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Effect of the Seasonality of Atlantic Bonito (*Sarda sarda*) on Chemical, Nutritional and Sensory Characteristics

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Portugal is one of the major fish consumers in Europe and the World. According to the FAO and the WHO, fish consumption should be increasingly recommended in a healthy and sustainable diet, not only for the diversity of species but also for its health benefits to consumers. Fish is an essential source of nutrients, as it is low in fat content and high level of protein, vitamins, and minerals. In recent decades, this food group's consumption has increased and become available to consumers far from coastal areas. This study aimed to compare Atlantic Bonito samples captured in two seasons (Spring and Autumn) to characterise the seasonality of this specie regarding nutritional, chemical and sensorial properties. Parameters such as pH, water activity, moisture, protein, lipids, carbohydrates, chlorides, fibre, and ash were determined using the fish's muscular tissue. A quantitative descriptive analysis (QDA®) was carried out with six semi-trained panellists. The fish attributes evaluated by the panellists were: characteristic colour, odour, and flavour; superficial shine; chipping; off-odour; ammoniacal and sea odour; hardness; juiciness; fibrousness; acid, bitter and sea/algae taste; and off-flavour. In order to compare not only seasonality but also the effect of the time during cooking, samples were divided into two batches: 5 and 10 min of cooking time. Results showed no significant differences in water activity, carbohydrates, chlorides, and fibre between fish fillets' capture in Spring and Autumn ($p>0.05$). On the contrary, significant differences were found for moisture, protein, and ash between the fish fillets' capture in Spring and Autumn ($p>0.05$). Regarding lipids content, Autumn fish samples were 6.32-fold higher than Spring fish samples ($p<0.05$). As for sensory analysis, panellists noticed some differences between Spring and Autumn samples regarding the following characteristics: superficial shine, chipping, characteristic odour, sea odour, hardness, juiciness, fibrousness, characteristic flavour, and acid taste. These differences were more pronounced on 10 min batch samples, regardless of the seasonality. The sensory analysis results showed that cooking time is the most important factor for the overall sensory evaluation regardless of the season. However, 5 min cooked fish fillets captured in Spring scored higher points than fish samples captured in Autumn. It can be concluded that the Atlantic Bonito seasonality influences sensory characteristics and nutritional properties, mainly the lipid content.

1. Introduction

Fish consumption should be increasingly recommended in a healthy and sustainable diet, since it helps meet an important part of human needs in terms of fatty acids, omega-3s and vitamins, preventing the risk of cardiovascular diseases and encouraging normal cognitive development, according to the Food and Agriculture Organization of United Nations (FAO) and the World Health Organization (WHO).
Fish flesh is one of the most popular sources of protein consumed worldwide but even though there is a great variety of fish in the ocean, only a small fraction is commercialised (Silva et al., 2020).

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Fish is mainly composed of water (60 % to 70 % for oily fish and 80 % to 85 % for lean fish), lipids (0.1 % to 25 %) and protein (10 % to 25 %). The vitamins in fish are essentially the fat-soluble vitamins A, D, E and K and water-soluble vitamins B1, B12 and C (0.01 % to 0.7 %). Regarding mineral salts, Na, K, Ca, Fe and P are also present (0.9 % to 2 %) in fish. The nutritional composition of fish can also differ according to the species, individual, age, gender, environment, and time of year (Vaz-Pires et al., 2006).

The fatty acids found in fish are fundamentally unsaturated and long-chain fatty acids, often even polyunsaturated, called poly-unsaturated fatty acids (PUFA), considered the most beneficial lipids for human health. However, their chemical structure makes them more susceptible to oxidation. This lipid degradation generates shorter-chain fatty acids responsible for intense off-odour (Vaz-Pires et al., 2006).

The proteins present in fish have a high biological value since they are highly digestible and absorbed by the human organism, and because fish is rich in some essential amino acids (Huss et al., 1995).

The main relevant non-protein nitrogen compounds in fish are urea, trimethylamine, and histidine, which are abundant in dark muscle. These compounds influence the product's sensory characteristics and play an active role in fish spoilage (Vaz-Pires et al., 2006).

The factors that most contribute to fish degradation are protein alteration, lipid oxidation and microbial action. During protein degradation, free amino acids are formed, whose decarboxylation by bacteria gives rise to biogenic amines, namely cadaverine, putrescine and histamine (Brink et al., 1990).

