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Investigation of Quality Index Parameters and comparison of fatty acids of some Sparidae fish species in Çanakkale city (northern Aegean Sea, Türkiye)

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Abstract

This study examined the fatty acid contents of Blotched picarel (*Spicara maena* Linnaeus, 1758), Blackspot seabream (*Pagellus bogaraveo* Brünnich, 1768), Saddled seabream (*Oblada melanura* Linnaeus, 1758), Bogue (*Boops boops* Linnaeus, 1758) and Sand steenbras (*Lithognathus mormyrus* Linnaeus, 1758) fish species in Çanakkale province and compared them with each other. In this study, fatty acids and quality parameters (LQI) in the meat of some sparid fish species which are important in human consumption were examined. There are three main differences that set this study apart from others. Firstly, the study area is located in the Çanakkale region. Secondly, the meats of sparid fish species are examined. Finally, the third difference is the investigation of the quality index of the fat in addition to the fatty acids in the region and the fish meats. The quality index parameters of these fish oils were calculated and compared with each other. Unsaturated fatty acid ratios were found to be over 60% in all fish studied. The highest unsaturated fatty acid content was observed in *Boops boops* with 67.34%. ω-3 fatty acids were highest in *Oblada melanura* with 43.33% and lowest in *Lithognathus mormyrus* with 34.77%. Eicosapentaenoic Acid (EPA) and Docosahexaenoic Acid (DHA) were found to be between 6-9% and 22-30%, respectively, in the fish. The AI, h/H, and TI quality index parameters were calculated between 0.42-50, 2.28-2.75, and 0.22-0.26, respectively. In

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addition, within the scope of the study, the amount of fatty acids was calculated on edible 100 g portion (EP: Edible portion, mg FA/ 100 g fresh portion) of each fish. The highest EP value for ω-3 fatty acids was calculated as 1367 mg/100 g in *Pagellus bogaraveo*.

Keywords: Fatty Acids; Quality Index Parameters; EPA; DHA.

1. Introduction

Fish are among the most important foods due to their high nutritional quality and rich composition of beneficial nutrients such as quality fats, protein, vitamins, and minerals. Factors such as digestibility, the richness of amino acids, vitamins, and minerals, as well as the importance of fish oil in nutrition physiology, make fish meat a high-value food ingredient in human nutrition (Göğüş and Kolsarıcı, 1992; Shahidi and Botta, 1994; Kobya, 2017). The beneficial effects of fish consumption on human health, along with other factors, are associated with the high content of ω-3 fatty acids, especially eicosapentaenoic acid (EPA, C20:5n 3) and docosahexaenoic acid (DHA, C22:6n 3) (Zlatanos and Laskaridis, 2007; Leaf *et al*., 2003). It is well known that fish oil is one of the primary and most common sources of polyunsaturated fatty acids (PUFAs), particularly eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA). These fatty acids are of great importance to human health in terms of preventing coronary artery disease, inflammatory and autoimmune disorders, and arrhythmias (Leaf *et al.*, 2003; Schmidt *et al*., 2005; Özoğul *et al.*, 2009). Crude oil and fatty acid contents of fish show differences (Zlatanos and Laskaridis, 2007; Kalyoncu and Yay, 2017). These differences in fish species and their lipid and fatty acid compositions have been reported in the literature to be dependent on factors such as food sources, age, water salinity, location, diet, gender, and season (Steffens, 1997; Gorgun and Akpinar, 2007; Akpinar *et al*., 2009).

It is known that the parameters of the quality index of fat (LQI) in fish are an important research area. Significant information on the subject was provided in our previous study (Kizilkaya and Ücyol, 2022). It was investigated the fatty acids and quality index parameters in the skin and bones of cultured fish species such as *Sparus aurata* (Sea bream), *Dicentrarchus labrax* (Sea Bass) and *Oncorhynchus mykiss* (Rainbow trout) in the study. The skin and bones of these cultured fish, which are considered waste, were used in the study. The main aim of the study was to investigate the quality and usability of fat in waste products produced by cultured fish. In this study, different fish species were used and the edible meats of the fish were studied. Since the fish and materials used in the two studies are different, both of our studies provide important information on fatty acids in the literature.

