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COMPARATIVE STUDY ON NUTRITIONAL COMPOSITION OF FISH AVAILABLE IN PORTUGAL

Running Title: NUTRITIONAL COMPOSITION OF FISH IN PORTUGAL

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Abstract

Purpose - The Mediterranean Diet is one of the healthiest eating patterns and relies much on the regular consumption of fish, source of unsaturated fatty acids, protein, vitamins and minerals. The present study was undertaken to describe and compare the macro and micronutrients' profile of 24 commercial fish species available in the Portuguese market.

Methodology – A comparative study was undertaken based on nutritional datasheets information provided by laboratories and from database of the Portuguese National Health Institute Doutor Ricardo Jorge.

Findings - The results obtained showed that most of the fish species are low fat but the gilthead (*Sparus aurata*) and salmon (*Oncorynchus keta*) are considered high in fat, with salmon presenting important amounts of unsaturated fatty acids. The blue shark (*Prionace glauca*) shows the highest protein while the codfish (*Gadus morhua*) evidenced a very high salt content. While sardine (*Sardina pilchardus*) is much richer in terms of vitamins as compared to the other species, with respect to minerals, they vary a lot among species. Nevertheless, it stands out the skate (*Raja* spp.) with high amounts of sodium, calcium and phosphorus. Statistical analysis evidenced some relations between the properties evaluated, and most especially between lipids and saturated fatty acids ($r = 0.958$) or monounsaturated fatty acids ($r = 0.951$), or even between ash and phosphorus ($r = 0.817$) or between carbohydrates and zinc ($r = 0.903$) (correlations significant with $p < 0.01$). Furthermore, it was possible to establish two distinct groups of fish through Hierarchical Cluster Analysis, one of them including species like salmon, sardine, seabass (*Dicentrarchus labrax*) and mackerel (*Trachurus trachurus*) which are not, however, belonging to the same fat category.

Practical implications - The species evaluated revealed a very important nutritional value that should be an incentive to their regular consumption. Moreover, a lack of nutritional information about some micronutrients was found in several fish species, which should be studied in future studies.

Value – This paper fulfils an identified need to compare nutritional composition of fish available in Portugal.

Keywords: Fish, Human consumption, Mediterranean Diet, Energetic and nutritional composition

1. INTRODUCTION

The Mediterranean Diet (MD) is one of the healthiest eating patterns in the world with a number of studies showing that its followers have a lower mortality rate and a higher average life expectancy. The consumption of fish is thus recommended inside this food pattern as it presents numerous health benefits. The MD is a complete and balanced model providing an important source of unsaturated fatty acids (from olive oil), oleic acid and omega-3 (from fish and nuts), which, together with a low consumption of saturated and trans fatty acids (from red meats), is important for cardiovascular and cerebral health (Martinez-Gonzalez et al., 2009; Martins et al., 2012; Trichopoulou et al., 2005, 2009; Willett, 2006).

World consumption of fish *per capita* increased in developing regions from 5.2 kg in 1961 to 18.8 kg in 2013 while in the least developed countries with food deficits increased from 3.5 kg to 7.6 kg in the same period. Hence, fish accounts for about 17% of the intake of animal protein by the world population (FAO, 2016). Portuguese consumers record the highest fish consumption in the EU, around 56.8 kg/capita/year, while the European average is less than half of that (24.9 kg/capita/year) (PCP, 2016). Portuguese sardines and codfish are some of the most commonly consumed fish species in Portuguese cuisine (Lidon and Silvestre, 2009).

Fish supply to the fish processing industry comes from two sources, domestic production (fish landings and aquaculture) and imports. Bjørndal et al. (2016) analysed the development in the Portuguese fish processing industry from the 1960s to 2016 as well as prospects for future expansion. The evolution of fisheries in Portugal, from an economic point of view, was also investigated and analysed (Goulart et al., 2018). Besides, in a recent review, Anastacio et al. (2019) compiled for the first time the list of non-native faunal species in Portuguese freshwaters, briefly discussing the history of introductions since 1800 and identifying the most probable vectors of introduction and their regions of origin.

Fish is a healthy food, containing high quality protein, with all essential amino acids, being also a source of dietary minerals such as calcium, iodine or selenium and providing important amounts of polyunsaturated fatty acids (Araújo et al., 2010; Pestana, 2007). Pelagic species, usually smaller ones such as sardines, are generally rich in omega-3 fatty acids, mainly eicosapentaenoic acid (EPA, 20:5 ω3) and docosahexaenoic acid (DHA, 22:6 ω3) (Pestana, 2007).

For a better food balance intake, the World Health Organization (WHO) recommends a regular consumption of fish, corresponding to at least twice a week (Sousa, 2015). Nevertheless, other organizations also make similar recommendations:

- World Health Organization (WHO, 2018): Regular consumption of fish (1-2 servings per week) protects against coronary heart disease and stroke. The dose should provide an equivalent of 200-500 mg of eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA).

- American Heart Association (AHA, 2015): Eat several fish at least twice a week, especially those that contain omega-3, such as, for example, salmon or trout (*Oncorhynchus mykiss*).
- Academy of Nutrition and Dietetics (Vannice and Rasmussen, 2014): Because of the health benefits, consumption of omega-3 should be increased by eating more fish, nuts and seeds.
- German Nutrition Association (DGE, 2018): Daily consumption of 1.1 to 1.2 g of omega-3.
- EFSA European Food Safety Association (EFSA, 2017): A daily intake of 250 mg of long-chain omega-3 fatty acids in adults may reduce the risk of heart disease.
- Portuguese Heart Foundation (Ferreira, 2016): A balanced consumption of omega-6 and omega-3 fatty acids is achieved for a ratio varying from 2:1 to 4:1.