Due to their high content of polyunsaturated fatty acids, they are very susceptible to auto-oxidation reactions in the presence of oxygen. In the first stage of this chemical oxidation, after oxygen reacts with the double bonds, hydroperoxides are formed, which cause a yellow/brown discolouration in fish tissues. The subsequent compounds' degradation generates aldehydes and ketones with a strong odour and rancid taste. Oxidation can be accelerated by exposure to heat, light and various organic and inorganic compounds (Brites et al., 2012).

Microorganisms are the main factor in the degradation of fish, so if their development is avoided, it is possible to delay its degradation. For these microorganisms to grow and develop, there must be adequate nutrients, water, temperature and pH, and fish is a foodstuff that provides all these favourable conditions. During storage, many reactions occur leading to changes in quality, such as endogenous chemical and enzymatic reactions. Safety and shelf life are related to food spoilage and pathogenic microorganisms (Dehghani et al., 2017). The storage temperature is one of the most critical factors, as it interferes with the shelf life and the type of microbial alterations that may occur in the food (Huss, 1995).

The Atlantic Bonito (*Sarda sarda*) is a Bonito species with an elongated and hydrodynamic body shape, which is covered with small scales and the tail fin is forked, characteristic of the Scombridae family, such as tuna and mackerel. The dorsal fins are contiguous and the front one is wide. Its colouration is greyish green with about 5 to 11 dark oblique stripes in the upper part of the body (being vertical in juveniles) and it has a silver belly (DocaPesca, 2020). This species feeds mainly on members of the families Scombridae, Atherinidae, Clupeidae, Alosa pseudoharengus and many other species of fish and cephalopods.

Compared to other common commercial species, it stands out for its favourable aspects, such as its nutrient-rich lipid/protein composition, high yield, and specific taste (Altan et al., 2022). The Atlantic bonito is a valuable small tuna species to coastal countries and local communities. The common gears used in fisheries for catching Atlantic bonito are gillnets, purse seines, longlines, and sleeping nets (Sarr et al., 2023).

Generally, the nutritional properties of marine fish fat content are largely determined by the advantageous fatty acid profiles that have health-promoting properties. However, the fatty acid composition in fish can vary among species and individuals of a given species as the result of diet, reproductive cycle, capture site, and season, among other variables (Bandarra et al., 2018; Li and Cheng, 2018; Primo et al., 2018; Brauer et al., 2020; Pousis et al., 2019; Gonzalez-Silvera et al., 2020; Souza et al., 2020). Thus, some studies performed comparative chemical analyses on fish caught in different seasons (Zotos and Vouzanidou, 2012, Döring et al., 2018; Leaf et. al., 2018; Ferreira et al., 2020; Souza et al., 2020).

Data on the nutritional composition of Atlantic Bonito fish are crucial to assist in diet formulation, fish processing and conservation and dissemination of nutritional information that may stimulate change in dietary habits. Therefore, this study aimed to compare the chemical, nutritional and sensory profiles in Atlantic Bonito (*Sarda sarda)* species captured in different seasons (Spring and Autumn).

2. Materials and Methods

2.1 Raw materials

This study was performed with Atlantic bonito (*Sarda sarda*) captured from Ocean Atlantic, North Zone, Portugal. In total, 6 kg of bonito were purchased from fisherman in the months of March and October of 2022, spring and autumn, respectively. The marine fish, Bonito, was transported to the laboratory in ice in a Styrofoam box. After that, fish was cut into fillets, gutted, and washed under running tap water.

2.2 Sample preparation

The fillet samples were ground in an IKA Ultra-Turrax (model T18D) for chemical and nutritional analysis.
For the sensorial analysis, the fillets were placed in trays and then cooked in a convector oven at 180 ºC for 5 and 10 min.

2.3 Analytical methods

For pH and water activity determination, pH-meter CRISON pH 25+, and a Novasina, AW Lab Set H were used, respectively. The moisture content was determined according to the AOAC Method 925.10:1995. Carbohydrate content was determined using DNS colorimetric method based on Analytical Chemistry of Foods (James, 1995). Crude fibre, chlorides and ash content were determined using AOAC Method 962.09:1995, NP 2929:2009 and AOAC Method 938.08:1995, respectively. Protein was determined using AOAC Method 955:04:1995 and lipidic content was determined using AOAC Method 920.39:1995. All the analysis were performed in triplicate.
For sensory analysis, a quantitative descriptive analysis (QDA®) was carried out with six semi-trained panellists, according to ISO 6658:2005. The attributes evaluated by the panellists were: colour, superficial shine, chipping, characteristic odour, off-odour, ammoniacal and sea odour, hardness, juiciness, fibrousness, characteristic flavour, acid, bitter and sea/algae taste, and off-flavour. These attributes were evaluated on an intensity scale of 10 points (1 - lowest intensity, 10 - higher intensity). In addition, the samples were classified in terms of general taste (1 to 5 points: 1 - very bad, 5 - excellent). Afterwards, panellists evaluated the attributes of each fish Atlantic Bonito fillet cooked for 5 and 10 min in blinded assays.

