutrophication represents a rapidly growing environmental crisis and is one of the main threats to biodiversity in the Baltic Sea. Nitrogen and phosphorus loads are the main cause of the eutrophication in the Baltic Sea. About 80 % of all nutrients in the sea come from land-based activities, including sewage treatment, generation of industrial and municipal waste and agricultural runoff. The Baltic Sea now contains four times the amount of nitrogen and eight times that of phosphorus as it did in the early 1900s. High area-specific nitrogen and phosphorus loads are related to high levels of agricultural activity, including large-scale intensive livestock farming as well as the intensive use of fertilizers in specialized conventional farming systems⁴⁴.

Eutrophication potential, the impact of 1 kg of phosphorous contamination in the water, is described by phosphate equivalents (PO₄ eq). Fertilizer runoffs from crop cultivation are the main sources of nutrient emissions in the food chain. When calculating PO₄ eq, N (water), P (water), NH⁴⁺ (water), NH₃ (air) and NO_x (air) releases are taken into account by multiplying by the equivalent coefficients of 0.42, 3.06, 0.18375, 0.04025 and 0.01495 respectively.

The eutrophication intensity varies among different foodstuffs: beef has the highest eutrophication intensity of all meats (51.5 g PO₄ eq/kg), about three times higher than that of pork (15.4 g PO₄ eq/kg), and seven times that of poultry (7.1 g PO₄ eq/kg)¹⁴. About 75 % of nitrogen and 52 % of phosphorus come from agriculture and the livestock sector. The biggest problem is industrialized animal production, which produces more manure than can be absorbed by proximal crop production⁴⁵. However, such problems could be minimised through Ecological Recycling Agriculture (ERA)⁴⁶.

The eutrophication intensity of milk is relatively low (3.3 g PO₄ eq/kg)¹⁴. Nevertheless, the values associated with beef and milk are partly bound together since a significant share of beef comes from milking cows. Although the eutrophication intensity of milk production is not particularly high, milk production is one of the main agricultural activities, and thus has large production volumes, which are reflected in the substantial contribution to the total eutrophication impact.

The eutrophication impacts of plants also vary among species: grain has the highest intensity of the plant-based raw materials (5 g PO₄ eq/kg). In general, plant-based materials have about five times lower eutrophication intensities than those that are animal based¹⁴.

Catching fish in the wild removes nutrients from the waters and reduces eutrophication, but the numbers are reversed when calculating the effects of farmed rainbow trout (Figure 13). One kilo of farmed rainbow trout has triple the eutrophication impact of one kilo of beef, and quadruple that of one kilo of pork. However, the environmental impact of rainbow trout has fallen by about a fifth over the last ten years as a result of more efficient use of feed⁴³.

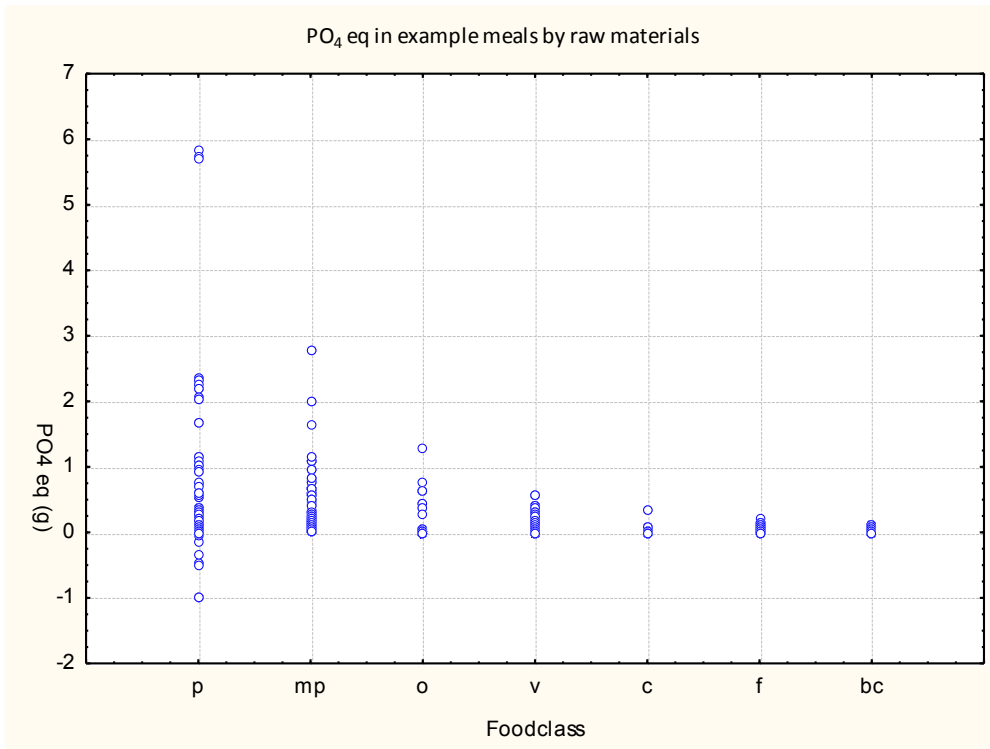


Figure 13. Fish caught in the wild reduce eutrophication (negative value at class p) while farmed fish have the opposite effect (highest value at class p). Different food plates are expressed by food raw materials (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates).

3.2.3. Ecotoxicity (MCPA eq)

MCPA equivalent is an indicator of freshwater ecotoxicity, estimating the use of pesticides, or more precisely plant protection products (ppp), during food production. In Finland, pesticide use is low by European standards, averaging 0.8 kg per hectare per annum. The cooler climate reduces the amount of plant pests and diseases in Finland, but increasing survival rates of harmful pests and diseases over the Finnish winter due to climate change will increase the use of plant protection products⁵⁰.

The most commonly used pesticides in Finland are herbicides (killing harmful plants or plant parts or preventing undesired plant growth), accounting for some 77 % of active ingredients sold in 2013⁴⁷. In addition, 16.4 % of plant protection products were used to protect plants or plant products against harmful organisms (insecticides and fungicides) and 14.7 % of plant protection products were growth regulators (influencing the life processes of plants, other than as a nutrient). The total sale of plant protection products in Finland was 1475.4 tonnes in 2013⁴⁸.

Glyphosate and MCPA are the most commonly used herbicides in Finland. Glyphosate (N-[phosphonomethyl]glycine) is a non-selective systemic herbicide registered for use on many food and non-food crops. Glyphosate's primary action is the inhibition of the enzyme involved in the synthesis of the aromatic amino acids tyrosine, tryptophan and phenylalanine. MCPA is a selective, systemic, hormone-type herbicide belonging to the phenoxyacetic acid family. It is used to control annual and perennial weeds in cereals, grassland and turf⁴⁹.

Despite pesticide use in agriculture only according to needs, pesticide use increases 'chemicalisation' of the environment. Products that are toxic to aquatic organisms may not be used within a specific safety clearance from water bodies, while those harmful to soil organisms may not be used repeatedly in the same field and products that can be mobile may not be used in groundwater areas⁵⁰. The impact on the environment caused by pesticides depends on their stability, climatic and soil conditions and type of farming practised. Some pesticides used may end up in the water bodies. The Baltic Sea in particular is vulnerable to the impact of human activities because a drainage area four times as large as the sea itself surrounds it.

The analysis of basic meals showed that the highest MCPA eq values were found in potato products (c class), beer (o class), rainbow trout (p class) and milk (mp class) (Figure 14). Both potato and barley production may require intensive pesticide use to combat plant diseases.

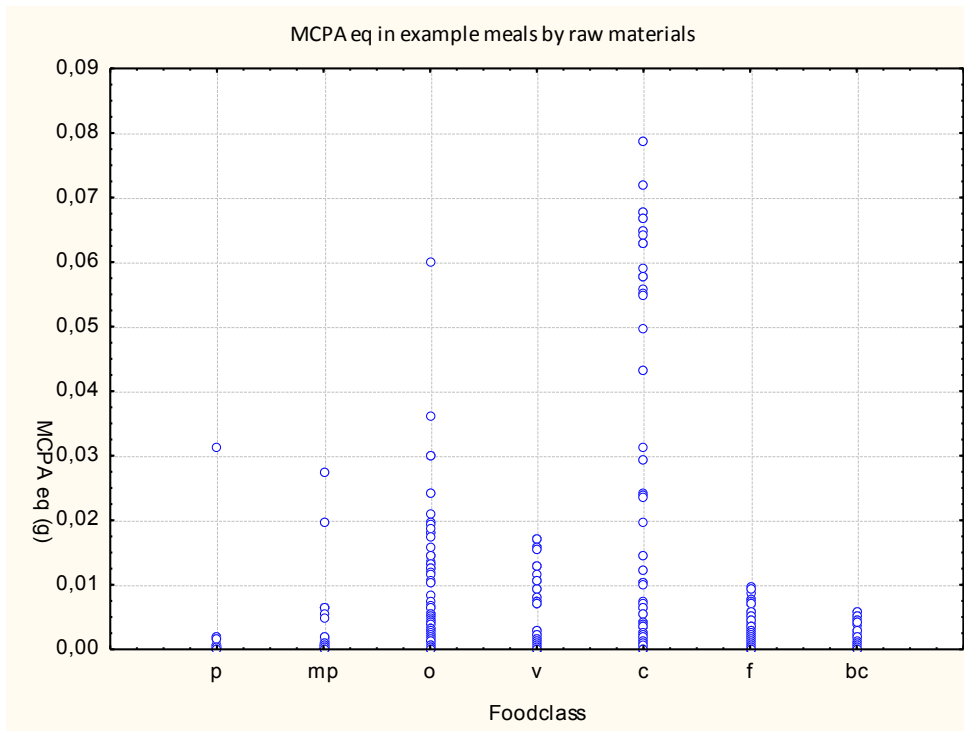


Figure 14. The highest potential ecotoxicity risk measured as MCPA equivalent stemming from ppp use was found for potato products (c class), beer (o class), rainbow trout (p class) and milk (mp class). Different food plates are expressed as food raw materials (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates).

The most widely used fungicides against potato late blight are fluazinam and mancozeb⁵¹. Late blight is one of the most devastating diseases of potato worldwide. Malting barley is one of the principal ingredients in the manufacture of beer. In Finland, typical diseases barley are spot diseases, powdery mildews, and various other fungal diseases. Treatments with plant protection products may be necessary at any stage of development of the crop to combat pests, weeds and fungal diseases⁵². Prochloraz is a broad-spectrum contact imidazol fungicide that is widely used in Europe against several cereal diseases⁵³. Production of animal feed may also require the use of plant protection products.

Human exposure to harmful compounds is discussed in Section 3.3.

3.2.4. Weighted environmental impact

The weighted environmental impact indicates the impact of total food production on the environment, including carbon footprint (61 %), eutrophication impact on the Baltic Sea (28 %) and use of pesticides (MCPA eq) during food production (11 %).

The analysis of basic meals showed that the highest weighted environmental impact values were for meat products (p class) and milk products (mp class) (Figure 15). Beef, rainbow trout, pork, chicken, milk and cheese showed the highest environmental impact of the all raw materials. The high weighted environmental impact of meat and milk products is due to the large carbon footprint and the eutrophication impact of these products. Fish farming has a substantial impact on eutrophication that increases the weighted environmental impact. Also, the amount of food consumed was a major factor affecting the environmental impact of the meal. In Finland, the consumption of milk and milk products is one of the highest in Europe and the consumption of meat and meat products exceeds Finnish nutrition recommendations⁵⁴.

