The initial model to design SHARP diets, based on nutritional adequacy and preliminary sustainability metrics

Deliverable No. 7.1

SUSFANS DELIVERABLES

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This paper collates food and nutrient intake data from Denmark, Czech Republic, Italy and France. Nutritional adequacy of the diets will be assessed using a protocol developed in WP2. This is the basis for the initial model to design SHARP diets, based on nutritional adequacy and preliminary sustainability metrics.

Version	Release date	Changed	Status	Distribution
V1	31/05/2017	-	,,,	...

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 633692

SUSFANS Deliverable document information

Project name	SUSFANS
Project title:	Metrics, Models and Foresight for European SUStainable Food And Nutrition Security
Project no	633692
Start date:	April 2015
Report:	The initial model to design SHARP diets, based on nutritional adequacy and preliminary sustainability metrics
Work package	WP 7
WP title (acronym):	
WP leader:	Modelling SHARP diets for EU-consumers
Period, year:	2, 2017
Responsible Authors:	Elly Mertens, Anneleen Kuijsten, Marianne Geleijnse, Pieter van 't Veer (WUR) with contributions from the nutritional team: Ellen Trolle and Inge Tetens (DTU, Denmark), Marcela Dofková (SZU, Czech Republic), Lorenza Mistura, Laura D'Addezio, and Marika Ferrari (CRA, Italy), Carine Dubuisson and Sandra Favret (ANSES, France).
Participant acronyms:	WUR, DTU, SZU, CRA, ANSES
Dissemination level:	Public
Version	V1
Release Date	31/05/2016
Planned delivery date:	31/05/2016 (see DoA and/or portal)
Status	Internal review.
Distribution	

ACKNOWLEDGMENT & DISCLAIMER

This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement No 633692. Neither the European Commission nor any person acting on behalf of the Commission is responsible for how the following information is used. The views expressed in this publication are the sole responsibility of the author and do not necessarily reflect the views of the European Commission.

Part I. Scientific paper on the diversity and nutritional adequacy of European diets

Heterogeneity of EU diets in terms of food groups and nutrients

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Acknowledgements

Financial support

Financial support for this original contribution was obtained from funding from the European Union's H2020 Programme under Grant Agreement number 633692 (SUSFANS: Metrics, models and foresight for European sustainable food and nutrition security) and from the TiFN's research programme under Grant Agreement number SD004 (SHARP-BASIC: Scientific knowledge base and data platform for modelling SHARP diets).

Conflict of interest

The authors have no conflicts of interest.

Authors' contribution

JMG and PvtV initiated the topic of the paper. MD, LM, LD, AT, CD, SF, and ET were responsible for the data collection and data analysis. EM, AK and were responsible for data interpretation. EM drafted the manuscript, which was reviewed by all authors for intellectual content. All authors read and approved the final submission of the paper.

Abstract

Background There is a shift in health and climate policy and decision-making from the national to the European level. The aim of the present study was, therefore, to describe the European heterogeneity and geographical diversity of dietary intake addressing both food and nutrient composition using four countries.

Methods Individual-level dietary intake data in adults were obtained from nationally representative dietary surveys from Denmark (Scandinavia) and France (Western Europe) using a 7-day diet record, Italy (Mediterranean region) using a 3-day diet record, and Czech Republic (Central East Europe) using two replicates of a 1-day recall. Energy-standardised intakes were calculated for each subject from the mean of two randomly selected days, and were evaluated against reference intakes that were derived for food groups from different European food-based dietary guidelines, and for nutrients from the Dietary Reference Values of the European Food Safety Authority.

Results For foods, standardised mean daily intakes of fruit, vegetables, fish, dairy products, sugar-sweetened beverages and alcohol varied most between countries, with a between-country range for fruit from 118 to 215 g/day, for vegetables from 95 to 258 g/day, and for fish from 12 to 48 g/day, all representing lower intakes for Czech Republic, moderate intakes for Denmark and France, and higher intakes for Italy. Dairy intake ranged from 136 to 302 g/day with higher intakes in Denmark and lower intakes in Czech Republic, Italy and France, and sugar-sweetened beverage intake ranged from 23 to 224 ml/day and alcohol from 8.9 to 14.6 g/d with higher intakes in Denmark, moderate intakes in Czech Republic and France, and lower intakes in Italy. In all countries, intakes were low for legumes (< 20 g/day), and nuts and seeds (< 5 g/day), but high for red and processed meat (> 80 g/day). For nutrients, intakes were low for vitamin D and dietary fibre in all countries, and for potassium and magnesium except for Denmark, for vitamin E in Denmark, and folate in Czech Republic.

Discussion There is considerable variation in food group and nutrient intake between different European countries. This variation may have implications for policy making.

Keywords

diet – nutrients – dietary guidelines – Europe – SUSFANS

Introduction

Unhealthy diets are a major contributor to non-communicable diseases (NCDs), accounting for 12.1 million deaths and 264.4 million disability-adjusted life-years at the global level in 2015 [1]. High intakes of sodium and alcohol, and low intakes of fruit and vegetables, whole grains, and nuts and seeds ranked among the leading risk factors for early death and disability in European populations in 2015 [1]. However, as westernisation of diets progressed, increasing intakes of red and processed meat, and sugar-sweetened beverages are becoming a growing public health concern [1].

Dietary patterns are shaped by cultural, environmental, technological and economic factors, and they have become more similar over time owing to a general rise in living standards and globalisation of the food sector [2,3]. Also in Europe there is a growing similarity of diets, in which traditional diets of Northern and Mediterranean countries are converging towards a more Western diet, viewed by the increased share of fruit and vegetables in Northern countries and the increased share of animal-based products in Mediterranean countries [4-6]. Excess caloric intake has been thought as a key factor in nutrition transition, which warrants the need for public health action to promote healthier food patterns consistent with traditional cultural preferences.

Public health policies of European countries have their main focus on addressing problems related to high intakes of energy along with unhealthy eating habits, hence the need for national food-based dietary guidelines. Food-based dietary guidelines are evidence-based integrated messages aimed at the general population for the prevention of NCDs [7,8]. Promoting the intake of whole grains, fruit and vegetables, low-fat dairy and fish, and limiting the intake of red and processed meat, sugar-sweetened food products, alcohol and salt is covered by most national food-based dietary guidelines [9], although recommended quantities may differ. Furthermore, some European countries have developed guidelines for diets that are both healthy and environmentally friendly [10-13]. Such recommendations mostly emphasise the reduction of greenhouse gas emissions through limiting the intake of animal-based products and promoting plant-based products.

In recent years, there has been a shift in health and climate policy and decision-making from the national to the European level, however the design of sustainable diets for consumers remains a major challenge [14]. In the present study, the focus is on describing European dietary patterns in food groups and nutrients in order to find nutritional gaps that are most in need of improving the healthiness of dietary intake. In view of this, the variation in dietary intakes should be captured in the best possible way by using four countries representing the cultural diversity. Besides, socio-economic and anthropometric factors including age, gender, educational level [15,16] and body mass index (BMI) [17] were suggested to be relevant determinants explaining some of the between- and within-country variations in dietary intakes.

We set up the present study to describe the heterogeneity of diets in Europe using national survey data from four countries. The intake of food groups and nutrients were compared with current food-based dietary guidelines and nutrient reference values, overall and in relevant population subgroups.

Populations and methods

Data sources

Individual-level dietary intake data from national dietary surveys representative for different European regions, i.e. Denmark (Scandinavia) [18], Czech Republic (Central East Europe) [19], Italy (Mediterranean) [20] and France (Western Europe) [21], were collated within the SUStainable Food and Nutrition Security in the EU (SUSFANS) project [14]. These four countries were chosen to capture the wide range of foods and agricultural commodities that are incorporated in the diverse European food consumption patterns.

Survey characteristics

Survey characteristics are shown in TABLE 1. National representativeness was ensured by using random sampling based on civil registration systems, electoral registers, census information or phone books that served as sampling frame [18-21], and followed by appropriate weighing for socio-demographic parameters, as applied in Denmark [18] and France [21]. Surveys were organised throughout the whole year and have dietary data on week and week-end days, covering the four seasons of the year.

Method of dietary assessment

In the four study countries, dietary intake was assessed over two to seven 24-hour periods, either consecutively for three to seven days using a diet record, as applied in Denmark, Italy and France [18,20,21], or non-consecutively spaced over a three to five months sampling period using two replicates of 24-hour recalls, as applied in Czech Republic [19]. In the present analyses, dietary intake from two random days has been reported. To this end, two non-consecutive days were sampled in Denmark, Italy and France, whereas all available days were used in Czech Republic.

Food and nutrient intakes

Intakes of food groups and nutrients were calculated for each subject from the mean of the selected two days, and were standardised to energy using the density method expressed per 2,000 kcal. Harmonised food groups, including similar foods, have been elaborated by re-allocating foods to different categories in a consistent way using the 'Exposure Hierarchy' of the FoodEx2 food classification and description system developed by the European Food Safety Authority (EFSA) [22,23]. Nutrient intakes were calculated from dietary sources only, i.e. excluding dietary supplements, by using country-specific food composition tables [24-30]. Estimates of sodium intake are prone to be under-estimated due to difficulties in quantifying sodium concentration in recipes and discretionary salt intake [31]. Intakes of added sugar, plant and animal protein were calculated based on food selection. Added sugar was defined as the total sugar intake minus sugars naturally occurring in fruits, vegetables and dairy. Plant proteins were defined as proteins derived from cereals, legumes, nuts and seeds, and others (including potatoes, vegetables, fruits, etc.). Animal proteins were defined as proteins derived from meat and meat products, fish and fish products, egg and egg products, milk and milk products (including cream, cheese and butter). None of the data excluded under- and over-reporting, however misreporting was identified using Goldberg equation [32] and adopted by Black [33], as shown in Supplementary Material 1.

Dietary quality

Foods

To evaluate European populations' standardised food group intakes, the 'FoodEx2 Exposure Hierarchy' [22,23] was used at a level that allows for a comparison with food-based dietary guidelines for a healthy diet. References values were set for the food groups that are important for disease risk reduction based on an inventory of the various food-based dietary guidelines of European countries (Supplementary Material 2). Minimum values were set for foods that are beneficial for health, such as fruits and vegetables, and maximum values for foods that are unfavourable for health, such as red and processed meat, both using recommended quantities from current food-based dietary guidelines (see BOX 1).

