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FishChoice 2.0: Information on health benefits / risks and sustainability for seafood consumers

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ABSTRACT

Since seafood is a significant source of nutrients with known health benefits, its consumption is promoted as a healthy food choice. However, seafood can also contain potentially hazardous environmental pollutants. In the context of the ECsafeSEAFOOD FP7 project, FishChoice (www.fishchoice.eu) was developed as a communication tool to help to the consumers to take the most appropriate decisions on their seafood consumption habits. FishChoice relies on scientific information that allows calculating, on an individual basis, intakes of nutrients and pollutants derived from seafood consumption. In the framework of the EU-H2020 funded SEAFOOD[TOMORROW] project, an optimized version of the online tool has been released. FishChoice is available in 25 EU languages with a customized list of seafood species per EU country, considering specific (national) consumption habits. The list of nutrients has been extended according to the latest EFSA recommendations, while pollutants data incorporate results from recent studies. The sustainability of seafood consumption has been also implemented, providing recommendations to help preserve the marine environment. Finally, FishChoice is suitable not only for consumers, but also health professionals, schools and academia, as well as the industrial sector and public health providers.

1. Introduction

Seafood consumption provides numerous nutrients such as protein, minerals, vitamins and the polyunsaturated long chain omega-3 fatty acids EPA (eicosapentanoic acid) and DHA (docosahexaenoic acid) (Nøstbakken et al., 2021). Benefits from seafood consumption are related to weight control, childhood cognitive development, reduction in risk of succumbing cardiovascular diseases (i.e.: high blood pressure, coronary heart disease, stroke), inflammatory diseases (i.e.: rheumatoid arthritis) and cancer (i.e.: colorectal) (Lund, 2013). Consequently, the World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations (UN) recommend a regular seafood consumption of one to two servings per week (FAO/WHO, 2011). Promotion of seafood consumption as a healthy eating habit is one of the reasons why consumption has doubled in the last 50 years, putting stress on fragile resources (Guillen et al., 2019). However, seafood can be a significant source of exposure to a number of environmental pollutants such as toxic metals, polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs) and polychlorinated biphenyls (PCBs) (Perelló et al., 2015a; González et al., 2018, 2019). In turn, the exposure to these chemicals is linked to a wide range of well-known adverse effects on human health, such as cancer, liver and kidney damage, immunosuppression and reproductive effects (Tiktak et al., 2020). Furthermore, although endocrine disrupting chemicals (EDCs) have been also detected in seafood, information about their potential adverse effects on human health is still limited, (Álvarez-Munoz et al., 2015; Aznar-Alemany et al., 2017; Domingo, 2016; Trabalón et al., 2017; Ojemaye and Petrik, 2019; Cruz et al., 2020; He et al., 2021).

This duality of benefits and risks gives rise to a nutritional-toxicological conflict (Sioen et al., 2008). While scientists and

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policymakers address this communication dilemma, consumers, industries, policy, and non-governmental organizations describe a deficit in food-related benefit/risk information (van Dijk et al., 2012; Tediosi et al., 2015). In parallel, concerns about environmental impact are increasing among some consumers (Ratliff et al., 2018).

The increased use of Internet offers new opportunities for online tools with tailored information for stakeholders (Tediosi et al., 2015). In 2006, RIBEPEIX, a computer program focused on quantitative

