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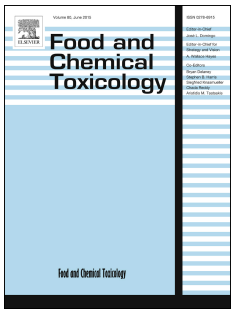

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Health risk/benefit information for consumers of fish and shellfish: FishChoice, a new online tool

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ONLY TO LOG IN DURING THE PEER-REVIEW PROCESS:

Website: www.fishchoice.eu

Username: Reviewer

Password: Review&FCT

1. Introduction

In recent decades, the importance of fish and shellfish as part of a healthy diet has meant an important promotion of their consumption among the general population. Fish and shellfish species are an important source of nutrients such as proteins, lipids, omega-3 polyunsaturated fatty acids (n-3 PUFAs), vitamins and minerals (Domingo et al., 2007a; Matos et al., 2015). The World Health Organization (WHO) and the Food and Agriculture Organization (FAO) of the United Nations (UN) recommend a regular fish consumption of 1–2 servings per week in order to provide an equivalent of 200–500 mg of n-3 PUFAs, namely eicosapentaenoic (EPA) and docosahexaenoic acids (DHA) (FAO/WHO, 2011). Furthermore, a diet including a high consumption of fish and shellfish reduces the risks of cardiovascular diseases (CVD), mainly due to the beneficial effects of the n-3 PUFAs, EPA and DHA (Tediosi et al., 2015). However, a number of studies have also shown that fish and shellfish consumption can simultaneously be a dietary source of various environmental pollutants, which have well-known adverse effects on human health (Vandermeersch et al., 2015; Domingo, 2016). According to Frewer et al. (2016), there has been a considerable focus on fish or seafood as a product category in food risk/benefit communication studies, possibly owing to this controversy associated with health benefits from nutrients versus health risks from potential contaminants.

Meanwhile, it has been repeatedly shown that consumers and stakeholders flag specific information needs and expectations regarding the communication of risks and benefits from seafood consumption. Van Dijk et al. (2012) reported that consumers perceived food-related risk/benefit information often as asymmetrical, confusing and not truthful. Their study participants also expressed a preference for more balanced and

scientifically derived information. In addition, Pieniak et al. (2007) and Altintzoglou et al. (2014) identified seafood consumer segments with differentiated information needs in relation to seafood consumption. The largest segments in both studies (referred to as "Enthusiasts" and "Info seekers", respectively, in those two studies) consisted of consumers who reported a strong need for more trustworthy, simple and easily accessible information about seafood. This type of evidence underscores the potential interest among consumers in having access to specific seafood-related information. Furthermore, Tediosi et al. (2015) have shown that also a wide diversity of stakeholders from policy, industry, and non-governmental organizations flagged a deficit of information and data in the field of seafood safety. Meanwhile, the stakeholders who participated in that study perceived online tools to be most useful communication tools in this respect.

Already back in 2006, we launched RIBEPEIX (Domingo et al., 2007b), a simple computer program focused on quantitatively establishing the intake of a number of chemical pollutants versus that of EPA and DHA, whose consistent consumption is related to an improved cardiovascular risk, especially in high risk patients and populations (Colussi et al., 2014). RIBEPEIX was a basic Microsoft Access-based application containing data on the levels of cadmium, mercury, lead, polychlorinated dibenzo-*p*-dioxins and furans (PCDD/Fs), polychlorinated biphenyls (PCBs), hexachlorobenzene, polycyclic aromatic hydrocarbons (PAHs), polychlorinated naphthalenes (PCNs), polybrominated diphenyl ethers (PCDEs), and polychlorinated diphenyl ethers (PCDEs), as well as EPA and DHA, in 14 edible marine species.

Ten years later, a new online tool, FishChoice, has been launched in order to solve some limitations of RIBEPEIX. The new software, which has been designed in a friendlier graphical interface, has been developed in the framework of the European

Union (EU) FP7-funded project ECsafeSEAFOOD. This project aimed at assessing food safety issues related to priority contaminants contained in fish and shellfish, as result of environmental contamination, as well as to evaluate their impact on public health.