A recent study (Ribeiro et al., 2019) conducted in Portugal based on a self-administered questionnaire showed that high consumption rate of fish (between daily, and a minimum of three times a week), was reported by 47% of the respondents.

The link between fish consumption and health benefits seems to be well established. In fact, studies have shown that the introduction of fish into the diet of infants (aged from 6 to 9 months) as well as regular consumption of different types of fish at least once a week reduces asthma. Besides, the fat intake from fish in older children helps their healthy development (Øyen et al., 2018; Papamichael et al., 2018). A proper diet including fish during pregnancy and the introduction of fish into the infant's diet promotes the production of antibodies against any food allergen (Zhang et al., 2017). Also Miles and Calder (2017) report that the consumption of fish oil in pregnancy reduces asthma in children between 3 and 5 years of age, as well as, prevents childhood allergic diseases. A diet with a high omega-3 content allows to fight the excess of inflammatory factors responsible for several pathologies, particularly chronic noncommunicable diseases (NCDs).

Because Portugal is one of the countries with the highest level of fish consumption it is important to characterize the energetic and nutritional composition of different fish species. Nevertheless, as far as we know, a comparative study focused on this subject was never done. Hence, the main objective of this work was to compare the energy value and nutritional composition, namely macro and micronutrients, of 24 different fish species available on the Portuguese market.

2. MATERIALS AND METHODS

The data collection was carried out between January and March 2018 and was based on two sources of information: a) data provided by a company from the central region of Portugal that is engaged in the trade of frozen products, which includes a high variety of fish and b) database available online developed by the National Health Institute Doutor Ricardo Jorge (INSA). The quantitative data obtained through the company were collected from the original independent external laboratory reports in order to ensure its reliability. However, since for many of the species there were no data available, the authors consulted data available in the national database for food composition. The collected data from the different sources considered were complementing and were then organized into tables to facilitate the comparison of the energy value and amount of macro and micronutrients of a total of 24 different fish species. The species included in this work cover the most representative of the Portuguese fish consumption.

2.1. Data analysis

The Pearson correlation coefficients (r) were used to evaluate the possible associations and interdependence between properties. For absolute value of $r = 0$ there is no correlation, for $r \in]0.0, 0.2[$ the correlation is very weak, for $r \in [0.2, 0.4[$ the correlation is weak, for $r \in [0.4, 0.6[$ the correlation is moderate, for $r \in [0.6, 0.8[$ the correlation is strong, for $r \in [0.8, 1.0[$ the correlation is very strong, for $r = 1$ the correlation is perfect (Maroco, 2012; Pestana and Gageiro, 2014).

Also a factor analysis (FA) was undertaken. The correlation matrix between the variables was analysed to identify the level of intercorrelation between variables (Broen et al., 2015). After confirming that the data were suitable for application of FA, this approach was applied considering extraction by Principal Component Analysis (PCA) and Varimax rotation with Kaiser Normalization. The number of components was established by the Kaiser criterion (eigenvalues ≥ 1). In all cases, the communalities were calculated to show the percentage of variance explained by the factors extracted (Broen et al., 2015). Factor loadings with an absolute value exceeding 0.4 were used, because this lower limit accounts for about 16% of the variance in the variable (Rohm and Swaminathan, 2004; Stevens, 2009). Finally, a Hierarchical Cluster Analysis (HCA) was performed, following the Ward linkage method, with Squared Euclidean Distance. For all statistical analyses was used the software SPSS version 25 (IBM, Inc.) and the level of significance considered was 5% ($p < 0.05$), unless otherwise specified.

3. RESULTS AND DISCUSSION

3.1. Composition of the fish consumed in Portugal

A healthy diet involves the consumption of all the constituents necessary for the proper functioning of the human body and, therefore, it is essential to incorporate fish in a balanced diet. The diversity of species, the high nutritional value, the beneficial effects on health, particularly in the prevention of cardiovascular accidents and the fact that they are the basis of the gastronomy of numerous coastal populations, are factors that demonstrate the importance of fishery products worldwide. Knowledge of the chemical composition of fishery products is one of the basic aspects to assess their nutritional value, as well as, the benefits associated with their consumption. This is of great interest to consumers and professionals in the fields of medicine and nutrition but also to all participants in the fishing industry (Maulvault, 2009).

The main chemical components of fish muscle are water, protein and lipids, which together account for 98% of the total weight of the muscle. These constituents are very important for determining the nutritional value, texture, organoleptic quality and storage (Sikorski, 1994).

The chemical composition of the fish varies greatly, either interspecifically or intraspecifically, depending on the age, sex, environment and time of year. However, the edible fraction of the fish usually corresponds to about 45-50% of the total weight of its body and the fundamental constituents of the edible part are: water, lipids and proteins. Among the minor components stand the non-protein nitrogenous substances, minerals, vitamins and a small amount of carbohydrates (Rodrigues, 2014).