Nutrients

To evaluate European populations' standardised nutrient intakes, the nutrient density of the diet was quantified using a Nutrient Rich Diet (NRD) score [34,35], i.e. an overall summary estimate of nutrient intakes based on the principles of the Nutrient Rich Food Index [36,37]. The NRD algorithm was calculated as:

$$NRD\ X.Y = \sum_{i}^{i=X} \frac{Nutrient\ i}{DRV\ i} x100 - \sum_{j}^{j=Y} \frac{Nutrient\ j}{MRV\ j} x100$$

where X is the number of qualifying nutrients, Y is the number of disqualifying nutrients, nutrient i or j is the average daily intake of nutrient i or j, DRV is the Dietary Reference Value of qualifying nutrient i and MRV j is the Maximum Recommended Value of the nutrient to limit j. DRVs are defined using reference values from EFSA [38]: Average Requirement (AR), and Adequate Intake (AI), if AR cannot be set, and MRVs using reference values of World Health Organisation [39,40] and Food and Agriculture Organisation [41].

In the present analyses, the NRD9.3 including nine nutrients for which intake should be promoted (protein, dietary fibre, calcium, iron, potassium, magnesium, and vitamin A, C and E) and three nutrients for which intake should be limited (saturated fat, added sugar, and sodium) standardised for 2,000 kcal/d and capped at 100% DRV was primarily chosen based on validation results among US populations [36,37]. To capture more nutrients that are potentially relevant for European populations we also used the extended version, i.e. NRD15.3 that additionally includes mono-unsaturated fatty acids, zinc, vitamin D and B-vitamins (B1, B2, B12, folate), but excluding magnesium.

Estimating the dietary quality of European populations' diets

Percentages of the population that adhere to food-based dietary guidelines and percentages of the population with inadequate nutrient intakes were estimated using the AR cut-point method [42], without correction for within subject variability. This percentage would be interpreted as proxy figures for adherence and inadequacy, because of different survey's methodologies. When the DRV of the nutrient under study was defined as an AI (dietary fibre, potassium, magnesium, vitamin D, E and

B12), this percentage of populations with intake below AI was only applicable for comparison between countries and population subgroups. Dietary intakes were characterised in the overall country-specific population of adults aged ≥ 18 years and in relevant population subgroups by age, gender, education level, and overweight status. Subgroups by age included younger and middle-aged adults (18 – 64 years) and elderly (≥ 65 years). Younger and middle-aged adult populations were additionally stratified by gender, educational level using three categories, i.e. primary or lower secondary degree ('low'), higher secondary degree ('intermediate') and university or post-university degree ('high'), and overweight status using two categories, i.e. BMI < 25 and ≥ 25 kg/m^2.

Results

Foods

TABLE 2 shows the standardised intakes of food groups and general adherence to food-based dietary guidelines in the four European populations. Intakes of fruit, vegetables, fish, dairy, sugar-sweetened beverages and alcohol varied between countries. In particular, mean fruit intake ranged from 118 to 215 g/day, vegetable intake from 95 to 258 g/day, and fish intake from 12 to 48 g/day, all representing lower intakes for Czech Republic, moderate intakes for Denmark and France, and higher intakes for Italy. Conversely, dairy intake ranged from 136 to 302 g/day with higher intakes in Denmark and lower intakes in Czech Republic, Italy and France, and sugar-sweetened beverages from 23 to 224 ml/day and alcohol from 8.9 to 14.6 g/d, with higher intakes in Denmark, moderate to high intakes in Czech Republic and France, and lower intakes in Italy.

Intakes of legumes, nuts and seeds, and whole grain products were low in all countries. Meat intake was high, which comprised mainly red meat in Denmark, Italy and France, and processed meat in Czech Republic. Intakes of butter and hard margarines were only slightly higher than intakes of soft margarines and vegetable oils, except for Denmark where butter and hard margarines were predominately chosen as fat source and for Italy where vegetable oils were dominating.

Food group intakes in population subgroups are shown in TABLE 3. Elderly consumed more fruit than young and middle-aged adults in all countries, more alcohol in Denmark, Italy and France, and more vegetables in France, but less in Denmark. Women consumed more fruit and vegetables, and less alcohol than men in all countries, and less red and processed meat in Denmark, Czech Republic and France. Lower educated subgroups consumed more red and processed meat in all countries, more legumes in France, and less fruit and vegetables, and fish in Denmark and Czech Republic. Intakes of alcohol tended to decrease with educational level in Czech Republic and Italy, but to increase in Denmark and France. Subgroup comparison by overweight status revealed no clear differences, except for alcohol in Italy and France where intakes were higher in the overweight subgroup.

Nutrients

TABLE 4 shows the standardised nutrient intakes, their corresponding proxy prevalence figures for inadequate intakes, and the NRD scores in European populations, aged ≥ 18 years. Low intakes were observed for vitamin D and dietary fibre in all countries with proxies for prevalence inadequacy of above 80%, and for potassium, and magnesium, with proxies for prevalence inadequacy of above 75% except for Denmark. Intake of vitamin E was clearly lower in Denmark, and folate in Czech Republic with a proxy for prevalence inadequacy of around 75%. Proxy for prevalence inadequacy was below 25% for protein, mono-unsaturated fatty acids, and iron in all countries analysed. Remaining nutrients, including calcium, zinc, vitamin A, C, B1, B2, and B12, showed varying intake levels between countries, of which proxies for inadequacy were between 50 – 75% in Czech Republic for all nutrients except for vitamin B1, in France for vitamin C, and in Italy for calcium and vitamin B1.Of the three nutrients to limit, a large penalty was obtained from saturated fatty acids, and from estimated sodium intake. Based on the NRD scores, it is apparent that the nutrient density of the diet was highest in Italy, followed by Denmark, and the lowest in Czech Republic

Nutrient density of the diet was strongly associated with gender in all countries, showing higher scores for women, and by educational level in Denmark and (less pronounced in Czech Republic), showing higher scores for the higher-educated subjects (TABLE 5). No clear differences were observed for population subgroup comparison by age and overweight status.

Discussion

Energy-standardised food consumption patterns showed considerable variation across the four European countries that we studied. Within countries, patterns also varied by age, gender, and educational level, but not by overweight status. For food groups, mean daily intakes of fruit and vegetables, sugar-sweetened beverages, and alcohol varied most between countries, showing lower intakes of fruit and vegetables, and higher intakes of sugar-sweetened beverages and alcohol in the non-Mediterranean countries. For nutrients, energy-standardised intakes of zinc, vitamin A, C, E, and folate varied most between countries, with lower intakes in non-Mediterranean countries.

Intakes of protein-source foods were associated with educational level, with the higher-educated subjects having higher intakes of fish and nuts and seeds along with lower intakes of meat and legumes, except for Denmark where legumes are increasing with educational level. This association with educational level may be related to the diminishing social value of meat and health consciousness among higher-educated subjects [43]. Furthermore, in line with previous studies conducted in European populations [44-46], we found a positive association between vegetable consumption and educational level in Northern Europe, Central-Eastern Europe and Western Europe, but not in the Mediterranean region. This region-dependent association has been attributed to the long-standing cultural tradition of using vegetables in Mediterranean countries along with a higher availability and affordability of vegetables throughout the year, and therefore vegetable intakes might be less likely to vary with the educational level in these countries [45].

Previously, the EURopean micronutrient RECommentations Aligned Network of Excellence had prioritised ten nutrients that are most likely to be of concern across the European populations [47]. In the present study, high proxy of prevalence of inadequacy was observed for vitamin D and dietary fibre in all countries, and for potassium, magnesium, vitamin E and folate with variability between countries. Previous studies evaluating nutrient inadequacy [48-50] observed that, although between-study differences exist, intakes of calcium, magnesium, iron, vitamin D, C, and folate were nutrients consistently showing a higher prevalence of inadequate intakes in European countries. A note of caution is due here since comparability of nutrient inadequacies might be limited by various methodological aspects, e.g.: method of dietary assessment, the use of DRVs affecting the number of individuals whose intake was below AR.

In the European Food COnsumption VALidation project, it has been suggested to adjust for BMI when analysing and interpreting dietary data of nutritional monitoring surveys to reduce mean bias at population level [17]. Given that the stratified analysis by overweight status showed no clear differences in dietary intake within a country, it is questionable whether BMI-adjusted values should be the main exposure of interest in the present study describing the heterogeneity of European diets.

Cross-country comparison of dietary data is challenged by the dietary surveys conducted with different survey characteristics and data collection methods that may influence the comparability of the results. Replicates of 24-hour recall as applied in Czech Republic yielded a higher mean estimate for energy intake as compared to the diet record as applied in Denmark, Italy and France, which might be explained by factors related to the methods themselves [(51-53)] and/or characteristics of the populations. Standardising intakes to 2,000 kcal per day would, therefore, have had the largest impact on results of Czech Republic, resulting in lower dietary estimates which are unfavourable for the desirable food groups and nutrients, but favourable for the undesirable food groups and nutrients. In addition, standardisation for energy is one of the more practical ways of reducing measurement error for specific food groups and nutrients, which are strongly correlated with measurement errors for total energy intake and explain an appreciable part of the variation in dietary estimates.

In this study, dietary data were standardised for the number of days, but have not been corrected for time-interval between the two selected record/recall days, hence not corrected for within-subject day-to-day variability. Correcting for within-person day-to-day variability would have resulted in comparable means for dietary intakes compared to unadjusted data, though with a shrinkage of intake distributions which in turn would have decreased the percentage of the population above and below a cut-off point [(54)]. However, relying on consecutive days, including days spaced over a week time-interval, is likely to underestimate the within-subject day-to-day variation [(55)] because of the interdependence of days that captures some of the day-to-day variation in the between-subject variation [(56,57)]. Thus, this day-interdependence would have resulted in a shrinkage of the observed intake distribution that is too much toward the group mean, hence an under-estimation of true percentage of the population above and below a cut-off when statistically correcting intake distributions. Despite the methodological limitations in dietary data, results provided are consistent with the literature regarding the geographical variation of food and nutrient intakes over Europe [(58)], which underline the robustness of the results presented.

Exclusion of under-reporters would have increased the prevalence of adherence to the food-based dietary guidelines and decreased the prevalence of inadequate nutrient intakes, and inclusion of supplementation used would have decreased the prevalence of inadequate nutrient intakes even further. The present study did estimate the percentage of under-reporters (Supplementary Material 1), but did not estimate intakes excluding under-reporters, because some of the under-reporters may truly be consuming a low-energy diet. Over the past decades, dietary supplementation use has increased in Europe with a clear north-south gradient [59], showing a high number of users in Denmark (Supplementary Material 1). Hence, it is likely that in countries with higher level of supplementation use, dietary supplementation might have contributed to improved total nutrient intakes, however its impact is dependent on the supplementation formulation, the frequency of use, and the level of micronutrient intakes of those taking supplements.

