



Review

Review of availability of food composition data for fish and shellfish



Doris Rittenschober*, Verena Nowak, U. Ruth Charrondiere

FAO, Rome, Italy

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ABSTRACT

The FAO/INFOODS database on fish and shellfish (aFiSh) is a collection of analytical data from primary sources and holds values for 2,277 entries on raw and processed food with sufficient quality. Most data were entered on fatty acids (60%), followed by macronutrients and their fractions (16%), minerals (10%), amino acids (7%), (pro)vitamins (2%), heavy metals (2%) and other components (3%). Information on several factors that contribute to the variation of compositional data (e.g., biodiversity, catch season, habitat, size and part of fish/shellfish analysed) as well as the bibliographic references are presented alongside with each food entry. The data were published in the FAO/INFOODS Food Composition Database for Biodiversity (BioFoodComp2.0) and in the FAO/INFOODS Analytical Food Composition Database (AnFood1.0), freely available at the INFOODS webpage http://www.fao.org/infoods/biodiversity/index_en.stm. The provision of easy accessible, analytical compositional data should be seen as stimulation for researchers and compilers to incorporate more analytical and detailed data of fish and shellfish into future food composition tables and databases and to improve dietary assessment tools.

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1. Introduction

Seafood includes fish, crustaceans and molluscs, which are seen as part of a healthy and balanced diet. Globally, the total capture and aquaculture production of aquatic animals reached 148.5 mil-

lion tonnes in 2010, out of which 86% were used for direct human consumption. In 2009, the global per capita food supply of fish was estimated at 18.4 kg, where fish accounted for 6.4% of the global population's intake of all proteins consumed and provided 2,900 million people with almost 20% of their average per capita intake of animal proteins (FAO, 2012).

Seafood is considered as a low-fat and protein-rich source, with other nutritional components that are positively attributed to health. There are some micronutrients that are in general more

* Corresponding author. Address: FAO, Viale delle Terme di Caracalla 1, 00153 Rome, Italy. Tel.: +39 06 570 56 134; fax: +39 06 570 53 879.

E-mail address: doris.rittenschober@fao.org (D. Rittenschober).

abundant in aquatic animals than in mammalian meats or plants, e.g., vitamin D in oily fish or minerals such as iodine, selenium, zinc, magnesium and calcium. Seafood is known for its high content of long-chain omega-3 fatty acids eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) that are primarily linked to the prevention and protection against several epidemic lifestyle diseases, in particular cardiovascular diseases (Larsen, Eilertsen, & Elvevoll, 2011). The importance of fish in the human diet and its beneficial effects have been proven e.g., for non-communicable diseases (Larsen et al., 2011; Ruxton, 2011), which show an increasing prevalence both in developed and developing countries (Daar et al., 2007), or for food security (Garcia & Rosenberg, 2010) as well as for combating undernutrition and micronutrient deficiencies in developing countries (Kawarazuka & Béné, 2011).

Data on food composition, available in food composition databases (FCDBs) or tables (FCTs), build the basis for evaluating the dietary intake of individuals and population groups, provide information for the development of food-based dietary guidelines and are needed for food labelling purposes (Elmadfa & Meyer, 2010; Greenfield & Southgate, 2003; Pennington, 2008). However, currently available FCTs and FCDBs do not reflect the whole range of consumed fish and shellfish, which limits the precision of the nutrient intake estimations.

It is a key role of FAO/INFOODS to improve the quality, availability and accessibility of high-quality food composition data (FAO/INFOODS, 2012a). Therefore, INFOODS and FAO collected compositional data and published several FCDBs, e.g., the West African Food Composition Table (Stadlmayr et al., 2012). Since biodiversity is a major explanation for the variability of the composition of foods (Toledo & Burlingame, 2006), it was decided to publish the FAO/INFOODS Food Composition Database for Biodiversity 2.0 – BioFoodComp2.0 (Charrondière et al., 2012; FAO/INFOODS, 2012b), which is a growing repository of analytical data. Other special databases were published by FAO/INFOODS containing solely analytical data such as the FAO/INFOODS Analytical Food Composition Database 1.0 – AnFood1.0 (FAO/INFOODS, 2012c).

The objective of this article is to assess publicly available data on nutrient composition of fish, crustaceans and molluscs in terms of quality and quantity. The nutrient profile of Atlantic horse mackerel (*Trachurus trachurus*, HOM) will be used as an example to illustrate the characteristics of the archival data collection of this food group and to highlight the necessity of capturing intra-species variation of compositional data in databases.

2. Materials and methods

2.1. Literature research and data collection

With assistance of the FAO Fisheries Department, the ASFIS List of Species for Fishery Statistics Purposes, holding over 10,000 species on aquatic animals (FAO, 2011) was narrowed down to nearly 2,000 by focusing on those, which are important for production. Using this abridged list a comprehensive literature research was carried out to obtain analytical compositional values for fish and shellfish (marine and freshwater) for human consumption. The aim was to cover as many different species as possible while giving attention to differences between wild and farmed fish and shellfish. Both scientific and English names provided by the ASFIS list were entered in combination with several keywords: chemical/nutritional/fillet/tissue/muscle composition, fatty acid/amino acid composition/profile, farmed/cultured, seasonal variation/change, minerals, fat-soluble/water-soluble vitamins. Reference lists of relevant literature were cross-checked and further articles were included, resulting in a total amount of around 800 articles on

compositional data for fish and shellfish. In addition, analytical data have been obtained from related international institutes using the INFOODS network.

2.2. Inclusion/exclusion of data and quality of data

All data were evaluated for data quality and presentation according to a set of quality criteria (Table 1). Exclusion criteria varied from imprecise food and analytical methodology descriptions, missing data and lack of units and denominators. Subsequently 40% of the papers originally obtained were rejected.

Selected data quality checks, which are included in the FAO/INFOODS Guidelines for Checking Food Composition Data prior to the Publication of a User Table/Database – version 1.0 (FAO/INFOODS, 2012d) were applied to screen the data for consistency and reliability. Checks on the sum of proximate composition were carried out with an accepted range of 95–105 g, where proximates are water, protein, fat, carbohydrates, dietary fibre (except if fibre values are included in carbohydrates), alcohol and ash. Additionally, the sum of individual constituents was scrutinised for agreement with the corresponding components (e.g., sum of minerals should not exceed the ash content, sum of individual fatty acids should not exceed the content of total lipids). Variation of data within species was checked and outliers were sorted out.

These checks were constantly applied, both during the initial data evaluation and during the compilation of the database in order to detect implausible data.

2.3. Standardisation of data

The standardisation aims to uniform the expressions of nutrients and their units, which allows a comparative evaluation and analysis of the data at a later stage. All nutrient values are expressed per 100 g edible portion on a fresh weight basis (EP).