Fish can be classified according to the fat content present in the muscles as very low fat, if the percentage of fat is less than 2%, low in fat if the percentage varies between 2% and 4%, average fat content, if the percentage is between 4% and 8%, and finally high fat if greater than 8% (Ackman, 1990; Afonso, 2009; Gonçalves, 2010). However, these criteria for classification of fat content may vary depending on the authors (Gonçalves, 2009, 2010). For example, Dias (2012) classifies fish in terms of fat content into only three categories: lean, semi-fatty or fat. On the other hand, according to Lopes (2009) lean species, also known as whitefish, include codfish (*Gadus morhua*), sole (*Solea solea*) and European hake (*Merluccius merluccius*), and have a fraction of less than 5% of fat. Fatty species (also called blue fish) have a lipid content of more than 10% and include pelagic species such as sardine (*Sardina pilchardus*, between summer and autumn), chub mackerel (*Scomber colias*) and salmon (*Oncorynchus keta*) (Lopes, 2009). Fish species which store lipids in small quantities similarly to the fatty species or in limited areas of the body, qualify as semi-fatty species in which the lipid content is between 5 to 10%. This is the case of sardine (between winter and spring), wreckfish (*Polyprion americanus*) and European seabass (*Dicentrarchus labrax*) (Lopes, 2009).

The lean fish is typical of deep water and tends to accumulate fat in the liver. On the contrary, fatty fish tend to remain close to the surface of the water and accumulate fat, not only in the liver, but also in the muscular tissue, causing a darker coloration of the muscle as compared to that of lean fish. This fat can, if necessary, be used as an energy reserve (Silva, 2016). Table 1 shows the classification of the 24 fish species analysed according to their fat content, energy value and nutritional composition.

<u>*Please insert Table 1 here*</u>

From the fish species analysed there are several that can be considered as lean since their fat content is lower than 2%. Among these are tadpole codling (*Salilota australis*), pink cusk-eel (*Genypterus blacodes*), skate (*Raja* spp.), monkfish (*Lophius piscatorius*), dentex (*Dentex dentex*), catfish (*Pangasius hypopthalmus*), smooth-hound (*Mustelus mustelus*), codfish (*Gadus morhua*), hake from South Africa (*Merluccius capensis*), croaker (*Protonibea diacanthus*), hake from Chile (*Merluccius australis*), plaice (*Hipoglossoides platessoides*), hake from Argentina (*Merluccius hubbsi*), mackerel (*Trachurus trachurus*) and sand smelt (*Atherina boyeri*). Some fish species have a low fat content, namely perch (*Lates niloticus*), black scabbardfish (*Aphanopus carbo*), sardine (*Sardina pilchardus*) and redfish (*Sebastes* spp.). Fish that have a medium fat content are fewer and include blue shark (*Prionace glauca*), seabass (*Dicentrarchus labrax*) and sprat (*Sprattus sprattus*). In relation to the fish classified as fat, with a high fat content, stand out gilthead (*Sparus aurata*) and salmon (*Oncorynchus keta*), with 9.8% and 21.9%, respectively.

From the evaluated fish species, many do not contain saturated fatty acids, namely: tadpole codling (*Salilota australis*), cusk-eel (*Genypterus blacodes*), skate (*Raja* spp.), monkfish (*Lophius piscatorius*), common dentex (*Dentex dentex*), catfish fillet (*Pangasius hypopthalmus*), smooth-hound (*Mustelus mustelus*) and perch (*Lates niloticus*). On the other hand, the species with higher lipid content also showed higher content of saturated fatty acids: gilthead seabream and salmon, with 2.1 and 4.2 g/100 g, respectively. In what concerns the energetic value, the catfish fillet (*Pangasius hypopthalmus*) and streak (*Raja* spp.) present the lowest values, 50 and 58 kcal/100 g, respectively. The highest energetic content was found in salmon (*Oncorynchus keta*), with 262 kcal/100 g and gilthead (*Sparus aurata*) with 167 kcal/100 g.

As for the protein content, also evaluated in this work, the seabass (*Dicentrarchus labrax*) and catfish fillet (*Pangasius hypopthalmus*) are those that present a lower content, with 10 and 11 g/100 g. Fish with the highest protein content include the smooth-hound (*Mustelus mustelus*) with 20 g/100 g, the croaker (*Protonibea diacanthus*) with 20.4 g/100 g and blue shark (*Prionace glauca*) with 21 g/100 g.

Regarding the carbohydrate content for most of the evaluated species this they are absent: catfish fillets (*Pangasius hypopthalmus*), skate (*Raja* spp.), black scabbardfish (*Aphanopus carbo*), salmon (*Oncorynchus keta*), tadpole codling (*Salilota australis*), cusk-heel (*Genypterus blacodes*), monkfish (*Lophius piscatorius*), hake from South Africa (*Merluccius capensis*), hake from Chile (*Merluccius australis*), codfish (*Gadus morhua*), sand smelt (*Atherina boyeri*), plaice (*Hipoglossoides platessoides*), perch (*Lates niloticus*), dentex (*Dentex dentex*), gilthead (*Sparus aurata*), smooth-hound (*Mustelus mustelus*), croaker (*Protonibea diacanthus*) and blue shark (*Prionace glauca*). However, it stands out the seabass (*Dicentrarchus labrax*) and the sardine (*Sardina pilchardus*) both with a value of 2.3 g/100 g of carbohydrates.

In what concerns sugars, the short chain carbohydrates – monosaccharides and disaccharides, they are absent in all those species analysed which did not contain carbohydrates and which were referred before. The seabass (*Dicentrarchus labrax*) which has the highest carbohydrates content also shows the highest sugar content, 1.5 g/100 g. Nevertheless, from the carbohydrates present sugars represent just a minority.