In Europe, food consumption and production have been recognised as a major human-induced driver of climate change, and accordingly shifting towards a more plant-based diet has been attracting a lot of interest. Given the present European dietary intakes, the intake of plant protein as opposed to total protein was observed in a percentage of around 35% in the present study. However, the predominant food groups contributing to animal and plant protein intake have been associated with regional and cultural traditions around dietary habits. Meat intake is regarded as the most important contributor to animal protein in European diets, but with differences related to the amount and types of meat consumed, as also denoted by previous studies [60,61]. With regard to plant protein, cereals and cereal products has been identified as the main contribution to plant protein in European diets [62], while contributions from vegetables, legumes and fruit combined varied between countries, showing lower intakes in Czech Republic, median intakes in Denmark and France, and higher intakes in Italy.

In conclusion, there is considerable variation in food and nutrient intakes between different European countries. The present study indicated that the intake of food groups showed larger deviations from the current food-based dietary guidelines for the non-Mediterranean countries. In addition, results suggested inadequate nutrient intakes from foods for vitamin D and dietary fibre in all countries, and for potassium, magnesium, vitamin E and folate in specific regions. This variation may have implications for policy making at the European level.

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Tables

TABLE 1 Food consumption surveys in the four European countries, standardised for analysis.

Country	Survey	Year	Population (age, gender)	Sample size (Response %)	Method of dietary assessment	Number of week- and weekend-days	Seasonality	Number of food items reported by 2 days of the survey
Denmark	The Danish National Survey on Diet and Physical Activity– National Food Institute, Technical University of Denmark (DTU) [18]	2005 - 2008	18 - 75 years M (46%) + F	2,025 (54%)	7-day diet record on consecutive days of which 2 random days were included using random selecting techniques	70% week days 30% weekend days	30% spring 21% summer 32% autumn 16% winter	288
Czech Republic	Czech National Food Consumption Survey (SISP04) – National Institute of Public Health [19]	2003 - 2004	18 - 90 years M (47%) + F	1,869 (54%)	2 x 24-hour recall on non-consecutive days	74% week days 26% weekend days	34% spring 22% summer 15% autumn 29% winter	459
Italy	Italian National Food Consumption Survey - INRAN-SCAI - National institute for Research on Food and Nutrition [20]	2005 - 2006	18 - 98 years M (45%) + F	2,831 (33%)	3-day diet record on consecutive days of which the first and the last day were inlcuded	78% week days 22% weekend days	26% spring 24% summer 25% autumn 25% winter	1114
France	Individual and National Study on Food Consumption 2 (INCA-2) - Agence Française de Sécurité Sanitaires des Aliments (AFSSA) [21]	2006 - 2007	18 - 79 years M (41%) + F	2,624 (60%)	7-day diet record on consecutive days of which 2 random days were included using random selecting techniques	71% week days 29% weekend days	21% spring 17% summer 25% autumn 37% winter	1343

BOX 1 A set of food-based dietary guidelines

	Exposure definition	Reference values
Foods to increase		
Fruit	All kind of fruits (including fresh, dried, tinned or canned fruit products, but excluding fruit juice)	≥ 200 g/day
Vegetables	All kind of vegetables (including fresh, dried, tinned or canned vegetable products, but excluding vegetable juices and vegetables from soup, sauces and ready-to-eat products)	≥ 200 g/day
Legumes	Kidney beans, pinto beans, white beans, black beans, garbanzo beans (chickpeas), lima beans (mature, dried), split peas, lentils, and edamame (green soybeans)	≥ 135 g/week (≥ 19 g/day)
Nuts and seeds	Walnuts, almonds, hazel, cashew, pistachio, macadamia, Brazil, pecan, pine nuts, flax seeds, sesame seeds, sunflower seeds, pumpkin seeds, poppy seeds, and peanut	≥ 15 g/day
Dairy products	Food products produced from the milk of mammals, including milk, yoghurt, fresh cheese, quark, custard, milk puddings, excluding cheese and butter	≥ 300 g/day
Fish	All kind of fish and fish products	≥ 21 g/day
Foods to decrease		

Red and processed meat	Red meat: all mammalian muscle meat, including beef, veal, pork, lamb, mutton, horse and goat, excluding rabbit meat; Processed meat: meat transformed through salting, curing, fermentations, smoking or other processed to enhance flavour or improve preservation (e.g. meat products as sandwich filling, ready-to-eat minced meat, sausages, etc.	≤ 500 g/week (≤ 71 g/day)
Cheese	All types of cheese that is food product derived from milk and formed by coagulation of the milk protein casein	≤ 150 g/week (≤ 21 g/day)
Sugar-sweetened beverages	Cold beverages with added sugars (sucrose, fructose or glucose), for example fruit juices, fruit nectars, soft drinks, ice teas, vitamin-water or sports drinks with added sugars	≤ 500 ml/week (≤ 71 ml/day)
Ethanol	Calculated from all kind of alcoholic beverages	≤ 13 ml/day

TABLE 2 Standardised food group intakes and the adherence to their corresponding food-based dietary guidelines in the selected four EU study populations, aged ≥ 18 years[1].

	cut-	Denmark			Czech Republic			Italy			France		
	offs	Mean	Median(P25;P75)	%adh	Mean	Median(P25;P75)	%adh	Mean	Median(P25;P75)	%adh	Mean	Median(P25;P75)	%adh
Foods to increase													
Fruit, g/d	≥ 200	174	133(36.0; 255)	35%	118	83(12.0; 171)	20%	215	177(82; 296)	45%	134	90 (0.0; 204)	26%
Vegetables, g/d	≥ 200	147	112(63; 184)	21%	95	74(39.0; 127)	10%	258	224(151; 327)	58%	185	157 (83; 253)	37%
Legumes. g/d	≥ 19	6.45	1.6(0.0; 6.7)	10%	7.5	0.0(0.0; 3.0)	12%	12.0	0.0(0.0; 3.0)	20%	16.7	0.0 (0.0; 1.0)	18%
Nuts and seeds, g/d	≥ 15	2.2	0.0(0.0; 0.0)	5%	2.6	0.0(0.0; 0.0)	7%	0.6	0.0(0.0; 0.0)	1%	1.7	0.0 (0.0; 0.0)	3%
Dairy products, g/d	≥ 300	302	248(113; 422)	41%	136	94(31.0;192)	12%	174	159(62; 251)	16%	199	151 (54; 294)	24%
Fish, g/d	≥ 21	18.0	5.5(0.0; 24.1)	28%	11.7	0.0(0.0;0.0)	17%	48.4	7.2(0.0; 84)	43%	34.4	7.4 (0.0; 54)	43%
Foods to decrease													
Red and processed meat, g/d	≤ 71	93.6	85(50.6; 127)	39%	89	82(46.0; 125)	42%	83	76(36.5; 118)	64%	93	82 (41.4; 132)	43%
Hard cheese, g/d	≤ 21	29.3	24.3(11.3;42.0)	44%	20.9	13.2(0.0; 33.0)	63%	23.6	13(3.7; 37.6)	61%	29.7	23.6 (3.1; 45.2)	46%
Sugar-sweetened beverages, ml/d	≤ 71	224	127(0.0; 305)	40%	108	0.0(0.0; 144)	63%	23.1	0.0(0.0; 0.0)	88%	130	19.1 (0.0; 183)	56%
Alcohol (ethanol), g/d	≤ 10	14.6	7.3(0.0; 22.6)	56%	10.3	4.4(0.0; 16.0)	66%	8.9	0.1(0.0; 14.8)	73%	9.9	0.1 (0.0; 16.1)	67%

TABLE 2 Continued.

	cut-offs	Denmark			Czech Republic			Italy			France		
		Mean	Median(P25;P75)	%adh	Mean	Median(P25;P75)	%adh	Mean	Median(P25;P75)	%adh	Mean	Median (P25;P75)	%adh
Foods to switch													
Cereals, total, g/d	-	26.1	16.9(6.7; 35.0)	-	48.2	32.5(11.0; 72)	-	50.7	41.6(0.6; 79)	-	40.6	16.5(0.0; 60)	-
Cereals, wholegrains, g/d	-	0.35	0.0(0.0; 0.0)	-	0.1	0.0(0.0; 0.0)	-	0.7	0(0.0; 0.0)	-	1.6	0.0(0.0; 0.0)	-
Bread, total, g/d	-	149	140(94; 194)	-	122	118(83; 157)	-	118	113(66; 162)	-	98	92(51; 140)	-
Bread, wholegrains, g/d	-	52	44.3(22.4; 72)	-	7.9	0.0(0.0; 0.0)	-	5.3	0(0.0; 0.0)	-	15.4	0.0(0.0; 2.8)	-
Pasta, total, g/d	-	5.18	0.0(0.0; 1.2)	-	39.9	13.6(0.0; 66)	-	56	53(29.8; 82)	-	10.3	0.0(0.0; 0.0)	-
Pasta, wholegrains, g/d	-	-	--	-	0.0	0.0(0.0; 0.0)	-	0.1	0.0(0.0; 0.0)	-	9.9	0.0(0.0; 0.0)	-
Breakfast cereals, total, g/d	-	11.8	0.6(0.0; 18.0)	-	2.9	0.0(0.0; 0.0)	-	1.6	0.0(0.0; 0.0)	-	5.2	0.0(0.0; 0.0)	-
Breakfast cereals, wholegrains, g/d	-	9.3	0.0(0.0; 12.1)	-	1.9	0.0(0.0; 0.0)	-	0.9	0.0(0.0; 0.0)	-	3.2	0.0(0.0; 0.0)	-
Red meat, g/d	-	66	57.1(28.3; 93)	-	34.7	28.4(0.0; 55)	-	55	48.2(0.0; 87)	-	59	47.0(0.0; 92)	-
Processed meat, g/d	-	27.3	19.4(7.1; 37.2)	-	54	44.5(14.0; 80)	-	27.7	21.2(0.0; 42.1)	-	34.6	23.1(0.0; 53)	-
White meat, g/d	-	21.3	1.6(0.0; 29.9)	-	22.5	0.0(0.0; 41.0)	-	25.2	0.0(0.0; 48)	-	32.9	0.0(0.0; 53)	-
Butter and hard margarines, g/d	-	24.8	22.7(13.5;33.8)	-	17.9	15.5(7.0; 25.0)	-	3.0	0.0(0.0; 4.3)	-	16.1	13.5(5.9; 23.8)	-
Soft margarine and oils, g/d	-	1.9	0.0(0.0; 1.5)	-	15.0	13.1(7.0; 21.0)	-	37.6	36.9(28.8; 45.8)	-	11.2	7.3(0.3; 16.8)	-

[1]%adherence represents a proxy for the percentage of the population that adhere to food-based dietary guidelines.