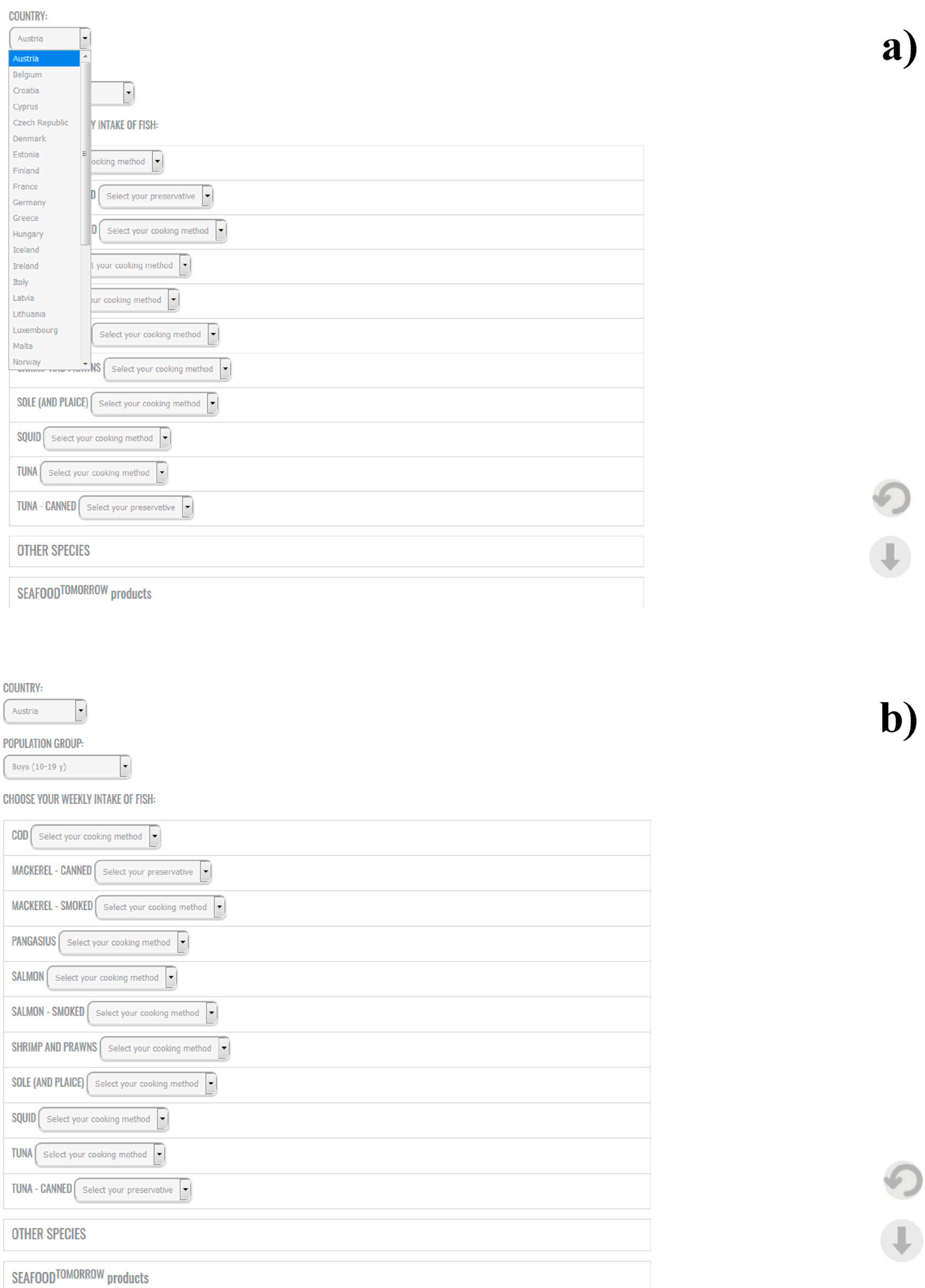

Fig. 1. Country selection (a) and default list of species according to the selected country (b).

establishment of intakes of several chemical pollutants versus ingestion of EPA and DHA omega-3 fatty acids was launched (Domingo et al., 2007). Between 2013 and 2017, FishChoice was first developed to address some limitations of RIBEPEIX (Vilavert et al., 2017), as a part of the European Union (EU) FP7-funded project ECsafeSEAFOOD (GA No. 311820). FishChoice is a user-friendly online tool providing personalized risk-benefit information, based on weekly seafood intake (Minnens et al., 2020). Recently, an improved version of FishChoice has been launched. The new version was developed in the framework of the European Union (EU) H2020-funded project SEAFOOD^{TOMORROW} (GA No. 773400). This project aimed to develop innovative sustainable solutions to improve the safety and dietary value of seafood in Europe. To the best of our knowledge, FishChoice is the first tool addressing the three pillars of seafood consumption, specifically intake of nutrients, exposure to chemical pollutants, and sustainability.

2. Functionality of FishChoice

FishChoice is available at www.fishchoice.eu. Technical details of the tool are described elsewhere (Vilavert et al., 2017). Briefly,