Because the salt content is very important due to its relation with heart and cardiovascular diseases this was also evaluated in this work. It was observed that sand smelt (*Atherina boyeri*) and croaker (*Protonibea diacanthus*) present the lowest salt content, both with 0.1 g/100 g. On the other hand, the seabass (*Dicentrarchus labrax*) and codfish (*Gadus morhua*) present the highest values: 1.1 and 9.3 g/100 g, respectively. It is worth mention that in Portugal the codfish is not consumed *in natura*, being firstly salted for storage and then desalted in soaking water prior to preparation. Because this process takes at least 24-48 hours, nowadays it is a common practice to desalt the codfish industrially and then freeze the product for a ready usage by the consumers. Due to this processing, it is natural that the salt content of the codfish might be quite higher when compared to other fish species. According to the USDA – Food Composition Database (USDA, 2018), the sodium content in Atlantic codfish is 54.0 mg/100 g, which is equivalent to 0.1 g/100 g of sodium chloride, thus evidencing that the high salt content in Portuguese codfish results from the salting process.

One other aspect evaluated within this work was the fatty acids and cholesterol contents of the 24 fish species consumed in Portugal. It is worth noting that regarding this type of food constituents there is still much unavailable data, which highlights the need to proceed with further studies in this area.

The results presented in Table 1 show that some species do not present monounsaturated fatty acids (MUFAs), namely, tadpole codling (*Salilota australis*), smooth-hound (*Mustelus mustelus*), cusk-eel (*Genypterus blacodes*), skate (*Raja* spp.) and monkfish (*Lophius piscatorius*). Salmon (*Oncorynchus keta*) on the other hand stands out with a high value, 10 g/100 g, followed by sardine (*Sardina pilchardus*) with 4 g/100 g. The tadpole codling (*Salilota australis*) and monkfish (*Lophius *piscatorius*) also do not present polyunsaturated fatty acids (PUFAs), while salmon (*Oncorynchus keta*) and sardine (*Sardina pilchardus*) show a high value: 5.1 g and 5.6 g/100 g. Most of the evaluated fish species do not have linoleic acid (LA), being this present only in salmon (*Oncorynchus keta*), which is the richest with 0.7 g/100 g, in sardine (*Sardina pilchardus*) and seabream (*Sparus aurata*), both with 0.5 g/100 g, in seabass (*Dicentrarchus labrax*), 0.4 g/100 g and in monkfish (*Lophius piscatorius*), 0.1 g/100 g. The values of cholesterol show that the hake species (*Merluccius capensis*, *Merluccius hubbsi* and *Merluccius australis*), present the lowest content, 19.0 mg/100 g while the plaice (*Hipoglossoides platessoides*) shows the highest cholesterol content, 85.0 mg/100 g. Also the vitamin content was evaluated for some selected vitamins, namely A, D, B_6, B_{12} and C, and the values are presented in Table 2.

<u>*Please insert Table 2 here*</u>

Regarding the vitamin A content, the plaice (*Hipoglossoides platessoides*) reveals absence of this fat soluble vitamin, while the codling (*Salilota australis*) and croaker (*Protonibea diacanthus*) show a residual content of 1 µg/100g. Nevertheless, this vitamin can be found in higher amounts in sardine (*Sardina pilchardus*), with 47 µg/100g, followed by seabass (*Dicentrarchus labrax*), with 36 µg/100g. The vitamin D is not found in monkfish (*Lophius piscatorius*) while the sardine shows a high value of 21 µg/100g, followed by croaker (*Protonibea diacanthus*), with 16 µg/100g. With relation to vitamin B_6 the hake from South Africa (*Merluccius capensis*) presents the lowest value, with 0 mg/100g whereas the sardine (*Sardina pilchardus*) is the richest, with 0.6 mg/100g, followed by seabass (*Dicentrarchus labrax*) with 0.5 mg/100g. The monkfish (*Lophius piscatorius*) shows a low content of vitamin B_{12}, 0.3 µg/100g, and once again the sardine (*Sardina pilchardus*) shows the highest content of this vitamin among the studies fish species, 10 µg/100g. It is noteworthy that concerning the vitamins contents, sardine stands out by presenting the highest values for all the evaluated vitamins, just with exception for vitamin C. By the way, from the 24 evaluated species neither of them revealed the presence of vitamin C, for this reason, there is no data for vitamin C in Table 2.

The total mineral content, measured by ash, was very similar in all species, varying from 1 g/100 g in pink cusk-eel (*Genypterus blacodes*) and plaice (*Hipoglossoides platessoides*) to the maximum value of 1.9 g/100 g in skate (*Raja* spp.). Regarding sodium (Na), while the salmon (*Oncorynchus keta*) is the poorest, with only 38 mg/100 g, the skate (*Raja* spp.) is the species with the highest content, 220 mg/100 g. The potassium (K) is less variable among the species evaluated, varying from 230 mg/100 g in plaice (*Hipoglossoides platessoides*) to 430 mg/100 g in croaker (*Protonibea diacanthus*). The calcium (Ca) varies markedly from specie so specie, being as low as 7.0 mg/100 g in monkfish

(*Lophius piscatorius*) while for the skate (*Raja* spp.) it is very high, 160 mg/100 g. Phosphorus (P) is important in all species, with plaice (*Hipoglossoides platessoides*) showing the lowest content, 170 mg/100 g, as opposing to skate (*Raja* spp.), which shows a high amount, 320 mg/100 g. In relation to magnesium (Mg), the contents vary from 23 mg/100 g in salmon (*Oncorynchus keta*) to 38 mg/100 g in seabass (*Dicentrarchus labrax*). The iron (Fe) is very low for all species, with a maximum content of 1.2 mg/100 g in mackerel (*Trachurus trachurus*). Regarding the zinc (Zn), the values are also low in all cases, with sardine (*Sardina pilchardus*) showing the highest value, 1.6 mg/100 g.