The Sparidae is a family of the order Perciformes and contains 164 species in 38 genera (Paruğ and Cengiz, 2020). Recently, the family Centracanthidae (picarels) has also been merged with the Sparidae (Santini *et al*., 2014) while they were previously listed separately (Golani *et al*., 2006; Nelson, 2006). Blotched picarel (*Spicara maena* Linnaeus, 1758), belonging to the family Sparidae, is a commercial species inhabiting the Eastern Atlantic: Portugal, Morocco, and the Canary Islands including the Mediterranean and even the Black Sea. It mostly occurs over *Posidonia* beds and sandy or muddy bottoms and distributes up to 100 m of depth. This species mainly feeds on zooplankton and is a protogynous hermaphrodite (Froese and Pauly, 2020). The Blackspot seabream (*Pagellus bogaraveo* Brünnich, 1768), belongs to the family Sparidae, is a demersal and omnivorous (predominantly carnivores) teleost fish feeding mainly on crustaceans, mollusks, worms, small fish, and sometimes on plants (Wheeler, 1997). They live near the coast as juveniles and on the continental slope down to 400 meters in the Mediterranean but down to 700-800 meters in the Atlantic as adults, above different types of substrates, like mud, sand, and rocks (Fischer *et al*., 1987). This species prevalently shows the protandrous hermaphroditic feature in culture conditions while a high incidence of gonochorism occurred in the wild (Micale *et al*., 2011).

It is relatively widespread species from the south of Norway to the west of Saharan Africa, including the Azores and Canary Islands in the continental slope of Atlantic, and is more common in the western Mediterranean Sea than in the eastern basin, besides it is absent in the Black Sea (Spedicato *et al*., 2002). The saddled bream (*Oblada melanura* Linnaeus, 1758) is common throughout the Mediterranean and eastern Atlantic, inhabiting littoral waters above rocky bottoms and posidonia beds, up to 30 m depth (Bauchot and Hureau, 1986). They are omnivorous but feed mainly on small invertebrates (Froese and Pauly, 2019). *Boops boops* is a demersal or semipelagic species inhabiting inshore waters above various bottoms (sand, mud, rocks or posidonia beds) in the whole Mediterranean, eastern and western Atlantic (Bauchot and Hureau, 1986) and moves in aggregations, ascending to the surface mainly at night (Bauchot, 1987). It is known to be distributed in all Turkish seas (Fricke *et al*., 2007). *Lithognathus mormyrus* (Linnaeus, 1758 is a demersal fish species that inhabits sandy-muddy areas at depths of 0–80 m (Bauchot and Hureau, 1986). The natural habitats of this species are the Atlantic and Indian oceans, Bay of Biscay, Canary Islands, Red Sea, and the Mediterranean (Kallianiotis *et al*., 2005). The present study aimed the investigation of quality index parameters and comparison of fatty acids of some sparidae fish species in Çanakkale City (Northern Aegean Sea, Türkiye).

2. Materials and methods

2.1. Supply of Samples

The samples were obtained from the local fish market in the central district of Çanakkale in the autumn of 2018.

2.2. Crude oil extraction

In order to determine the fatty acid composition of crayfish, the samples were homogenized and dried at 105 ^{0}C until they reached a constant weight in a drying oven. The extraction of crude fat was performed three times on the dry tissue. The commonly used Bligh and Dyer (1959) method was used for fat analysis. In summary, the samples were treated with methanol/chloroform. The homogenate was washed with methanol-chloroform and filtered through filter paper into a round-bottomed flask. The filtrate was evaporated using a rotary evaporator (IKA RV10 basic) in a water bath at 60ºC. After the separation of fat in the round-bottomed flask, the flask was removed from the device and kept in a drying oven at 65ºC (Nüve FN500), then transferred to a desiccator and cooled, and finally weighed for the final determination.

2.3. Esterification of fatty acids

The fatty acid analysis was performed according to AOAC (1995). The crude fats of the samples were used. In summary, the crude fat samples were treated with methanolic NaOH to esterify the crude fat. Then, it was saponified by boiling in a water bath. After BF3 reagent was poured over the cooler, it was heated and heptane was added. After that, it was cooled again without boiling and treated with saturated NaCI to form a phase. The heptane phase was then transferred to a test tube and transferred to a glass vial. Next, it was injected into gas chromatography (GC) to determine the fatty acid composition.