2. Design and functionality: The FishChoice layout

FishChoice is based on the popular WordPress Content Management System (CMS), with the plugin acting on its codex. This enables a responsive interface on any display device and constant updates to prevent security problems. Furthermore, there is a whole community behind, constantly updated to ensure that the system adapts to the changes in Internet. Updated data regarding the concentration of a wide range of emerging pollutants, as well as those of nutrients in different edible marine species, were introduced. Two versions of FishChoice have been developed: a simple version for the general public, and a more extended (Pro) version for health professionals. Both of them are available at www.fishchoice.eu. This online tool has been structured in several screens to which the users can go while browsing.

2.1. Main screen

The calculator tab is positioned at the top left of the first screen. When starting, a specific profile can be selected. Different profiles were created according to age and gender: children (3-9 y), boys (10-19 y), girls (10-19 y), men (20-65 y), women (20-65 y), pregnant or nursing women, senior males (>65 y), and senior females (>65 y). The average body weights assigned to each profile were 24, 56, 53, 70, 55, 55, 65 and 60 kg,

respectively. Afterwards, the users can choose each one of the fish and shellfish species included in FishChoice, enter their weekly frequency of consumption, as well as their common portion sizes. Since in some cases this can be a difficult task for users, three pictures corresponding to three different portion sizes are depicted for each species (see an example in Fig. 1). Once the users have entered their fish and shellfish consumption, they can access the results by clicking the calculator symbol located at the bottom of the screen.

2.2. Pollutants

In the simple version, the user can see the list of pollutants on the left. Clicking each one, a brief summary of information about the contaminant is displayed. Furthermore, alongside each contaminant, a symbol of a fish is depicted. If its intake is below the health-based guidance value (HBGV)– in accordance with recommendations of different international organizations – a green fish will be shown next to the considered contaminant, indicating that the consumption is healthy (Fig. 2). By contrast, if the intake is above the HBGV, the symbol of the fish is shown in red (Fig. 2). A legend at the top of the page explains that a red fish means that the user should change the species of fish and shellfish and/or their consumption for a healthy intake. Furthermore, other foods with a high potential contribution through the daily diet are shown on the right of the screen (for each contaminant). The pollutant intakes are based on the respective body weight according to the consumer profile selected, the weekly fish and shellfish consumption, and the portion sizes. Finally, at the bottom of the screen a narrow icon offers the possibility to go back in order to modify the consumption data.

Although the Pro version is very similar to that designed for the general population, it provides additional information. In this case, above the fish legend, the screen shows the specific intake value for each pollutant, considering the contribution of the sum of species consumed (Fig. 2). Moreover, for each pollutant, the HBGVs according to different international organizations are also given (see Fig. 2).

2.3 Pollutants graph

In both versions, the tool also includes a visual presentation regarding pollutants. If the user clicks on the Pollutant Graph tab, a new screen is shown. The user can see the contribution of each consumed species for each contaminant (Fig. 3). In the Pro version, the software also allows the users to move the mouse cursor over the different colors of the bars. The user can then check the pollutant intake for each species individually consumed (Fig. 3).

2.4. Nutrients

Micro- and macronutrient intakes are displayed on the Nutrients screen. On the left, the user can find the list of micro- and macronutrients. Clicking each nutrient, a brief summary of information about the concerned nutrient is given. As FishChoice considers only the consumption of fish and shellfish and not the overall food consumption, the nutrient recommendations used to evaluate the nutrient intakes are recalculated based on average percentages of contribution from fish and shellfish consumption to the considered nutrient. These average percentages are obtained from the scientific literature, particularly some Spanish studies (ACSA, 2015; Perelló et al., 2015; Ruiz et

al., 2016). In addition, if the intake is found to be above the recalculated nutrient recommendation, a green fish is shown next to the considered nutrient (see Fig. 4). Otherwise, if the nutrient intake via fish and shellfish consumption is found to be below these recommended levels, the fish is shown in a blue color. Moreover, a message encouraging the consumption of more fish and shellfish is displayed. Additionally, for each nutrient the software also includes other foodstuffs having a high potential contribution (on the right of the screen). Finally, at the bottom of the screen an arrow icon offers the possibility to go back in order to modify the consumption data. In the Pro version, some additional information is provided. The intake value for each nutrient is shown considering the contribution of all species consumed (Fig. 4). Moreover, the recalculated nutrient recommendation for each nutrient is also given.