3.2. Analysis of the data by means of Pearson correlations

Table A.1 in Annex A shows the values obtained for the Pearson correlations between all the properties considered for the 24 species most representative of the fish under study. The most expressive correlations, corresponding to values of r between 0.8 and 1.0, were found for the relations between lipids with saturated fatty acids ($r = 0.958$), with monounsaturated fatty acids ($r = 0.951$) and with polyunsaturated fatty acids ($r = 0.856$). Very strong correlations were also found between saturated fatty acids and MUFAs ($r = 0.957$), PUFAs ($r = 0.812$) or linoleic acid ($r = 0.900$). The correlation between MUFAs and PUFAs as well as that between MUFAs and LA were also very strong ($r = 0.874$ and $r = 0.891$, respectively), and similarly the correlation between PUFAs and LA ($r = 0.919$). These correlations between different classes of lipids are expectable, as it is the association between carbohydrates and sugar, expressed also by a very strong correlation ($r = 0.925$).

Regarding the ash content, the strongest correlation was with phosphorus ($r = 0.817$). Apart from these it was also found a less intuitive correlation between carbohydrates and zinc ($r = 0.903$), being this indicative a very strong association between these variables. All these signalled correlations were significant at the level of 1% ($p < 0.01$).

3.3. Analysis of the data by using Factor Analysis

The correlation matrix showed that there were some significant correlations between the variables, with 33% of the values of r being over 0.4, and with 12 values higher than 0.8. The solution obtained by FA with Varimax rotation of PCA solution produced 4 components, based on the Keiser criterion to consider eigenvalues greater than 1. The percentage of total variance explained by the solution was 96.3%, distributed by the factors as: F1 – 10.6%, F2 – 19.6%, F3 – 24.2% and F4 – 41.9%. The rotation converged in 6 iterations and extracted 4 factors, as previously mentioned, which arrange the variables as presented in Table 3.

<u>*Please insert Table 3 here*</u>

Factor 1 was visibly linked to fat and it also included the fat soluble vitamins, although there were some other components that contributed for the definition of this factor, and all with high loadings (absolute value), being the lowest equal to 0.505, indicating that all variables contributed importantly for the definition of this factor. On the other hand, factors 2, 3 and 4 were clearly more linked to the mineral composition, with some very expressive loadings (over 0.8). While factor 2 related strongly with ash, calcium and phosphorus, factor 3 was very much determined by potassium and factor 4 essentially by magnesium. The variables sugar and iron did not present a representative loading (over 0.4) in any of the factors extracted.

3.4. Analysis of the data by Hierarchical Cluster Analysis

By performing the Hierarchical Cluster Analysis using the Ward linkage method considering Squared Euclidean Distance, the fish species evaluated were grouped into two major groups, as indicated by the dendogram in Figure 1.

Please insert Figure 1 here

The first group includes the following species: salmon, sardine, seabass and mackerel, while the second group includes all other types of fish evaluated in this study. Nevertheless, as the as the distance changes, the division of the samples becomes more frequent, based on the individual composition of each species. Species that stayed in the same group, i.e., were not differentiated after all the levels, include hake from Argentina, hake from Chile and tadpole codling, constituting a homogenous subgroup. Another subgroup was defined by 6 species, cusk-eel, smooth-hound, common dentex, redfish, monkfish and black scabbardfish. The croaker and gilthead seabream constituted another subgroup and finally another subgroup was formed by other two species: mackerel and seabass.

4. CONCLUSION

As regards the fat content, fish species like gilthead and salmon are highlighted for having a fat content of about 10% and 22%, respectively. Particularly the salmon presents very high values of unsaturated fatty acids, 10 and 5 g/100 g, respectively for MUFAs and PUFAs. As for protein, the blue shark is that with a higher content, 21 g/100g of edible part. Codfish evidenced a very high salt content, 9.3 g/100 g, which is probably due to the fact that in Portugal the codfish is used after a salting process. Regarding the vitamin content, sardine presents a considerable higher amount as compared with the other species evaluated. Concerning dietary minerals, skate and salmon show the highest amounts of phosphorus, 320 and 310 mg/100 g, respectively. Particularly rich in calcium appears also the skate, 160 mg/100 g, being the difference to the generality of other species much pronounced. The croaker and the hake from Argentina are the species with more potassium (430 and 410 mg/100 g, respectively), while the sodium content is higher in skate and in smooth-hound (220 and 170 mg/100 g). Magnesium is highlighted in species like seabass (38 mg/100 g) and hake from South Africa (37 mg/100 g). The mackerel is the richest in iron (1.2 mg/100 g) and sardine stand out for the highest zinc content (1.6 mg/100 g).

Very strong correlations were found between the properties related to lipid content, with values ranging from 0.812 to 0.958. Factor analysis extracted 4 factors, explaining more that 96% of the variance, being one factor much linked to the lipids whereas the other 3 factors were mostly explained by the mineral composition of the species evaluated. Furthermore, cluster analysis allowed identifying two major groups of fish and 4 undistinguishable subgroups.