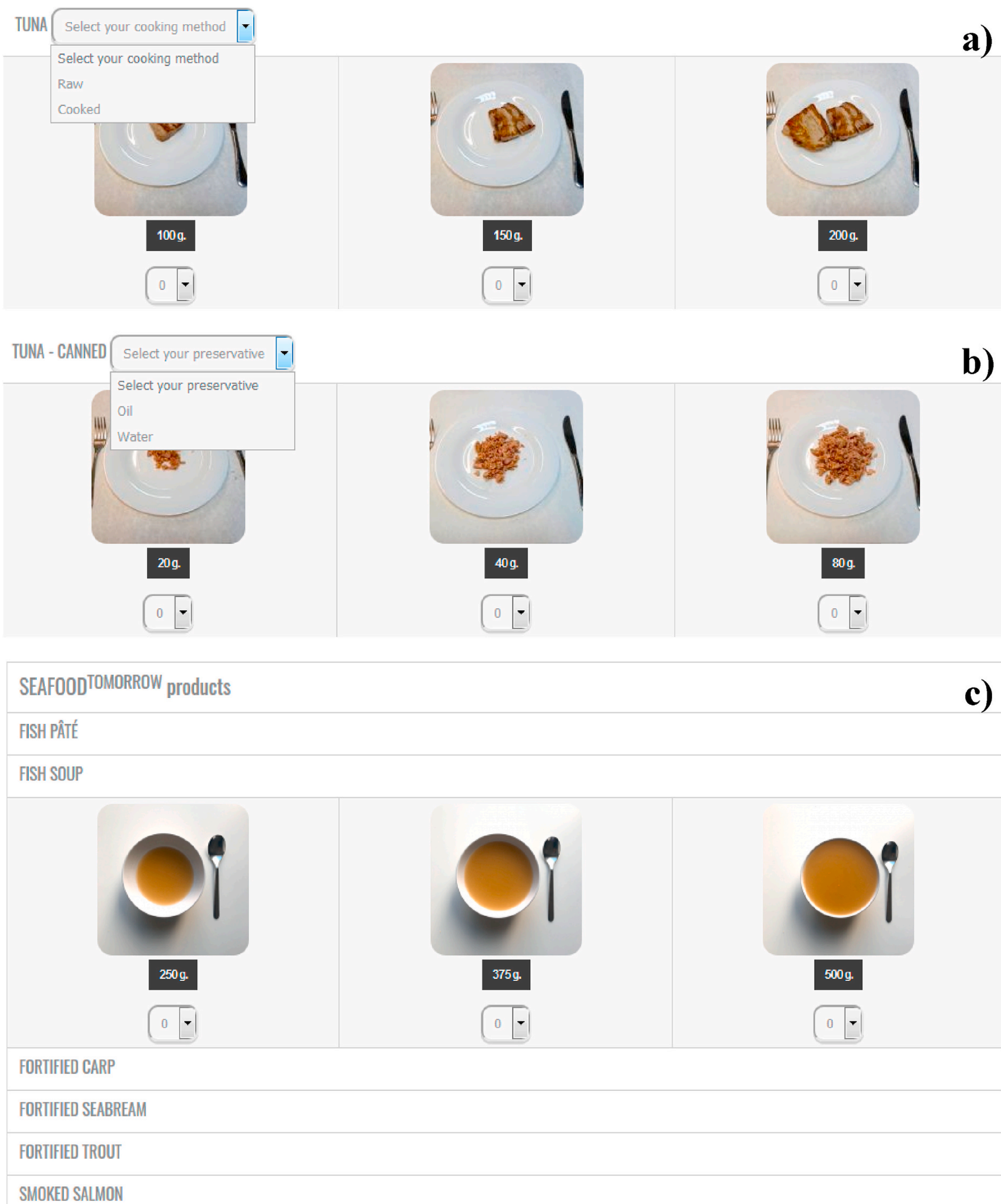

Fig. 2. Cooking method (a), preservative (b) and *SEAFOOD^{TOMORROW}* products (c) drop-down menu included in FishChoice for consumers' selection.

FishChoice was developed based on the popular WordPress content management system with a plugin acting on its codex. There are two versions of FishChoice: *simple calculator* for the public, and the *pro calculator* for health professionals, schools and academia, seafood industries, and public food providers. The updated FishChoice has a responsive web design to support access through smartphones, tablets, and other mobile devices.

2.1. Seafood species

The total number of fish, shellfish, and other seafood species included the first version of FishChoice was extended, considering seafood consumption habits across the EU. For this, seafood species were selected from seafood consumption habits studies (EUFOMA, 2016; EUFOMA, 2017; Cardoso et al., 2013; Willemsen, 2003; Sveinsdóttir et al., 2011; NORGE, 2016; OFAG, 2017). In addition, data from these studies were supplemented with a survey of seafood consumption habits based on the seafood species available in FoodEXplorer (see section 2.2.1). Species included in the survey were limited to those available in FoodEXplorer to assure the availability of nutrients data. This survey was circulated among the SEAFOOD^{TOMORROW} consortium. At least one partner (out of 35) from each of the 19 European countries represented in the consortium participated to the survey. The full list of seafood species per country is shown in Supplementary Information (Table S1). The current updated version of FishChoice displays a default list of fish and seafood species based on the EU country selected. The species that were identified as less commonly consumed, are included in a second box “other seafood species” (Fig. 1), which users may also select.

FishChoice seafood species were integrated as either raw and/or cooked products. Values for cooked species were an average of values, for a range of cooking methods (boiling, steaming, microwaving, grilling, baking), included in FoodEXplorer. Cooking methods included in the average for each species depended on data available in FoodEXplorer and included cooking methods that would typically be used for each species. Values for fried fish were not included in cooked averages because of the change in composition due to addition of cooking fat. Canned tuna, mackerel, sardines and anchovies, preserved in either water or oil, as well as smoked salmon and smoked mackerel, were incorporated independently. Finally, we also included novel SEAFOOD^{TOMORROW} products, created by the project (i.e., fortified carp, fortified trout, fortified seabream, fish pâté, smoked salmon, and fish soup) (Barbosa et al., 2020; Granby et al., 2020; Muñoz et al., 2020; Nielsen et al., 2020; Sobczak et al., 2020) (Fig. 2).

2.2. Nutrients

The list of nutrients previously included was significantly extended based on those, which according to the EFSA (2014a), represent the main benefits of seafood consumption. Thus, protein, omega-3 fatty acids (EPA and DHA), omega-6 fatty acids, iodine, selenium, cholesterol, calcium, iron, sodium, vitamin B6, vitamin B12, and vitamin D, have been included. As in the former version of the tool, the *simple calculator* shows only graphical information for each nutrient (i.e., a blue or green fish, if the intake is below or above the recommended intakes, respectively). In addition to the graphical information, the *pro calculator* provides numerical intakes and minimum recommended intakes for each nutrient. In order to help users making informed decisions, both versions of FishChoice include a list with other foods (i.e.: meat, eggs, dairy products, nuts legumes, cereals, etc.) with potential to contribute to the intakes of each nutrient.

2.2.1. Dataset of nutrient composition

The FoodEXplorer tool (EuroFIR AISBL, 2009), which includes composition data from 39 national datasets, was used to collect nutrient data for all fish and seafood species included in FishChoice. Scientific names, LanguaL food description codes (https://www.langual.org/default.asp) and FoodEX2 codes (https://www.efsa.europa.eu/en/data/data-standardisation) were retrieved for each species. Nutrient values representative of fish and seafood consumed in Europe were calculated from the available data for all nutrients and species. In order to help to identify any possible error or unusual values, the compiled values were compared -when possible- with those published in the FAO/INFOODS Global Food Composition Database for Fish and Shellfish, version 1.0 (uFiSh1.0) (FAO, 2016).