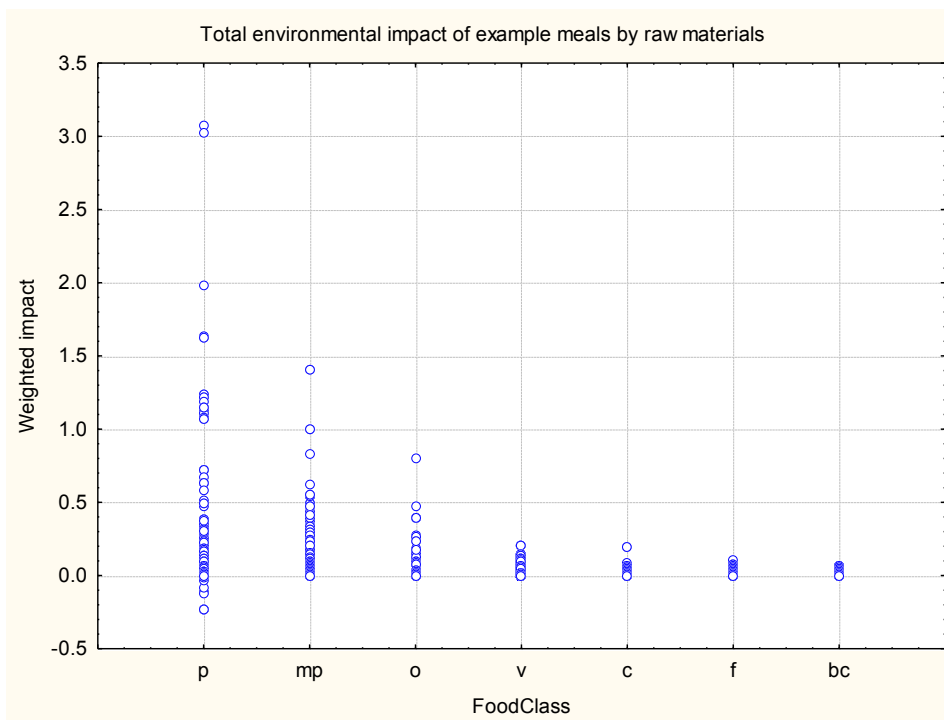


Figure 15. Beef has the highest environmental impact of all food items of the basic meals. Different food plates are expressed as food raw materials classes (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates).

A good correlation was established between carbon footprint and eutrophication value (Figure 16). The main reasons for this are, firstly, plant production, which is involved in the chains of all essential food raw materials, and is a major source of greenhouse gas emissions and nutrient runoffs, and secondly, livestock production, which is involved in all meals of the basic set with an energy share varying from 12 % to 65 % of the total energy of the meal. CO₂ emissions due to use of fossil energy, direct and indirect emissions of nitrous oxide, and the methane emissions from enteric digestion and manure management are related to feed use (Hermansen et al. 2013⁵⁵). Feed use, in turn, depends directly on the energy content of animal products. Due to metabolic losses, the energy content of the feed used is much greater than that stored in animals. Hence, the importance of the feed production for climate change and eutrophication impact of livestock production is emphasized, and the correlation between these impacts remains strong, even though the methane emissions from enteric digestion and manure management tend to reduce it to some extent.

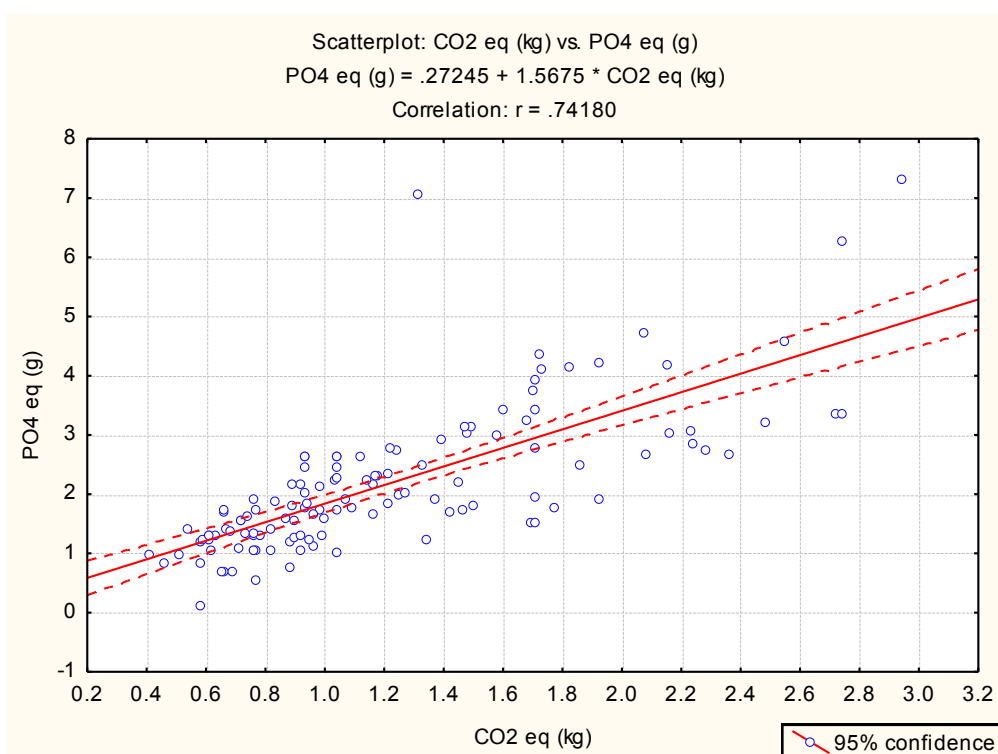


Figure 16. Increasing carbon emissions correlated positively with eutrophication impact. The values represent the total impacts of each basic meal.

3.3. Toxic exposure

People can be exposed to toxic chemicals through the food they consume. Food contamination can originate from the natural environment, farming and partly from food processing. It can also occur further down the food chain, such as through eating contaminated fish. Many foods contain toxins as naturally occurring constituents. Although the risk for toxicity due to consumption of food toxins is fairly low, there are some food items consumers should pay special attention to⁵⁶.

3.3.1. Contaminants

The consumption of salmon, sea trout, river lamprey and large herring caught in the Baltic Sea may expose people to higher than normal amounts of industrial pollutants that are damaging to health: **dioxins, dioxin-like PCB (DL -PCB) compounds and non-dioxin-like compounds (NDL-PCB)**. Dioxins and PCBs may cause endocrinological disorders. At high levels they are carcinogenic. The accumulation of dioxins and PCB compounds in fish varies among species and habitats. Levels of dioxins and PCB compounds are low in lake fish and farmed fish (rainbow trout and Atlantic salmon). In polluted areas, however, freshwater fish can also contain high levels⁵⁷.

It is estimated that 95 % of human exposure to dioxins comes from the diet (food of animal origin, particularly with meat, dairy products and fish) and human breast milk. Choosing a balanced diet that is low in saturated fats and total fats from animal sources helps consumers minimize any potential exposure to dioxin from food because dioxins are found mostly in animal fats (due to their fat soluble properties)⁵⁶. The main sources of dioxin and dioxin-like compounds in basic meals analysed with the “Foodplate” application were Baltic herring (especially when smoked) and other fish species (trout, salmon, rainbow trout, pike, flounder, perch). The contamination through meat and dairy products was minimal (Figure 17).

Furans and acrylamide are process contaminants and produced naturally in food during manufacturing or home cooking. They are absent in the raw foods or raw materials used to make the food, and are only formed when components within the raw foods or raw materials undergo chemical changes during processing.

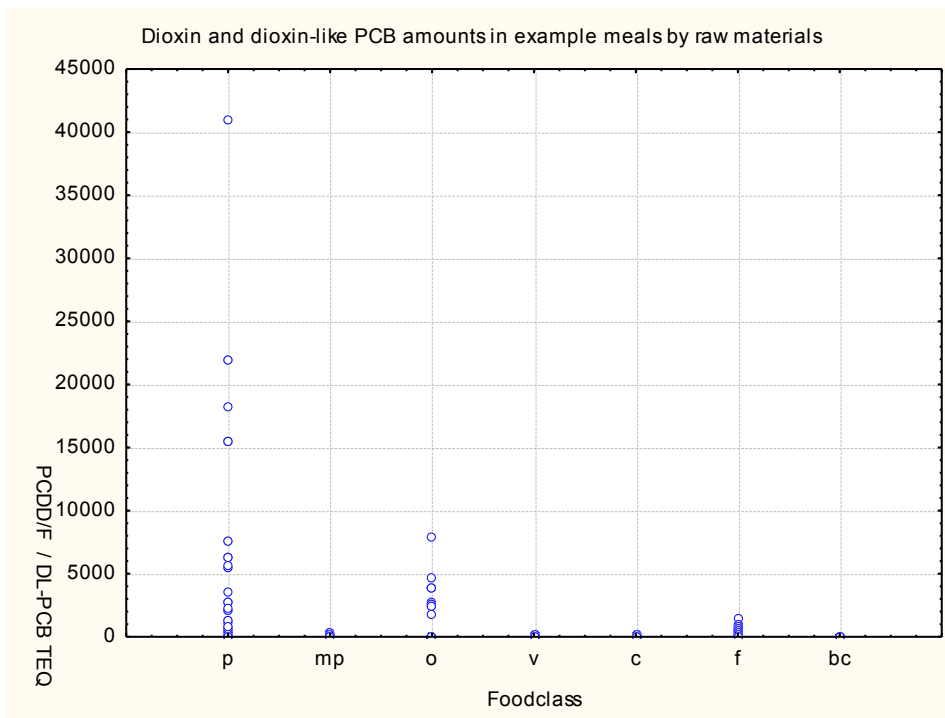


Figure 17. The highest levels of PCDD/F and dl-PCBs in basic meals expressed on a raw-material basis (g/bw) were recorded for fish (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates). Values are normalized as tolerable weekly intake (twi) values.

Acrylamide is formed when foods containing the natural amino acid asparagine and sugars are heated at temperatures above 120°C, including in breads, bakery products, breakfast cereals, and potato products (e.g., crisps, French fries). It is also found in cocoa-based products and coffee. It is less likely to occur in foods processed by boiling or steaming. Acrylamide has been proven to be genotoxic (affecting the genetic material) and to cause cancer in laboratory animals. There is only limited information about whether it causes cancer in humans, but the International Agency for Research on Cancer (IARC) categorizes acrylamide as being probably carcinogenic in humans⁵⁸. Exposure to acrylamide can be reduced by avoiding deep-fried foods, soaking potato slices before cooking, cooking French fries at lower temperatures and to a lighter colour, and toasting bread to a lighter colour⁵⁹.

Furan is formed in food during roasting, frying and canning as a result of the thermal degradation of carbohydrates, oxidation of polyunsaturated fatty acids or decomposition of amino acids. Furan is cytotoxic and carcinogenic in the livers of rats and mice. It is possibly carcinogenic to humans according to the IARC. An estimate of the furan intake for Danish adults revealed that 95 % is from consumption of coffee, whereas the food group contributing most to Danish children's intake of furan is breakfast cereals⁶⁰. Furan has been detected in different types of foods, especially in coffee and jarred meals for babies. Breakfast cereals and dry bread products may have relatively high levels of furan. Furthermore, biscuits, snacks, and sun-dried fruits and vegetables contain furan⁵⁶. The main ingredients of basic meals containing furan using the "Foodplate" application were coffee, milk powder, beer, fish fillets, pork steak and chicken fillet (Figure 18). The amount of furan in beer is misleading because the "Foodplate" application used the general value of furans for all beverages.