As it was evidenced by this work, still much information is not available for the species concerned, so it is recommended that more studies focus on the determination of those nutritional properties. Also, because the information used in this study never referred if the species were collected from the wild or if they were grown in aquaculture, further comparative studies would be advisable in the future.

5. CONFLICT OF INTEREST

The authors have no conflict of interest to declare.

6. ACKNOWLEDGEMENT

Not included for anonymity purposes.

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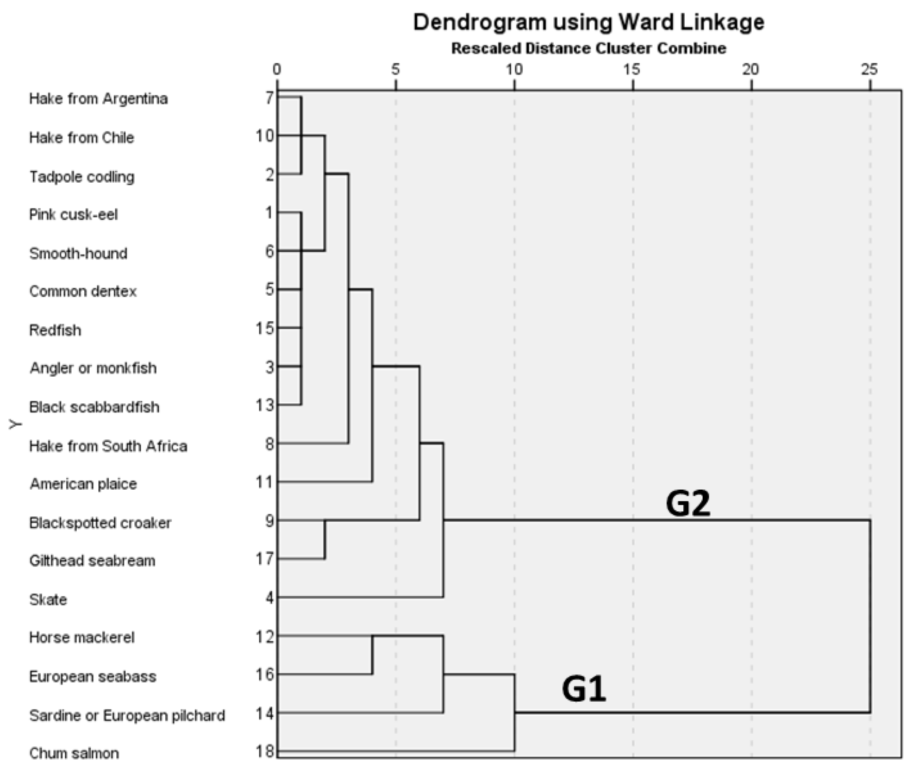

Figure 1. Dendogram obtained with Ward linkage for the 24 fish species analysed. Two main groups (G1 and G2) were found as grouping categories for distances higher than 10.

Table 1 – Energetic and nutritional value of the most important fish species consumed in Portugal.

Fish[1]	Energy (kcal)	Fat content category[2]	Values per 100 g of edible part										
			Lipids (g)	Of which saturated fatty acids (g)	Proteins (g)	Carbohydrates (g)	Of which sugars (g)	Salt (g)	Monounsaturated fatty acids (MUFAs) (g)	Polyunsaturated fatty acids (PUFAs) (g)	Linoleic acid (LA) (g)	Cholesterol (mg)	Source[4]
Pink cusk-eel (*Genypterus blacodes*)	70	Very low	0.1	0	17.2	0	0	0.3	0	0.1	0	28	INSA
Tadpole codling (*Salilota australis*)	70	Very low	0.1	0	17.2	0	0	0.2	0	0	0	22	INSA
Angler or monkfish (*Lophius piscatorius*)	73	Very low	0.2	0	17.9	0	0	0.2	0	0	0.1	42	INSA
Skate (*Raja* spp.)	58	Very low	0.2	0	14.1	0	0	0.6	0	0.1	0	39	INSA
Common dentex (*Dentex dentex*)	79	Very low	0.2	0	19.4	0	0	0.2	0.1	0.2	0	34	INSA
Atlantic codfish (*Gadus morhua*)	80	Very low	0.4	0.1	19	0	0	9.3	N.A.	N.A.	N.A.	N.A.	
Striped catfish [fillet] (*Pangasius hypopthalmus*)	50	Very low	0.5	0	11	0	0	0.4	N.A.	N.A.	N.A.	N.A.	TF
Smooth-hound (*Mustelus mustelus*)	82	Very low	0.7	0	20	0	0	0.4	0.0	0.1	0	25	INSA
Hake from Argentina (*Merluccius hubbsi*)	83	Very low	1.2	0.4	18.1	<0.5	<0.5	0.3	0.4	0.4	0	19	IAB, INSA
Hake from South Africa (*Merluccius capensis*)	80	Very low	1.3	0.2	17.2	0	0	0.8	0.4	0.4	0.0	19	INSA