2.4. Determination of Fatty Acid Contents by Gas Chromography (GC)

In this study, Gas Chromatography which is one of the chromatographic methods was used to analyze the fatty acids in fish meat (Kizilkaya and Ucyol, 2022). Shimadzu GC was used as the gas chromatography system. The chromatography system consists of FID (Flame Ionization Detector), a gas chromatograph (Shimadzu, GC 2014, Japan) and auto-injector (AOC-20i, Shimadzu, Japan). The device is controlled by GC solution software (Version 2.41.00 su_1). FAME WAX (polyethylene glycol, 30 meter0.25 mm I.D0.2 µm, GC Columns Restek) was used as the chromatographic column.

In this research, GC working conditions are as follow:

- Injection mode: split ratio, split: 1/10;
- Injection and detector temperature: 260 and 280ºC,
- Carrier gas and column flow: helium and 1.4 mL/min,
- Temperature program: starting temperature 5 minutes 100 ºC, increase of 5 ºC per minute from 100 ºC to 150 ºC, 15 minutes at 150 ºC, increase of 10 ºC per minute to 210 ºC, and 20 minutes at 210 ºC.

Peak identification was determined by gas chromatography using (Supelco 37 Component FAMEs Mix) standard. The data were obtained by calculating the methyl esters of fatty acids as a percentage of total fatty acids.

The percentage of fatty acid composition obtained from GC was used to calculate the amounts of fatty acids in the samples in mg/100g portion as edible fats according to Weihrauch *et al*. (1977) using the fatty acid conversion factor.

2.5. Calculation of the Lipid Quality Indexes (LQI)

The calculation of quality index parameters in fats plays an important role. Therefore, when fatty acids are determined in food products, quality index parameters are also calculated, so that comparable and evaluable data can be obtained for food products. After the amounts of fatty acids in lipids are determined, quality index parameters are calculated according to the literature (Kizilkaya and Ucyol, 2022). Nine different calculation methods were used for the lipid quality index. LQI calculations were obtained using percent fatty acids results and the calculated LQI results are percent values (%). These calculation methods are as follows:

1- Atherogenicity Index (AI): [C12:0 + (4×C14:0) + C16:0]/ (n-3PUFA + n-6PUFA + MUFA)] (Ulbricht and Southgate, 1991; Garaffo *et al*., 2011; Luczynska and Paszczyk, 2019).

2- Thrombogenicity Index (TI): [C14:0 + C16:0 + C18:0]/[(0.5×C18:1) + (0.5×sum of other MUFA) + (0.5×n-6PUFA) + (3×n-3PUFA) + n-3PUFA/n-6PUFA)] (Ulbricht and Southgate, 1991; Garaffo *et al*., 2011; Łuczyńska and Paszczyk, 2019).

3- Flesh-lipid quality (FLQ): 100*(EPA + DHA)/ total fatty acids (Abrami *et al*.,1992; Senso *et al*., 2007; Łuczyńska and Paszczyk, 2019).

4- Hypercholesterolaemic fatty acids (OFA): C12:0 + C14:0 + C16:0 (Łuczyńska and Paszczyk, 2019).

5- Desirable fatty acids (DFA): C18:0 + UNSAT (Costa *et al*., 2008; Silva *et al*., 2019; Łuczyńska and Paszczyk, 2019).

6- Hypocholesterolemic/hypercholesterolemic ratio (h/H): h/H= [(C18:1 + C18:2 + C18:3 + C20:3 + C20:4 + C20:5 + C22:4 + C22:5 + C22:6) / (C14:0 + C16:0)] (Santos-Silva *et al*., 2002, Dağtekin *et al*., 2018).

7- Health-promoting index (HPI): UNSAT/[C12:0 + (C14:0×4) + C16:0] (Chen and Liu, 2020).

8- Unsaturation Index (UI): 1*(% monoenoics) + 2 *(% dienoics) + 3*(% trienoics) + 4*(% tetraenoics) +5*(% pentaenoics) + 6*(% hexaenoics) (Logue *et al*., 2000; Chen and Liu, 2020).

9- The polyene index (PI): (C20:5 + C22:6)/C16:0 (Lubis and Buckle, 1990; Küçükgülmez *et al*., 2018).