Data were compiled according to international standards for food composition and compilation as outlined by Greenfield and Southgate (2003) and by using the FAO/INFOODS compilation tool, a simple food composition database management system in Microsoft Excel (Charrondière & Burlingame, 2011). All components have been identified and assigned to INFOODS food component identifiers, also called tagnames (Klensin, Feskanich, Lin, Truswell, & Southgate, 1989). Different tagnames for one nutrient exist, if analytical methods, modes of expression or definitions of a component result in significant different nutrient values. When a clear assignment to a tagname was not possible due to e.g., imprecise description of analytical method, a tagname indicating “unknown” was selected.

Further standardisation included the conversion from values into standard units, the recalculation to a fresh weight basis per 100 g edible portion and the adjustment of component expressions according to the FAO/INFOODS Guidelines for Converting Units, Denominators and Expressions – version 1.0 (FAO/INFOODS, 2012e). Due to international disagreement on fatty acid conversion factors (XFA) and the application of the Sheppard factors for fish and shellfish, a proposal for a harmonised use was developed by FAO/INFOODS (Nowak, Rittenschober, Exler, & Charrondière, Unpublished results). Fatty acid contents were calculated by using XFA as proposed by Weihrauch, Posati, Anderson, and Exler (1977) and by applying the Sheppard factors (Sheppard, 1992).

In addition, the ASFIS list was used to identify all fish and shellfish according to their scientific name given in the original source by assigning two codes, namely the ISSCAAP code, a double figure code, which divides commercial species into groups on the basis of their taxonomic, ecological and economic characteristics. Furthermore, the “Inter-Agency 3-Alpha Code”, which was developed by the Coordinating Working Party on Fishery Statistics (CWP) was

Table 1

Examples for the exclusion of scientific articles for food composition database on fish and shellfish.

Food description
• Imprecise/missing description of food parts analysed (e.g., if whole fish or fish fillet).
• Imprecise description of the state of analysed food (e.g., if raw or cooked).
Data description
• Missing units and denominators.
• Inconsistency in data presentation (e.g., in the manuscript data refer to fresh weight basis but the corresponding table presents data on dry matter basis).
• Imprecise description of nutrient definitions (e.g., not clear if vitamin A is expressed as retinol equivalent, as retinol activity equivalent or as retinol).
• Data presentation in graphs/figures, without providing related values.
• Misleading table/graph description.
• Insufficient documentation of the analytical method.
Missing data that are needed to transform data to 'per 100 g edible portion on a fresh weight basis' (EP)
• Missing water (or dry matter) content per 100 g EP, if data were expressed as percentage or g dry matter.
• Missing protein content per 100 g EP, if data on amino acids were expressed as percentage or g protein.
• Missing value for lipid or total fatty acid per 100 g EP, if data on fatty acids were expressed as percentage or g of total lipids or total fatty acids.
Inconsistency
• Sum of proximates higher/lower than accepted range of 95–105 g/100 g EP.
• Sum of individual constituents is not in accordance with corresponding component (e.g., sum of amino acids and protein content).

assigned. It is a unique identifier per species made of three letters that is widely used for the exchange of data among fishery agencies (FAO, 2011). In this paper the 3-alpha code (e.g., OYG, HOM, TRR) is provided alongside the scientific name when presenting an explicit species.

2.4. Compilation

All screened data were subsequently included in the Archival Analytical Database on Nutrient Values for Fish and Shellfish (aFiSh). The data were then separated and are publicly available in two FAO/INFOODS databases: Those data which are in accordance with the criteria of the Nutritional Indicator for Biodiversity (FAO, 2008) were included in the online FAO/INFOODS Food Composition Database for Biodiversity 2.0 (BioFoodComp2.0) (FAO/INFOODS, 2012b): (1) wild, edible, raw or processed/preserved (e.g., boiled, fried, dried, smoked) fish and shellfish identified at species level, and (2) edible, raw or processed/preserved fish and shellfish identified below species level. Data found for recipes or for farmed fish and shellfish that were identified at higher taxonomic levels, were entered separately in the FAO/INFOODS Analytical Food Composition Database 1.0 (AnFoodD1.0) (FAO/INFOODS, 2012c). However, if not indicated otherwise, the findings of the article are based on the entire data set of the aFiSh.

3. Results and discussion

3.1. Description of the database for fish and shellfish

All data of the aFiSh are well documented with adequate food descriptions and additional information e.g., catch area and season, habitat (i.e., wild or farmed incl. fish diet) and biometric data, so that users can utilise them without referring back to the original published sources. Assigned ASFIS codes, which are identical for several food entries, indicate the same species despite different scientific names (e.g., when older, non-accepted scientific names have been used in the original source). Both codes in combination with the scientific name will allow users to locate, sort and obtain the data of interest in a simple way. No documentation on the

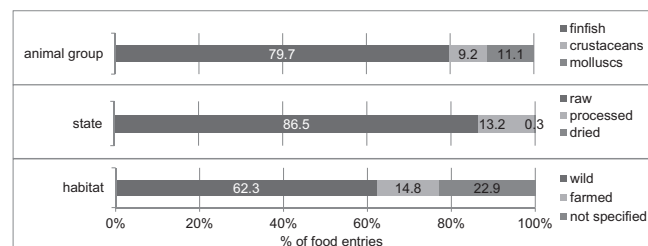


Fig. 1. Percentage of data entries for different animal groups, processing states and habitats.

sampling method, value description or standard deviation is given in the aFiSh, even if published in the articles.

The database holds data from 238 scientific articles and one report. Individual references for all data are not listed in this article, but can be found in the corresponding FAO/INFOODS analytical databases, where the bibliography is given for each food entry.

The database contains 2,277 food entries, of which the majority of data accounts for finfish (80%), followed by molluscs (11%) and crustaceans (9%) (Fig. 1). For most of the 2,000 species targeted, no compositional data were found. For 641 different seafood species data were identified and compiled into the aFiSh database but for 45% of which only one single food entry exists. The most frequent species of finfish, crustaceans and molluscs presented in the database are those of economic interest and therefore studied more intensively resulting in more publications available, such as *Oncorhynchus mykiss* (Rainbow trout, TRR), *Homarus gammarus* (European lobster, LBE) and *Crassostrea gigas* (Pacific oyster, OYG).

Most of the data compiled were found for raw fish and shellfish. Only 0.3% of all data were entered for dried food, exclusively found for finfish. Different states of processing comprise various cooking (e.g., boiling, frying, baking, grilling) and preserving methods (e.g., smoking, brining). It has to be mentioned that data on processed fish and shellfish were not a main focus of the work.

In regard of the animals' habitat, most fish and shellfish were caught in the wild (60%) and less were farmed fish (14%); for 26% of the food entries the habitat was not specified. In cases where the habitat was not well described, some assumptions have been made. If, for example, the samples were obtained from local fishermen or taken directly from landing sites, the food was assumed to be wild. Most data on farmed animals are for the common species of aquaculture, such as different salmon species (e.g., *Salmo salar*, Atlantic salmon, SAL) and bivalves (e.g., *Crassostrea gigas*, Pacific oyster, OYG).