TABLE 3 Standardised food group intakes and the adherence to their corresponding food-based dietary guidelines in the selected four EU study populations in subgroups by age, gender, educational level, and body weight status: main findings[1].

	cut-offs	Denmark			Czech Republic			Italy			France		
		Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh
Young and middle-aged adults, aged 18 - 64 years			(n = 1,739)			(n = 1,666)			(n = 2,313)			(n=2,276)	
Fruit, g/d	≥ 200	171	126 (32.2; 251)	34%	115	79 (10.0; 167)	19%	201	167 (75; 278)	42%	122	77 (0.0 ; 190)	23%
Vegetables, g/d	≥ 200	151	114 (64; 189)	22%	95	75 (39.0; 128)	10%	258	222 (149; 325)	58%	180	152 (78; 248)	36%
Legumes, g/d	≥ 19	6.6	1.8 (0.0; 7.1)	10%	7.6	0.0 (0.0; 2.0)	11%	11.7	0.0 (0.0; 3.3)	20%	15.9	0.0 (0.0 ; 0.9)	17%
Red and processed meat, g/d	≤ 71	95	87 (52; 128)	38%	90	83 (46.0; 126)	42%	85	77 (37.6; 120)	65%	94	84 (41.7; 133)	43%
Alcohol (ethanol), g/d	≤ 10	13.8	6.4 (0.0; 21.5)	58%	10.7	5.0 (0.0; 17.0)	65%	8.5	0.1 (0.0; 13.9)	72%	9.4	0.0 (0.0; 14.8)	69%
Elderly, aged ≥ 65 years			(n = 286)			(n = 203)			(n = 518)			(n = 348)	
Fruit, g/d	≥ 200	197	159 (81; 281)	40%	143	118 (39.0; 216)	28%	275	242 (134; 362)	58%	201	166 (70; 285)	42%
Vegetables, g/d	≥ 200	119	98 (54; 167)	16%	94	70 (40.0; 120)	8%	258	233 (162; 334)	62%	212	192 (108; 288)	46%
Legumes, g/d	≥ 19	5.3	0.9 (0.0; 4.6)	10%	6.7	0.0 (0.0; 4.0)	13%	13.3	0.0 (0.0; 0. 0)	20%	20.7	0.0 (0.0; 4.8)	20%
Red and processed meat, g/d	≤ 71	83	73 (41.5; 108)	48%	85	79 (46.0; 118)	42%	75	68 (31.6; 111)	62%	88	77 (39.0; 129)	45%
Alcohol (ethanol), g/d	≤ 10	20.5	15.0 (1.7; 29.8)	40%	7.4	0.0 (0.0; 9.0)	77%	10.7	2.9 (0.0; 18.3)	81%	12.6	5.8 (0.0; 20.5)	56%

TABLE 3 Continued

	cut-offs	Denmark			Czech Republic			Italy			France		
		Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh
Men, aged 18 - 64 years			(n = 777)			(n = 873)			(n = 1,068)			(n = 936)	
Fruit, g/d	≥ 200	120	74 (0.5; 172)	21%	66	39 (1.0; 93)	6%	165	136 (55; 235)	33%	98	57 (0.0; 152)	17%
Vegetables, g/d	≥ 200	117	95 (54; 146)	13%	78	61 (35.0; 106)	5%	240	208 (137; 302)	52%	152	133 (66; 207)	26%
Legumes, g/d	≥ 19	5.9	1.3 (0.0; 5.6)	8%	6.1	0.0 (0.0; 2.0)	10%	11	0.0 (0.0; 4.3)	20%	17.1	0.0 (0.0; 1.8)	19%
Red and processed meat, g/d	≤ 71	109	100 (66; 143)	29%	109	104 (70; 143)	27%	88	81 (43.6; 122)	65%	103	92 (49.3; 145)	38%
Alcohol (ethanol), g/d	≤ 10	16.6	10.0 (0.0; 25.6)	50%	15.8	12.4 (1.0; 23.0)	47%	12.3	7.5 (0.0; 20.2)	73%	13.5	6.0 (0.0; 21.6)	57%
Women, aged 18 - 64 years			(n = 962)			(n = 996)			(n = 1,245)			(n = 1,340)	
Fruit, g/d	≥ 200	222	187 (74; 324)	47%	160	128 (51; 224)	31%	232	198 (97; 321)	49%	143	98 (0.0; 215)	28%
Vegetables, g/d	≥ 200	185	141 (84; 231)	31%	111	87 (46.0; 151)	14%	274	239 (159; 352)	62%	206	179 (95; 280)	45%
Legumes, g/d	≥ 19	7.3	2.2 (0.0; 8.6)	11%	9.0	0.0 (0.0; 3.0)	12%	12.3	0.0 (0.0; 2. 6)	20%	14.9	0.0 (0.0; 0.5)	16%
Red and processed meat, g/d	≤ 71	82	75 (43.3; 114)	47%	72	65 (29.0; 104)	55%	82	74 (32.7; 119)	64%	86	75 (35.1; 121)	47%
Alcohol (ethanol), g/d	≤ 10	10.9	0.0 (0.0; 17.0)	66%	6.1	0.0 (0.0; 9.0)	81%	5.2	0.0 (0.0; 7.8)	71%	5.5	0.0 (0.0; 6.8)	81%

TABLE 3 Continued.

	cut-offs	Denmark Mean	Denmark Median (P25;P75)	Denmark %adh	Czech Republic Mean	Czech Republic Median (P25;P75)	Czech Republic %adh	Italy Mean	Italy Median (P25;P75)	Italy %adh	France Mean	France Median (P25;P75)	France %adh
low education level, aged 18 - 64 years			(n = 248)			(n = 345)			(n = 692)			(n = 1,039)	
Fruit, g/d	≥ 200	152	94 (0.0; 234)	29%	89	61 (1.0; 141)	11%	196	170 (76; 273)	42%	119	69 (0.0; 196)	24%
Vegetables, g/d	≥ 200	126	96 (56; 152)	16%	90	71 (40.0; 123)	8%	260	222 (150; 324)	58%	179	152 (75; 248)	36%
Legumes, g/d	≥ 19	6.1	0.4 (0.0; 6.7)	10%	8.9	0.0 (0.0; 3.0)	12%	12.9	0.0 (0.0; 4.5)	23%	19.8	0.0 (0.0; 2.8)	21%
Red and processed meat, g/d	≤ 71	102	90 (58; 143)	39%	96	89 (48.0; 137)	42%	88	81 (41.0; 122)	65%	101	91 (49.0; 144)	39%
Alcohol (ethanol), g/d	≤ 10	13.2	6.3 (0.0; 21.4)	58%	11.7	5.0 (0.0; 19.0)	61%	9.5	0.0 (0.0; 16.6)	76%	8.6	0.0 (0.0; 12.3)	73%
Intermediate education level, aged 18 - 64 years			(n = 943)			(n = 1,194)			(n = 985)			(n = 495)	
Fruit, g/d	≥ 200	159	115 (30.4; 233)	32%	122	82 (13.0; 172)	21%	199	163 (71; 272)	41%	114	74 (0.0; 184)	21%
Vegetables, g/d	≥ 200	150	118 (63; 185)	21%	94	74 (37.0; 126)	10%	258	223 (148; 327)	58%	178	147 (71; 246)	33%
Legumes, g/d	≥ 19	6.5	1.6 (0.0; 6.8)	10%	7.3	0.0 (0.0; 2.0)	11%	11.5	0.0 (0.0; 3.6)	19%	12.9	0.0 (0.0; 0.4)	15%
Red and processed meat, g/d	≤ 71	99	92 (58; 131)	33%	89	83 (46.0; 124)	41%	85	77 (37.5; 119)	65%	92	79 (36.6; 131)	44%
Alcohol (ethanol), g/d	≤ 10	13.7	6.0 (0.0; 20.6)	59%	10.5	4.8 (0.0; 16.0)	66%	7.8	0.1 (0.0; 13.1)	69%	9.6	0.1 (0.0; 15.4)	66%
high education level, aged 18 - 64 years			(n = 553)			(n = 127)			(n = 507)			(n = 737)	
Fruit, g/d	≥ 200	214	167 (64; 305)	42%	121	96 (42.0; 178)	20%	226	187 (92; 311)	45%	131	92 (5.1; 193)	23%
Vegetables, g/d	≥ 200	184	137 (84; 238)	32%	120	85 (59; 157)	15%	254	215 (146; 317)	57%	184	157 (87; 249)	37%

TABLE 3 Continued.

	cut-offs	Denmark			Czech Republic			Italy			France		
		Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh	Mean	Median (P25;P75)	%adh
Legumes. g/d	≥ 19	7.7	2.8 (0.0; 7.8)	11%	7.3	0.0 (0.0; 3.0)	11%	11.0	0.0 (0.0; 5.0)	18%	12.6	0.0 (0.0; 0.5)	15%
Red and processed meat, g/d	≤ 71	82	75 (44.5; 111)	46%	81	73 (45.0; 117)	48%	83	77 (35.9; 121)	65%	86	76 (36.5; 123)	47%
Alcohol (ethanol), g/d	≤ 10	15.0	8.8 (0.0; 24.5)	52%	10.1	7.7 (0.0; 17.0)	61%	8.1	0.2 (0.0; 12.4)	69%	10.3	0.4 (0.0; 16.4)	67%
BMI < 25, aged 18 - 64 years			(n = 960)			(n = 802)			(n = 1,484)			(n = 1,379)	
Fruit, g/d	≥ 200	167	124 (33.1; 246)	34%	112	79 (19.0; 165)	19%	201	170 (75; 273)	42%	118	74 (0.0; 185)	22%
Vegetables, g/d	≥ 200	154	118 (66; 191)	23%	96	77 (40.0; 126)	10%	250	216 (145; 311)	56%	170	145 (71; 239)	33%
Legumes, g/d	≥ 19	6.4	1.9 (0.0; 6.9)	9%	7.3	0.0 (0.0; 2.0)	11%	11.5	0.0 (0.0; 2.5)	20%	16.6	0.0 (0.0; 1.9)	19%
Red and processed meat, g/d	≤ 71	94	86 (52; 126)	38%	84	75 (40.0; 122)	48%	84	77 (36.8; 118)	65%	91	79 (39.6; 128)	44%
Alcohol (ethanol), g/d	≤ 10	13.2	6.2 (0.0; 20.5)	58%	10.4	4.5 (0.0; 17.0)	65%	7.5	0.0 (0.0; 11.9)	70%	8.1	0.0 (0.0; 12.4)	73%
BMI ≥ 25, aged 18 - 64 years			(n = 740)			(n = 864)			(n = 828)			(n = 871)	
Fruit, g/d	≥ 200	174	129 (23.5; 255)	33%	118	79 (6.0; 168)	19%	202	164 (73; 287)	42%	128	82 (0.0; 198)	24%
Vegetables, g/d	≥ 200	146	108 (63; 182)	21%	95	73 (38.0; 128)	9%	274	230 (155; 347)	61%	193	165 (88; 258)	39%
Legumes. g/d	≥ 19	6.9	1.5 (0.0; 7.4)	11%	7.9	0.0 (0.0; 2.0)	11%	12.1	0.0 (0.0; 4.6)	20%	15.1	0.0 (0.0; 0.5)	16%
Red and processed meat, g/d	≤ 71	99	90 (54; 134)	37%	95	89 (52; 130)	37%	86	78 (39.2; 124)	64%	101	91 (47.3; 145)	40%
Alcohol (ethanol), g/d	≤ 10	14.5	6.7 (0.0; 23.4)	57%	11.0	5.5 (0.0; 17.0)	64%	10.4	4.2 (0.0; 17.2)	75%	11.5	0.3 (0.0; 18.8)	64%