Fish[1]	Energy (kcal)	Fat content cetegory[2]	Values per 100 g of edible part Lipids (g)	Of which saturated fatty acids (g)	Proteins (g)	Carbohydrates (g)	Of which sugars (g)	Salt (g)	Monounsaturated fatty acids (MUFAs) (g)	Polyunsaturated fatty acids (PUFAs) (g)	Linoleic acid (LA) (g)	Cholesterol (mg)	Source[4]
Blackspotted croaker (*Protonibea diacanthus*)	94	Very low	1.4	0.3	20	0	0	0.1	0.5	0.2	0	50	INSA
Hake from Chile (*Merluccius australis*)	86	Very low	1.5	0.3	18	0	0	0.5	0.4	0.4	0	19	INSA
American plaice (*Hippoglossoides platessoides*)	90	Very low	1.6	0.3	19	0	0	0.7	0.4	0.4	0	85	INSA
Big-scale sand smelt (*Atherina boyeri)*	90	Very low	1.7	0.5	19	0	0	0.1	N.A.	N.A.	N.A.	N.A.	TF
Horse mackerel (*Trachurus trachurus*)	93	Very low	1.9	0.6	17.5	1.5	0.6	0.8	0.8	0.9	.0	36	INSA
Nile perch (*Lates niloticus*)	94	Low	2	0	19.0	0	0	0.2	N.A.	N.A.	N.A.	N.A.	TF
Sardine or European pilchard [small] (*Sardina pilchardus*)	94	Low	2	0.8	16.6	1.5	0.6	0.3	N.A.	N.A.	N.A.	N.A.	IAB
Black scabbardfish (*Aphanopus carbo*)	88	Low	2.8	0.5	15.7	0	0	0.3	1.6	0.2	0	24	INSA
Sardine or European pilchard (*Sardina pilchardus*)	108	Low	3.6	1.3	16.5	2.3	0.7	0.9	4	5.6	0.5	20	INSA
Redfish (*Sebastes* spp.)	111	Low	4	0.9	18.8	<0.5	<0.5	0.3	0.9	0.5	0	42	INSA
European sprat (*Sprattus sprattus*)	99	Medium	4.2	1.9	15	0.9	0.1	0.8	N.A.	N.A.	N.A.	N.A.	TF
Blue shark (*Prionace glauca*)	130	Medium	5.0	1.0	21	0	0	N.A.[3]	N.A.	N.A.	N.A.	N.A.	TF

Fish[1]			Values per 100 g of edible part											
	Energy (kcal)	Fat content cetegory[2]	Lipids (g)	Of which saturated fatty acids (g)	Proteins (g)	Carbohydrates (g)	Of which sugars (g)	Salt (g)	Monounsaturated fatty acids (MUFAs) (g)	Polyunsaturated fatty acids (PUFAs) (g)	Linoleic acid (LA) (g)	Cholesterol (mg)	Source[4]
European seabass (*Dicentrarchus labrax*)	145	Medium	7.9	1.8	10	2.3	1.5	1.1	2	1.7	0.4	52	INSA
Gilthead seabream (*Sparus aurata*)	167	High	9.8	2.1	19.7	0	0	0.2	3.6	2.8	0.5	51	INSA
Chum salmon (*Oncorynchus keta*)	262	High	21.9	4.2	16.2	0	0	0.2	10	5.1	0.7	40	INSA

[1]Common name (*Scientific name*).

[2]Very low fat content: < 2%; Low fat content: 2-4%; Medium fat content: 4-8%; High fat content: > 8% (classification according to Ackman (1990), Afonso (2009) and Gonçalves (2010).

[3]N.A. – Not available.

[4]TF – Technical File (documentation from the Company); IAB – Internal Analysis Bulletin (documentation from the company); INSA – National Health Institute Doutor Ricardo Jorge.

Table 2 – Vitamin and minerals content of the most important fish species consumed in Portugal.

Fish[1]	Values per 100 g of edible part												
	Vitamin A (µg)	Vitamin D (µg)	Vitamin B_6 (mg)	Vitamin B_{12} (µg)	Ash (g)	Sodium (Na) (mg)	Potassium (K) (mg)	Calcium (ca) (mg)	Phosphorus (P) (mg)	Magnesium (Mg) (mg)	Iron (Fe) (mg)	Zinc (Zn) (mg)	Source[3]
Pink cusk-eel (*Genypterus blacodes*)	9	0.4	0.1	0.5	1.0	120	260	25	180	25	0.2	0.7	INSA
Tadpole codling (*Salilota australis*)	1	0.4	0.1	0.4	1.1	63	360	11	230	28	0.2	0.5	INSA
Angler or monkfish (*Lophius piscatorius*)	24	0	0.1	0.3	1.1	86	330	7	210	27	0.2	0.5	INSA
Skate (*Raja* spp.)	2	0.4	0.2	0.5	1.9	220	260	160	320	28.	0.3	0.8	INSA
Common dentex (*Dentex dentex*)	6	0.9	0.2	1.3	1.1	81	320	12	180	28	0.5	0.5	INSA
Atlantic codfish (*Gadus morhua*)	N.A.[2]	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Striped catfish [fillet] (*Pangasius hypopthalmus*)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Smooth-hound (*Mustelus mustelus*)	3	0.4	0.1	3.3	1.1	170	290	14	190	32	0.1	0.3	INSA
Hake from Argentina (*Merluccius hubbsi*)	10	1.4	0.1	0.7	1.1	69	410	15	220	26	0.5	0.7	INSA
Hake from South Africa (*Merluccius capensis*)	7	1.1	0	0.6	1.3	120	330	20	180	37	0.3	0.6	INSA
Blackspotted croaker (*Protonibea diacanthus*)	1	16	0.3	0.3	1.2	56	430	13	230	31	0.3	0.5	INSA
Hake from Chile (*Merluccius australis*)	5	1.3	0.1	0.8	1.3	85	380	43	200	26	0.3	0.5	INSA
American plaice (*Hippoglossoides platessoides*)	0	10	0.1	1.5	1.0	110	230	54	170	29	0.4	0.6	INSA