2.4 Statistical analysis

Results were submitted to an analysis of variance (ANOVA), followed by a post-hoc Tukey test. Statistically significant differences were set at $p<0.05$. Data mining was performed to investigate patterns using principal component analysis (PCA) with sensory analysis data. These statistical approaches were carried out using TIBCO® Statistica®, v.14.0.0, TIBCO Software Inc, Palo Alto, CA, USA.

3. Results and Discussion

Table 1 summarises the chemical and nutritional parameters obtained for Atlantic Bonito (*Sarda sarda*) marine fish captured in March (spring) and October (autumn), shows that the fish captured in March and October obtained similar pH values, 5.85±0.03 and 5.95±0.01, respectively, with no significant differences ($p>0.05$).
Concerning the water activity there are no significant differences for both marine fish fillets capture in March and October. Results for moisture content showed that the marine fish fillets of March obtained higher values than October fillets, 72.64 ± 0.32 % and 68.45 ± 0.39 %, respectively ($p<0.05$), higher than the obtained in an experiment by Altan et al., (2022), which reported 58.05 % of moisture in fish. Regarding protein content it was found that fillets from March were slightly higher than October fillets 25.4 ± 0.32 % and 22.9 ± 0.35 %, respectively ($p<0.05$). Özden et al., (2010) found similar results and reported protein and fat content of Bonito to be 17.78 – 24.56 % and 1.13 – 17.37 %, respectively. Also, Öksüz et al., (2008) reported a protein value of 24.1 %, and Altan et al., (2016) 24.43 %, results within the obtained in this study.
The same pattern was found for ash content, fillets from March were slightly higher than October fillets 1.41 ± 0.02 % and 0.96 ± 0.02 %, respectively ($p<0.05$), results similar to the ones obtained in the studies by Öksüz et al., (2008) and Altan et al., (2016) - 1.4 % and 1.33 %, respectively.
In relation to chloride and fibre content there were no significant differences ($p>0.05$) between Spring and Autumn marine fish fillets, 0.27 ± 0.09 % and 1.52 ± 0.14 %, and 0.3 ± 0.04 % and 1.47 ± 0.11 %, respectively. Both the spring and autumn samples had absorbance readings below the detection limit for the carbohydrate content, meaning that this marine fish species, Atlantic Bonito (*Sarda sarda*), has no carbohydrate content.
According to Romotowska et al., (2016) the lipid content in fish may vary according to the species, diet, geographical origin, season, and farming conditions. Lipid content results showed that fish fillets from Autumn were 6.32-fold higher than Spring fish fillets, 7.55 ± 0.29 % and 1.21 ± 0.32 %, respectively ($p<0.05$). Similar results were obtained by Guerra et al., (2022) for the marine fish species of Hemiramphus brasiliensis, Hyporhamphus unifasciatus, Scomberomorus cavalla, Opisthonema oglinum, and according to Murillo et al., (2014) for the species Caranx caballus, Cynoscion phoxocephalus, Lutjanus guttatus, and Scomberomorus sierra.

Table 1. Results of chemical and nutritional analyses of Atlantic Bonito fillets, obtained in Spring and Autumn. Mean values ± standard deviation (n=3). Means within same column with different superscripts are significantly different at p<0.05.