[1]%adherence represents a proxy for the percentage of the population that adhere to food-based dietary guidelines

TABLE 4 Standardised mean nutrient intakes, prevalence of inadequate intake, and Nutrient Rich Diet scores in the selected European populations, aged ≥ 18 years[1].

	AR	Denmark		Czech Republic		Italy		France	
		Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR
Non-standardised total energy intake, alcohol included kcal/d	-	2264 ± 818	-	2523 ± 989	-	2119 ± 643	-	1980 ± 688	-
Standardised total energy intake, alcohol excluded, kcal/d	-	1895 ± 138	-	1928 ± 101	-	1943 ± 83	-	1931 ± 107	-
Protein, g/d	0.66 g/BW	68.7 ± 14.0	16%	67.1 ± 12.0	12%	79.0 ± 13.0	1%	83.5 ± 18.3	2.4%
Protein, E%/d	-	13.9 ± 2.3	-	13.4 ± 2.4	-	15.6 ± 2.6		16.7 ± 13.7	
Animal protein, g/d	-	44.8 ± 14.1	-	38.8 ± 13.5	-	48.6 ± 14.8	-	[3]	
Plant protein, g/d	-	20.3 ± 5.2	-	23.9 ± 5.7	-	30.3 ± 5.9	-	[3]	
Dietary fibre, g/d [2]	25	19.4 ± 6.7	81%	15.8 ± 4.7	96%	18.1 ± 6.4	88%	16.6 ± 6.0	91%
MUFA, g/d [2]	-	25.7 ± 6.6	-	32.0 ± 6.5	-	39.0 ± 8.4	-	29.7 ± 8.6	-
MUFA , E%/d	10 - 20 E%	11.7 ± 3.0	31%	14.4 ± 2.9	8%	17.6 ± 3.8	25%	13.4 ± 3.9	23%
Calcium, mg/d	750	983 ± 388	30%	660 ± 337	69%	742 ± 289	57%	899 ± 360	38%
Iron, mg/d	M: 6; F: 7	9.1 ± 2.1	8%	10.6 ± 3.1	4%	11.1 ± 4.7	2%	12.4 ± 5.3	2%
Potassium, mg/d [2]	3500	3143 ± 881	69%	2288 ± 575	96%	2938 ± 787	81%	2879 ± 787	82%

TABLE 4 Continued

	AR	Denmark		Czech Republic		Italy		France	
		Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR
Magnesium, mg/d [2]	M: 350; F: 300	322 ± 76	54%	285 ± 66	75%	268 ± 75	80%	282 ± 88	77%
Zinc, mg/d	M: 7.5; F: 6.2	9.5 ± 2.1	10%	7.0 ± 2.0	52%	11.0 ± 3.0	3%	10.2 ± 3.1	9%
Vitamin A, µg RE/d	M: 570; F:490	1032 ± 858	23%	692 ± 1243	62%	854.1 ± 1217.5	34%	1200 ± 1491	23%
Vitamin C, mg/d	M: 90; F: 80	102 ± 66	50%	78 ± 59	65%	125.9 ± 91.2	38%	91 ± 65	56%
Vitamin E, mg/d [2]	M: 13; F: 11	6.7 ± 3.4	95%	11.7 ± 4.5	56%	12.7 ± 13.7	53%	10.6 ± 5.4	66%
Vitamin D, µg/d [2]	15	3.0 ± 4.3	97%	2.9 ± 2.7	99%	2.4 ± 3.3	99%	2.6 ± 3.0	99%
Vitamin B1, mg/d	0.3/1000 kcal	1.12 ± 0.34	3%	1.09 ± 0.36	2%	1.10 ± 2.00	53%	1.20 ± 0.50	0%
Vitamin B2, mg/d	1.1/1000 kcal	1.47 ± 0.46	20%	1.08 ± 0.43	65%	1.40 ± 0.60	16%	1.80 ± 0.70	8%
Vitamin B12, µg/d [2]	4	4.7 ± 3.0	45%	4.4 ± 3.8	64%	6.1 ± 3.9	48%	5.6 ± 7.2	50%
Folate, µg DFE/d	250	293 ± 143	41%	212 ± 113	76%	350 ± 477	23%	278 ± 115	49%
SFA, g/d	-	30.4 ± 7.7	-	30.6 ± 7.2	-	24.6 ± 6.2	-	33.5 ± 8.3	-
SFA, E%/d [4]	< 10 E%	13.8 ± 3.5	14%	13.8 ± 3.3	20%	11.1 ± 2.8	38%	15.1 ± 3.7	9%
Added sugar, g/d	-	43.2 ± 32.9	-	36.6 ± 25.4	-	38.6 ± 23.7	-	[3]	-
Added sugar, E%/d [4]	< 10 E%	8.8 ± 6.7	68%	7.3 ± 5.1	79%	7.7 ± 4.7	76%	[3]	[3]
Sodium, mg/d [4]	< 2400	3012 ± 795	20%	4244 ± 1027	2%	1703 ± 627	87%	2797 ± 935	35%

TABLE 4 Continued.

	AR	Denmark		Czech Republic		Italy		France	
		Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR	Mean ± SD	%<AR
Nutrient Rich Diet Scores									
Sub-score NRD9	-	765 ± 81	-	715 ± 97	-	781 ± 79	-	[3]	-
Sub-score NRD15	-	1245 ± 96	-	1175 ± 117	-	1295 ± 84	-	[3]	-
Sub-score NRDX.3	-	349 ± 73	-	338 ± 63	-	244 ± 42	-	[3]	-
Total score NRD9.3	-	416 ± 126	-	327 ± 108	-	537 ± 86	-	[3]	-
Total score NRD15.3	-	896 ± 135	-	787 ± 126	-	1051 ± 90	-	[3]	-

Abbreviations: AR, Average Requirement; AI, Adequate Intake; RE, Retinol Equivalents; DFE, Dietary Folate Equivalents; E%, energy percentage; MUFA, mono-unsaturated fatty acids; SFA, saturated Fatty Acids; NRD, Nutrient Rich Diet scores, including their sub-scores.

[1] %<AR represents a proxy for the percentage of the population that have an inadequate intake, i.e. intake lower than the average requirement. [2] Nutrients where AR cannot be set, hence adequate intake is defined. [3] cannot be computed. [4] %<AR represents a proxy for the percentage of the population that have an inadequate intake, i.e. intake higher than the average requirement.

TABLE 5 Population subgroup comparison by age, gender, educational level and overweight status for the nutrient density of the diet using Nutrient Rich Diet scores in the selected European populations.

	Denmark	Czech Republic	Italy	France *
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
Younger and middle-aged adults, aged 18 - 64 years	(n = 1,739)	(n = 1,666)	(n = 2,313)	(n=2,276)
Sub-score NRD9	764 ± 81	714 ± 97	777 ± 79	
Sub-score NRD15	1243 ± 94	1174 ± 118	1293 ± 85	
Sub-score NRDX.3	351 ± 74	387 ± 63	245 ± 42	
Total score NRD9.3	413 ± 128	327 ± 109	533 ± 87	
Total score NRD15.3	892 ± 136	787 ± 126	1048 ± 91	
Elderly, aged ≥ 65 years	(n = 286)	(n = 203)	(n = 518)	(n = 348)
Sub-score NRD9	772 ± 78	729 ± 93	796 ± 75	
Sub-score NRD15	1256 ± 103	1185 ± 113	1305 ± 81	
Sub-score NRDX.3	333 ± 63	396 ± 58	242 ± 41	
Total score NRD9.3	439 ± 108	333 ± 102	554 ± 78	
Total score NRD15.3	923 ± 124	789 ± 121	1064 ± 82	
Men, aged 18 - 64 years	(n = 777)	(n = 873)	(n = 1,068)	(n = 936)
Sub-score NRD9	731 ± 76	659 ± 88	747 ± 80	
Sub-score NRD15	1215 ± 91	1119 ± 111	1264 ± 88	
Sub-score NRDX.3	355 ± 73	375 ± 62	242 ± 43	
Total score NRD9.3	376 ± 119	284 ± 99	505 ± 89	
Total score NRD15.3	860 ± 126	744 ± 119	1022 ± 95	
Women, aged 18 - 64 years	(n= 962)	(n = 996)	(n = 1,245)	(n = 1,340)
Sub-score NRD9	796 ± 72	793 ± 76	803 ± 69	
Sub-score NRD15	1271 ± 89	1223 ± 101	1317 ± 73	
Sub-score NRDX.3	346 ± 74	398 ± 63	247 ± 41	
Total score NRD9.3	450 ± 126	366 ± 102	556 ± 78	
Total score NRD15.3	925 ± 138	826 ± 120	1070 ± 81	

TABLE 5 continued.