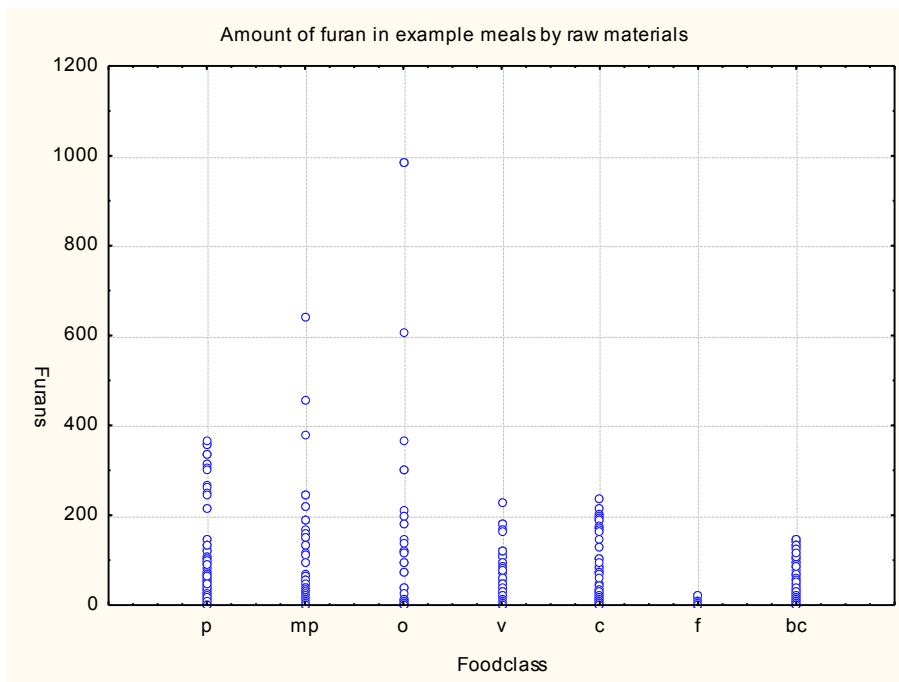


Figure 18. According to basic meals the food group contributing most to the intake of furan (g/BW) is coffee. Finns are among the biggest coffee consumers in the world. Other contributors of furan included beer and milk powder (p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates). Values are normalized as tolerable weekly intake (twi) values.

Glycoalkaloids, such as solanine and chaconine in potatoes and tomatine in raw tomatoes, are natural toxic compounds produced as pesticides by plants. α -Solanine is also found in eggplant, apples, bell peppers, cherries, sugar beets and tomatoes. Glycoalkaloids are toxic to humans if consumed in high concentrations. Exposure of potatoes to light in the field or marketplace can lead to glycoalkaloid concentrations that are unsafe for human consumption⁶¹. Glycoalkaloids do not accumulate in the body, and are not destroyed by heat. Symptoms of glycoalkaloid toxicity in humans include gastrointestinal disturbances and neurological disorders⁵⁶. The basic meals contained only minimal amounts of glycoalkaloids if potatoes were used as ingredients.

The highest intake of **nitrates** comes from natural sources such as vegetables, culinary herbs (parsley, dill, basil, thyme, and salad rocket) and water. Therefore, the intake of nitrates can be relatively high if the consumption of vegetables, especially leafy vegetables such as salads and spinach or beetroot, is high^{62, 63}. These foods showed the highest values also in the basic meals expressed on a raw-material basis. Washing, peeling and cooking vegetables lowers nitrate content in most cases. In 2008, the European Food Safety Authority (EFSA) estimated that by eating fruit and vegetables according to the recommendations, the health benefits would be greater than any adverse impact possibly caused by exceeding the ADI for nitrates on a temporary basis⁶⁴.

The most common **Fusarium** toxins produced by various mycotoxins include T-2 and HT-2 toxins, deoxynivalenol (DON), nivalenole and zearalenone. Fusarium toxins are commonly found in cereals, particularly in oat (Figure 19). Long-term exposure to Fusarium toxins may cause adverse effects in animals and humans, such as weakening of the immune system. Not all the effects of long-term exposure are

known at present. The symptoms induced in acute poisoning include nausea, vomiting and stomach pain^{65,66}.

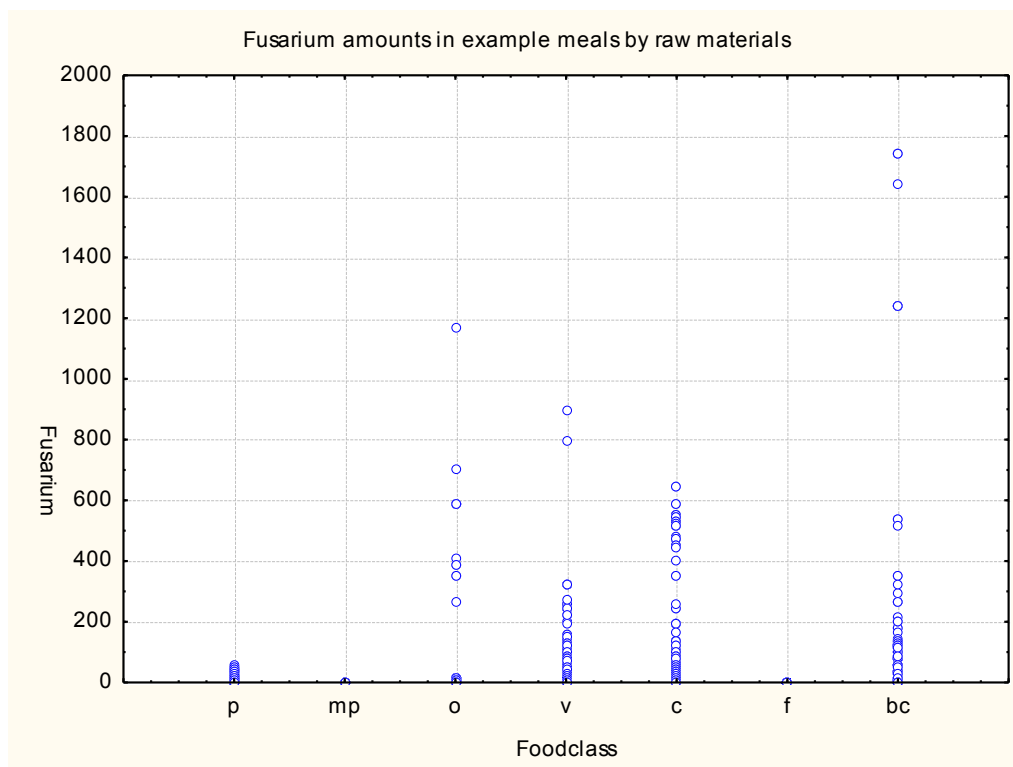


Figure 19. The highest amounts of fusarium toxin T-2/ HT-2 in basic meals expressed on a raw-material basis were found in cereal products (bc class), beer (o class) and maize (v class). Classification: p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates. Values are normalized as tolerable weekly intake (twi) values.

Polycyclic aromatic hydrocarbons (PAHs) have been shown to be toxic and carcinogenic in laboratory animals and are formed as a result of incomplete combustion of fossil fuels such as coal, wood and crude oil. There are several hundred PAHs, the best known and most harmful being benzo[a]pyrene. PAHs can enter the food chain from environmental contamination, industrial food processing or from home cooking (especially smoking, frying and barbecuing meat and fish)⁶⁷. Foods containing the highest concentrations of PAHs include cooked or smoked meat and fish, smoked and cured cheese, tea and roasted coffee⁶¹. Milk will normally not contain high levels of PAHs. However, high milk in the basic meals was one of the main sources of PAHs.

Heavy metals are the most serious environmental contaminants because they are so stable. They accumulate at the top of the food chain. Humans are mainly exposed to heavy metals through food and drinking water. Although levels of heavy metals have decreased, they are still a threat to human health and the environment. Dietary intake of many heavy metals through consumption of plants has long-term detrimental effects on human health⁶⁸.

Cadmium (Cd) occurs naturally in the environment in its inorganic form as a result of volcanic emissions and weathering of rocks. Cadmium is used in many technological applications and is released into the environment mainly through anthropogenic activities like smelting, burning of fossil fuels, incineration of waste materials and the use of phosphate and sewage sludge fertilizers. Cadmium is toxic for both plants

and animals. Cadmium can also enter the food chain from water and through agricultural soils. Compounds of cadmium are more soluble than those of other heavy metals, so are easily taken up by plants and accumulate in various edible plant parts⁶⁹. Cadmium is found in foods such as cereals, cereal products, vegetables, nuts, pulses, potatoes, meat, meat products, fish, smoked fish, seafood and fungi. Cadmium also causes groundwater, surface water and soil pollution. It has been shown to be toxic to cattle, earthworms and aquatic organisms, especially freshwater organisms such as molluscs, lobsters and fish.

Lead occurs naturally in the environment, but it is also used in technological processes (e.g. mining, smelting, processing pigments, batteries, ceramics, electricity and heat generation, combustion of waste, using leaded fuel in the past etc.). Routes of exposure to lead may occur via contaminated food, water (e.g. lead pipes), soil, dust and air. Food sources of lead include fish, cereal products, potatoes, vegetables and drinking water. Effects of lead on the environment are manifold. Lead causes groundwater, surface water, soil and air pollution. Lead is a carcinogen and poisoning can cause a number of adverse human health effects. Lead is absorbed more in children than in adults and accumulates in soft tissues (e.g. liver, kidneys) and bone tissue with age. Lead affects every system in the body, including the blood, cardiovascular, renal, endocrine, gastrointestinal, immune, reproductive and central nervous systems (particularly the developing brain)⁷⁰.

Arsenic is a ubiquitous metalloid present at low concentrations in rocks, soil and natural groundwater. In natural groundwater, arsenic is typically present in inorganic forms; organic forms are rare in water as they are the result of biological activity. Although dermal and inhalation exposure is possible, food and drinking water are the principal routes. Continuous low-level exposure to arsenic is associated with skin, vascular and nervous system disorders. According to the EFSA⁷¹, the main contributor to dietary exposure to inorganic arsenic was wheat bread, rice, milk and dairy products (main contributor in infants and toddlers), and drinking water. Arsenic in root crops is a result of both soil uptake and atmospheric deposition. Other possible dietary sources are meat, chicken, juice, juice concentrates, crab, lobster, shellfish, fish, smoked fish and seafood, including seaweed.

Mercury is emitted into the environment from a number of natural (volcanic activity) and anthropogenic sources. Methyl-Hg is formed naturally mainly in the freshwater and marine environments. Methyl mercury is highly toxic, particularly to the nervous system, and the developing brain is thought to be the most sensitive target organ to methyl mercury toxicity. It can also damage kidneys, causes depression, irritability, memory disturbance and spasms. The major potential dietary sources of exposure to methyl mercury are fish and seafood. Also, globally, air and water exposure pathways are considered to contribute little to the daily intake of Methyl-Hg⁷².

3.3.2. Human exposure index (HEI)

Human exposure index (HEI) indicates whether the food plate or individual food items contain particular contaminants. The value expresses the joint intake of 19 contaminants per tolerable weekly intake.

The analysis of basic meals showed that the highest HEI values were in potato products (c class), smoked Baltic herring (p class), rainbow trout (p class), beer (o class) and lettuce (v class) (Figure 20). High HEI values for potato and potato products are possibly due to formation of acrylamide during processing and accumulation of cadmium. Consuming smoked Baltic herring and rainbow trout can increase exposure to dioxins, PCBs and mercury. Cadmium and nitrate concentration in lettuce plants may be elevated. Beer also has high HEI values because of the possible formation of furan during processing. The large volumes of beer consumed with basic meals increased the HEI value significantly.