3. Results and Discussion

3.1. Fatty acids of Sparide Fishes

Todays, feeding and diversity of nutrients are among the important problems, depending on the human population. Especially, the quality and quantity of components that constitute the content of the food source are essential. The diversity of components within the food source reveals the quality of the food for the development and continuity of the human life. For this reason, one of the most important nutrients in food sources is fat and fatty acids. The diversity and quantity of fatty acids that make up the structure of fat are crucial for the development and continuity of human metabolism. Mainly for children in the developmental stage, fatty acids are of great importance. In this regard, the importance of ω-3 (omega-3), EPA (Eicosapentaenoic Acid), and DHA (Cis-4,7,10,13,16,19-Docosahexaenoic Acid) fatty acids, is well-known by everyone. The importance of fat and fatty acids in a food source during the consumption stage is significant in this regard. It is known that food sources obtained from marine and freshwater environments are rich in terms of fat content and composition.

The composition of fat and fatty acids in the meat of some fish species sold in the fish market in Çanakkale province was examined. Gas Chromatography (GC) system, and the standard mixture for component analysis contains 37 fatty acid compounds were used. Gas Chromatography (GC) system was used to determine the fatty acid compositions of the lipids in this study. A Supelco 37 Component FAMEs Mix standard, containing 37 fatty acid compounds, was used to identify the components of the fatty acids. Furthermore, 30 types of fatty acids were analyzed using the chromatographic system. Butyric Acid (C4:0), one of the unidentified fatty acids, has a low molecular weight. Butyric Acid (C4:0) has the same retention time as the solvent heptane, making it impossible to determine chromatographically. On the other hands, C6:0, C8:0, C10:0, and C11:0 were not detected, because their concentrations were below the detection limits of the chromatographic measurements. Oleic Acid (C18:1n9 C) and Elaidic Acid (C18:1n9 T) are fatty acids' components that have the same molecular and chemical structure but are isomers of each other. Chromatographic separation of isomeric compounds with the same structure may not always yield accurate results. Due to the column system used in the measurements, Oleic Acid (C18:1n9 C) and Elaidic Acid (C18:1n9 T) came at the same retention time in the chromatographic analysis, and these two isomeric compounds with the same structure were given as a total of C18:1n9 C+T. The analyses were carried out in triplicate for each sample, and the standard averages were given.

The study examined the fatty acid content of five fish species: *Spicara maena*, *Pagellus bogaraveo*, *Oblada melanura*, *Boops boops*, and *Lithognathus mormyrus*. The fatty acid content of the fish is provided in Table 1, which includes 30 different types of fatty acids ranging from C12:0 to C24:1n9. Upon examining the Table 1, it is apparent that the most prominent and important ω-3 fatty acid in all the fish is Docosahexaenoic acid (DHA, C22:6n3). DHA varies between approximately 22-32% in all fish, with the highest percentage being 32.42% in Maena and the lowest being 2.2% in *Lithognathus mormyrus*. The second highest fatty acid is the 16-carbon saturated fatty acid Palmitic acid (C16:0), which ranges from approximately 17-22%. To make these fatty acids more comparable and understandable, Table 2 has been prepared.

Table 1. Percentage values of fatty acid contents of fish samples (%, Flesh, wet)