A total of 40,881 component values were compiled into the aFiSh. The majority of data (Fig. 2) was found for fatty acids (FAs; 60%), followed by proximates (16%), minerals (10%), and amino acids (AAs; 7%). This fits well with the widespread consideration of fish and shellfish as good contributors to fat, protein and mineral intake. Heavy metals (2%), (pro)vitamins (2%) and data on other

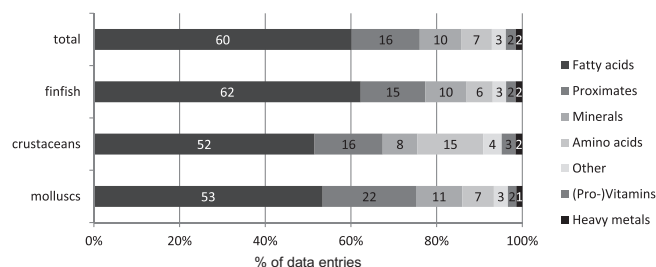


Fig. 2. Percentage distribution of total data entered (and separated by animal group) according to component classes.

components (3%) represent the classes with the least amount of data entered. More detailed information on each component class is given below.

Data on proximates (Fig. 2) cover values for energy, water, fat, protein, carbohydrates, fibre and ash (including their fractions e.g., total nitrogen, non-protein nitrogen, phospholipids, triglycerides). Proximate data form the second biggest component group among all animal groups, where the highest amount of data was noted for molluscs (22%). Fat is the predominant component and is noticeably associated with the amount of data entered for FAs, which show the highest proportion compared to all other component classes. Differences for FAs could be noted among the three animal groups, indicating that more data were collected for finfish than for crustaceans and molluscs (62%, 52%, and 53%, respectively).

In regard of the total data entered on FAs, the predominant saturated FAs (excl. branched-chain FAs) were C18:0 (stearic acid), C16:0 (palmitic acid) and C14:0 (myristic acid), each is accounting for 4% of total data on FAs, whereas data on short-chain saturated FAs (C4:0–C11:0) were hardly reported (about 0.2%). The polyunsaturated FAs C20:5 n-3 (EPA) and C22:6 n-3 (DHA) were the most occurring representatives of the omega-3 chain FAs (each 4% of total data on FAs entered), whereas C18:2 n-6 (linoleic acid) and C20:4 n-6 (arachidonic acid) were the prevailing FAs of the omega-6 chain (4% and 3%, respectively). Most data on monounsaturated FAs were for C18:1 n-9 (3%) and C16:1 n-7 (2%).

In the literature, FA data are reported in differing levels of precision depending on the accuracy of the analytical method used. In some cases (9% of all FA data), information on the position of the double bond(s) of unsaturated FAs was not available. In total, 173 different INFOODS Component Identifiers (tagnames) were selected to report data on FAs.

The FA data were predominately obtained from scientific articles published within the last 5 years which reflects the recent trend in research of omega-3 FA in fish as an important health issue. Eighty-one papers including 552 food entries were published within the last 5 years; 59 articles (386 food entries) were published before 2007, the oldest is dating back to 1981.

A separation between essential minerals and heavy metals cannot be done easily as various classifications and definitions are used among publications. In the present paper, the group of heavy metals and contaminants include the following toxic trace elements: aluminium, arsenic, barium, cadmium, lead, mercury and strontium; all other data on the remaining 27 minerals and trace elements are aggregated in the component class of minerals. This group represents 10% of all data entered, where calcium (10%), iron (10%), magnesium (9%) and zinc (9%) were found to be the predominant representatives.

Several publications investigated the content of heavy metals and contaminants in fish and shellfish as the discussions on the risks/health benefits of fish consumption are ongoing (Bushkin-Bedient & Carpenter, 2010; Turyk et al., 2011). Only 2% of all data account for heavy metals, which are mainly represented by chromium, mercury and lead. This small amount of data does not represent the availability of data from this component group but rather results from the fact that the literature search focused on nutritive components and not on non-nutritive or toxic components. However, when data on heavy metals were presented together with nutritive components, those data were as well included in the database. Even though the aFiSh contains little information on heavy metal contents in fish and shellfish, it is a reliable data source that can easily be expanded and updated in the future as recommended by FAO/WHO (2011). In this context it should be noted that other databases exist providing data on heavy metals for fish and shellfish, e.g., by the European Food Safety Authority (EFSA), the Global Environment Monitoring

System (GEMS/Food) and unpublished databases of the Joint FAO/WHO Expert Committee on Food Additives (JECFA).

Data on AAs amount to 7% of the entire dataset. Comparing the animal groups among each other, 15% of the total data of crustaceans were found on AAs. Finfish and molluscs show lower percentages, namely 6% and 7%, respectively. The AA tryptophan (TRP) contains the least amount of data in contrast to the other essential AAs, which might be explained because of a different hydrolysis methods applied prior to measurement (Greenfield & Southgate, 2003).

In total, only few data were entered on vitamins and their provitamins (2%) with higher amount of data values found for fat-soluble (58%) than for water-soluble vitamins (42%). Crustaceans showed, in comparison to finfish and molluscs, the highest amount of compiled vitamin data (3%). The small amount of data on vitamins is thought to either reflect the low interest in vitamins, the higher cost or the limited capacity of some laboratories to analyse them.

Nevertheless, seafood is seen to be rich in fat-soluble vitamins with varying concentrations depending on the lipid content and they often contain higher amounts than land animals (Venugopal and Shahidi, 1996). Vitamin A, D and E are present in the flesh and meat of fish and shellfish, but are more concentrated in the liver, viscera and eyes (Exler & Weihrauch, 1976; Roos, Chamnan, Loeng, Jakobsen, & Thilsted, 2007). Beta-carotene is the most frequent representative within the group of vitamin A and its provitamins, for which data were obtained. However, the description of the food entries referring to these values chiefly reveals that the edible portion includes eyes and viscera or is referring to fish or shellfish consumed as whole. Cholecalciferol (vitamin D3) is the most frequently occurring fat-soluble vitamin and amounts to 15% of all data on (pro)vitamins; however, vitamin D3 data were exclusively compiled for finfish.

The flesh of fish and shellfish is moreover attributed to be a good source of water-soluble vitamins (Exler & Weihrauch, 1976; Gordon, Roberts, & Heintz, 1979). Most values were obtained for thiamin, riboflavin and niacin (6%, 7% and 5% of all (pro)vitamin data entered, respectively); only 3% were found for folate and pantothenic acid each. An outsize amount of data on vitamin B12 was found for molluscs (18%).