2.5. Nutrients graph

The tool also shows an icon referring to a Nutrients Graph. If the users click this Nutrients Graph tab, a new screen will appear where they can find for each nutrient the contribution of each species indicated in their diet.

2.6. Comparing seafood species

According to the results concerning the intake of pollutants, and only in the Pro version, the user can decide optimizing the balance between health benefits and risks. On this screen, for each one of the pollutants included, the species of fish and shellfish are ranked according to the content of the concerned pollutant. With this information, users can modify their fish and shellfish consumption habits in order to reduce the

potential health risks derived from exposure to pollutants, while striving to maintain the health benefits provided by nutrient intake.

2.7. Recommendations

For some species such as tuna or other top predatory fish, the European Food Safety Authority (EFSA) and other regulators recommend limiting their consumption, at least by pregnant or nursing women, as well as by children. This is mainly due to the high MeHg content (see e.g. Jacobs et al., 2017). In both versions, FishChoice shows for these particular cases, a message recommending to limit the consumption to a maximum of 250 g per week of tuna for pregnant or nursing women, and to a maximum of 100 g of tuna per week for children. These amounts were calculated according to the tolerable weekly intake (TWI) of 1.3 µg/kg bw/week for methyl mercury, as established by EFSA (2012).

3. FishChoice as an improvement of RIBEPEIX

With respect to RIBEPEIX, FishChoice has advanced in several directions. Firstly, the new program database includes a number of emerging pollutants, for which concentration data were not available when RIBEPEIX was designed. These include endocrine disruptors (bisphenol A, methylparaben, and triclosan), musk fragrances (galaxolide and tonalide), brominated flame retardants (BFRs; tetrabromobisphenol A-TBBPA and α-β-γ-hexabromocyclododecane-HBCD), pharmaceuticals (venlafaxine), perfluoroalkyl substances (PFASs; perfluorootanoic acid-PFOA, perflurooctane sulfonate-PFOS, perfluorononanoic acid-PFNA and perfluoroundecanoic acid-PFUnA),

and UV-filters (benzophenone 1-BP1; 2,4-dihydroxybenzophenone, benzphenone 3-BP3; oxybenzone, 4-methylbenzylidene camphor-4-MBC, 2-ethylhexyl-4-methoxycinnamate-IMC). Two types of toxic elements, inorganic arsenic (InAs) and methylmercury (MeHg), have been also included in the new online tool. Finally, information regarding some pollutants, which were already included in RIBEPEIX (namely, 2 PBDE congeners and PAHs) has been updated. Moreover, regarding the benefits of fish and shellfish consumption, not only PUFAs, but also other nutrients (iodine, selenium and proteins) have been included.

The second important improvement of FishChoice is the notable enlargement in the number of species for selection, which has been increased from 14 to 21. These fish and shellfish species were selected according to the most frequently consumed species in five EU countries: Belgium, Ireland, Italy, Portugal and Spain (Jacobs et al., 2015). These were: Alaska Pollock (*Theragra chalcogramma*), mussels (*Mytilus galloprovincialis*), sole (*Pleuronectes platessa* or *Solea solea*), tuna (*Thunnus Thynnus*), sardine (*Sardina pilchardus*), hake (*Merluccius merluccius*), monkfish (*Lophius sp.*), pangasius (*Pangasius hypophthalmus*), cod (*Gadus sp.*), mackerel (*Scomber scombrus*), shrimps or prawns (*Aristeus antennatus* and *Penaeus spp.*), octopus (*Octopus vulgaris*), salmon (*Oncorhynchus sp.*), seabream (*Sparus aurata*), clams (*Molluscans*), cuttlefish (*Sepia officinalis*), haddock (*Melanogrammus aeglefinus*), herring (*Clupea harengus*), lobster (*Homarus sp.*), seabass (*Dicentrarchus labrax*), and squid (*Loligo vulgaris*). In FishChoice, tuna and sardine can be selected as fresh or canned, while cod can be selected as fresh or dry/salted.