	Fish species				
	Spicara maena	*Pagellus bogaraveo*	*Oblada melanura*	*Boops boops*	*Lithognathus mormyrus*
C12:0	ND. ± ND.0	ND. ± ND.	ND. ± ND.	0.08 ± ND.7	0.27 ± 0.015
C13:0	ND. ± ND.0	ND. ± ND.	ND. ± ND.	ND. ± ND.0	0.86 ± 0.03
C14:0	2.04 ± 0.07	1.99 ± 0.10	2.10 ± 0.06	1.44 ± 0.05	2.54 ± 0.17
C14:1	ND. ± ND.	ND. ± ND.	0.08 ± 0.02	ND. ± ND.	0.42 ± 0.07
C15:0	0.45 ± 0.08	0.95 ± 0.11	0.52 ± 0.01	0.67 ± 0.19	0.37 ± 0.03
C15:1	ND. ± ND.	0.08 ± 0.07	ND. ± ND.	0.06 ± 0.01	ND. ± ND.
C16:0	19.00 ± 0.94	22.24 ± 0.73	22.39 ± 0.57	20.65 ± 0.74	20.69 ± 1.08
C16:1	3.24 ± 0.07	5.01 ± 0.42	5.36 ± 0.32	3.41 ± 0.09	3.09 ± 0.18
C17:0	0.57 ± 0.07	0.79 ± 0.06	0.95 ± 0.13	0.84 ± 0.10	0.28 ± 0.04
C17:1	0.33 ± 0.07	0.50 ± 0.13	0.29 ± 0.01	0.31 ± 0.01	0.22 ± 0.04
C18:0	10.83 ± 0.41	8.18 ± 0.81	8.98 ± 0.88	7.63 ± 0.68	9.62 ± 0.13
C18:1n9C+T (*n*-9), (ω-9)	15.83 ± 0.20	12.53 ± 0.67	9.20 ± 0.41	15.89 ± 0.92	15.89 ± 0.66
C18:2n6c (*n*-6), (ω-6)	1.89 ± 0.06	1.31 ± 0.07	1.56 ± 0.03	1.68 ± 0.09	3.49 ± 0.12
C18:2n6t (*n*-6), (ω-6)	ND. ± ND.	0.23 ± 0.19	ND. ± ND.	0.39 ± 0.01	ND. ± ND.
C18:3n6 (*n*-6), (ω-6)	0.27 ± 0.02	0.57 ± 0.03	0.20 ± 0.01	0.65 ± 0.11	0.33 ± 0.02
C18:3n3 (*n*-3), (ω-3), ALA	0.54 ± 0.05	0.62 ± 0.07	0.47 ± 0.01	0.51 ± 0.02	1.29 ± 0.09
C20:0	0.37 ± 0.04	0.26 ± ND.	0.30 ± 0.01	0.21 ± 0.01	0.65 ± 0.05
C20:1n9, (ω-9)	0.23 ± 0.07	0.50 ± 0.09	0.16 ± 0.01	1.27 ± 0.07	0.96 ± 0.05
C20:2	0.47 ± 0.03	0.48 ± 0.04	0.56 ± 0.01	0.61 ± 0.11	0.47 ± 0.03
C20:3n6 (*n*-6), (ω-6)	0.18 ± 0.01	ND. ± ND.	0.17 ± 0.01	0.20 ± 0.01	ND. ± ND.
C21:0	ND. ± ND.	ND. ± ND.	ND. ± ND.	ND. ± ND.	ND. ± ND.
C20:3n3 (*n*-3), (ω-3)	1.50 ± 0.22	2.97 ± 0.06	4.16 ± 0.08	3.47 ± 0.09	4.96 ± 0.18
C20:4n6 (*n*-6), (ω-6)	1.09 ± 0.09	1.50 ± 0.13	1.34 ± 0.14	0.96 ± 0.12	1.82 ± 0.08
C20:5n3 (*n*-3), (ω-3), EPA	9.38 ± 0.35	11.43 ± 0.47	8.26 ± 1.33	7.42 ± 0.26	6.31 ± 0.18
C22:0	0.19 ± 0.04	0.09 ± 0.02	0.47 ± 0.10	0.36 ± 0.07	0.24 ± 0.04
C22:1n9, (ω-9)	1.17 ± 0.05	0.35 ± 0.06	0.80 ± 0.07	0.07 ± 0.01	1.09 ± 0.15
C22:2	1.65 ± 0.10	0.76 ± 0.08	0.28 ± 0.07	0.71 ± 0.03	1.73 ± 0.06
C23:0	0.18 ± 0.04	0.61 ± 0.07	0.77 ± 0.04	0.79 ± 0.07	ND. ± ND.
C22:6n3 (*n*-3), (ω-3), DHA	27.18 ± 2.40	25.97 ± 0.34	30.45 ± 1.34	29.57 ± 1.05	22.20 ± 0.66
C24:1n9, (ω-9)	1.43 ± 0.12	0.09 ± ND.	0.18 ± 0.02	0.16 ± 0.02	0.22 ± 0.03

*ND: Not Detected

Table 2. Same calculations as percentage of fish fatty acids (percentage in total oil) and EP amount (mg FA/ 100 g fresh portion) and quality index parameters