As most of the vitamins exist in different chemical forms with vitamin-activity, generic names do not indicate precisely which component is reported. The component name “vitamin E” does not specify whether the expression refers e.g., to alpha-tocopherol only or to the summation of all vitamin E active tocopherols and tocotrienols. For “vitamin A”, e.g., the following INFOODS tag-names exist: VITA (total vitamin A activity expressed as retinol equivalents), VITA_RAE (total vitamin A activity expressed as retinol activity equivalents), VITAA (vitamin A determined by bioassay) or RETOL (retinol). Due to ambiguous descriptions of the components in scientific articles, 5% of all (pro)vitamin data entered could not be assigned to a specific tagname and tagnames indicating “unknown” needed to be used, such as for vitamin E, unknown (VITE-), vitamin A unknown (VITA-), thiamin unknown (THIA-), niacin unknown (NIA-), folate unknown (FOL-) and vitamin B6 unknown (VITB6-). Already almost 20 years ago, Aminullah Bhuiyan, Ratnayake, and Ackman (1993) have pointed out the inaccuracy in the description of vitamin data in the literature and the necessity to improve the report of these; there is still a big need for improvement.

3.2. Descriptive analysis of nutrient data of *Trachurus trachurus* (HOM)

In the following, the data set of *Trachurus trachurus* (Atlantic horse mackerel, HOM) will be used to illustrate the characteristics

of the aFiSh and to highlight the necessity of capturing intra-species variation of compositional data and precise and detailed food descriptions.

Atlantic horse mackerel (HOM) is a widely consumed pelagic fish species with 206,785 tonnes of capture production worldwide in 2010 (FAO, 2012). The species is commonly found in North-East and East-Central Atlantic waters alongside the shelf edge as well as in Mediterranean and Black Seas (Eaton, 1983; Zimmermann & Hammer, 1999).

Data on HOM were available from 10 papers, accounting for 42 food entries. Reported catching places were the Mediterranean Sea (11 food entries; Turkey, Italy, Greece) and the central Atlantic Sea (11 food entries; Portugal). Sixteen food entries were sampled at

Turkish or Greek markets but the exact origin of the fish was not further specified and for four entries no origin was indicated at all.

Most of the food entries (88%) were assigned to be wild. It can however be assumed that the remaining, non-specified data (12%) entered on HOM refer to wild fish too, as no data on aquaculture production has so far been reported to FAO by any country (FAO, 2011).

In regard to the processing state, 37 entries were reported for raw fish, while the rest (5 entries) refers to processed fish (grilled, oven-baked, steamed or fried fish fillet).

The selection of the nutrient profile of raw HOM with values expressed per 100 g EP is based on the availability of data allowing a meaningful evaluation (Table 2). In total, 888 data points on

Table 2

Selected nutrient profile of raw *Trachurus trachurus* (Atlantic horse mackerel, HOM), with values presented per 100 g edible portion on fresh weight basis (EP).

	Source	INFOODS FCDB (aFiSh) ^a	German FCT (G-FCT)	Spanish FCT (S-FCT)	Portuguese FCT (P-FCT)
	Scientific name	<i>Trachurus trachurus</i>	<i>Trachurus trachurus</i>		
	English name(s)	Atlantic horse mackerel	Horse mackerel, Jack mackerel, Scad	Horse mackerel	
	Common name(s) in own language	Atlantic horse mackerel (HOM)	Stöcker, Schildmakrele	Jurel	Carapau
	Food description	wild, skinless fillet	edible portion	edible portion	skin-on fillet, incl. bones
Water (g)	Mean ± SD (min–max) n	73.1 ± 4.2 (66.0–79) 21	75.1	78.3	75.6
Protein (g)	Mean ± SD (min–max) n	18.6 ± 1.62 (15.7–21.2) 19	19.8 (19.5–20)	15.4	19.7
Fat (g)	Mean ± SD (min–max) n	5.44 ± 3.87 (0.4–14.5) 36	3.85 (2.50–5.20)	5.2	2.9
Ash (g)	Mean ± SD (min–max) n	1.61 ± 0.34 (1–2.17) 17	1.29 (1.20–1.60)	–	1.4
Calcium (mg) (Ca)	Mean ± SD (min–max) n	239 ± 106 (106–413) 11	65	17	69
Selenium (mcg) (Se)	Mean ± SD (min–max) n	36 ± 17 (8.9–77) 11	47 (43–49)	37	–
Iodine (mcg) (I)	Mean ± SD (min–max) n	28 ± 22 (11–66) 11	48	10	–
FASAT (g)	Mean ± SD (min–max) n	1.13 ± 1.08 (0.11–4.84) 20	–	2	0.7
FAMS (g)	Mean ± SD (min–max) n	0.88 ± 0.65 (0.06–2.10) 19	–	1.4	0.8
FAPU (g)	Mean ± SD (min–max) n	1.01 ± 0.76 (0.07–2.36) 18	–	1.3	0.9
FAPU n-3 (g)	Mean ± SD (min–max) n	1.01 ± 1.05 (0.06–2.75) 8	–	–	–
FAPU n-6 (g)	Mean ± SD (min–max) n	0.12 ± 0.11 (0.01–0.31) 8	–	–	–
FA C20:5 n-3 (g) (EPA)	Mean ± SD (min–max) n	0.316 ± 0.287 (0.015–1.08) 20	0.17	–	–
FA C22:6 n-3 (g) (DHA)	Mean ± SD (min–max) n	0.579 ± 0.439 (0.040–1.85) 20	0.29	–	–

SD, standard deviation; min, minimum; max, maximum; n, number of data points; FA, fatty acid; FASAT, saturated fatty acids; FAMS, monounsaturated fatty acids; FAPU, polyunsaturated fatty acids; FAPU n-3, omega-3 polyunsaturated fatty acids; FAPU n-6, omega-6 polyunsaturated fatty acids; EPA, eicosapentaenoic acid; DHA, docosahexaenoic acid.

^a Bandarra et al. (2001), Celik (2008), Erkan, Selçuk, and Özden (2009), Kalogeropoulos, Andrikopoulos, and Hassapidou (2004), Karakoltsidis et al. (1995), Ostermeyer and Schmidt (2005), Özden (2010), Pirini et al. (2010), Tanakol, Yazici, Sener, and Sencer (1999), Visentainer et al. (2007).

different components were compiled for raw HOM. Most of the data were on FAs (49%), which reflects indeed the overall data distribution of the entire data set (Fig. 2).

Nutritional profiles of HOM were found in three national (European) FCTs, which confirms the origin of this species. The food entries were identified either by the scientific name as given in the German FCT (G-FCT; Souci et al., 2000), the English name as e.g., in the Spanish FCT (S-FCT; AESAN/BEDCA, 2010) and/or by the name in own language as reported in the Portuguese FCT (P-FCT; INSA, 2006). No scientific name is available for horse mackerel in the Spanish and Portuguese tables. Based on the nomenclature provided by Eaton (1983), where common names are listed in several languages (Portuguese “Carapau”, Spanish “Jurel”), it was assumed that the values refer to *Trachurus trachurus*.