2.2.2. Recommended intakes for nutrients

The population reference intake (PRI), average requirement (AR), adequate intake (AI) and reference intake (RI) for selected nutrients were obtained from the latest EFSA scientific opinions (EFSA, 2010; EFSA, 2012; EFSA, 2014b,c; EFSA, 2015a,b,c; EFSA, 2016a,b; EFSA, 2019). These values indicate the amounts of specific nutrients that should be consumed on a regular basis to maintain health in an otherwise healthy individual (or population). They were included considering: i) the average percentages of contribution from seafood consumption to the considered nutrient (ACSA, 2016; Perelló et al., 2015b; Ruiz et al., 2016); and ii) special requirements for each population group included in FishChoice: children (3–9 years), girls and boys (10–19 years), women and men (20–65 years), senior females and senior males (>65 years), and pregnant women.

2.3. Pollutants

The tool shows results for pollutants grouped as follows: mercury (methylmercury); arsenic (inorganic arsenic); plasticizers (bipshenol A); Persistent Organic Pollutants (POPs) (PAH4, perfluorononanoic acid (PFNA), perfluorooctanoic acid (PFOA), perfluorooctane sulfonate (PFOS), perfluoroundecanoic acid (PFUnA)); flame retardants (pentabromodiphenyl ether (PBDE99), tetrabromodiphenyl ether (PBDE47), tetrabromobisphenol A (TBBPA), hexabromocyclododecane (HBCD)); musks (galaxolide, tonalide); personal care products (triclosan, isoamyl-4 methoxycinnamate (IMC), 2-ethylhexyl salicylate (EHS), 2-ethylhexyl-4-methoxycinnamate (EHMC), benzophenone 3 (BP3), benzophenone 1 (BP1), 4-methylbenzylidene camphor (methylparaben); and pharmaceuticals and drugs (venlafaxine).

The existing database of pollutants was completed for 34 newly included seafood species according to information from the scientific literature (Duedahl-Olesen et al., 2020; González et al., 2019; Vandermeersch et al., 2015; Alves et al., 2017; Lee et al., 2015; Trabalón et al., 2017). For those pollutants that have not been assessed in a specific species, it was assumed that concentrations were the same as any seafood of the same genus. For metal species, the following classifications were used to fill the gaps: blue fish, white fish, mollusks, crustaceans, and cephalopods. Finally, if a pollutant had never been determined in any species of the same genus, the tool reports 0 for the calculations, being this gap reported under the highlight: “Pollutant and seafood species that have not been analyzed”.

Following the same strategy as for nutrients, the *simple calculator* shows only graphical information (i.e., green or red fish symbols, if intakes of pollutants are below or above tolerable weekly intakes, respectively). The *pro calculator* provides numerical intakes and tolerable weekly intakes for each pollutant. In order to help consumers modify their seafood consumption habits, both versions of FishChoice also include information about other foods (i.e.: meat and meat products, vegetables, tubers, oils and fats, etc.) with a high potential to contribute to intakes of each pollutant. Finally, if the intake of certain pollutant is above the tolerable weekly intake, the user is advised with alternative seafood species to replace those most polluted (i.e.: try to eat mackerel instead of tuna).

2.4. Sustainability

FishChoice also provides information to support good practices regarding sustainability of seafood consumption. The tool encourages consumers to make responsible consumption decisions in terms of environmental impact and sustainability by providing information on ecosystem quality, and natural resource depletion.

The module for sustainability links each product and country combination with codified traffic-light messages according to three levels of sustainable consumption: 1) green, when the seafood consumption is recommended; 2) yellow, advising consumers to eat moderately; and 3) red, when seafood consumption should be avoided (Fig. 3). Based on the literature, traffic-light labels are a good strategy to successfully reduce environmental impacts of food choices (Muller et al., 2019; Osman and Thornton, 2019; Panzone et al., 2018). The FishChoice database was constructed according to a risk-based assessment evaluating impacts of the species-technology-location combinations.

The basis of this sustainability report relies on different aspects, depending on whether species are farmed or wild. Specifically, for (farmed) aquaculture systems the sustainability factors assessed were the following: exposure of the surrounding environment to diseases, parasites, and release of chemicals affecting wildlife (mainly in open systems), farmed fish escapes that can affect wild populations equilibrium, direct damage over surrounding ecosystems (habitat transformation and pollution), and depletion of fish stocks (wild) used for fish feed production. In the case of (wild) fisheries, key aspects were overfishing, unsustainable depletion of wild fish stocks, by-catches of non-target species (landed or discarded), impacts over sensitive areas due to aggressive gears of fishing, and fishing management, in general.