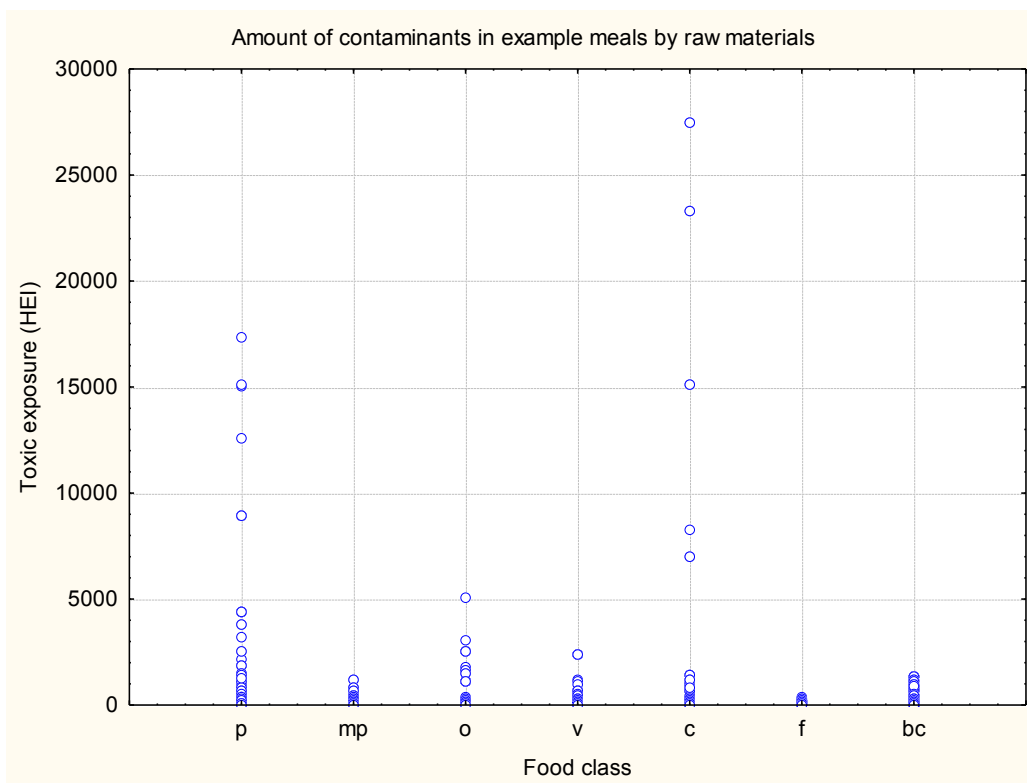


Figure 20. The highest HEI values (g/bw) in basic meals expressed on a raw material basis were in potato products (c class). Classification: p = proteins, mp = milk proteins, o = other, v = vegetables, c = carbohydrates, f = fats, bc = bread carbohydrates.

4. Scenarios for food consumption

4.1. The overall impact factors of basic meals

Comparing nutritional values of basic meals with environmental impact and toxin exposure (Figure 21), it was found that exposure to harmful compounds (red area in foreground) increased if the meals included wild fish as a raw material. The nutritionally rich food plates (green area in foreground) contained mainly vegetable and fibre-rich foods served with fruit and bread as side dishes. The nutritional value of meals decreased mostly if the recipe included added sugars, salt (sodium) and saturated fat, in ready-made meals known as 'hidden ingredients'.

High environmental impact meals (rear sector yellow and green area) generally included beef. The nutritional value of meals was reduced if sugar-containing soft drinks were included (left rear sector, green area). A wide range of raw materials was also found in all nutritionally/environmentally/toxicologically rich/poor areas of the meal set, including meat. The amount of raw material consumed and how versatile raw materials were was also important. In other words, by using a wide range of raw materials it is possible to design nutritionally rich and environmentally friendly lunch plates.

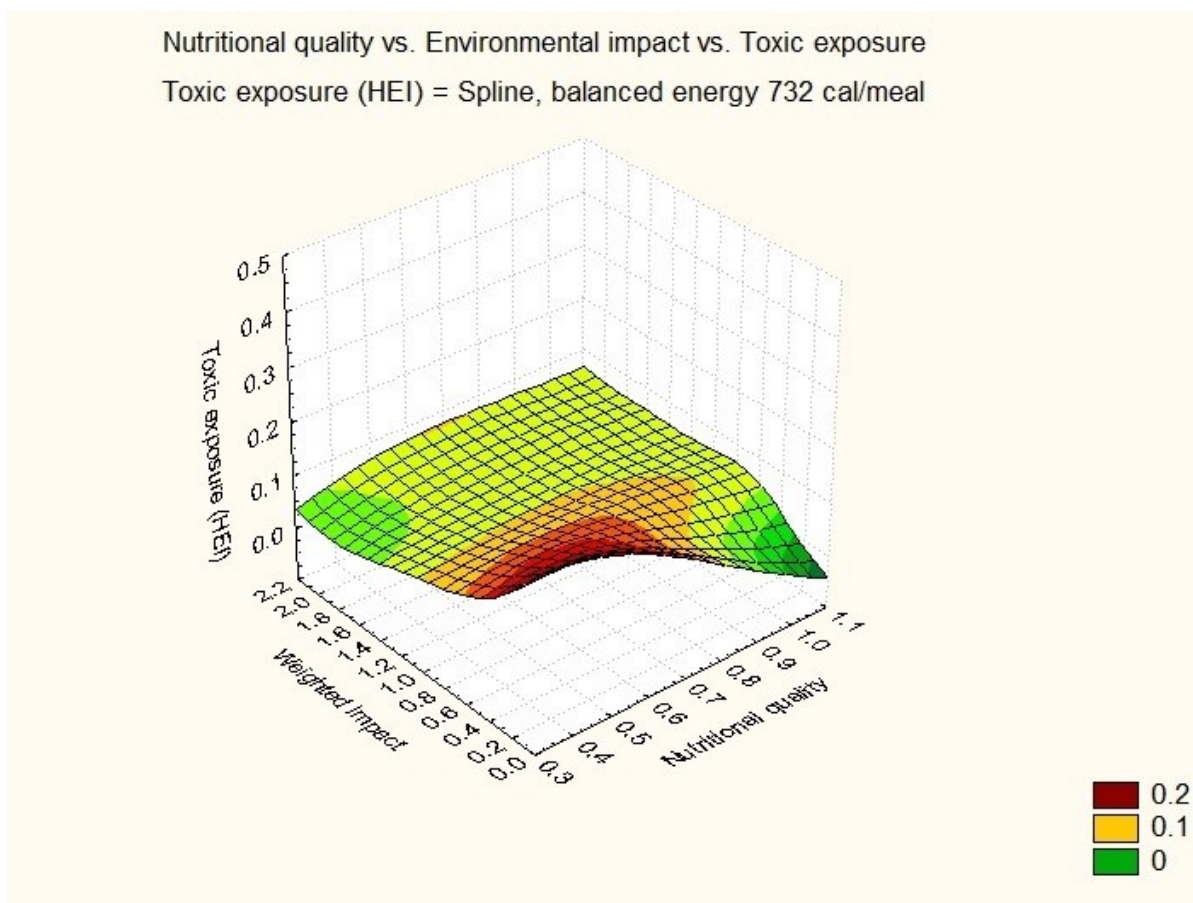


Figure 21. Healthy and environmentally rich meals can be composed by selecting a wide variety of foods and avoiding a single ingredient in large quantities.

When the nutritional values of basic meals were compared with ecotoxicity (MCPA eq) and toxic exposure (HEI) values, the result showed the highest MCPA eq and HEI to be associated with meals including fish or meat with potatoes (and if beer was included). However, the uncertainty in the ecotoxicity data is considerable. Relevant data were not available for all raw materials.

Comparing nutritional values for the basic meals with carbon footprints and eutrophication impact values indicated that meals containing beef and milk products had the highest impacts (Figure 22, red area). Nutritional values for these meals were relatively high. Lowest impacts (Figure 22, green area) for respective nutritional values were for meals with diverse raw materials, including vegetables, bread, potato, milk products, beef, pork, chicken, eggs etc. In general, these meals were not based on a single dominant raw material. A wide range of raw materials in meals seems to be advantageous when striving for lower carbon footprints and reduced eutrophication impact of diets.

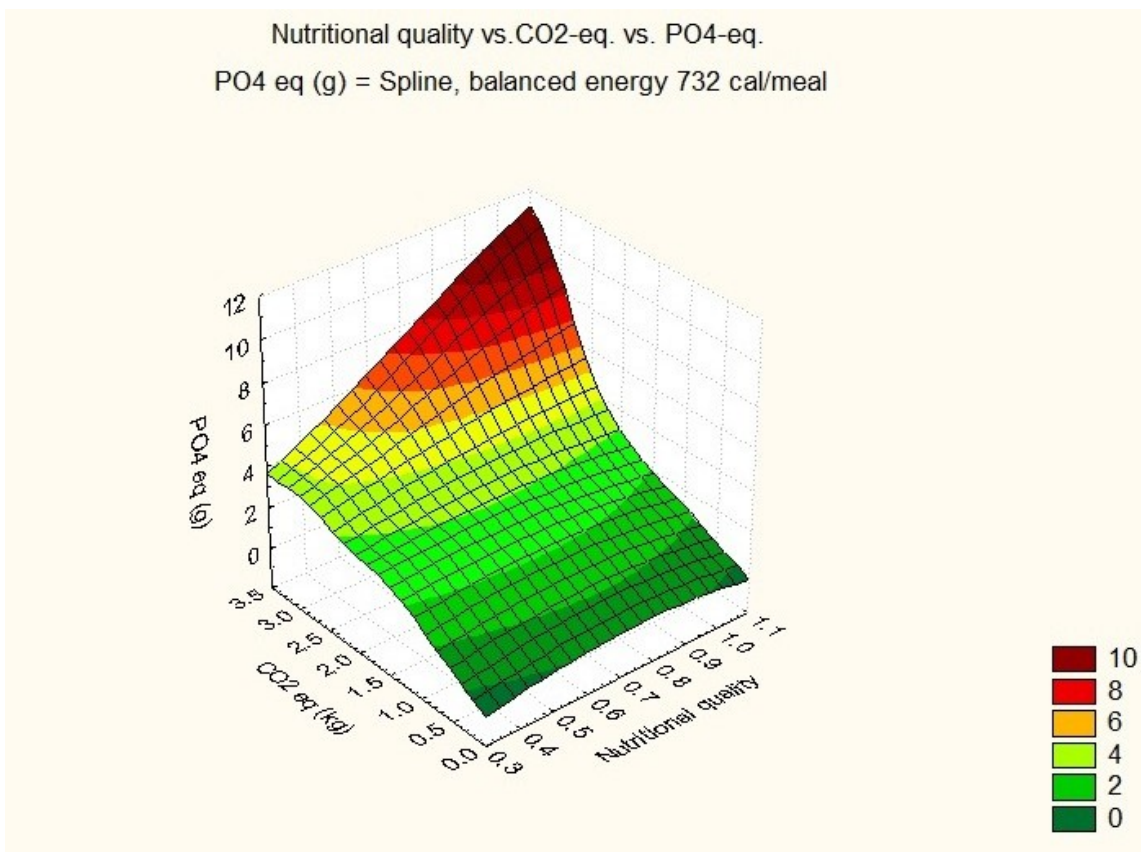


Figure 22. Meals containing milk and meat based products had the highest carbon footprint and eutrophication intensity values.

4.2. Overall impact factors of the modified meals

The major future challenge regarding dietary change is to increase nutritional quality and reduce environmental impact and toxic exposure of food. The first two challenges largely relate to increase in the intake of fruit, vegetables and whole grain cereals, and decrease in the consumption of meat products. Accordingly, three scenarios were analysed to study the balance of nutritional value, environmental impact and toxic exposure.

Scenario 1. Decreasing the carbon footprint of meals

Target: The carbon footprints of the meals will be lessened by reducing the amount of animal protein raw materials and by increasing the amount of vegetables, carbohydrates and fish. The amounts of other raw materials will remain the same.

Result: According to the “Foodplate” model, under constant total energy of a meal, a 15 % shift from the energy of animal protein raw materials to carbohydrate and vegetable raw materials would, on average, increase the nutritional value by about 6 %, reduce the climate change impact indicator (CO₂ eq) by about 8 %, the eutrophication impact indicator (PO₄ eq) by about 10 %, and the weighted overall impact (environmental impact) indicator by about 8 %. The ecotoxic impact indicator (toxic exposure) would increase by about 9 % (Figure 23).