Identification by using solely “mackerel”, a term widely used in the English language, would lead to a wrong classification of the species as it is normally associated with the *Atlantic mackerel* (*Scomber scombrus*, MAC) from the scombridae family, whereas *Trachurus trachurus* is part of the carangidae family (Eaton, 1983).

Mean values of the aFiSh are in accordance with values in the presented FCTs, though some differences were noted (Table 2). The present study observed the lowest mean water content of 73.1 g/100 g EP, while the highest value was observed in the S-FCT (78.3 g/100 g EP). The calculated mean value for protein (18.6 g/100 g EP) is comparable to values reported in the G-FCT and P-FCT (19.8 g and 19.7 g/100 g EP, respectively), while the S-FCT gives a lower value (15.4 g/100 g EP). Fat content was highest in the present study (5.4 g/100 g EP) and similar to the value presented in the S-FCT, while the lowest value was observed in the P-FCT (2.9 g/100 g EP). Although a selected mineral profile is given in the S-FCT, no ash value is reported.

Iodine (I; 28 mcg/100 g EP) and selenium content (Se; 36 mcg/100 g EP) from the aFiSh vary but are comparable with data presented in the G-FCT (48 mcg I and 47 mcg Se per 100 g EP) and the S-FCT (37 mcg I and 10 mcg Se per 100 g EP). Large differences between values were noted in particular for calcium (Ca; 239 mg/100 g EP), which derives from one source only (Özden, 2010). It is three times higher than the highest value found in the P-FCT (69 mg/100 g EP) and is therefore considered too high in comparison with the reference data. No description was provided that would give a meaningful explanation; it is not believed that the high Ca content is the result of sample preparation, i.e. that bones have not been removed carefully before analysing the fillets, because fillets of HOM may contain low amounts of bones (Fisheries and Aquaculture Statistics and Information Service, FAO, personal communication, June 28, 2013). One explanation could be that the values were erroneously given on dry matter basis even though the authors state that values are presented on wet weight basis. One review paper (Sidwell et al., 1977) presented analytical data on minerals for “scad and mackerel (Carangidae spp.)”, where the mean value for Ca (46 mg/100 g EP) and the range (12–71 mg/100 g EP) were in alignment with data presented in the G-FCT and P-FCT. However, the taxonomic classification at the family rank as given in the review paper is very broad (the ASFIS lists, for example, counts 136 species for the family carangidae) to perform meaningful evaluations. Furthermore, direct comparison of data between the aFiSh and national FCTs are difficult as the way of data compilation from the latter sources are not always clearly described and may have been generated by extrapolation from other species.

Information on the content of total saturated (FASAT), monounsaturated (FAMS) and polyunsaturated FAs (FAPU) is available in the P-FCT and S-FCT, but missing in the G-FCT. Regarding these component groups, our study reported lower values than given in the S-FCT but higher values than reported in the P-FCT. It can be noted that there is no uniform FA profile among the three sources. While the P-FCT reports the higher content for FAPU,

followed by FAMS and FASAT (0.9, 0.8, and 0.7 g/100 g EP, respectively), the S-FCT ranks the contents of the FA groups in a reverse order (1.3, 1.4 and 2 g/100 g EP, respectively). Our study observed higher mean values for FASAT (1.13 g/100 g EP) and lower values for FAPU (1.01 g/100 g EP) and FAMS (0.88 g/100 g EP).

Factors influencing the composition of fish flesh have been investigated exhaustively throughout the literature. Conditions that fish encounter during their life cycle (spawning, food) as well as environmental conditions (water temperature, pollution) have a great effect on the chemical composition. Fat is the main constituent, which varies to the greatest extent (Stansby, 1976). In fact, a high variability of fat values was reported for HOM, ranging from 0.4 to 14.5 g/100 g EP. Different methods used for fat extraction could cause some variation, but this is not the fact for the present study as out of 36 values for fat, only three values were assigned to the tagname “FATCE”, i.e., Soxhlet method with continuous extraction, while all the others were assigned to “FAT”, i.e., mixed-solvent extraction. The difference can better be explained by the annual cycle of fat content of pelagic fish, which is characterised by its feeding and spawning activities (Eaton, 1983). The resulting inverse relationship between fat and moisture content of HOM, depending on seasonal variation, is well portrayed in the database. Özden (2010) observed the highest fat values in autumn and lowest in summer after the spawning period. The findings are in accordance with the fish's annual cycle described by Zimmermann and Hammer (1999) and Eaton (1983), when fat content reaches a peak in autumn and declines throughout the winter due to less feeding. During the spawning period, the fish is generally in a poor condition, but starts building up fat stores for the next overwintering period. However, Pirini, Testi, Ventrella, Pagliarini, and Badiani (2010) and Celik (2008) generally reported significant lower fat contents for HOM, with peak values identified in spring. FCTs normally report one single food entry representing values that are valid for an “overall year”. A separation of food entries according to the season would decrease the fat variation per food entry, especially for fish underlying an annual cycle of fat.

An unambiguous food description and identification is essential in order to match data obtained from dietary intake assessment tools with food composition data when estimating nutrient intakes (FAO/INFOODS, 2011; Greenfield & Southgate, 2003). National FCTs commonly report fish data with a very generic food description, which does often not allow a clarification of the edible portion (fillet with or without bones, skin-on or skinless fillet). This detail is important when considering e.g., the lipid distribution of fish and its underlying content of FAs. While lean fish deposits lipid in muscle tissue, liver and mature gonads, fatty fish stores lipids subcutaneously (Venugopal and Shahidi, 1996). The content of FAs, e.g., omega-3 FAs, may vary significantly if skin of fish is trimmed off or not (Ackman, 1989) and depends further on the part of the tissue (dark muscle vs. light muscle, ventral vs. dorsal fillet, caudal vs. middle vs. cranial portion of muscle) analysed (Ackman, 1989; Álvarez, Medina, Prego, & Aubourg, 2009).

In case of HOM, the mean value for the omega-3 FA EPA is 0.316 g/100 g EP and 0.579 g/100 g EP for DHA and were almost twice as high as the values reported in the G-FCT (0.17 g and 0.29 g/100 g EP, respectively). However, the food description of HOM in aFiSh refers to “skinless fillet”, whereas the G-FCT reported values per 100 g EP without further specification.

Harris, Fleming, and Kris-Etherton (2011) discussed in detail the importance that nutrient databases should reflect intra-species variation of nutrient values (EPA + DHA) and pointed out associated challenges. Indeed, four out of seven papers that were used to generate the mean EPA + DHA values in Table 2 have investigated the variability of FAs depending on the catch month (Bandarra, Batista, Nunes, & Empis, 2001; Celik, 2008) or on a season (Karakoltsidis et al., 1995; Pirini et al., 2010) and results in EPA

values ranging from 0.015 up to 1.08 g/100 g EP and DHA from 0.040 up to 1.85 g/100 g EP. Values from G-FCT are perfectly within this broad range.