Parameters	Spring (March 2022)	Autumn (October 2022)
Fat (%, w/w)	1.21 ± 0.32^b	7.55 ± 0.29^a
Carbohydrate (%, w/w)	< 0.002*	< 0.002*
Fibre (%, w/w)	1.52 ± 0.14	1.47 ± 0.11
Protein (%, w/w)	25.4 ± 0.32^a	22.9 ± 0.35^b
Chlorides (%, w/w)	0.27 ± 0.09	0.3 ± 0.04
Moisture (%, w/w)	72.64 ± 0.32^a	68.45 ± 0.39^b
Ash (%, w/w)	1.41 ± 0.02^a	0.96 ± 0.02^b
pH	5.85 ± 0.03	5.95 ± 0.01
$\mathbf{a_w}$	0.97	0.97

* - Values under the method's limit of detection

The results of the sensory analysis of for both fish fillets captured in March and October are shown in Figure 1. Also, PCA (Figure 1) was used to investigate relationships between Spring and Autumn marine fish fillets and the two cooking batch times, 5 min and 10 min. PC1 (Factor 1) and PC2 (Factor 2) summarized almost 76 % and 21 % of this study information, respectively. A good separation of groups was achieved, with the main differences to be seen in the fillets cooked during 10 min. Fillets cooked for 5 min obtained closer overall scores, regardless of the fish capture seasonality, compared to the other samples. Panellists scored fish samples cooked for 5 min with higher scores for superficial shine, chipping, characteristic and sea odour, juiciness, characteristic flavour and sea/algae flavour compared to fish samples cooked for 10 min. On the other, fillets samples cooked for 10 min were placed further away from these attributes (Figure 1). Instead, fillets samples cooked for 10 min were close to hardness or fibrousness scores, which are characteristics seen as less favourable in fish fillets. However, fillets from the Autumn season cooked for 10 min had higher characteristic colour scores than Spring season cooked for 10 min.
PCA results indicated that cooking time is the most important factor for the overall sensory evaluation: the characteristics considered most valued for fish fillets had higher scores in the cooking time of 5 min, since overcooking (10 min) lead to lower satisfaction scores.

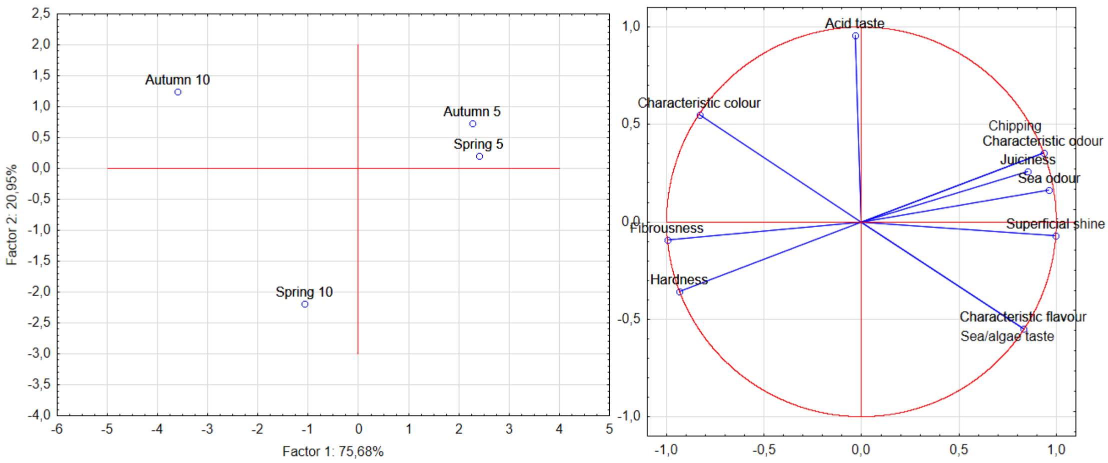

Figure 1. Principal component analysis of sensory evaluation—score plot for the mean classification of condition groups (left) and loading plot of different attributes (right), performed on Sarda sarda captured on Spring and Autumn seasons.

A defect detection/sensory conformity test was also performed using a 5-point scale to perceive potential defects in the product's overall quality. The results (Table 2) showed that fish fillets cooked during 5 min had higher scores than fish fillets cooked during 10 min, regardless of the capture season. The preferred sample was the Spring fish cooked during 5 min, which was scored with 5 points.

Table 2. Overall quality of Sarda sarda capture in Spring and Autumn of 2022, and cooked for 5 or 10 min.

Samples	Final Classification (1-5)
Spring 5	5
Spring 10	3
Autumn 5	4
Autumn 10	3

4. Conclusions

It was possible to conclude that there were no significant differences between fillets from *Sarda sarda* capture in Spring and Autumn ($p>0.05$) regarding pH, water activity, carbohydrates, chlorides and fibre content. On the contrary, differences were found between the Spring and Autumn fish fillets ($p>0.05$) for moisture, protein, and ash. Regarding lipids content, Autumn fish fillets were 6.32-fold higher than Spring fillets ($p<0.05$). As for sensory analysis, panellists noticed some differences between Spring and Autumn captured fish samples regarding the following characteristics: superficial shine, chipping, characteristic and sea odour, hardness, juiciness, fibrousness, characteristic flavour, and acid taste.