To collect appropriate messages avoiding inconsistencies for each species-technology-location, searches were carried out using the scientific names of seafood products as a reference (FAO, 2020). Guidelines were found to be available for several countries, where they were developed for different species commonly consumed in these locations. Many country-specific guides used recommendations from a shared pool of WWF (World Wildlife Fund for Nature) assessments, and therefore, provide consumers with similar recommendations for individual species. To fill the gaps, a default database was created for country-species combinations not found in country-specific guides. Criteria to select suitable sources for each species were: i) guidelines from other countries when species consumption was clearly linked (e.g., species commonly consumed in Sweden and Finland); ii) adaptation of reports from the Marine Conservation Society (MCS) online guide (MSC, 2020); iii) data from countries with propinquity due to location/culture; iv) information easy to adapt to FishChoice output format; v) when all the above failed, information about the level of concern for a species was included according to the International Union for Conservation of Nature (IUCN, 2020) Red List. Details about countries and sources for each species can be found in Supplementary Material (Table S2).

3. Improvement of FishChoice

Compared with the first version of FishChoice, the updated tool has been improved in many aspects. Firstly, FishChoice is now tailored at the country level. The users may select a country as the first step and the tool switches automatically to the default language of the country selected. FishChoice is now available in 25 EU languages. In addition to English, Spanish, Portuguese, Italian, and Dutch, FishChoice is also available in Catalan, Croatian, Czech, Danish, Estonian, Finnish, German, Greek, Hungarian, Icelandic, Irish, Latvian, Lithuanian, Maltese, Norwegian, Swedish, Polish, Slovak, Slovenian, and Turkish. FishChoice can still be used in English, regardless of the selected country, as a user-defined choice.

Secondly, the number of species has been extended from 21 to 62. Species were selected considering not only consumption patterns in Belgium, Ireland, Italy, Portugal, and Spain, as previously, but also in the rest of the EU. FishChoice is easier to use, since only more frequently consumed species are displayed. The remaining species are displayed in a second box “other seafood species”, which the user can decide including or not. Finally, integration of seafood items as raw and/or cooked, as well as canned products, improved the overall performance of the tool. The range of nutrients was also significantly increased. Following updated EFSA recommendations, the new database includes information for proteins, EPA and DHA, iodine and selenium, which mean the main benefits of seafood consumption, although cholesterol, omega-6, calcium, iron, sodium, vitamin B6, vitamin B12, and vitamin D are also included. On the other hand, inclusion of sustainability in a benefit/risk tool is novel. To the best of our knowledge, FishChoice is the first communication tool developed to help consumers make decisions including aspects of marine environment preservation.

Lastly, a feedback tab has been implemented to monitor users’ experiences. This feature gathers anonymous opinions to facilitate an improvement of the tool, which is necessary to support and assure continued adoption of FishChoice among users. FishChoice is a communication tool aimed at promoting seafood consumption as a healthy dietary habit. The clear information provided helps to increase consumer trust and awareness of fish and seafood as a safe and highly nutritious food. Moreover, the tool also contributes to socio-economic and environmental sustainability, and food security, by providing free,

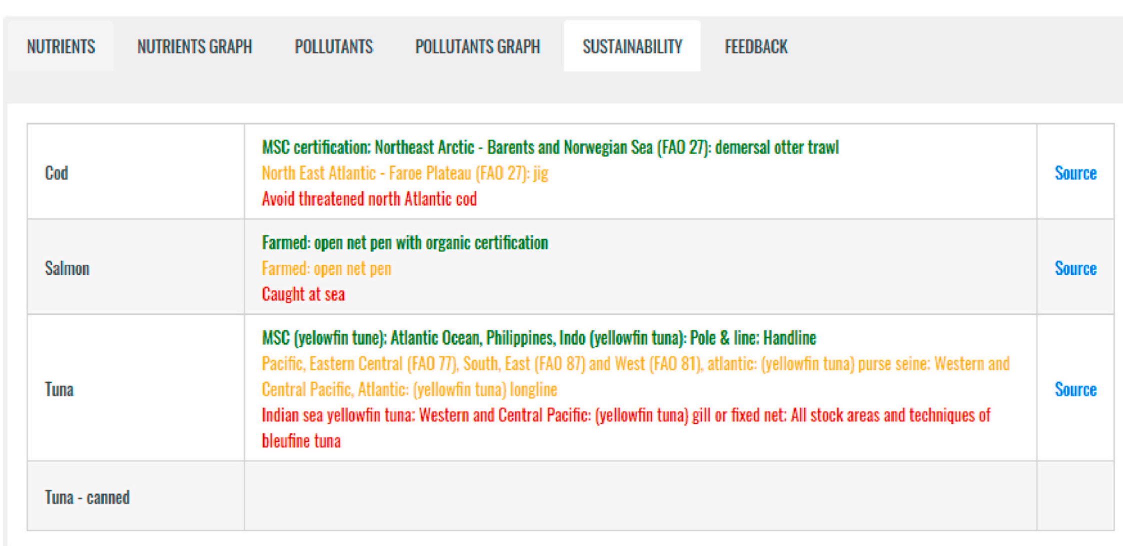

Fig. 3. Traffic-light sustainability messages in FishChoice. Example for Austria and cod, salmon and tuna species.

user-friendly, accessible information empowering consumers and other users to make responsible, healthy food choices, which improve dietary habits, and consequently, public health. FishChoice has the potential to contribute to the improved health profile of the European population overall, as described in the EC Green Deal, especially the Farm-to-Fork Strategy, as well as support increased growth in the fish and seafood sectors, assuring sustainability and profitability. FishChoice also contributes to the UN Sustainable Development Goal 12: Responsible consumption and production.