Another improvement of FishChoice with respect to RIBEPEIX is the possibility to adjust data for sensitive subpopulation groups, such as pregnant or nursing women, or children. For these groups, the food safety authorities provide special food intake

recommendations. Furthermore, the software can also provide suggestions when the user exceeds the HBGV for any pollutant. In that case, a message is displayed indicating the species accounting for the main risk according to the consumption pattern, suggesting diversifying the fish and shellfish consumption, reducing the weekly intake of the specific species, or shifting to other species with similar nutritional properties, but with lower concentrations of the specific contaminant.

As an alternative to RIBEPEIX, FishChoice can be used as an online tool to improve the balance between benefits (nutrients) and risks (pollutants) of fish and shellfish consumption, guiding consumers and health professionals for a healthy, nutritious and balanced selection of fish and shellfish species, the frequency of consumption, and the size of the portions. Moreover, FishChoice means a step forward in terms of visual attractiveness, which is a key issue when developing scientifically robust software that is aimed at appealing the general population. Unfortunately, resources originating from academics frequently lack visual appeal, intuitive user interfaces, and a user experience likely to yield long-term engagement (Hingle and Patrick, 2016). Young generations tend to use more frequently and more intensively new technologies, while they have a higher day-to-day variability in their daily diet (Chen et al., 2017). Moreover, dietary assessment methods using technology are preferred over traditional methods for collecting information, such as pen- and paper-food records (Boushey et al., 2009). As a consequence, the development of digital tools must be enhanced. However, it is essential to assure scientific rigor and quality, as a lack of professional, evidence-based content of some apps and online tools currently available in the market raises concerns about efficacy and patient or consumer safety (Nikolaou and Lean, 2017). Taking these issues into account, FishChoice has been

developed and validated in the framework of an EU-FP7 research program, therefore assuring that the information contained in the software is of high scientific quality.

Future challenges concern the further refinement of the tool, including a continuous updating of background data on pollutants, nutrients, and species as new evidence emerges, as well as assessing its attractiveness and potential use among the envisaged target groups of seafood consumers, health professionals and other stakeholders.

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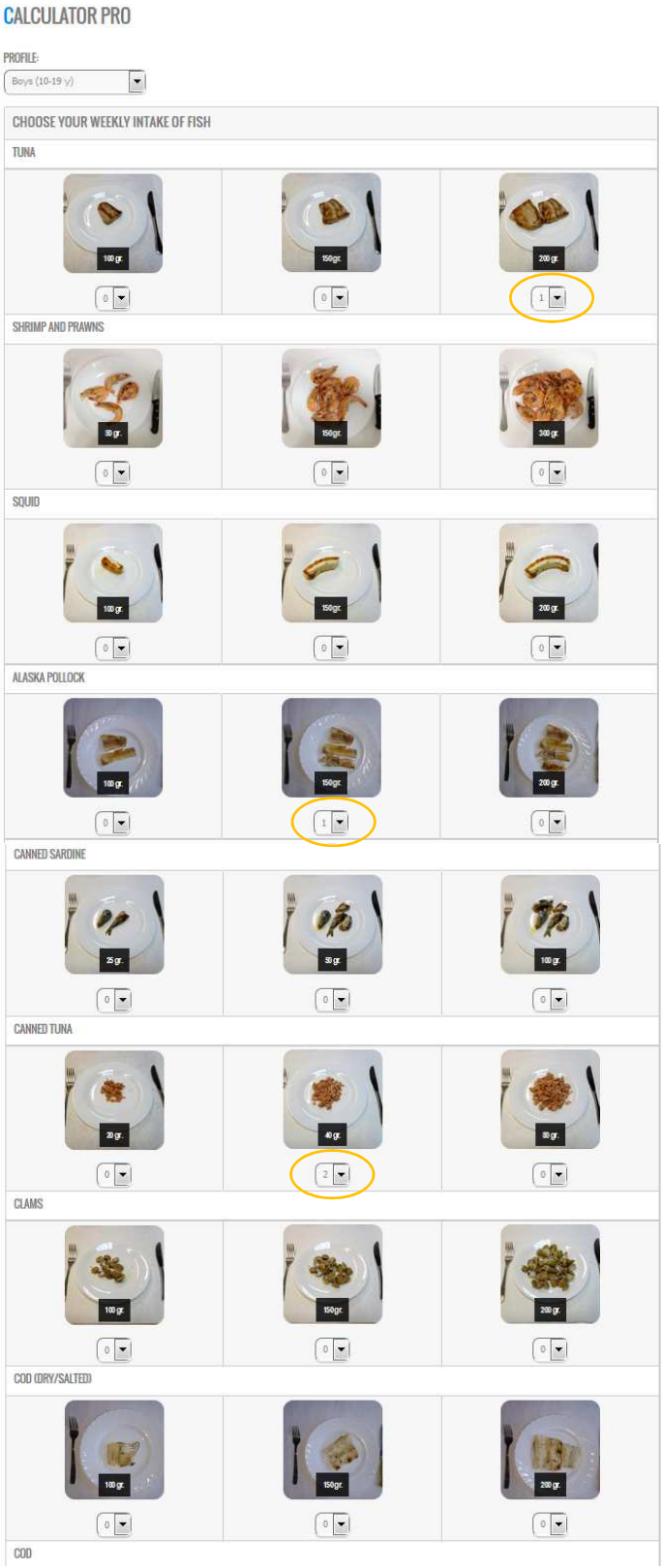