Furthermore, the habitat plays an important role on the overall nutrient composition and especially on the FA profile of fish (Dincer, Cakli, & Cadun, 2010; Harris et al., 2011; Jankowska, Zakes, Zmijewski, & Szczepkowski, 2003). Aquaculture allows controlling environmental conditions and the composition of the feed, which is a main influencing factor on the nutritional values of fish, especially on EPA and DHA (Harris et al., 2011).

The dataset of HOM does not allow evaluating differences that occur when comparing the FA profile between wild and farmed fish, as all food entries used to calculate the FA data refer to HOM caught in the wild (with exception of one single food entry with missing specification).

In general, a differentiation between wild and farmed seafood is made in a few published FCDBs only. The USDA FCT e.g., (Standard Release 24; USDA, 2011) indicates the habitat explicitly for 26 fish and shellfish entries (10%) and the Icelandic FCT (Mátis, 2003) specifies clearly two out of 130 fish and shellfish entries as farmed (raw *Salmo salar* and *Salvelinus alpinus*), while the rest (excluding five preparations made from the two mentioned species) refers to seafood caught in the wild. Therefore, no further clarification in the food description is provided, as wild fish (as opposed to farmed) is usually consumed (Ó. Reykdal, Mátis, personal communication, May 18, 2012).

The total aFiSh dataset, for example, shows fat values for wild *Diplodus puntazzo* (Sharpsnout seabream, SHR) ranging from 0.92–3.87 g/100 g EP, while the values for farmed species range from 3.84 to 7.59 g/100 g EP. Accordingly, the content of the omega-3 FAs is different: the EPA value for wild species range from 0.038 to 0.237 g/100 g EP, for cultured fish 0.004 to 0.7 g/100 g EP; DHA for wild fish is 0.063 to 0.322 g/100 g EP, while for farmed fish the range is 0.315–0.749 g/100 g EP. These differences would also find expression in the intake estimations of omega-3 FAs and it is therefore necessary to indicate the habitat of the animal in FCTs and FCDBs. However, the differences noted in the content of fat and FAs could also be due to catch season or part of the fillet analysed, but the data and food description available does not allow further conclusions.

3.3. Implications for FCTs and FCDBs

Data that have been collected for the aFiSh will contribute considerably to the promotion of food biodiversity. Almost 60% of the entire dataset of aFiSh were included in the update of the FAO/INFOODS Food composition database for biodiversity version 2.0 (BioFoodComp2.0). This database gathers data for, indigenous or wild foods at species level and for cultivars, varieties and breeds, respectively, following the inclusion criteria counting for food biodiversity (FAO, 2008; FAO/INFOODS, 2012b). It is a comprehensive collection of analytical data, which is presented in a uniform, easy accessible database (Charrondière et al., 2012). No data on fish and shellfish were available in the former version of BioFoodComp, but with the update 2.0 about 1,304 data entries counting for fish (82%), crustaceans (10%) and mollusks (8%), were published. The entire collection will help to strengthen the linkage of food biodiversity and nutrition adequacy and to raise awareness that more studies on food composition and consumption are needed that take biodiversity into account (Charrondière et al., 2012).

Besides the publication of the BioFoodComp, a future FAO/INFOODS activity is the development of a comprehensive user database on fish and shellfish, based on the aFiSh. The database will give “all-year” food entries as commonly done in user databases, but it is further aimed at representing data entries with maintaining diverse characteristics, e.g., different entries for different seasons for fish underlying a seasonal fat cycle (summer, winter), detailed

description of the edible portion (skin-on, skinless fillet) and differentiation of the habitat (wild, farmed). This information will be useful to better estimate the nutrient intake if these attributes were also considered in the dietary assessment tool.

The aFiSh, moreover, is not only a suitable and outstanding source for the development of new databases, but could also be used to improve the quality of already existing data. In general, a periodic or continuous revision of a database is essential due to progresses in analytical methodology or changes in the food itself (e.g., animal husbandry) and implies the need to re-analyse foods for a particular nutrient (Greenfield & Southgate, 2003). In addition, the completeness of a database can be seen as a criterion of quality (Burlingame, 2004). Limitations of financial resources or of infrastructure capacity may be the reason why the nutritional profile of a food in a national FCTs or FCDBs is based on extrapolation or borrowing of data from other sources, e.g., from USDA tables. However, when doing so, regional attributes should be considered to ensure that the nutrient values of the selected foods correspond to the local foods (FAO/INFOODS, 2011). The use of the aFiSh would allow selecting peer-reviewed, analytical data from primary sources that additionally include the country of origin. These steps would contribute to the improvement of the quality of databases and tables.

4. Conclusions

The aFiSh is a comprehensive and expandable data repository of publicly available high-quality nutrient data of fish, crustaceans and molluscs, where the variability of nutrient values due to biodiversity, season, habitat and/or food parts analysed is well portrayed. This information should help to increase the awareness and the understanding of the possible variation of compositional data of fish and shellfish, and should further find consideration in dietary assessment tools and in future developments and updates of food composition databases and tables.

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References

- Ackman, R. G. (1989). Nutritional composition of fats in seafoods. *Progress in Food & Nutrition Science*, 13(3–4), 161–289.
- AESAN/BEDCA. (2010). Base de Datos Española de Composición de Alimentos. AESAN/BEDCA v1.0 (Spanish Food Composition Database). Retrieved June, 2012, from http://www.bedca.net/bdpub/index_en.php.
- Álvarez, V., Medina, I., Prego, R., & Aubourg, S. P. (2009). Lipid and mineral distribution in different zones of farmed and wild blackspot seabream (*Pagellus bogaraveo*). *European Journal of Lipid Science and Technology*, 111(10), 957–966. <http://dx.doi.org/10.1002/ejlt.200800282>.
- Aminullah Bhuiyan, A. K. M., Ratnayake, W. M. N., & Ackman, R. G. (1993). Nutritional composition of raw and smoked Atlantic mackerel (*Scomber scombrus*): Oil- and water-soluble vitamins. *Journal of Food Composition and Analysis*, 6(2), 172–184. <http://dx.doi.org/10.1006/jfca.1993.1019>.
- Bandarra, N., Batista, I., Nunes, M., & Empis, J. (2001). Seasonal variation in the chemical composition of horse-mackerel (*Trachurus trachurus*). *European Food Research and Technology*, 212(5), 535–539. <http://dx.doi.org/10.1007/s002170100299>.
- Burlingame, B. (2004). Fostering quality data in food composition databases: Visions for the future. *Journal of Food Composition and Analysis*, 17(3–4), 251–258. <http://dx.doi.org/10.1016/j.jfca.2004.03.026>.
- Bushkin-Bedient, S., & Carpenter, D. O. (2010). Benefits versus risks associated with consumption of fish and other seafood. *Reviews on Environmental Health*, 25(3), 161–191.
- Celik, M. (2008). Seasonal changes in the proximate chemical compositions and fatty acids of chub mackerel (*Scomber japonicus*) and horse mackerel (*Trachurus trachurus*) from the north eastern Mediterranean Sea. *International Journal of Food Science & Technology*, 43(5), 933–938. <http://dx.doi.org/10.1111/j.1365-2621.2007.01549.x>.