Finally, future steps and challenges include: i) continuous updates of background data on pollutants, nutrients, and sustainability; ii) the launch of a FishChoice mobile app available for Android® and iOS® operating systems; iii) integration of seafood identification tool, where users upload fish and seafood images and the tool outputs information automatically (nutrients, contaminants, and sustainability).

Credit authors statement

Montse Marquès contributed to the development of the tool and article writing. Carmen Torres contributed to sustainability data and article writing. Fernando García-Fernández programmed FishChoice. Angelika Mantur-Vierendeel and Mark Roe provided nutrients data and writing, reviewing and editing the article. Annette M. Wilson and Marieke Reuver contributed to FishChoice exploitation and reviewing the article. Martí Nadal worked on the development of the tool, and article review and edition. José L. Domingo attracted funding and reviewed the article.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.fct.2021.112387.

References

ACSA, 2016. Estudi de dieta total de iode i contribució de la llet en l'exposició de la poblacióo catalana, 2015. Catalan Agency of Food Safety, Barcelona, Catalonia, Spain ([in Catalan]).

Álvarez-Munoz, D., Rodriguez-Mozaz, S., Maulvault, A.L., Tediosi, A., Fernandez-Tejedor, M., Van den Heuvel, F., Kotterman, M., Marques, A., Barceló, D., 2015. Occurrence of pharmaceuticals and endocrine disrupting compounds in macroalgaes, bivalves, and fish from coastal areas in Europe. Environ. Res. 143, 56–64.

Alves, R.N., Maulvault, A.L., Barbosa, V.L., Cunha, S., Kwadijk, C.J.A.F., Álvarez-Muñoz, D., Rodríguez-Mozaz, S., Aznar-Alemany, Ò., Eljarrat, E., Barceló, D., Fernandez-Tejedor, M., Tediosi, A., Marques, A., 2017. Preliminary assessment on the bioaccessibility of contaminants of emerging concern in raw and cooked seafood. Food Chem. Toxicol. 104, 69–78.

Aznar-Alemany, O., Trabalón, L., Jacobs, S., Barbosa, V.L., Fernández Tejedor, M., Granby, K., Kwadijkh, C., Cunha, S.C., Ferrari, F., Vandermeersch, G., Sioen, I., Verbeke, W., Vilavert, L., Domingo, J.L., Eljarrat, E., Barceló, D., 2017. Occurrence of halogenated flame retardants in commercial seafood species available in European markets. Food Chem. Toxicol. 104, 35–47.

Barbosa, V., Maulvault, L.A., Anacleto, P., Santos, M., Mai, M., Oliveira, H., Delgado, I., Coelho, I., Barata, M., Araújo-Luna, A., Ribeiro, L., Eljasik, P., Sobczak, M., Sadowski, J., Tórz, A., Panicz, R., Dias, J., Pousão-Ferreira, P., Carvalho, M.L., Martins, M., Marques, A., 2020. Enriched feeds with iodine and selenium from natural and sustainable sources to modulate farmed gilthead seabream (Sparus aurata) and common carp (Cyprinus carpio) fillets elemental nutritional value. Food Chem. Toxicol. 139, 111330.

Cardoso, C., Lourenço, H., Costa, S., Gonçalves, S., Nunes, M.L., 2013. Survey into the seafood consumption preferences and patterns in the Portuguese population. Gender and regional variability. Appetite 64, 20–31.

Cruz, R., Mendes, E., Maulvault, A.L., Marques, A., Casal, S., Cunha, S., 2020. Bioaccessibility of polybrominated diphenyl ethers and their methoxylated metabolites in cooked seafood after using a multi-compartment in vitro digestion model. Chemosphere 252, 126462.

Domingo, J.L., 2016. Nutrients and chemical pollutants in fish and shellfish. Balancing health benefits and risks of regular fish consumption. Crit. Rev. Food Sci. Nutr. 56, 979–988.

Domingo, J.L., Bocio, A., Martí-Cid, R., Llobet, J.M., 2007. Benefits and risks of fish consumption: Part II. RIBEPEIX, a computer program to optimize the balance between the intake of omega-3 fatty acids and chemical contaminants. Toxicology 230, 227–233.

Duedahl-Olesen, L., Iversen, N.M., Kelmo, C., Jensen, L.K., 2020. Validation of QuEChERS for screening of 4 marker polycyclic aromatic hydrocarbons in fish and malt. Food Contr. 108, 106434.

EFSA, 2010. Scientific Opinion on Dietary Reference Values for fats, including saturated fatty acids, polyunsaturated fatty acids, monounsaturated fatty acids, trans fatty acids, and cholesterol. EFSA Journal 8, 1461.

EFSA, 2012. Scientific opinion on dietary reference values for protein. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 10, 2557.

EFSA, 2014a. Scientific Opinion on health benefits of seafood (fish and shellfish) consumption in relation to health risks associated with exposure to methylmercury. EFSA Journal 12 (7), 3761. https://doi.org/10.2903/j.efsa.2014.3761, 2014, 80.

EFSA, 2014b. Scientific opinion on dietary reference values for selenium. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 12, 3846.

EFSA, 2014c. Scientific opinion on dietary reference values for iodine. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 12, 3660.