Fig. 1. Data on weekly fish and shellfish intake habits for a boy aged 10-19, used as an example.

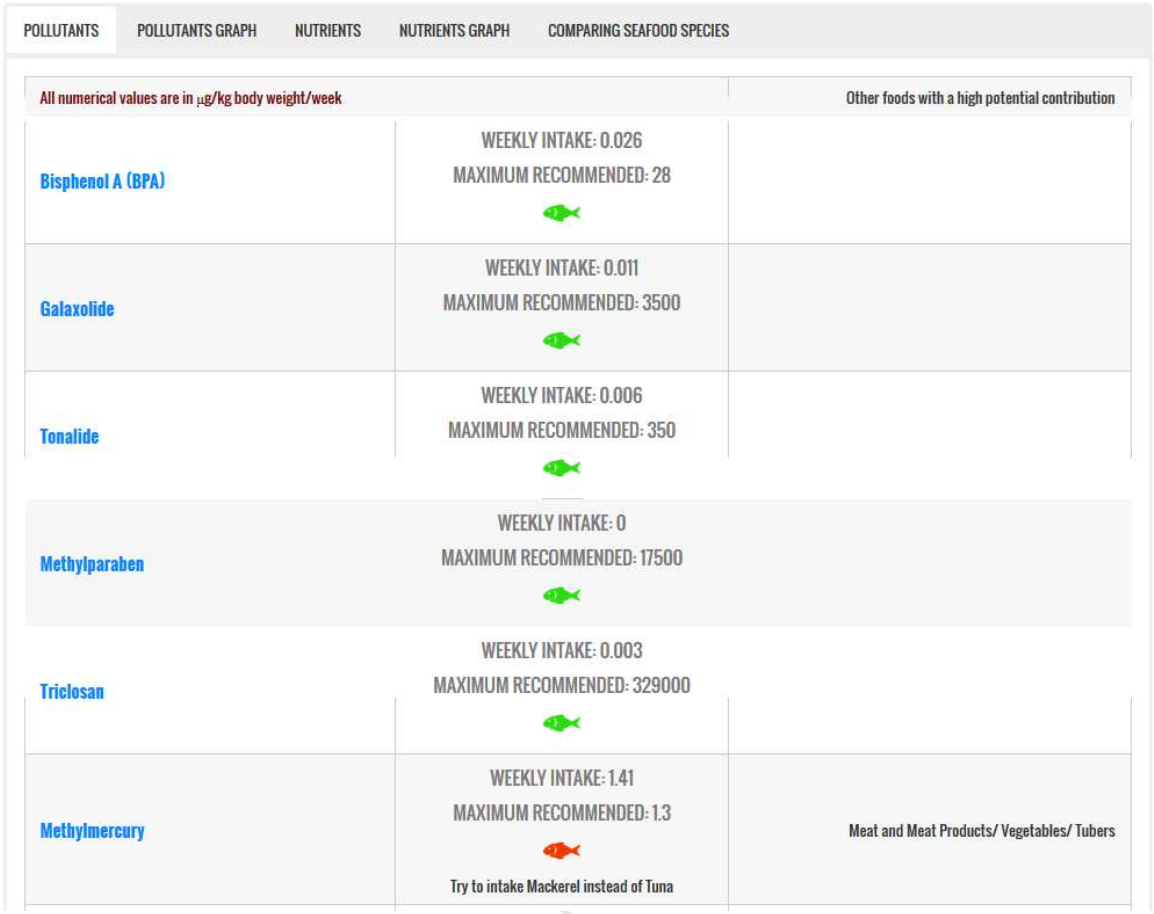

Fig. 2. Intake of various chemical pollutants through fish and shellfish consumption by a boy, as an example. The health-based guidance value for each contaminant, expressed as "maximum recommended" for an easier comprehension by users, is also shown.

Fig. 3. Contribution for each species consumed individually by a boy, as an example.