	Denmark	Czech Republic	Italy	France *
	Mean ± SD	Mean ± SD	Mean ± SD	Mean ± SD
low education level, aged 18 - 64 years	(n = 248)	(n = 345)	(n = 692)	(n = 1,039)
Sub-score NRD9	746 ± 88	695 ± 102	774 ± 80	
Sub-score NRD15	1221 ± 101	1153 ± 126	1291 ± 87	
Sub-score NRDX.3	356 ± 81	378 ± 63	240 ± 42	
Total score NRD9.3	390 ± 143	317 ± 107	534 ± 89	
Total score NRD15.3	865 ± 151	775 ± 128	1051 ± 94	
intermediate education level, aged 18 - 64 years	(n = 943)	(n = 1,194)	(n = 985)	(n = 495)
Sub-score NRD9	760 ± 79	716 ± 96	776 ± 78	
Sub-score NRD15	1242 ± 93	1175 ± 116	1292 ± 83	
Sub-score NRDX.3	356 ± 74	390 ± 64	246 ± 42	
Total score NRD9.3	405 ± 124	327 ± 110	530 ± 84	
Total score NRD15.3	887 ± 133	785 ± 126	1046 ± 88	
high education level, aged 18 - 64 years	(n = 553)	(n = 127)	(n = 507)	(n = 737)
Sub-score NRD9	791 ± 71	740 ± 83	788 ± 79	
Sub-score NRD15	1271 ± 83	1217 ± 103	1300 ± 83	
Sub-score NRDX.3	334 ± 63	384 ± 55	249 ± 43	
Total score NRD9.3	456 ± 110	356 ± 98	539 ± 87	
Total score NRD15.3	937 ± 114	833 ± 112	1051 ± 91	
BMI < 25 kg/m^2, aged 18 - 64 years	(n = 960)	(n = 802)	(n = 1,484)	(n = 1,379)
Sub-score NRD9	782 ± 70	719 ± 93	779 ± 79	
Sub-score NRD15	1261 ± 85	1175 ± 116	1294 ± 84	
Sub-score NRDX.3	351 ± 71	389 ± 62	248 ± 42	
Total score NRD9.3	431 ± 119	330 ± 106	531 ± 88	
Total score NRD15.3	909 ± 127	786 ± 126	1046 ± 92	
BMI ≥ 25 kg/m^2, aged 18 - 64 years	(n = 740)	(n = 864)	(n = 828)	(n = 871)
Sub-score NRD9	775 ± 79	709 ± 101	775 ± 80	
Sub-score NRD15	1251 ± 93	1172 ± 120	1291 ± 86	
Sub-score NRDX.3	351 ± 76	385 ± 64	240 ± 43	
Total score NRD9.3	424 ± 128	324 ± 111	535 ± 85	
Total score NRD15.3	900 ± 139	787 ± 127	1051 ± 90	

*cannot be computed

SUPPLEMENATRY MATERIAL

Supplementary Material 1: Identification of misreporting and dietary supplementation use

Misreporting

Underreporting of food intake is a widely-acknowledged issue in dietary assessment methods due to varied reasons (voluntary omission of foods consumed, inaccurate estimation of portion sizes eaten, etc.). This might have a particular impact on the estimates at low percentiles of the intake distribution, resulting in an underestimation of the prevalence of adequate intake. Under-reporting at the individual level is identified by comparing the ratio of energy intake to basal metabolic rate to Goldberg cut-off points(Goldberg, Black et al. 1991). Using the Goldberg cut-off limit to evaluate reported energy intakes at the individual level is based on the comparison between individual energy intake reported : basal metabolic rate estimated and a physical activity level (PAL)-value of 1.55 for light activity. This comparison is based on the assumption that BMR x PAL of 1.55 is likely to represent a probable minimum energy requirements for a normally active individual with a sedentary lifestyle. However, the Goldberg's cut-offs have a moderately low sensitivity in identifying under-reporters, i.e. subjects identified as extreme under-reporters are likely to have truly underestimated energy intake, but a proportion of the subjects identified as normal reporters are likely to be under-reporters (Black 2000). Correcting cut-offs on the basis of physical activity level, as suggested by Black, is therefore likely to improve the identification of under-reporters, when complementary information on individual's physical activity level is available (Goldberg and Black 1998, Black 2000).

The following equations as proposed by Goldberg and Black (Black 2000) were applied to derive cut-offs for evaluating misreporting, of which the first equation refers to the lower cut-off value to identify under-reporters and the second on to the upper cut-off value to identify over-reporters in a defined study population.

$$EIrep: BMRest > PAL \times \exp\left[SDmin \times \frac{S/100}{\sqrt{n}}\right]$$

$$EIrep: BMRest < PAL \times \exp\left[SDmax \times \frac{S/100}{\sqrt{n}}\right]$$

where

EIrep refers to energy intake as reported and is calculated as the average value based on energy intakes reported for each of non-consecutive days of 24-hour recall or diet-record.

BMRest refers to the basal metabolic rate as calculated using equations of Schofield for estimating sex-specific BMR from weight and height.

PAL refers to the physical activity level, which is set at 1.55 for a normally activity, but sedentary lifestyle, because of lack of data on physical activity

SDmin is -2 for the 95% lower confidence limit

SDmax is +2 for the 95% upper confidence limit

S is the factor that represent the variation in energy intake, BMR and PAL, and is calculated with the following formula using the revised factors by Black:

$$S = \sqrt{\frac{CV^2{}_{wEI}}{d} + CV^2{}_{wB} + CV^2{}_{tP}}$$

where

CVwEI is the within-subject variation in energy, i.e. factor 23%.

d is the number of days of diet assessment, i.e. two in the present analysis

CVwB is the within-subject variation in repeated BMR measurements or the precision of estimated BMRest compared with measured BMR, including measurement error and variation with time on repeated BMR measurements, i.e. 8.5%.

CVtP is the total (between-subject) variation in PAL, including within-subject variation and the methodological errors, i.e. factor 15%

- ⇨ Lower 95% confidence limit = 0.96 to identify under-reporters
- ⇨ Upper 95% confidence limit = 2.49 to identify over-reporters

SUPPLEMENTAL TABLE 1: Percentage of under- and over-reporters as identified by Goldberg/Black equation in the European population aged ≥ 18 years..

	%under-reporters			%over-reporters		
	Total	Males	Females	Total	Males	Females
Denmark	15.2%	14.4%	15.8%	0.5%	0.5%	0.5%
Czech Republic	12.9%	7.0%	18.1%	3.6%	5.6%	1.9%
Italy	11.0%	12.3%	9.9%	1.1%	0.9%	1.3%
France	23.7%	22.9%	24.3%	1.6%	2.0%	1.2%

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Dietary supplementation use

SUPPLEMENTAL TABLE 2: Percentage of dietary supplementation use in the European population aged ≥ 18 years..

	%supplement users		
	Total	Males	Females
Denmark	60.5%	55.0%	65.9%
Czech Republic	29.7%	23.3%	35.4%
Italy	4.5%	3.0%	5.8%
France	12.4%	6.1%	16.8%

Supplementary Material 2: A single set of reference values for the intake of food groups

Food-based dietary guidelines are defined at the national level, resulting in different set of food-based dietary guidelines across Europe. An overview of the different European food-based dietary guidelines is given in **SUPPLEMENTAL TABLE 3**, and a summary of the food-based dietary guidelines of the countries that are part of SUSFANS (Denmark, Czech Republic, Italy and France) is given in **SUPPLEMENTAL TABLE 4** Based on this information, a single set of reference values for the intake of food groups was used to facilitate cross-country comparison, as also shown in **TABLE 2**. Minimum intake levels were set for foods that are beneficial for health, such as fruits and vegetables, and maximum intake levels for foods that are unfavourable for health, such as red and processed meat. Cut-off points were defined in grams per day with the aim to increase the comparability of food intake between the countries, as serving sizes are country-specific. For most food groups, it was expected that actual dietary intake levels largely deviate from recommended intakes levels in European populations, and therefore cut-off level were loosened to be able to examine differences and shifts in nutritional adequacy across countries and across relevant population subgroups as a way of population dissimilation. Qualitative guidelines were formulated for food groups for which evidence only concerns the replacement of one food by another, such as replace white grains by whole grains, butter and hard margarine by vegetable oils and soft margarine.

SUPPLEMENTAL TABLE 3 Food-based dietary guidelines across Europe

Country	Official name of Food-based dietary guidelines across Europe	Publication year	Reference
Albania	Recommendations on healthy nutrition in Albania (Albanian: *Rekomandime për një ushqyerje të shëndetshme në Shqipëri*)	2008	(63)
Austria	The Austrian food pyramid – 7 steps to health (German: *Die österreichische Ernährungspyramide – 7 Stufen zur Gesundheit*)	2010	(64)
Belgium	Actieve voedingsdriehoek	2012	(65) (66)
	La Pyramide Alimentaire	2011	
Bosnia and Herzegovina	Guide on nutrition for the adult population (Bosnian: Vodič o ishrani za odraslu populaciju)	2004	(67)
Bulgaria	Food Based Dietary Guidelines for Adults in Bulgaria 2006	2006	(68)
Croatia	Dietary guidelines (Croatian: *Prehrambene smjernice*)	2002	(69)
Cyprus	National nutrition and exercise guidelines (Greek: *εθνικές οδηγίες διατροφής και άσκησης*).	2007	(70)
Czech Republic	Nutrition recommendations for Czech Republic (Czech: Výživová doporučení pro obyvatelstvo České republiky)	2012	(71)
Denmark	The official dietary guidelines (Danish: *De officielle kostråd*).	2013	(72)
Estonia	Estonian food and nutrition recommendations (Estonian: *Eesti toitumis-ja toidusoovitused*).	2012	(73)
Finland	Finnish nutrition recommendations 2014 (Finnish: *Terveyttä ruoasta. Suomalaiset*	2014	(74)

	ravitsemussuositukset 2014).		
France	The French National Nutrition and Health Program's dietary guidelines. (*French: Guides nutritions du Programme national nutrition santé (PNNS))*	2016	(75)
Georgia	Healthy eating – the main key to health (Georgian: *jansaRi kveba – janmrTelobis mTavari gasaRebi*).	2005	(76)
Germany	Ten guidelines for wholesome eating and drinking from the German Nutrition Society (German: *Vollwertig essen und trinken nach den 10 Regeln der DGE*).	2013	(77)
Greece	Dietary guidelines for adults in Greece	2014	(78)
Hungary	Dietary guidelines for the adult population in Hungary (Hungarian: *Táplálkozási ajánlások a magyarországi*).	2004	(79)
Iceland	Dietary and nutrient guidelines (Icelandic: *Ráðleggingar um mataræði og næringarefni*).	2014	(80)
Ireland	Healthy Eating Guidelines and the Food Pyramid	2015	(81)
Israel	The Israeli food pyramid (Hebrew: *פירמידת המזון הישראלי*).	2008	(82)
Italy	Guidelines for healthy Italian food habits, 2003 (Italian: *Linee guida per una sana alimentazione italiana. Revisione 2003*).	2003	(83)
	Reference level for nutrient and energy for the Italian population IV Review: Quantification of standard portion sizes (Italian: Livelli di Assunzione di Riferimento di Nutrienti ed energia IV Revisione: Standard quantitative delle porzioni)	2014	(84)
Latvia	Dietary guidelines for adults (Latvian: *Veselīga uztura ieteikumi pieaugušajiem*).	2008	(85)
Lithuania	Healthy diet recommendations (Lithuanian: sveikos mitybos rekomendacijos)	2010	(86)