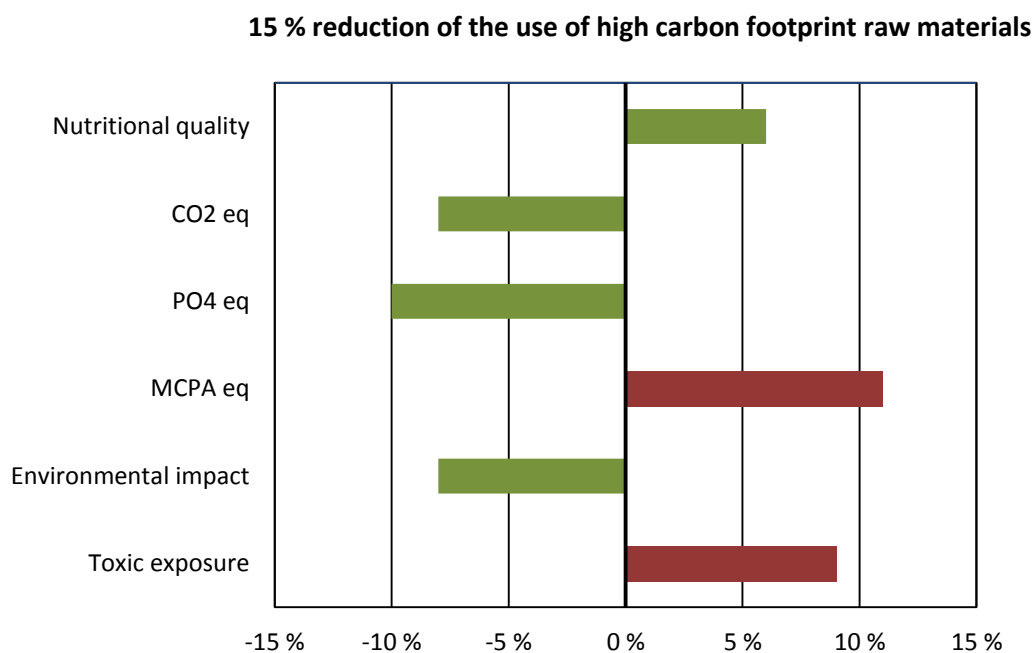


Figure 23. The impact of consumption changes for the CO₂ reduction scenario.

The CO₂ modified basic meals consisted of 15 % reduction in the consumption of meat protein and milk protein raw materials (especially beef, pork, chicken, cheese and milk), which was compensated for by a higher intake of vegetables, carbohydrates (including bread carbohydrates) and fish protein ingredients. The amount of raw materials classified as fat and other groups remained the same. The reductions and increases were based on the energy content of the raw materials. The 15 % decreases in raw materials did not change the composition of the whole meal significantly.

These changes in consumption increased the nutritional value of the meals and reduced the environmental impact (Figure 24). The intake of harmful compounds may increase due to the use of pesticides when producing plant based raw materials or more highly contaminated fish caught from the Baltic Sea.

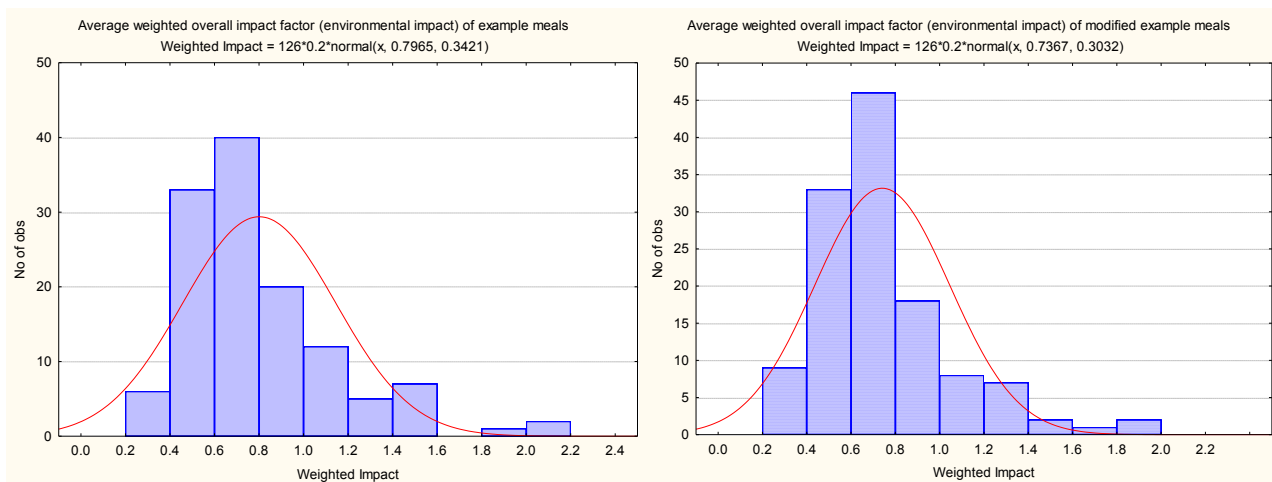


Figure 24. Distribution of the weighted overall impact factor (environmental impact) of basic meals before and after modification.

Scenario 2: Increasing the nutritional value of meals

Target: The nutritional value of meals will be increased by reducing the amount of saturated fats, salt and sugar-containing raw materials. The amount of other raw materials will be increased to balance the energy content of meals.

Result: According to the “Foodplate” model, under the constant total energy of a meal, a 25 % shift from the energy of saturated fats, salt and sugar-containing raw materials to other raw materials in the meals, such as protein, fibre-rich carbohydrate and vegetable raw materials, would, on average, increase the nutritional value by 12 %, reduce the climate change impact indicator (CO₂ eq) by about 3 %, the eutrophication impact indicator (PO₄ eq) by about 2 %, and the weighted overall impact indicator by about 3 %. The ecotoxicity impact indicator would increase by about 4 % (Figure 25).

25 % increase of the use of high nutritional raw materials

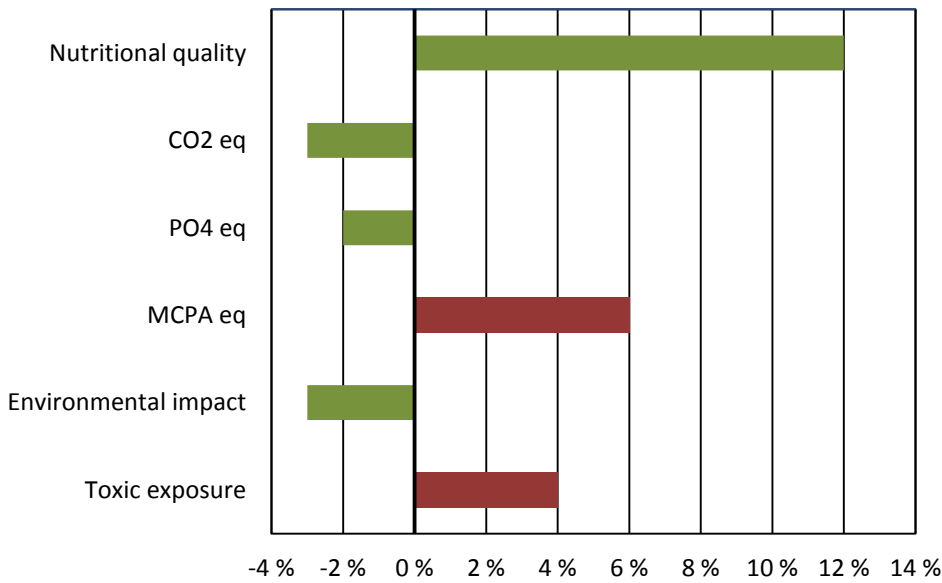


Figure 25. The impacts of consumption change for the increased nutrition scenario.

The nutritionally modified basic meals included 25% reduction in the consumption of butter, cream, cheese, milk, pork, French fries, salt and sugar, which was compensated for by increasing the amount of other raw materials to balance the energy content of the meals. The 25% decreases for those nutritionally poor ingredients did not change the composition of the whole meal significantly.

The changes in consumption increased the nutritional value of the meals markedly (Figure 26), and reduced the environmental impact slightly. The intake of harmful compounds may increase when the consumption of vegetables and fish increases.

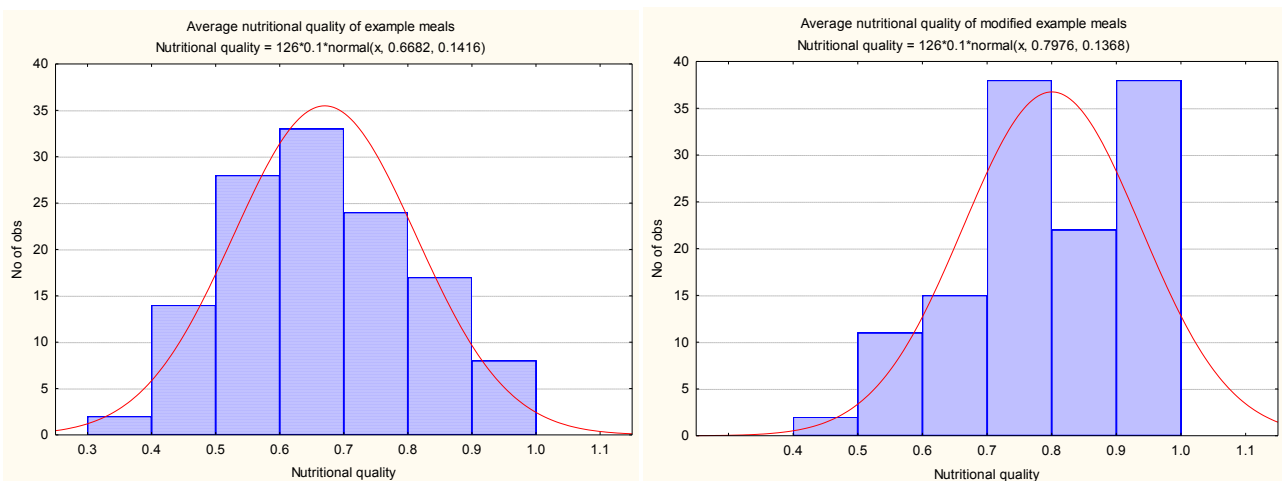


Figure 26. Distribution of the nutritional quality of basic meals before and after modification.

Scenario 3. Decreasing the toxic exposure of meals

Target: The nutritional value of meals will be increased by reducing the amount of raw materials with high toxicity values. The amount of other raw materials will be increased to balance the energy content of meals.

Result: According to the “Foodplate” model, under the constant total energy of a meal, a 15 % shift from the energy of high toxic exposure raw materials to protein, carbohydrate and vegetable raw materials would, on average, increase the nutritional value by 2 %, decrease the climate change impact indicator (CO₂ eq) by about 0.5 %, increase the eutrophication impact indicator (PO₄ eq) by about 1 %, and decrease the weighted overall impact indicator by about 0.5 %. The ecotoxicity impact indicator would decrease by about 4 % (Figure 27).

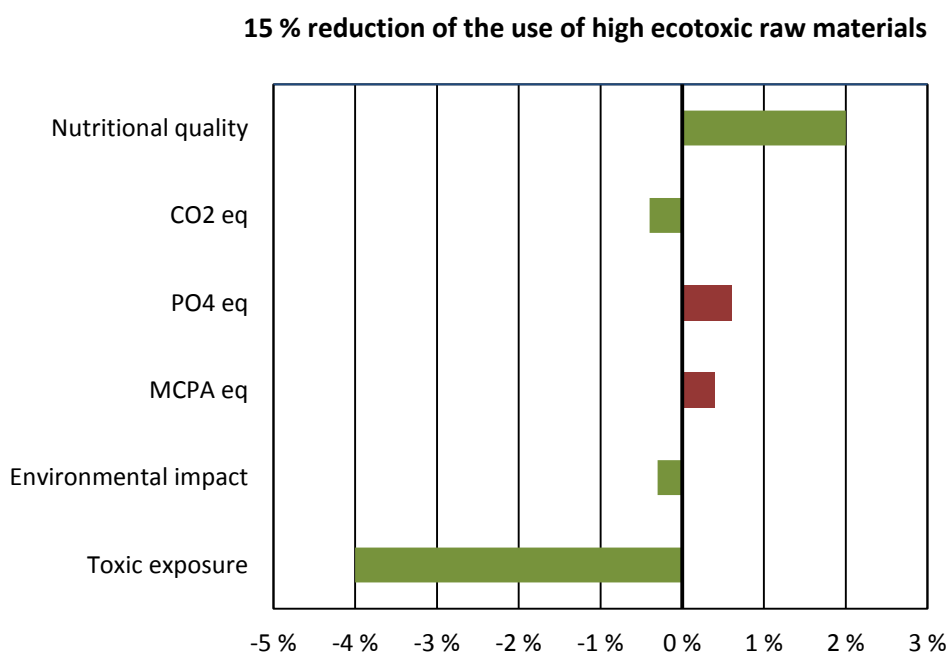


Figure 27. The impacts of consumption change for the toxicity reduction scenario.