Fish[1]	Values per 100 g of edible part												
	Vitamin A (µg)	Vitamin D (µg)	Vitamin B_6 (mg)	Vitamin B_{12} (µg)	Ash (g)	Sodium (Na) (mg)	Potassium (K) (mg)	Calcium (ca) (mg)	Phosphorus (P) (mg)	Magnesium (Mg) (mg)	Iron (Fe) (mg)	Zinc (Zn) (mg)	Source[3]
Big-scale sand smelt (*Atherina boyeri)*	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Horse mackerel (*Trachurus trachurus*)	15	4.1	0.4	5.7	1.4	80	400	69	260	33	1.2	1.2	INSA
Nile perch (*Lates niloticus*)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Sardine or European pilchard [small] (*Sardina pilchardus*)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Black scabbardfish (*Aphanopus carbo*)	23	2.1	0.2	1.7	1.2	140	330	14	180	29	0.1	0.5	INSA
Sardine or European pilchard (*Sardina pilchardus*)	47	21	0.6	10	1.7	65	370	72	310	31	1	1.6	INSA
Redfish (*Sebastes* spp.)	20	2.3	0.2	2.3	1.2	78	310	15	200	29	0.6	0.6	INSA
European sprat (*Sprattus sprattus*)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
Blue shark (*Prionace glauca*)	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	N.A.	
European seabass (*Dicentrarchus labrax*)	36	5	0.5	1.3	1.7	95	350	52	230	38	0.4	1.2	INSA
Gilthead seabream (*Sparus aurata*)	11	12	0.4	4.8	1.4	59	380	15	250	28	0.4	0.8	INSA
Chum salmon (*Oncorynchus keta*)	33	11	0.5	1.9	1.3	38	300	12	210	23	0.5	0.5	INSA

[1]Common name (*Scientific name*).

[2]N.A. – Not available.

[3]INSA – National Health Institute Doutor Ricardo Jorge.

Table 5 – Component matrix obtained by factor analysis with Varimax rotation.

Property	**Factor 1**[1]	**Factor 2**[1]	**Factor 3**[1]	**Factor 4**[1]
Lipids	0.61			
Saturated FA	0.67			
Protein		-0.44		
Carbs		0.47		
Sugar				
Salt		0.50		
MUFAs	0.66			
PUFAs	0.72			
Linoleic A	0.70			
Trans FA		0.44		
Cholesterol			-0.44	
Vit A	0.51			
Vit D	0.64			
Vit B_6	0.58	0.42		
Vit B_{12}				
Ash		**0.884**		
Na	-0.78		-0.50	
K			**0.986**	
Ca		**0.902**		
P		**0.919**		
Mg				**0.989**
Fe				
Zn		0.65		

[1]Loadings under 0.4 were excluded.

8. ANNEX A

Table A.1. Pierson correlations between the properties analysed in the 24 most representative species of fish consumed in Portugal.

	LIP	SFA	CAR	SUG	SALT	MUFAs	PUFAs	LA	Tr.FA	V.A	V.D	$V.B_6$	$V.B_{12}$	ASH	Na	Ca	P
Saturated FA	**0.958****	1															
Sugar	0.16	0.27	**0.925****	1													
MUFAs	**0.951****	**0.957****	0.19	0.14	0.00	1											
PUFAs	0.743**	**0.812****	0.503*	0.35	0.25	**0.874****	1										
Linoleic A	**0.856****	**0.900****	0.43	0.39	0.15	**0.891****	**0.919****	1									
Trans FA	0.01	0.12	0.615**	0.34	0.41	0.26	0.663**	0.41	1								
Vit A	0.519*	0.602**	0.691**	0.615**	0.40	0.617**	0.740**	0.712**	0.600**	1							
Vit D	0.42	0.498*	0.42	0.25	0.18	0.549*	0.738**	0.622**	0.636**	0.42	1						
Vit B_6	0.607**	0.698**	0.737**	0.662**	0.40	0.668**	0.812**	0.783**	0.532*	0.693**	0.737**	1					
Vit B_{12}	0.18	0.30	0.641**	0.39	0.41	0.36	0.687**	0.477*	0.788**	0.541*	0.612**	0.671**	1				
Ash	0.22	0.29	0.604**	0.570*	0.576*	0.26	0.44	0.43	0.41	0.43	0.29	0.625**	0.39	1			
Ca	-0.15	-0.11	0.35	0.28	0.543*	-0.10	0.076	-0.02	0.25	0.01	0.07	0.25	0.20	0.763**	0.562*	1	
P	0.06	0.15	0.502*	0.36	0.30	0.17	0.43	0.34	0.523*	0.29	0.40	0.541*	0.511*	**0.817****	0.07	0.704**	1
Zn	0.09	0.23	**0.903****	0.771**	0.715**	0.20	0.554*	0.43	0.690**	0.614**	0.485*	0.704**	0.717**	0.681**	-0.14	0.508*	0.678**

**. Correlation is significant at the 0.01 level (2-tailed); *. Correlation is significant at the 0.05 level (2-tailed). Lipids, protein, carbs, salt, cholesterol, Na, K, Mg, and Fe rows were not presented because correlations were not significant in the entire row. Protein, cholesterol, K, Mg, Fe, and Zn columns were not presented because the correlations were not significant in the entire column.