Regarding the sensorial analysis results, it was concluded that the cooking time caused higher influence on fish fillets attributes than the fish capture season, according to the panellists' opinion. However, fillets from March, Spring season, proved to be the preferred ones by the panellists since they attributed higher scores throughout the sensory analysis. Furthermore, according to the cooking times studied, the 5-min cooking time favoured the positive attributes of the fillets, namely the maintenance of meat juiciness.

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References

Altan, C. O., Turan, H., (2016). Synergistic Effect of Freezing and Irradiation on Bonito Fish (Sarda sarda Bloch, 1793). Journal of Food Protection, Vol. 79, No. 12, 2136–2142. https://doi.org/10.4315/0362-028X.JFP-16-026

Altan, C. O., Köstekli, B., Çorapcı B., Sedat˙Ipar, M., Kocatepe, D., Turan, H. (2022). The sensory characteristics, nutritional profile, and physical changes of the Atlantic bonito (Sarda Bloch, 1793) gravlax: Effect of dill (Anethum graveolens) and garden cress (Lepidium sativum). International Journal of Gastronomy and Food Science (28). https://doi.org/10.1016/j.ijgfs.2022.100490

AOAC 920:39 (1995). AOAC Official Methods of Fat (crude) or ether extract in animal feed. Official Methods of Analysis of AOAC International.

AOAC 925.10 (2000). AOAC Official Methods of Analysis for Moisture. Official Methods of Analysis of AOAC International.

AOAC 938.08 (1995). AOAC Official Method of Ash of Seafood. Official Methods of Analysis of AOAC International.

AOAC.955:04 (1995). AOAC Official Method of Nitrogen Total in Fertilizers Official Methods of Analysis of AOAC International.

AOAC.962:09 (1995). AOAC Official Method of Fiber Crude in Animal feeds. Official Methods of Analysis of AOAC International.

Bandarra, N.M., Marçalo, A., Cordeiro, A.R., Pous˜ao-Ferreira, P., 2018. Sardine (Sardina pilchardus) lipid composition: Does it change after one year in captivity? Food Chem. 244, 408–4013. 10.1016/j.foodchem.2017.09.147

Brauer, M., Behrens, J.W., Christoffersen, M., Hyldig, G., Jacobsen, C., Bj¨ornsdottir, K.H., van Deurs, M., 2020. Seasonal patterns in round goby (Neogobius melanostromus) catch rates, catch composition, and dietary quality. Fish. Research, 222, 105412. https://doi.org/10.1016/j.fishres.2019.105412

Brink, B., Damink, C., Joosten H.M., Huis in 't Veld, J.H.J. (1990). Occurrence and formation of biologically active amines in foods. International Journal Food Microbiology. 11(1), 73–84. 10.1016/0168-1605(90)90040-c

Brites, A., Oliveira e Silva, A., Dias Pereira, C., Gomes, D., Noronha J., Viegas, J., Costa, L., Conceição, M.A., Alves, R., Carvalheiro, S., Dias, S., Patrício, V. (2012). Manual de Conservação e Transformação de Produtos de Origem Animal. Ministério da Agricultura, do Desenvolvimento Rural e das Pescas. Coimbra.

Dehghani, S., Hosseini, S. V., & Regenstein, J. M. (2018). Edible films and coatings in seafood preservation: A review. Food Chemistry, 240, 505–513. 10.1016/j.foodchem.2017.07.034

DocaPesca, 2020, <http://www.docapesca.pt/pt/estatisticas/diarias.html> accessed 06.05.2021.

Döring, J., Hauss, H., Haslob, H., 2018. Spatial and seasonal variability in reproductive investment of Baltic sprat. Fish. Res. 204, 49–60. 10.1016/j.fishres.2018.02.002

FAO, 2018, Food Agriculture Organization of the United Nations <https://www.fao.org/> accessed 3.06.2022.