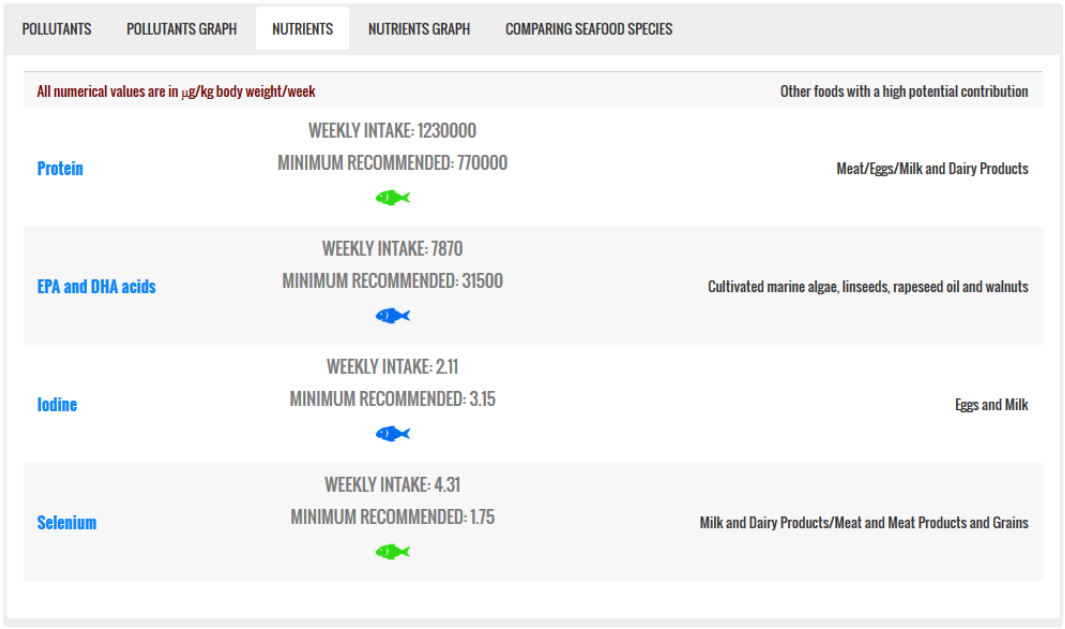

Fig. 4. Macro- and micronutrient intakes through fish and shellfish consumption by a boy, as an example.

HIGHLIGHTS

- Dietary assessment methods using technology are preferred by young generations.
- Fish consumption is a key dietary source of exposure to environmental pollutants.
- ECsafeSEAFOOD was aimed at analyzing the levels emerging pollutants in seafood.
- FishChoice is an online tool to balance benefits and risks of seafood consumption.