The high toxicity modified basic meals comprised a 15 % reduction in the consumption of smoked Baltic herring, fish, salt, herbs, coffee and lettuce, which was compensated for by a higher intake of other raw materials to balance the energy content of the raw materials. The 15 % decreases in raw materials did not change the composition of the whole meal significantly.

The dietary changes increased nutritional value of the meals slightly. The consumption change did not show a significant impact on the environmental load. The intake of harmful compounds decreased considerably (Figure 28).

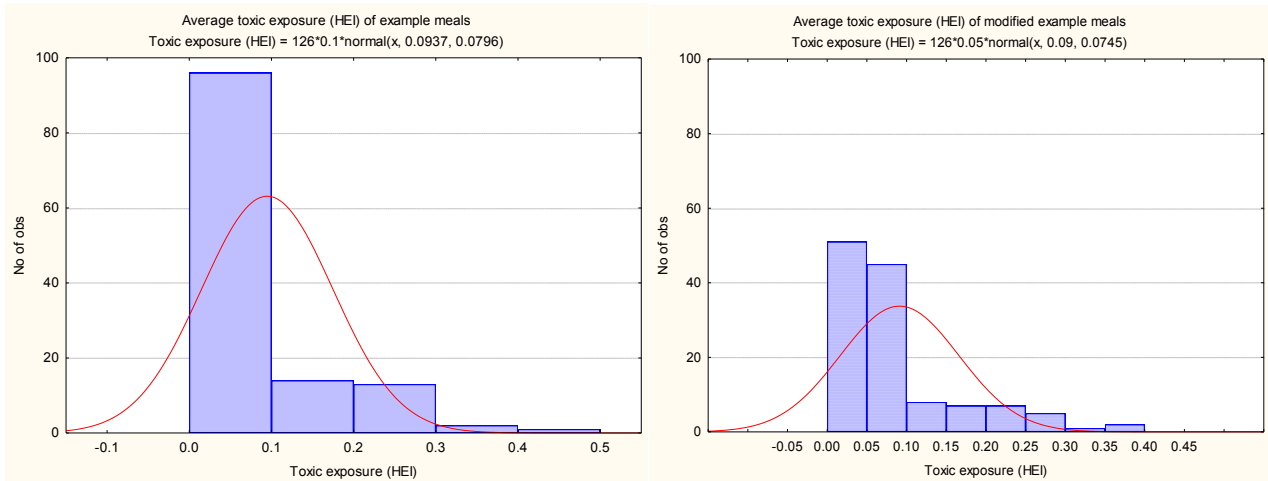


Figure 28. Distribution of the toxic exposure of basic meals before and after modification.

5. Scenario for some hazardous compounds for the Baltic Sea

Emissions of some hazardous compounds released during human activity originate from industries, municipalities, agriculture, landfills and from the use of sludge. Waste waters from the industrial sector and municipalities are purified but waste water treatment plants were originally designed to remove only nutrients and solid substances, not such a wide variety of chemical compounds, which is why POPs in particular are discharged into the marine environment in effluent.

Atmospheric emissions from traffic, shipping, energy production, incineration of wastes and even small-scale household combustion are important sources of some hazardous compounds. From these sources, they can enter the Baltic Sea and its drainage area via deposition. In 2006 almost half of the lead inputs into the Baltic Sea and quarter of the mercury originated from atmospheric deposition. Thus deposition is the major contributor of some heavy metals, and also of dioxins and many other POPs, to pollution of the Baltic Sea.

Some persistent compounds can also be transported from their original emission sources and end up in the Baltic Sea (HELCOM 2010⁷³). It has been estimated that 60 % of cadmium, 84 % of lead and 79 % of mercury deposited in the Baltic Sea originate from distant sources, mainly the UK, France, Belgium and the Czech Republic. In addition, several POPs can be transported long distances in the atmosphere. For example, in the case of dioxins it has been estimated that 60 % of the deposition in the Baltic Sea originates from outside the catchment area. Accordingly, emission reductions for POPs and some heavy metals should be implemented on a broad scale, and in some cases globally.

Within the framework of the Helsinki Convention (HELCOM) restrictions on production of the standard POPs and heavy metals have been implemented by the Baltic Sea countries since the late 1970s. In 2007 HELCOM adopted the so-called HELCOM Baltic Sea Action Plan (BSAP), including targets for the reduction of contaminant concentrations in biota close to natural levels and to make all fish safe to eat. Atmospheric mercury, lead and cadmium emissions have also been regulated by the UN ECE Protocol on heavy metals under the Convention on Long-Range Transboundary Air Pollution since 1998. Persistent organic pollutants; PCBs, DDT, dioxins, some brominated flame retardants and fluorinated compounds are included in the Stockholm Convention on Persistent Organic Pollutants (POP Convention), and a new convention on mercury (Minamata Convention on Mercury) was agreed in 2013 under the United Nations Environmental Programme (UNEP). Moreover, the EU parliament has adopted special strategies to control dioxin, PCB and mercury contamination in its territory. Releases of POPs and heavy metals from industrial installations are regulated by the IPPC Directive and Waste Incineration Directive. Actions are targeted to ensure decrease of these pollutants in the environment as well as in food and feed, and accordingly to reduce human exposure to these contaminants.

As a result of measures taken to reduce discharges of polychlorinated biphenyls (PCB) and dichlorodiphenyltrichloroethane (DDT) into the environment, concentrations of these compounds show significant declining trends in herring, perch and mussels in several regions surrounding the Baltic Sea (Figure 29 as one example). The decreasing levels of these classic contaminants have positively influenced the populations of marine predators, of which several suffered from reproductive disorders. However, although PCB is generally decreasing, elevated levels at some locations in the Baltic are still occasionally reported⁷⁴.

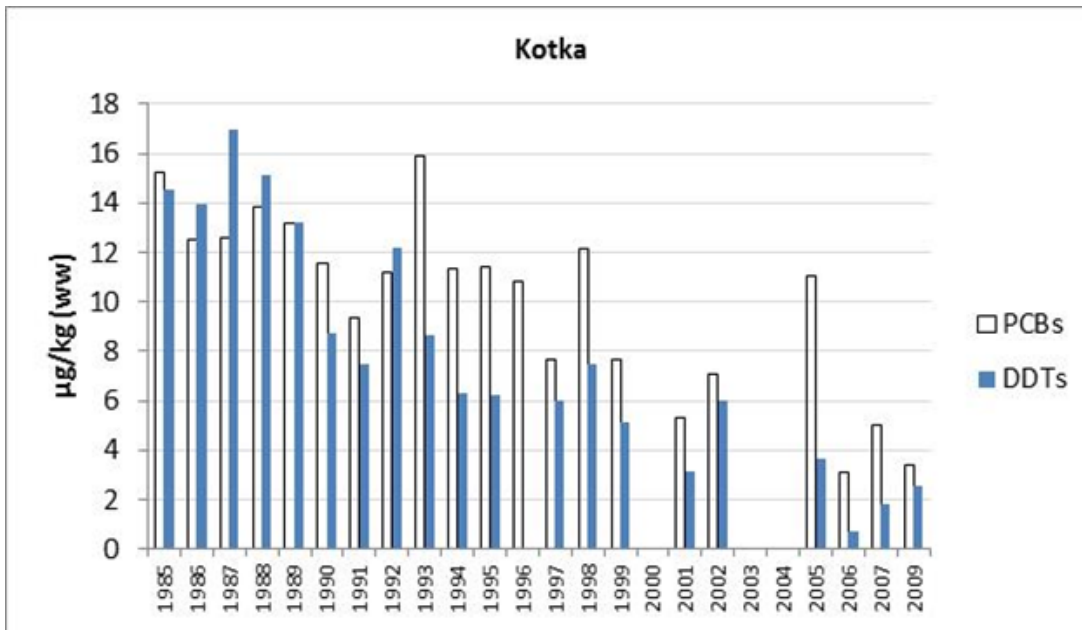


Figure 29. Total PCB and DDT concentrations in the muscle of Baltic herring in the Gulf of Finland (Kotka region) during 1985–2009.

Concentrations of these compounds are likely to decrease further in the future although at a slower rate. Both PCBs and DDT are included in the Stockholm Convention, but the use of DDT is still allowed in some developing countries. Some residues from its use still end up in the Baltic Sea through long-range transport. Although banned, PCBs are widely distributed in the environment through inappropriate handling of waste material or, for example, leakage from large condensers and hydraulic systems, from contaminated sites and as re-emission from soils. Because of resistance to degradation, PCBs persist in the environment for very long periods, and because of long-distance atmospheric transport they now represent a global contamination problem.

Dioxins and furans (PCDD/F)

Other compounds do not seem to show such clear positive trends as the contaminants described above. Unlike PCBs and DDT, dioxins and dibenzofurans (PCDD/F) are produced unintentionally, e.g. as minor impurities in several chlorinated chemicals (e.g. PCBs, chlorophenols, hexachlorophene), and are also formed in several industrial processes and combustion processes, such as municipal waste incineration and small-scale burning under poorly controlled conditions. Dioxins and furans occur in the Baltic Sea at much higher concentrations than their background level. It seems that most atmospheric deposition of PCDD/F originates from continental Europe. Higher winter concentrations indicate that non-industrial combustion sources dominate⁷⁵.

Emissions of dioxins have declined over recent decades as a result of strict regulation. This has led to declines in concentrations in Baltic Sea sediments, but not in all herring populations studied during recent years. Temporal changes in herring ecology (e.g., slower growth rates or decreased lipid content in some populations caused by, for instance, changes in feeding ecology) may halt downward temporal trends in concentrations of dioxins and dioxin-like polychlorinated biphenyls (dl-PCBs) in some herring populations⁷⁵.

It is not known if the slowly decreasing trend of dioxin concentrations in herring populations will continue because of uncertainties in emission trends and future changes in herring ecology. Herring and European sprat form the bulk of the fish biomass, and of the fish catches, in the Baltic Sea (ICES 2013). It is probable that the most efficient means to decrease dioxin concentrations in fish is to reduce atmospheric emissions. More actions are needed, and are under investigation, to reduce the emissions into the air in Europe and thus atmospheric deposition in the Baltic Sea. If further actions fail, levels of dioxins in some herring populations may remain close to and occasionally above the EU threshold values⁷⁵.

Brominated flame retardants (PBDEs)

Brominated flame retardants have been used as additives in a variety of different consumer products. Formerly widely used as retardants in the European Union, the technical penta- and octaBDEs, were banned in 2004. An EU-wide restriction of decaBDE followed in 2008. When PBDE compounds were measured in herring gull eggs, the results clearly showed that pentaBDE was the major contaminant even though decaBDE production volumes were considerably higher. In the Baltic Sea, the highest contamination with BDEs has been found in sediment and mussels close to populated urban areas. It has been noted that the penta-BDE congener -47 is both bioconcentrated and biomagnified to a higher degree than any other congeners.

PentaBDE decreased significantly during the period 1991/1996 to 2008 and started before the EU-wide ban in 2004⁷⁶ (Figure 30). The decline is still likely to be related to the political decisions concerning reduction and substitution before the final ban came into effect. OctaBDE concentrations increased until 2002 and 2003 but subsequently concentrations have decreased. In contrast, no decreases were recorded for BDE-209, the major component of commercial decaBDE, but there was an increase at some locations⁷⁶. PBDE concentrations, especially concentrations of the pentaBDE congener BDE-47, still exceed the threshold level in fish⁷⁷.