Luxembourg	(French: le plaisir de bien manger et d'être actif!)	2011	(87)
Malta	The healthy plate: Dietary guidelines for Maltese adults	2016	(88)
Netherlands	(Dutch: Richtlijnen Goede voeding; Gezond eten met de Schijf van Vijf)	2015	(8)
Norway	Norwegian guidelines on diet, nutrition and physical activity. 2014 (Norwegian: *Anbefalinger om kosthold, ernæring og fysisk aktivitet*).	2014	(89)
Poland	Principles of healthy eating (Polish: *Zasady zdrowego żywienia*).	2010	(90)
Portugal	Food wheel guide (Portuguese: *A roda dos alimentos).*	2004	(91)
Romania	Guidelines for a healthy diet (Romanian: *Reguli pentru o alimentaţie sănătoasă*).	2006	(92)
Russia	/		
Slovakia	/		
Slovenia	The healthy plate' (Slovene: *Zdrav krožnik)*	2015	(93)
Spain	Eat healthy and move: 12 healthy decisions (Spanish: *Come sano y muévete: 12 decisiones saludables*)	2008	(94)
Sweden	Find your way to eat greener, not too much and to be active!	2015	(95)
Switserland	The Swiss food pyramid (German: *Lebensmittelpyramide*).	2011	(96)
The former Yugoslav Republic of Maceonia	Dietary guidelines for the population in The former Yugoslav Republic of Macedonia (Macedonian: *Водич за исхрана на населението во Република Македонија*).	2014	(97)

Turkey	Dietary guidelines for Turkey (Turkish: *Türkiye'ye Özgü Beslenme Rehberi*).	2014	(98)
United Kingdom	The Eatwell Guide	2016	(99)

SUPPLEMENTAL TABLE 4 Food-based dietary guidelines in summary for Denmark, Czech Republic, Italy and France, including exposure definitions and a single set of reference values.

	DK (72)	CZ (71)	IT (83)	FR (75)	A single set of reference values
Whole grains and grain-based products					
Whole grains (bran, germ, and endosperm in their natural proportion) from breakfast cereals, bread, rice, pasta, biscuits, muffins, tortillas, pancakes and other sources					
	A minimum of 75 grams a day; including whole grains in bread, grain flour, cereals, rice and pasta	Replace refined grains by whole grains	Replace refined grains by whole grains	Replace refined grains by whole grains	Replace white grain products by whole grain products
Vegetables and vegetable products					
All kind of vegetables (including fresh, dried, tinned or canned vegetable products, but excluding vegetable juices and vegetables from soup, sauces and ready-to-eat products)					
	A minimum of 600 grams fruit and vegetables a day, with a minimum of 300 grams of vegetables a day, preferably the coarse vegetables	3 – 5 servings a day (300 – 500 grams a day)	2 servings a day (one serving is 200 gram raw or cooked vegetables and 80 gram leafy vegetables)	A minimum of 5 servings fruit and vegetables a day (one serving is 80 – 100 gram)	Minimum 200 grams a day
Legumes					
Kidney beans, pinto beans, white beans, black beans, garbanzo beans (chickpeas), lima beans (mature, dried), split peas, lentils, and edamame (green soybeans)					
	Included in vegetable guideline.	Included in meat guideline.	Not specified	Included in fruit and vegetable guideline.	Minimum 135 grams a week ≈ 19 grams a day
Nuts and seeds					
Walnuts, almonds, hazel, cashew, pistachio, macadamia, Brazil, pecan, pine nuts, flax seeds, sesame seeds, sunflower seeds, pumpkin seeds, poppy seeds, and peanut					

	Around 30 grams a day	Not included	Included in fruit guideline.	Included in fruit and vegetable guideline.	Minimum 15 grams a day
Fruit and fruit products					
All kind of fruits (including fresh, dried, tinned or canned fruit products, but excluding fruit juice)					
	A minimum of 600 grams fruit and vegetables a day	2 – 4 servings a day (200 – 400 grams a day) preferably raw fruit and undiluted fruit juice	3 – 4 servings a day (one serving is 150 gram fresh fruit, 30 gram nuts, or 30 gram dried fruit)	A minimum of 5 servings fruit and vegetables a day (one serving is 80 – 100 gram)	Minimum 200 grams a day
Meat and meat products					
Red meat: all mammalian muscle meat, including beef, veal, pork, lamb, mutton, horse and goat, excluding rabbit meat; Processed meat: meat transformed through salting, curing, fermentations, smoking or other processed to enhance flavour or improve preservation (e.g. meat products as sandwich filling, ready-to-eat minced meat, sausages, etc.); White meat: poultry and rabbit meat					
	Choose for lean meat, lean cold meat and/or poultry. A maximum of 500 grams a week from beef, veal, lamb or pork (prepared weight)	Choose for lean meat, lean cold meat and/or poultry. 1 – 2 servings a day (one serving is 125 gram meat, poultry or fish, 2 boiled egg whites, a bowl of soya beans, lentils or beans); eggs are limited to a maximum of 4 eggs a week	Choose for lean meat, lean cold meat and/or poultry. 1 – 2 servings a day (one serving is 100 gram meat or poultry, 50 gram processed meat, 150 gram fish and shellfish, 50 gram processed fish and shellfish, and one egg)	Choose for lean meat, lean cold meat and/or poultry. A maximum of 500 grams a week for red and processed meat, with a maximum of 25 grams of processed meat a day	Maximum 500 grams red and processed meat a day Replace red and processed meat by white meat
Fish and fish products					
All kind of fish and fish products					
	Around 350 grams a week; preferably 200 grams oily fish a week	1 – 2 servings a week (170 – 340 grams a week)	2 – 3 times a week (300 – 450 grams a week)	2 servings a week (200 grams a week), including one oily fish	Minimum 150 grams a week ≈ 21 grams a day
Milk and milk products					

Food products produced from the milk of mammals, including milk, yoghurt, fresh cheese, quark, custard, milk puddings, and cheese excluding butter					
	250 – 500 grams of dairy a day, excluding hard cheese; hard cheese 1 – 2 slices a day when eating healthy, with one slice corresponding to 25 grams	2 – 3 servings a day (one serving is 250 millilitres low-fat milk, 200 millilitres low-fat yoghurt, 55 gram cheese, and 40 gram cottage cheese)	3 servings a day (one serving is 125 millilitres milk, 125 gram yoghurt, 100 gram fresh cheese, and 50 gram hard cheese); hard cheese is limited to a maximum of 2 – 3 servings a week	3 servings a day (one serving is 200 millilitres milk, 125 gram yoghourt, 100 gram fromage blanc, 60 gram petit Suisse, and 30 gram hard cheese)	Minimum 300 grams dairy, excluding butter and cheese a day Maximum 150 grams hard cheese a week ≈ 21 grams a day
Fats & Oils					
	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils.	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils.	3 servings extra virgin olive oil or seed oil a day (one serving is 10 millilitres). Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils.	Replace butter, hard margarines and cooking fats by soft margarines, liquid cooking fats, and vegetable oils. Plus, promote fats rich in ALA and limit fats rich in myristic, lauric and palmitic fatty acids	Replace butter, hard margarines and/or hard cooking fats by soft margarines, liquid cooking fats and/or vegetable oils
Sugar-sweetened beverages					
Cold beverages with added sugars (sucrose, fructose or glucose), for example fruit juices, fruit nectars, soft drinks, ice teas, vitamin-water or sports drinks with added sugars					
	A maximum of 500 millilitres a week, including soft drinks, juice and energy drinks	Limit consumption	Limit consumption	Limit consumption. A maximum of one portion of fruit juice a day, corresponding to 150 millilitres a day	Maximum 500 millilitres a week ≈ 71 grams a day
Alcoholic beverages					
	Not in food-based dietary guidelines, but a separate	A maximum of 20 grams of alcohol a day, but avoid daily	In controlled quantities	Not included, because considered as not good for health	Maximum one serving a day ≈ 10 grams/ 13 millilitres ethanol

	guideline: a maximum of 14 glasses a week, corresponding to 20 grams a day, for men, and a maximum of 7 glasses a week, corresponding to 10 grams a day, for women, with a maximum of 5 glasses per occasion.	consumption			a day
Salt					
	A maximum of 6 grams a day	A maximum of 5 grams a day	Not specified	Not specified	Maximum 6 grams a day

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Part II. Description of the SHARP model

DESCRIPTION OF THE SHARP MODEL

This section presents Information for SHARP model provided by Marianne Geleijnse (WUR), Anneleen Kuijsten (WUR), Pieter van 't Veer (WUR). The material also appears in the relevant section in deliverable D1.4.

Theoretical framework

Most models on SFNS focus on the average production and per capita consumption, with the latter sometimes modelled for specific households. This serves to model and evaluate potential for sustainable production. However, this approach is not refined enough to model and evaluate nutrition security and dietary quality for public health in EU Member States. To arrive at models that account for the dietary quality and the potential impact on public health few models are available. The aim of the SHARP model is to enable modelling and evaluation of consumer diets for impact on public health and environmental sustainability, taking into account food consumption data rather than food production data.

SHARP models diets for EU consumers in sub-regions are based on individual-level data; such diets are environmentally Sustainable, Healthy (nutritional adequacy), Affordable (within the financial means of people), Reliable (secured access to the food supply via food outlets, retail, supermarkets, etc), and Preferred by consumers (consistent with cultural norms and preferences). Designing a SHARP diet requires quantitative methods and models to evaluate the relationship and trade-off between multiple conflicting indicators that represent adequately the environmental, economic and social nature of a SHARP diet. To achieve this, existing diet models are extended to account for multiple objectives (Gerdessen, 2015a; Gerdessen, 2015b). Several mathematical techniques will be used to quantify trade-offs between important health, economic and environmental indicators. The trade-offs will provide information about how much one indicator can improve without worsening the value of other indicators.