Ferreira, I., Gomes-Bispo, A., Lourenço, H., et al., 2020. The chemical composition and lipid profile of the chub mackerel (Scomber colias) show a strong seasonal dependence: contribution to a nutritional evaluation. ISSN 0300-9084 Biochimie Volume 178, 181–189. 10.1016/j.biochi.2020.09.022

Gonzalez-Silvera, D., Izquierdo-Gomez, D., Sanchez-Jerez, P., Elbal, M.T., Lopez- ´ Jim´enez, J.A., Martínez-Lopez, ´ F.J., (2020). Influence of aquaculture waste on fatty acid profiles and gonad maturation of wild fish aggregations at fish farms. Mar. Environ. Res. 156, 104902. 10.1016/j.marenvres.2020.104902

Guerra, J., Fernandes, C., Silva Vasconcelos, M., Ribeiro de Almeida, M., Andrade, S., Sarubbo, L., (2022). Seasonal influence on lipid profiles of fish in Northeastern Brazil. Aquaculture Reports. 24. 101174. https://doi.org/10.1016/j.aqrep.2022.101174

Huss, H., Ababouch, L. e Gram, L. (2003). Assessment and management of seafood safety and quality. FAO - Fisheries Technical Paper, 444.

Li, J., Cheng, C., 2018. Evolution of gonadotropin signaling on gonad development: insights from gene knockout studies in zebrafish. Biol. Reprod. 99, 686–694. https://doi.org/10.1093/biolre/ioy101

Murillo, E., Rao, K.S., Durant, A.A., (2014). The lipid content and fatty acid composition of four eastern central Pacific native fish species. J. Food Compos. Anal. 33, 1–5. 10.1371/journal.pone.0228276

Öksüz, A., A. Özeren, and A. Atlar. 2008. Comparison of some biochemical parameters in dark and light muscle of bonito (Sarda sarda). J. FisheriesSciences.com. 2:639–644. 10.3153/jfscom.2008028

Norma portuguesa 2929. Produtos de pesca e aquacultura. Determinação do Teor de Cloretos. 2009.

Özden, Ö., (2010). Micro, macro mineral and proximate composition of atlantic bonito and horse mackerel: a monthly differentiation. Int. J. Food Sci. Technol. 45 (3), 578–586. https://doi.org/10.1111/j.1365-2621.2009.02170.x

Pousis, C., Rodríguez, C., De Ruvo, P., De Virgilio, C., P´erez, J.A., Mylonas, C.C., Zupa, R., Passantino, L., Santamaria, N., Valentini, L., Corriero, A., 2019. Vitellogenin receptor and fatty acid profiles of individual lipid classes of oocytes from wild and captive-reared greater amberjack (Seriola dumerili) during the reproductive cycle. Theriogenology 140, 73–83. 10.1016/j.theriogenology.2019.08.014

Primo, A.L., Correia, C., Marques, S.C., Martinho, F., Leandro, S., Pardal, M., 2018. Trophic links and nutritional condition of fish early life stages in a temperate estuary. Mar. Environ. Res. 133, 78–84. 10.1016/j.marenvres.2017.12.007

Romotowska, P.E., Karlsd´ottir, M.G., Gudj´onsd´ottir, M., Kristinssona, H.G., Arason, S., (2016). Seasonal and geographical variation in chemical composition and lipid stability of Atlantic mackerel (Scomber scombrus) caught in Icelandic waters. J. Food Compos. Anal. 49, 9–18.

Sarr, O., Kindong, R., Ngom Sow, F., Tian S. (2023). Standardized catch per unit effort and size compositions of Atlantic bonito, Sarda sarda (Bloch, 1793), harvested by artisanal fisheries in the Senegalese Exclusive Economic Zone (SEEZ). Fisheries Research. 261. 106626. https://doi.org/10.1016/j.fishres.2023.106626

Silva, F., Duarte, A. M., Mendes, S., Borges, P., Magalh˜ aes, E., Pinto, F. R., et al., (2020). Adding value to bycatch fish species captured in the Portuguese coast—development of new food products. Foods, 10(1), 68. https://doi.org/10.3390/foods10010068

Souza, A.F.L., Petenuci, M.E., Camparim, R., Visentainer, J.V., Silva, A.J.I., 2020. Effect of seasonal variations on fatty acid composition and nutritional profiles of siluriformes fish species from the amazon basin. Food Res. Int. 132, 109051. 10.1016/j.foodres.2020.109051

Vaz-Pires, P. (2006). Tecnologia do Pescado. Universidade do Porto. Instituto de Ciências Biomédicas Abel Salazar. Porto.

Zotos, A., Vouzanidou, M., 2012. Seasonal changes in composition, fatty acid, cholesterol, and mineral content of six highly commercial fish species of Greece. Food Sci. Technol. Int. 18 (2), 139–149. 10.1177/1082013211414785