EFSA, 2015a. Scientific opinion on dietary reference values for cobalamin (vitamin B12). EFSA panel on dietetic products, nutrition, and allergies (NDA). EFSA Journal 13, 4150.

EFSA, 2015b. Scientific opinion on dietary reference values for calcium. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 13, 4101.

EFSA, 2015c. Scientific opinion on dietary reference values for iron. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 13, 4254.

EFSA, 2016a. Scientific opinion on dietary reference values for vitamin B6. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 14, 4485.

EFSA, 2016b. Scientific opinion on dietary reference values for vitamin D. EFSA panel on dietetic products, nutrition and allergies (NDA). EFSA Journal 14, 4547.

EFSA, 2019. Scientific opinion on dietary reference values for sodium. EFSA panel on nutrition, novel foods and food allergens (NDA). EFSA Journal 17, 5778.

EUFOMA, 2016. The EU Fish Market. European Market Observatory for Fisheries and Aquaculture Products.

EUFOMA, 2017. EU consumer habits regarding fishery and aquaculture products. Annex 1 Mapping and Analysis of Existing Studies on Consumer Habits.

EuroFIR AISBL, 2009. FoodEXplorer - Food Composition database 2020. http://www.eurofir.org/foodexplorer/foodgroups.php EuroFIR AISBL®. (Accessed 2 March 2021).

FAO, 2016. FAO/INFOODS global food composition database for fish and shellfish version 1.0 - uFiSh1.0 (Rome, Italy).

FAO, 2020. Food and Agriculture Organization (FAO) - Fisheries Division - Fish Fact Sheets. http://www.fao.org/fishery/factsheets/search/en.

FAO/WHO, 2011. Report of the joint FAO/WHO expert consultation on the risks and benefits of fish consumption. In: Rome, Food and Agriculture Organization of the United Nations. World Health Organization, Geneva, p. 50.

González, N., Marquès, M., Nadal, M., Domingo, J.L., 2018. Levels of PCDD/Fs in foodstuffs in Tarragona County (Catalonia, Spain): spectacular decrease in the dietary intake of PCDD/Fs in the last 20 years. Food Chem. Toxicol. 121, 109–114.

González, N., Calderón, J., Rúbies, A., Timoner, I., Castell, V., Domingo, J.L., Nadal, M., 2019. Dietary intake of arsenic, cadmium, mercury and lead by the population of Catalonia, Spain: analysis of the temporal trend. Food Chem. Toxicol. 132, 110721.

Granby, K., Amlund, H., Valente, L.M.P., Dias, J., Adoff, G., Sousa, V., Marques, A., Sloth, J.J., Larsen, B.K., 2020. Growth performance, bioavailability of toxic and essential elements and nutrients, and biofortification of iodine of rainbow trout (Onchorynchus mykiss) fed blends with sugar kelp (Saccharina latissima). Food Chem. Toxicol. 139, 111387.

Guillen, J., Natale, F., Carvalho, N., Casey, J., Hofherr, J., Druon, J.-N., Fiore, G., Gibin, M., Zanzi, A., Martinsohn, J.T., 2019. Global seafood consumption footprint. Ambio 48, 111–122.

He, K., Hain, E., Timm, A., Blaney, L., 2021. Bioaccumulation of estrogenic hormones and UV-filters in red swamp crayfish (*Procambarus clarkii*). Sci. Total Environ. 764, 142871.