First the dietary patterns will be evaluated from what is feasible from the viewpoint of Sustainability and Health. This will be based on indicators that reflect planetary boundaries (like GHGe, land use, etc.) and nutritional adequacy (nutrient requirements, food based dietary guidelines, energy balance, etc.). This will help to identify inefficiencies of current diets and identify the potential for improvement in these two SHARP dimension simultaneously (win-win situations). Moreover, the model will be generic and applicable in higher level application using information and data available at national, EU or global scale.

Second, the model will explore options to incorporate consumer's dietary choices using constraints on affordability, reliability and preferability (ARP).

The challenge here is to identify datasets and/or elicit heuristics to formulate realistic constraints to the model. This second modelling phase will assess the potential of a diet to be adopted by different groups of consumers, and could be modelled using indicators like food prices, meal composition, changeability of diets, etc. Alternatively, these analyses could also be conducted based on demographic factors (like age, sex, socioeconomic level) that tend to reflect lifestyles of consumers groups at a higher level of aggregation. The analyses will addressing questions like: will specific consumer groups take the additional costs of a more environmental friendly diet?

To develop the SHARP-model, existing Mathematical Programming diet models will be adapted and new methods will be developed to enable calculation of efficient alternative diets and at the same time provide support on appropriate diets for different target groups. The models will be calibrated to observed dietary choices of individuals using existing (multi-objective) techniques. Optimization of a utility function can be used to articulate the preferences of a decision maker and provide insights in scenario studies and forecasting. Determining the unknown parameters of the utility function, likely to be non-linear, is a challenging process that involves substantial interaction with decision makers.

In the case of designing SHARP diets the consumer is not available for participating in such interactive processes. Kanellopoulos et al. (Kanellopoulos, 2015) proposed a non-interactive calibration technique based on Compromise Programming to recover unknown coefficients of a non-linear approximation of utility function using a limited dataset of observed historical decisions. The non-interactive calibration technique will be explored when developing the SHARP diet model. The calibration and forecasting capacity will be evaluated in ex-post exercises i.e. the model will be calibrated for observed historical decision and used to forecast changes that occurred also at the past (Kanellopoulos, 2010). Comparing results of the model with observed historical decisions provide information about the capacity of the calibrated diet model to forecast dietary changes in different scenarios. The challenge will be to deal with discrete (integer) variables that are very common in existing optimization diet models.

Direct drivers of food system actors

Consumers habits play a key role in driving the demand of food. Mediated by the supply chain actors, they indirectly influence the food processing and production. Determinants of nutritional exposure have recently been reviewed and conceptualized in the DONE framework (Stok, 2017). This framework categorizes over 50 types of determinants that were sub-classified into 4 main themes (and 12 subgroups), i.e. individual level (biological, demographic, psychological), interpersonal level (social, cultural), (food) environment (product, micro, meso/macro) and (food) policy (industry, government).

Incorporating such (categories) of determinants into modelling is hindered by lack of (international) standardization of assessment tools. International comparisons tend to be limited to social surveys, whereas associations between determinants and dietary patterns tend to be limited to (few) multicentre studies. Thus, to describe dietary patterns the focus is necessarily limited to (1) meal composition combined with expert knowledge on food intake data, (2) changeability of food pattern over long period of time (FAO per capita data), and (3) (emerging) data on food intake based on purchase records of individual consumers.

Apart from consumer habits, health status of people is a determinant of food and nutrient intake. In apparently healthy people, a disturbed energy balance is an indicator of an unbalanced diet and/or food environment and can be summarized by BMI as a summary indicator and risk factor for a number of diet-related chronic diseases, among which diabetes (type 2), cardiovascular and some malignant diseases.

From an economic perspective, government policies that affect the market environment tend to show positive results and modest effects were seen for fruits in school environments. Effects of taxing (e.g. on foods high in salt, sugar and fat) and subsidies on (healthy) foods may influence food choice and are potentially cost saving, but may be less effective in the lower income groups; moreover they need to account for undesirable substitution effects in the dietary pattern as a whole. Food reformulation by food chain actors is another potentially cost-effective way to enhance dietary quality re salt intake, and might become more relevant for micronutrients in case severe environmental constraints would be used (McDaid, 2015). For modelling the consumer aspect of healthy and sustainable diet, food prices and socio-economic class are considered the most feasible indicators.

Indirect drivers of the food system

The indirect drivers of the food system refer to long run changes in society. SHARP is not designed for changes in the long run and therefore these indirect drivers are not accounted for.

Nevertheless, long term changes in the food system will affect food production and processing and thus the sustainability indicators. Moreover, health considerations and regulatory processes will affect the nutrient composition of foods, e.g. for salt, sugars, fats and possibly also for micronutrients. In addition, an altered food system will lead to changes food prices. Thus, although the targets regarding sustainability and health will remain similar over time, the food-based indicators in the SHARP model are time dependent; thus, the outcome of the model in terms of nutritional adequacy may change along with the food system transition itself.

Data sources

The SHARP model builds on health indicators (nutritional adequacy, adherence to food-based dietary guidelines, BMI), sustainability indicators (GHGe, land use, fossil energy use), economic indicators (e.g. product prices; to be identified), and consumer preferences (e.g. sensory and cultural aspects; to be identified). Such data will be made suitable for linkage to individual-level food intake data. Environmental and economic (income, prices) indicators will also be obtained from SUSFANS WP9. Usual food intakes in different EU regions will be characterized for these sustainability metrics, overall and in relevant population subgroups.

Nutritional data

Individual-level data are obtained from four EU Member States representing the diversity of food habits in the North, East, South and West of Europe, i.e., the Scandinavian (Denmark), CEE (Czech Republic), Mediterranean (Italy) and Western (France) regions of the EU (Ruprich, 2006; Dubuisson, 2009; Lioret 2009). They were selected to capture a wide range of food and agricultural commodities that are incorporated in the dietary patterns to supply the required nutrients, not as a representative sample of the EU as a whole. They illustrate the geographical diversity of dietary patterns that will enrich the foresight scenarios. These four countries participate in the emerging pan-European Nutrition Surveillance. The dietary assessment in these four countries is done by either food records or 24-hour recalls, all aiming at a complete picture of food and nutrient intake, and covering at least two non-consecutive days. This allows grouping of foods into commodities that can be linked to indicators of environmental sustainability, to other quantitative models in the 'toolbox' and that can be used to describe the sustainability indicators and nutrient intake for various diets modelled according to optimal health, optimal sustainability or their combination.

The nutritional adequacy of the diet will be defined using EU dietary guidelines and nutrient reference values by the European Food Safety Authority (Boer, 2011). Individual-level food intake data will be modelled together with sustainability metrics in a model framework (SHARP) for obtaining realistic sustainable FNS diets that fit the EU consumer, and which can be fine-tuned on the basis of various constraints (Gerdessen, 2015a; Gerdessen, 2015b). Using stakeholder input, different plausible scenarios will be developed, depending on priority settings (e.g. health impact vs. consumer preferences vs. environmental consequences vs. economic impact).

Sustainability data

Publicly available databases are used that characterize foods of food groups for environmental impact indicators. For the SHARP diet, the following sustainability indicators are considered:

- global warming potential (GWP). This indicator is used to indicate climate change and is expressed in the emission of the greenhouse gases NOx, CH4 (methane) and CO2. The unit is CO2-eq/kg product, in which the other gases are recalculated to CO2.

- land use. This indicator shows how much land was used to cultivate crops for food, feed and energy and is expressed in m2 or ha per kg product. It usually indicates the efficiency of a product.

- fossil energy use. For every kg of product that is produced for human consumption it is measured how much fossil energy was used. This indicator is expressed in MJ/kg product.

Research on the environmental impact of diets is increasing the last 10 years, however the results are often very location-bound and the data is not publicly available.

To assess the environmental impact of the SHARP diet environmental data will be collected on the primary commodities that have not been processed yet into foods, such as wheat, maize, oil seeds, etc. These data can be obtained from JRC, but this type of data is also available in the LCA software Simapro, in which databases such as Ecoinvent and Agrifootprint are accessible. The data from these different sources will demonstrate the range of the environmental impact of the primary food products in Europe. When the primary data has been collected, the primary commodities will be converted in ingredients (i.e. wheat flour, sunflower oil, etc.). The ingredients will then be mapped to the FoodEx2 system developed by EFSA, as the consumption data of the participating countries will also be linked to this system. This will accommodate the sustainability assessment of the diets. Recipes for composite dishes will be collected with the different countries so that the environmental impact of the ingredients can be combined to a recipe. Gaps in the data will be filled with data from literature studies.

Variables for SFNS

1. Key contributions, limitations and links - summary assessment of model's contribution to SFNS assessments (coverage of individual variables in spider diagram).

The SHARP diet model is used to describe dietary patterns under constraints for environmental sustainability and anticipated public health relevance.

In addition to (most) other models, SHARP includes a wider set of nutrients and food (groups) that are more close to consumers' dietary practices, and it includes BMI as a measure of long term energy balance.

Moreover, SHARP incorporates the consumer dimension based on observed data rather than on modelled data. This includes indicators for affordability (e.g. consumer food price, SES), reliability (to be explored) and preferability (social and cultural acceptance).

Finally, the data underlying the SHARP-model are based on individual consumption data on a daily basis, rather than aggregate data. As a result, the analyses can include the population-distribution of long term energy balance, food and nutrient intake and performance metrics in the study populations. This implies that the results are more suitable to evaluate the nutrition security dimension of the diet and that recommendations for healthy and sustainable diets can be better aligned with the state-of-the art approaches in nutrition and health research and policy.

2. Key limitations (e.g., resulting from assumptions in theoretical underpinning of the model, extent of coverage of interactions between food system parts, or specific drivers of behavioural changes).

SHARP is not suitable for developing long-term scenarios.

The SHARP model can be relatively easily developed for sustainability and health. The operationalization of the consumer-related ARP-dimensions is an explorative part of WP7. The explorative nature of this part is a result of limitations regarding the availability of (internationally comparable and standardized) data on determinants of consumer behaviour.

3. Links to other models in the toolbox (refer to D9.1 for proposed links in SUSFANS) and indicate how accomplishing these links would enhance the model's contribution to SFNS assessments compared to stand-alone use. Possible complementarity with DIET and CAPRI/MAGNET models is not yet analysed. Next, starting from long term agro-economic models, the model can be re-run to evaluate the nutritional adequacy under future scenarios of the food system. This can provide feedback for further fine-tuning of the agro economic models.

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