The occurrence of BDEs is widespread in the Baltic marine environment. It is probable that current legislative measures have already decreased penta- and octaBDE levels in the Baltic Sea. While pentaBDE and octaBDE do not seem to pose a risk to the marine environment in the western Baltic Sea, the situation may be different in the eastern reaches⁷⁷.

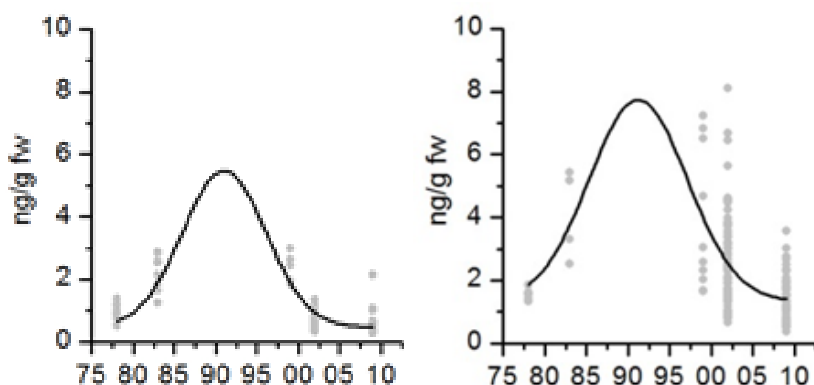


Figure 30. Summed PBDE concentrations in young ($a < 5$ years) and old ($b \geq 5$ years) Baltic herring during 1978–2009 (fresh weight) (Airaksinen et al. 2013).

Perfluorinated compounds

Perfluorinated compounds (e.g. perfluorooctane sulfonic acid [PFOS]) are extremely persistent. The recorded concentrations in guillemot eggs have increased almost 30-fold since the early 1970s⁷⁸ (Figure 31). The water-repelling capacity of PFOS made it very popular for impregnating paper, fabrics and leather and its use has been extensive up to recent years. Consumer disposal of PFOS-containing products may thus lead to continued releases of PFOS into the environment, even though its use currently strongly restricted⁷⁴. PFOS has now been regulated globally under the Stockholm Convention.

Exponentially increasing concentrations of perfluorinated compounds have been reported in wildlife during the 1990s⁷⁹. In the Baltic Sea PFOS concentrations are generally below the threshold level for fish but may exceed that level in some monitoring sites⁷³. The PFOS and PFOA (perfluorooctanoic acid) levels in fish and water seem to be similar in different parts of the Baltic Sea. Time series data for a fish-feeding bird (common guillemot) shows that the concentrations have increased since the late 1960s, but the first signs of decline are evident⁸⁰.

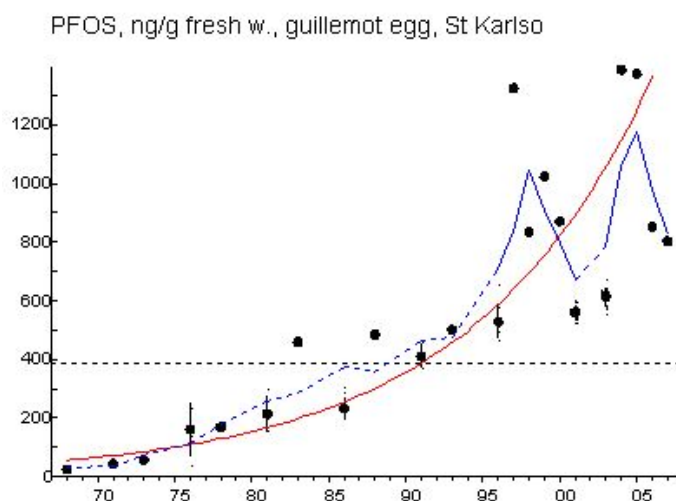


Figure 31. Increasing PFOS concentrations in common guillemot eggs (Bignert et al. 2008⁷⁸).

According to Swedish data, a significant increasing trend is apparent for PFOS in guillemot eggs at 7–10 % per year (Figure 31), which is equal to an increase of 25–30 times higher levels in the early 2000s as compared with during the late 1960s⁷⁸. It is noteworthy, however, that the time series shows considerable variation in the latter years, perhaps indicating also a levelling-off of the PFOS concentrations.

Heavy metals

Heavy metals are elements that occur naturally in the environment, but usually at low concentrations, and which vary among areas of different geological origin. The main pollution sources are mines, metal smelters, coal-fired power plants and the fertilizer industry. Previously pulp and paper mills and the chlor-alkali industry discharged large amounts of mercury into the Baltic Sea. In addition, organic mercury compounds were used as agricultural fungicides. In some coastal regions along the Gulf of Bothnia acid sulphide soils naturally leach large amounts of cadmium. The use of lead in gasoline was previously the main source of lead to the environment. The main sources of cadmium and mercury are point sources and riverine runoff. Atmospheric deposition accounts for a significant amount of cadmium and mercury and about half of the lead emissions into the Baltic Sea⁷³.

There are some indications that mercury levels in marine biota have halved since the 1970s and most monitoring sites currently show low levels comparable with the EU food limits. Cadmium, however, increased during the 1990s, but subsequently the trend has reversed, although levels in some Baltic localities remain high⁷⁴. Decline in the commercial use of use of lead, especially in gasoline, has resulted in substantial reduction in environmental lead levels. The EU has set an environmental target for mercury in fish that is considerably lower than for human consumption in order to protect top predators from mercury. This level is exceeded in the majority of fish when the background concentration is taken into account. Thus, even though fish seem to be safe to eat, the risk of bioaccumulation and harmful effects in fish predators persist⁷³.

Regulations concerning the use of tributyl tin (TBT) have been implemented within HELCOM countries and its use as an anti-fouling paint on marine vessels was banned in 2008. Following the ban, the levels of TBT in mussels and the coastal fish populations have decreased⁷³. Due to large historical use and a slow degradation in low oxic environments, TBT still seems to occur widely in sediments from coastal areas to the open sea. The highest concentrations have been found in several harbours, marinas and nearby shipyards, but strongly elevated concentrations have also been measured from many other point sources along the coastal areas⁷⁴. For example, several years ago high concentrations were measured in fish, especially perch, originating from the large bay areas including Vanhankaupunginlahti, in Helsinki⁸¹.

The high concentrations of TBT in sediments might pose a risk also in the future. According to studies, even low TBT concentrations can cause effects on bivalves and gastropods, such as shell deformation, endocrine disruption and impaired larval recruitment, and can accumulate in top predators⁷³. When such consequences affect species with key functions in the ecosystem, the effects can cascade through the system⁷⁴.

Impacts of food consumption on exposure of contaminants

Many heavily regulated compounds show a general decreasing trend in Baltic Sea biota and in many food items. It is likely that this trend will continue although at a low rate for many compounds because of their extremely slow degradation and capacity to be transported far from their initial sites of emissions and releases. Many compounds may also be released from products during their use and long after their disposal. Awareness of environmental impacts of substances released from anthropogenic activities is much higher today than only few decades ago. The future concentrations of the contaminants in the environment and biota depend strongly on human activities. Restrictions, substitutions and banning may decrease the concentrations of many compounds in the long run, but it has to be considered that for some contaminants, especially for those that are easily transported long distances, restrictions should be made globally in order to achieve the objectives for the reduction.

The long lifecycle of some consumer products, as well as building components have made it possible that compounds may still be released into the environment long after their having been banned. These can end up in the atmosphere, waste water treatment plants and in effluents and sludge. The use of municipal sludge as a fertilizer in agriculture potentially poses a risk in releasing contaminants into the environment and their accumulation in plants and livestock. Of the metal contaminants, cadmium is a special concern for atmospheric pollution, its presence in phosphate fertilizers and its presence in sewage sludge playing a major role in deposition in agricultural soils and consequently in food and feed. Thus future trends for cadmium concentrations in food are highly uncertain.

Due to increasing consumption of meat and dairy products it is expected that the exposure to some bio-accumulating compounds might increase slightly in the near future. It is recommended that the consumption of red meat be reduced for environmental and health reasons (other than for the contaminants it can contain). Baltic fish may represent some risk in the case of dioxins, some other POPs, and mercury if consumed more than is recommended. Currently the health benefits of eating fish outweigh health risks^{82, 83, 84}.

6. Conclusions

According to the results presented, the environmental load could be reduced by changing food consumption habits from animal protein raw materials to carbohydrate and vegetable raw materials. An increase in the nutritional value of meals was recorded, but exposure to some toxic compounds did increase. Furthermore, the nutritional value of meals can be increased by shifting 25 % from the energy of saturated fats, salt and sugar-containing raw materials to protein, fibre-rich carbohydrate and vegetable raw materials. This shift reduced the environmental impact slightly, but the intake of harmful compounds could increase as consumption of vegetables and fish increase. Finally, decreasing the consumption of possibly toxic raw materials, protein, carbohydrate and vegetable, would slightly increase nutritional value and decrease the ecotoxicity impact indicator. In conclusion, changing the raw materials slightly can have a significant impact on the nutritional and environmental value of a meal, but decreasing toxic exposure may require greater reductions in consumption of contaminated raw materials. However, in our scenario, reduction reach was relatively high considering that the raw materials selected represented a minor part of the meals in terms of weight and energy.

Key findings:

1. Changing the raw materials slightly can make a significant difference to nutritional and environmental quality of a meal. A 15 % shift from the energy of animal protein raw materials to carbohydrate and vegetable raw materials would increase the nutritional value by about 6 % and reduce the weighted overall impact (environmental impact) indicator by about 8 %. The 15 % decrease in raw materials did not change the composition of the whole meal significantly. A 25 % shift from the energy of saturated fats, salt and sugar-containing raw materials to other raw materials, such as protein, fibre-rich carbohydrate and vegetable, would, accordingly, increase the nutritional value by 12 %, reduce the climate change impact indicator (CO₂ eq) by about 3 %, the eutrophication impact indicator (PO₄ eq) by about 2 %, and the weighted overall impact indicator by about 3 %. The ecotoxicity impact indicator would increase by about 4 %. A 15 % shift from the energy of high toxic exposure raw materials to protein, carbohydrate and vegetable raw materials would decrease the ecotoxicity impact indicator by about 4 % and increase the nutritional value by 2 %, leaving the climate change impact indicator (CO₂ eq) and the eutrophication impact indicator (PO₄ eq) and weighted overall impact indicator practically unchanged.
2. There are many possibilities to choose healthy and environmentally friendly raw materials for the plate. As an example, replacing processed and red meat with vegetarian alternatives (such as pulses), fish, or poultry, increases the nutritional value and reduces the environmental impact markedly.
3. Increasing the nutritional value and decreasing the environmental impact can be done by changing recipes. It is possible to increase the nutritional value of meals by reducing the use of sugars, salt (sodium) and saturated fat, in ready-made meals known as 'hidden ingredients'.