- Charrondière, U. R., & Burlingame, B. (2011). Report on the FAO/INFOODS compilation tool: A simple system to manage food composition data. *Journal of Food Composition and Analysis*, 24(4–5), 711–715. <http://dx.doi.org/10.1016/j.jfca.2010.09.006>.
- Charrondière, U. R., Stadlmayr, B., Rittenschober, D., Mouille, B., Nilsson, E., Medhammar, E., et al. (2012). FAO/INFOODS food composition database for biodiversity. *Food Chemistry*. <http://dx.doi.org/10.1016/j.foodchem.2012.08.049>.
- Daar, A. S., Singer, P. A., Leah Persad, D., Pramming, S. K., Matthews, D. R., Beaglehole, R., et al. (2007). Grand challenges in chronic non-communicable diseases. *Nature*, 450, 494–496.
- Dincer, T., Cakli, S., & Cadun, A. (2010). Comparison of proximate and fatty acid composition of the flesh of wild and cultured fish species. *Archiv für Lebensmittelhygiene*, 61(1), 12–17. <http://dx.doi.org/10.2376/0003-925X-61-12>.
- Eaton, D. R. (1983). *Scad in the North-East Atlantic. Laboratory leaflet No. 56*. Lowestoft: Ministry of Agriculture, Fisheries and Food Directorate of Fisheries Research.
- Elmadfa, I., & Meyer, A. L. (2010). Importance of food composition data to nutrition and public health. *European Journal of Clinical Nutrition*, 64, 4–7. <http://dx.doi.org/10.1038/ejcn.2010.202>.
- Erkan, N., Selçuk, A., & Özden, Ö. (2009). Amino acid and vitamin composition of raw and cooked horse mackerel. *Food Analytical Methods*, 3(3), 269–275. <http://dx.doi.org/10.1007/s12161-009-9108-x>.
- Exler, J., & Weihrauch, J. L. (1976). Comprehensive evaluation of fatty acids in foods. VIII. Finfish. *Journal of the American Dietetic Association*, 69(3), 243–248.
- FAO (2008). Expert Consultation on Nutrition Indicators for Biodiversity – 1. Food Composition. Rome: FAO. Retrieved October, 2011, from <ftp://ftp.fao.org/docrep/fao/010/a1582e/a1582e00.pdf>.
- FAO (2011). ASFIS List of species for fishery statistics purposes. Retrieved October, 2011, from <http://www.fao.org/fishery/collection/asfis/en>.
- FAO (2012). 2010 FAO yearbook. Fishery and aquaculture statistics. Rome: Statistics and Information Service of the Fisheries and Aquaculture Department. FAO. Retrieved July, 2012, from ftp://ftp.fao.org/FI/CDrom/CD_yearbook_2010/index.htm.
- FAO/INFOODS (2011). FAO/INFOODS Guidelines on Food Matching. Rome: FAO. Retrieved June, 2012 from http://typo3.fao.org/fileadmin/templates/food_composition/documents/upload/INFOODSGuidelinesforFoodMatching_final_july2011.pdf.
- FAO/INFOODS (2012a). INFOODS – About INFOODS. Retrieved September 17, 2012, from <http://www.fao.org/infoods/infoods/en/>.
- FAO/INFOODS (2012b). FAO/INFOODS Food Composition Database for Biodiversity version 2.0 – BioFoodComp2.0. Rome: FAO. Retrieved July, 2012, from <http://www.fao.org/infoods/infoods/food-biodiversity/en/>.
- FAO/INFOODS (2012c). FAO/INFOODS Analytical Food Composition Database version 1.0 – AnFood1.0. Rome: FAO. Retrieved January, 2013, from <http://www.fao.org/infoods/infoods/tables-and-databases/faoinfoods-databases/en/>.
- FAO/INFOODS (2012d). FAO/INFOODS Guidelines for Checking Food Composition Data prior to the Publication of a User Table/Database – version 1.0. Rome: FAO. Retrieved December, 2012, from <http://www.fao.org/docrep/017/ap810e/ap810e.pdf>.
- FAO/INFOODS (2012e). FAO/INFOODS Guidelines for Converting Units, Denominators and Expressions – version 1.0. Rome: FAO. Retrieved December, 2012, from <http://www.fao.org/docrep/017/ap809e/ap809e.pdf>.
- FAO/WHO (2011). Report of the joint FAO/WHO expert consultation on the risks and benefits of fish consumption: Rome, 25–29 January 2010. Rome/Geneva: Food and Agriculture Organization of the United Nations; World Health Organization. Retrieved June, 2012, from <http://www.fao.org/docrep/014/ba0136e/ba0136e00.pdf>.
- Garcia, S. M., & Rosenberg, A. A. (2010). Food security and marine capture fisheries: Characteristics, trends, drivers and future perspectives. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 365(1554), 2869–2880. <http://dx.doi.org/10.1098/rstb.2010.0171>.
- Gordon, D. T., Roberts, G. L., & Heintz, D. M. (1979). Thiamin, riboflavin, and niacin content and stability in Pacific Coast seafoods. *Journal of Agricultural and Food Chemistry*, 27(3), 483–490.
- Greenfield, H., & Southgate, D. A. T. (2003). Food composition data: production, management, and use. Rome: Food and Agriculture Organization of the United Nations. Retrieved October, 2011, from <ftp://ftp.fao.org/docrep/fao/008/y4705e/y4705e00.pdf>.
- Harris, K., Fleming, J., & Kris-Etherton, P. (2011). Challenges in estimating omega-3 fatty acid content of seafood from US nutrient databases: A salmon case study. *Journal of Food Composition and Analysis*, 24(8), 1168–1173. <http://dx.doi.org/10.1016/j.jfca.2011.03.019>.
- INSA (2006). Tabela da Composição de Alimentos. National Health Institute Doutor Ricardo Jorge, IP. Retrieved June, 2012, from <http://www.insa.pt/sites/INSA/Portugues/AreasCientificas/AlimentNutricao/AplicacoesOnline/TabelaAlimentos/Paginas/TabelaAlimentos.aspx>.
- Jankowska, B., Zakes, Z., Zmijewski, T., & Szczepkowski, M. (2003). A comparison of selected quality features of the tissue and slaughter yield of wild and cultivated pikeperch *Sander lucioperca* (L.). *European Food Research and Technology*, 217(5), 401–405. <http://dx.doi.org/10.1007/s00217-003-0757-5>.
- Kalogeropoulos, N., Andrikopoulos, N. K., & Hassapidou, M. (2004). Dietary evaluation of Mediterranean fish and molluscs pan-fried in virgin olive oil. *Journal of the Science of Food and Agriculture*, 84(13), 1750–1758. <http://dx.doi.org/10.1002/jsfa.1878>.