IUCN, 2020. Union for Conservation of Nature (IUCN) Red List of Threatened Species. https://www.iucnredlist.org/.
Lee, S.-Y., Lee, J.-Y., Shin, H.-S., 2015. Evaluation of chemical analysis method and determination of polycyclic aromatic hydrocarbons content from seafood and dairy products. Toxicological Research 31, 265–271.
Lund, E.K., 2013. Health benefits of seafood; Is it just the fatty acids? Food Chem. 140, 413–420.
Minnens, F., Marques, A., Domingo, J.L., Verbeke, W., 2020. Consumers' acceptance of an online tool with personalized health risk-benefit communication about seafood consumption. Food Chem. Toxicol. 144, 111573.
MSC, 2020. Marine Conservation Society (MCS) – Good Fish Guide. https://www.mcsuk.org/goodfishguide/search.
Muller, L., Lacroix, A., Ruffieux, B., 2019. Environmental labelling and consumption changes: a food choice experiment. Environ. Resour. Econ. 73 (3), 871–897.
Muñoz, I., Guàrdia, M.D., Arnau, J., Dalgaard, P., Bover, S., Fernandes, J.O., Monteiro, C., Cunha, S.C., Gonçalves, A., Nunes, M.L., Oliveira, H., 2020. Effect of the sodium reduction and smoking system on quality and safety of smoked salmon (Salmo salar). Food Chem. Toxicol. 139, 111554.
Nielsen, T., Mihnea, M., Båth, K., Cunha, S.C., Fereira, R., Fernandes, J.O., Gonçalves, A., Nunes, M.L., Oliveira, H., 2020. New formulation for producing salmon pâté with reduced sodium content. Food Chem. Toxicol. 139, 111509.
NORGE, 2016. SEAFOOD STUDY 2016 INSIGHTS AND OUTLOOK : THE FRENCH & SEAFOOD. Available at. https://seafood.no/contentassets/6b8fa7b9742b4b0d9b2cc4a8d87af7a5/french-seafood-study.pdf.
Nøstbakken, O.J., Rasinger, J.D., Hannisdal, R., Sanden, M., Frøyland, L., Duinker, A., Frantzen, S., Dahl, L.M., Lundebye, A.-K., Madsen, L., 2021. Levels of omega 3 fatty acids, vitamin D, dioxins and dioxin-like PCBs in oily fish; a new perspective on the reporting of nutrient and contaminant data for risk–benefit assessments of oily seafood. Environ. Int. 147, 106322.
OFAG, 2017. Le Poisson est de plus en plus apprécié dans les ménages suisses. In: Bulletin du marché de la viande. Office fédéral de l'agriculture – OFAG. Suisse.
Ojemaye, C.Y., Petrik, L., 2019. Occurrences, levels and risk assessment studies of emerging pollutants (pharmaceuticals, perfluoroalkyl and endocrine disrupting compounds) in fish samples from Kalk Bay harbour, South Africa. Environ. Pollut. 252, 562–572.
Osman, M., Thornton, K., 2019. Traffic light labelling of meals to promote sustainable consumption and healthy eating. Appetite 138, 60–71.
Panzone, L.A., Ulph, A., Zizzo, D.J., Hilton, D., Clear, A., 2018. The impact of environmental recall and carbon taxation on the carbon footprint of supermarket shopping. J. Environ. Econ. Manag. 102137 (in press).
Perelló, G., Díaz-Ferrero, J., Llobet, J.M., Castell, V., Vicente, E., Nadal, M., Domingo, J.L., 2015a. Human exposure to PCDD/Fs and PCBs through consumption of fish and seafood in Catalonia (Spain): temporal trend. Food Chem. Toxicol. 81, 28–33.
Perelló, G., Vicente, E., Castell, V., Llobet, J.M., Nadal, M., Domingo, J.L., 2015b. Dietary intake of trace elements by the population of Catalonia (Spain): results from a total diet study. Food Addit. Contam. 32, 748–755.
Ratliff, E., Vassalos, M., Hu, W., 2018. What factors influence consumer preferences for search and credence seafood characteristics? An empirical analysis in Kentucky and South Carolina. J. Agric. Food Ind. Organ. 18, 20180012.
Ruiz, E., Ávila, J., Valero, T., del Pozo, S., Rodriguez, P., Aranceta-Bartrina, J., Gil, A., González-Gross, M., Ortega, R., Serra-Majem, L., Varela-Moreiras, G., 2016. Macronutrient distribution and dietary sources in the Spanish population: findings from the ANIBES Study. Nutrients 8, 177.
Sioen, I., Van Camp, J., Verdonck, F., Verbeke, W., Vanhonacker, F., Willems, J., De Henauw, S., 2008. Probabilistic intake assessment of multiple compounds as a tool to quantify the nutritional toxicological conflict related to seafood consumption. Chemosphere 71, 1056–1066.
Sobczak, M., Panicz, R., Eljasik, P., Sadowski, J., Tórz, A., Żochowska-Kujawska, J., Barbosa, V., Domingues, V., Marques, A., Dias, J., 2020. Quality improvement of common carp (Cyprinus carpio L.) meat fortified with n-3 PUFA. Food Chem. Toxicol. 139, 111261.
Sveinsdóttir, K., Eyþórsdóttir, D.Y., Einarsdóttir, G., Martinsdóttir, E., 2011. Viðhorf Og Fiskneysla Íslendinga 2011, Attitutes and Fish Consumption in Iceland 2011. Matús Food Research, Innovation, and Safety. Reykjavik, Iceland.
Tediosi, A., Fait, G., Jacobs, S., Verbeke, W., Alvarez-Munoz, D., Diogene, J., et al., 2015. Insights from an international stakeholder consultation to identify informational needs related to seafood safety. Environ. Res. 143, 20–28.
Trabalón, L., Vilavert, L., Domingo, J.L., Pocurull, E., Borrull, F., Nadal, M., 2017. Human exposure to brominated flame retardants through the consumption of fish and shellfish in Tarragona County (Catalonia, Spain). Food Chem. Toxicol. 104, 48–56.
van Dijk, H., van Kleef, E., Owen, H., Frewer, L.J., 2012. Consumer preferences regarding food related risk-benefit messages. Br. Food J. 114, 387–399.
Vandermeersch, G., Lourenço, H.M., Alvarez-Muñoz, D., Cunha, S., Diogène, J., Cano-Sancho, G., Sloth, J.J., Kwadijk, C., Barcelo, D., Allegaert, W., Bekaert, K., Fernandes, J.O., Marques, A., Robbens, J., 2015. Environmental contaminants of emerging concern in seafood–European database on contaminant levels. Environ. Res. 143, 29–45.
Vilavert, L., Borrell, F., Nadal, M., Jacobs, S., Minnens, F., Verbeke, W., Marques, A., Domingo, J.L., 2017. Health risk/benefit information for consumers of fish and shellfish: FishChoice, a new online tool. Food Chem. Toxicol. 104, 79–84.
Willemsen, F., 2003. Report on the seafood consumption data found in the European countries of the OT-SAFE project. In: WP3. Risk Assessment of TBT in Seafood in Europe. Institute for Environmental Studies Vrije Universiteit, Amsterdam, The Netherlands.