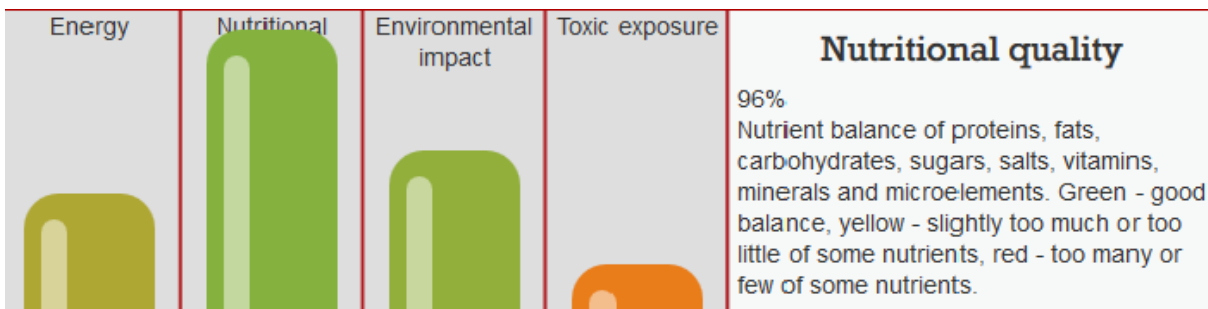
4. The amount of each raw material consumed is a most important factor affecting the nutritional quality and environmental impact of a meal. Excessively large portions of food can also increase the intake of harmful substances. When eating two servings of the food, the amount of calories, nutrients, environmental impacts and toxic substances also doubles.
5. According to average Finnish consumption values, the carbon footprint and the eutrophication impact largely bound together. The main reason is livestock production, which has an effect on a range of ecological impacts. Animal based products represent a large part of the Finnish diet and essentially are associated with the highest carbon footprint and eutrophication impact of all raw materials.
6. Consumers can reduce environmental impact by selecting environmentally friendly food items. Increasing the consumption of fruits and vegetables substantially reduces environmental impact. In addition, selection of seasonal fruits, vegetables and berries represents the basis of an environmentally friendly meal.
7. Many heavily regulated substances appear as a general decreasing trend in the Baltic Sea biota and in many food items. Of the metals, cadmium is of special concern, being present in atmospheric pollution, phosphate fertilizers and sewage sludge, the major contributors to deposition in agricultural soils and consequently in food and feed. Thus future trends for cadmium concentrations in food are highly uncertain.
8. Due to the increase in consumption of meat and dairy products it is expected that exposure to some bio-accumulating compounds might slightly increase in the near future. It is recommended that the use of red meat should be cut down for environmental and health reasons (other than contaminants).
9. Baltic fish may pose some risk in the case of dioxins, some other POPs, and mercury if consumed more than is recommended. Current understanding stresses that the health benefits of eating fish outweigh health risks.
10. The intake of toxic compounds can be reduced by eating a wide variety of foods and avoiding consumption of any one raw material in large quantities. Simultaneously, the nutritional value may increase and the environmental impact of meal decrease.

7. Appendix 1: Examples of the basic meals of the “Footplate” web-application

1. High nutritional quality – a good balance between different nutrients:

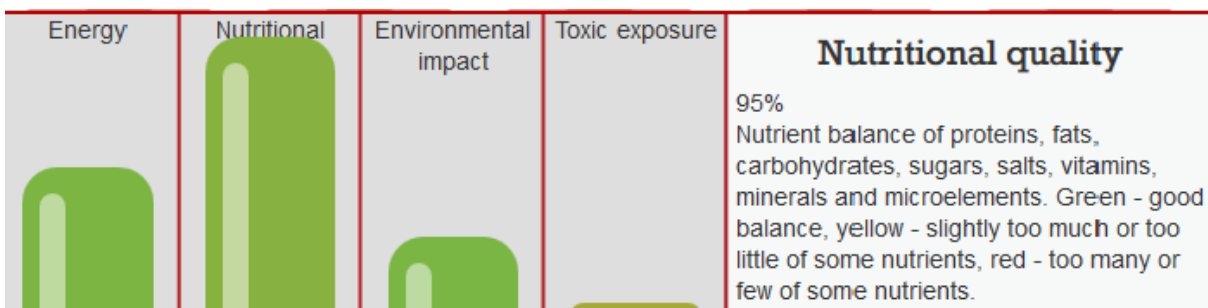
Baked rainbow trout with cooked potatoes

- rainbow trout in oven 150 g
- cooked potatoes 150 g
- cooked peas 65 g
- bread 30 g
- spread 6 g
- milk 200 g
- mixed berries 150 g
- sugar 10 g



Chili sin carne

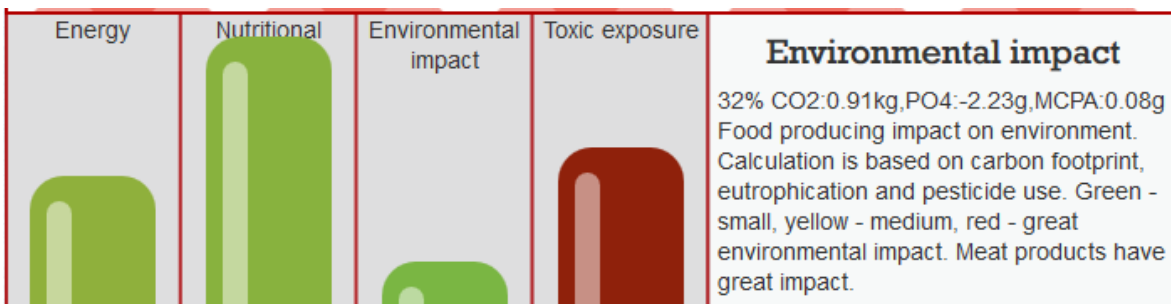
- chili sin carne (vegetables) 180 g
- cooked rice 120 g
- warm vegetables 150 g
- bread 30 g
- spread 6 g
- milk 200 g



2. Low environmental impact - the environmental impact is less than or similar to the Finnish average:

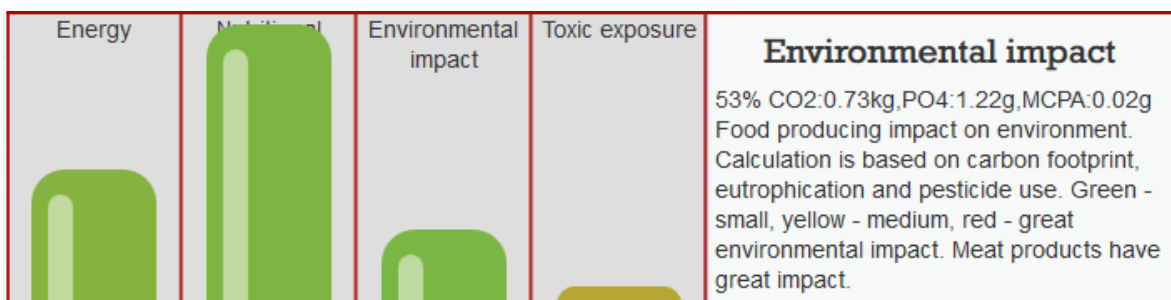
Baked pike with cooked potatoes

- pike in oven 200 g
- cooked potatoes 165 g
- cooked peas 65 g
- bread 30 g
- spread 6 g
- milk 200 g
- mixed berries 150 g
- sugar 10 g



Spinach pancakes

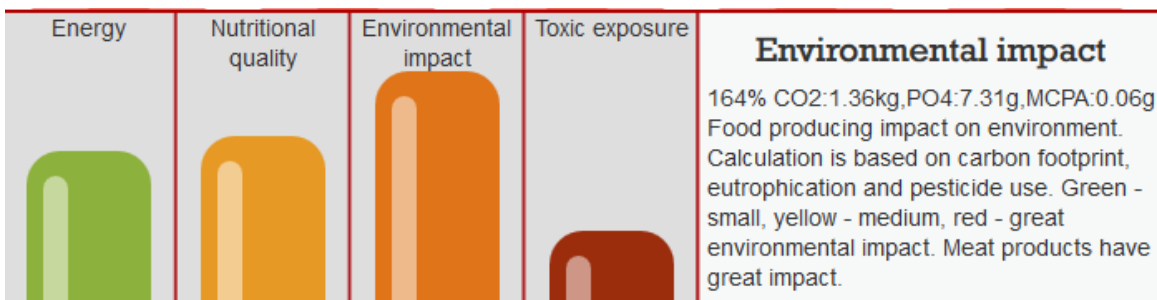
- spinach pancakes 150 g
- grated carrot 90 g
- tuna salad 90 g
- crushed lingonberries 40 g
- bread 30 g
- spread 6 g
- milk 200 g
- orange 300 g



3. Environmental impact - high

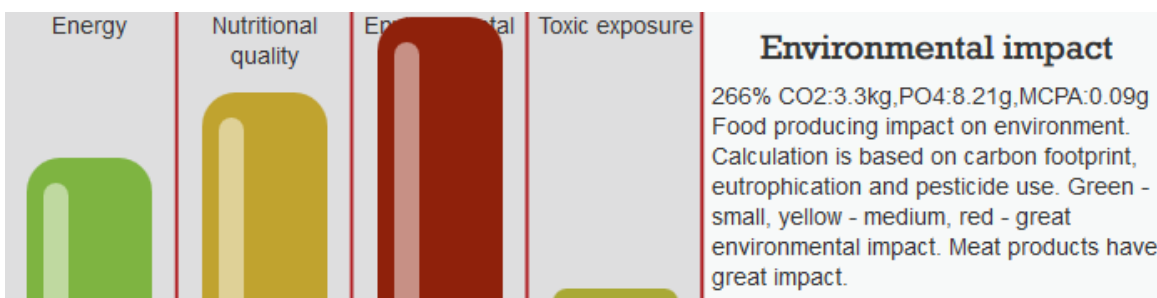
Omelette with smoked rainbow trout

- omelette 120 g
- smoked rainbow trout 150 g
- green salad 100 g
- oil dressing 5 g
- milk 200 g
- bread 30 g
- spread 6 g
- strawberries 200 g



Beef sirloin

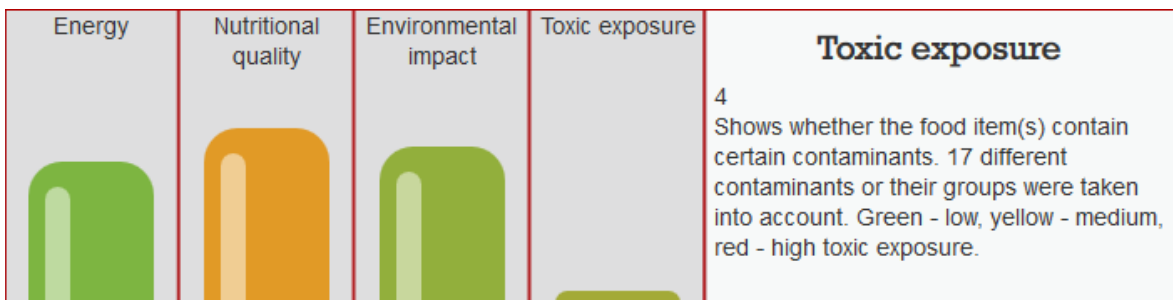
- beef sirloin 150 g
- cooked potatoes 165 g
- brown sauce 50 g
- cooked vegetables 90 g
- milk 200 g
- bread 30 g
- spread 6 g
- fromage frais with berries 150 g



4. Low toxic exposure (HEI <5, the intake of each contaminant is significantly less than its TWI).

Meatballs with spaghetti

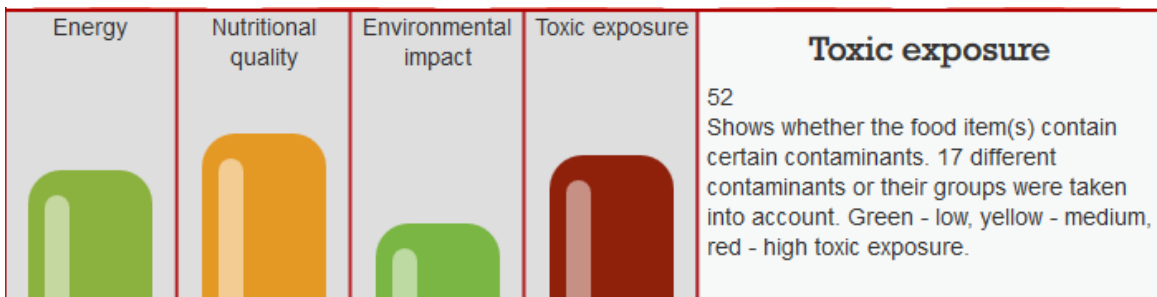
- meatballs 100 g
- cooked spaghetti 120 g
- brown sauce 50 g
- grated carrot 60 g
- orange juice 15 g
- milk 200 g
- bread 30 g
- spread 6 g
- orange 300 g



5. High toxic exposure (HEI >25 one or more contaminants may be exceeding their TWI).

Baltic Sea herring steaks

- Baltic herring steaks 130 g
- mashed potatoes 200 g
- sour cream sauce 50 g
- grated carrot 90 g
- orange juice 15 g
- bread 30 g
- spread 6 g
- milk 200 g



8. References

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