- Karakaltsidis, P. A., Zotos, A., & Constantinides, S. M. (1995). Composition of the commercially important Mediterranean finfish, crustaceans, and molluscs. *Journal of Food Composition and Analysis*, 8(3), 258–273. <http://dx.doi.org/10.1006/jfca.1995.1019>.
- Kawarazuka, N., & Béné, C. (2011). The potential role of small fish species in improving micronutrient deficiencies in developing countries: Building evidence. *Public Health Nutrition*, 14(11), 1927–1938. <http://dx.doi.org/10.1017/S1368980011000814>.
- Klensin, J. C., Feskanich, D., Lin, V., Truswell, S., & Southgate, D. A. T. (1989). Identification of food components for INFOODS data interchange. Tokyo: United Nations University Press. Retrieved May, 2012, from <ftp://ftp.fao.org/es/infodds/Klensinetal1989Identificationoffoodcomponents.pdf>.
- Larsen, R., Eilertsen, K.-E., & Elvevoll, E. O. (2011). Health benefits of marine foods and ingredients. *Biotechnology Advances*, 29(5), 508–518. <http://dx.doi.org/10.1016/j.biotechadv.2011.05.017>.
- Matís (2003). ISGEM. The Icelandic food composition database. Matís Ltd. Icelandic Food and Biotech R&D Institute. Retrieved July, 2012, from http://www.matis.is/media/utgafa/Naering_fiskur.pdf.
- Nowak, F., Rittenschober, D., Exler, J., & Charrondière, U. R. (Unpublished results.). FAO/INFOODS proposal to harmonize the use of conversion factors for fatty acids in fish and shellfish. Submitted.
- Ostermeyer, U., & Schmidt, T. (2005). Vitamin D and provitamin D in fish. *European Food Research and Technology*, 222(3–4), 403–413. <http://dx.doi.org/10.1007/s00217-005-0086-y>.
- Özden, Ö. (2010). Micro, macro mineral and proximate composition of Atlantic bonito and horse mackerel: A monthly differentiation. *International Journal of Food Science & Technology*, 45(3), 578–586. <http://dx.doi.org/10.1111/j.1365-2621.2009.02170.x>.
- Pennington, J. A. T. (2008). Applications of food composition data: Data sources and considerations for use. *Journal of Food Composition and Analysis*, 21(SUPPL), S3–S12.
- Pirini, M., Testi, S., Ventrella, V., Pagliarini, A., & Badiani, A. (2010). Blue-back fish: Fatty acid profile in selected seasons and retention upon baking. *Food Chemistry*, 123(2), 306–314. <http://dx.doi.org/10.1016/j.foodchem.2010.04.036>.
- Roos, N., Channan, C., Loeung, D., Jakobsen, J., & Thilsted, S. H. (2007). Freshwater fish as a dietary source of vitamin A in Cambodia. *Food Chemistry*, 103(4), 1104–1111. <http://dx.doi.org/10.1016/j.foodchem.2006.10.007>.
- Ruxton, C. H. S. (2011). The benefits of fish consumption. *Nutrition Bulletin*, 36(1), 6–19. <http://dx.doi.org/10.1111/j.1467-3010.2010.01869.x>.
- Sheppard, A. J. (1992). *Lipid manual: Methodology for appropriate fatty acid-cholesterol analysis*. Dubuque, IA: U.S. Food and Drug Administration, William C. Brown Publishers.
- Sidwell, V. D., Buzzell, D. H., Foncannon, P. R., & Smith, A. L. (1977). MFR Paper 1228. Composition of the edible portion of raw (fresh or frozen) crustaceans, finfish, and mollusks. II Macroelements: Sodium, potassium, chlorine, calcium, phosphorus, and magnesium. *Marine Fisheries Review*, 39(1), 1–11.
- Souci, S. W., Fachmann, W., Kraut, H., Scherz, H., Senser, F., & Germany (Federal Republic). Bundesministerium für Ernährung, Landwirtschaft und Forsten, & Deutsche Forschungsanstalt für Lebensmittelchemie (2000). *Food composition and nutrition tables (Die Zusammensetzung der Lebensmittel, Nährwert-Tabellen)* (6th ed.). Stuttgart; Boca Raton; London: Medpharm; CRC.
- Stadlmayr, B., Charrondière, U. R., Enuijgha, V. N., Bayili, R. G., Fagbohoun, E. G., Samb, B., et al. (2012). *West African food composition table/table De composition Des Aliments D'Afrique De L'ouest*. Rome: FAO.
- Stansby, M. E. (1976). Chemical characteristics of fish caught in the northeast Pacific Ocean. *Marine Fisheries Research Review*, 38(9), 1–11.
- Tanakol, R., Yazici, Z., Sener, E., & Sencer, E. (1999). Fatty acid composition of 19 species of fish from the Black Sea and the Marmara Sea. *Lipids*, 34(3), 291–297.
- Toledo, A., & Burlingame, B. (2006). Biodiversity and nutrition: A common path toward global food security and sustainable development. *Journal of Food Composition and Analysis*, 19(6–7), 477–483. <http://dx.doi.org/10.1016/j.jfca.2006.05.001>.
- Turyk, M. E., Bhavsar, S. P., Bowerman, W., Boysen, E., Clark, M., Diamond, M., et al. (2011). Risks and benefits of consumption of Great Lakes fish. *Environmental Health Perspectives*, 120(1), 11–18. <http://dx.doi.org/10.1289/ehp.1003396>.
- USDA (2011). USDA national nutrient database for standard reference, Release 24. U.S. Department of Agriculture, Agricultural Research Service. Retrieved February, 2012, from <http://www.ars.usda.gov/Services/docs.htm?docid=8964>.
- Venugopal, V., & Shahidi, F. (1996). Structure and composition of fish muscle. *Food Reviews International*, 12(2), 175–197.
- Visentainer, J. V., Noffs, M. D., Oliveira Carvalho, P., Almeida, V. V., Oliveira, C. C., & Souza, N. E. (2007). Lipid content and fatty acid composition of 15 marine fish species from the Southeast Coast of Brazil. *Journal of the American Oil Chemists Society*, 84(6), 543–547. <http://dx.doi.org/10.1007/s11746-007-1070-4>.
- Weihrauch, J. L., Posati, L. P., Anderson, B. A., & Exler, J. (1977). Lipid conversion factors for calculating fatty acid contents of foods. *Journal of the American Oil Chemists Society*, 54(1), 36–40.
- Zimmermann, C., & Hammer, C. (1999). Biologie des Stöckers in Nordsee und Nordostatlantik. *Informationen für die Fischwirtschaft aus der Fischereiforschung*, 46(4), 14–23.