	Spicara maena		*Pagellus bogaraveo*		*Oblada melanura*		*Boops boops*		*Lithognathus mormyrus*	
	%	EP	%	EP	%	EP	%	EP	%	EP
UNSAT	66.37	1930.09	64.89	2165.54	63.51	1443.78	67.34	1857.53	64.48	1189.22
SAT	33.63	977.82	35.11	1171.55	36.49	829.69	32.66	901.10	35.52	655.07
Σ MUFA	22.22	646.21	19.06	635.91	16.06	365.15	21.17	583.97	21.88	403.62
Σ PUFA	44.15	1283.89	45.84	1529.63	47.44	1078.64	46.17	1273.56	42.60	785.61
UNSAT/SAT	1.97	1.97	1.85	1.85	1.74	1.74	2.06	2.06	1.82	1.82
Σ PUFA/SAT	1.31	1.31	1.31	1.31	1.30	1.30	1.41	1.41	1.20	1.20
DHA/EPA	2.90	2.90	2.27	2.27	3.69	3.69	3.98	3.98	3.52	3.52
Total ω-3	38.61	1122.61	40.99	1367.84	43.33	985.16	40.96	1130.04	34.77	641.18
Total ω-6	3.43	99.63	3.61	120.33	3.27	74.27	3.88	107.12	5.63	103.87
Total ω-9	18.65	542.45	13.46	449.31	10.33	234.85	17.39	479.69	18.16	334.94
ω-6/ω-3	0.09	0.09	0.09	0.09	0.08	0.08	0.09	0.09	0.16	0.16
EPA	9.38	272.89	11.43	381.35	8.26	187.79	7.42	204.78	6.31	116.35
DHA	27.18	790.36	25.97	866.69	30.45	692.20	29.57	815.64	22.20	409.50
ALA	0.54	15.75	0.62	20.65	0.47	10.60	0.51	13.94	1.29	23.76
UNSAT-EPR	29.08		33.37		22.73		27.58		18.44	
*Fresh CO.	3.27±0.29		3.73±0.16		2.59±0.13		3.11±0.18		2.13±0.25	
AI	0.42		0.47		0.49		0.40		0.50	
TI	0.23		0.22		0.22		0.20		0.26	
FLQ	36.56		37.40		38.71		36.99		28.51	
h/H	2.75		2.36		2.28		2.75		2.42	
HPI	2.45		2.15		2.06		2.54		2.07	
UI	252		256		265		261		225	
PI	1.92		1.68		1.73		1.79		1.38	
DFA	77		73		72		75		74	
OFA	21		24		24		22		23	

*EP: Edible portion (mg FA/ 100 g fresh portion); Fresh CO: Fresh (Wet) Crude Oil (g/100 g portion); UNSAT-EPR: Ratio of unsaturated fatty acids to percentage (%) of edible portion (EP) (EP/%)

As can be seen in Table 2, two different methods have been used to calculate and evaluate the results of fatty acid content in fish. The results presented in Table 2 include the percentage (%) of certain fatty acid ratios in the total fat content and the amount of fatty acids in mg/100 g portion (EP: Edible portion, mg FA/ 100g fresh portion) in the fresh sample. In literature, both percentage and mg/100 portion calculation methods have been used in studies on fatty acid content. The purpose of providing both calculation methods is to make it easier to compare with other studies. Additionally, calculating the fatty acid content in fresh samples is important because these food raw materials are often consumed fresh in daily diets. Furthermore, to make the fatty acid components comparable with other food products, the amount of fatty acids in mg/100g portion in the fresh sample has been calculated, which is the form in which the fatty acid components are consumed. These calculations were made using fatty acid conversion factors (Weihrauch *et al*., 1977). In addition, Table 2 provides the raw fat content of the fish in terms of fresh weight (Fresh CO.). When the unsaturation (UNSAT) ratio is evaluated in percentage, it is seen that it clusters around 63-67% in all fish, whereas saturation (SAT) is around 33-36%. When the fatty acid contents of the fish are evaluated in terms of percentage, UNSAT is highest in Boops boops and lowest in Oblada melanura, respectively. As for EP, UNSAT was calculated as the highest in Pagellus bogaraveo with 2165mg/100g portion and the lowest in Lithognathus mormyrus with 1189 mg/100 g portion. It is evident that the results obtained through the percentage and EP methods are different. This is because in the EP calculation, the raw fat content is taken into account, leading to differences in the results obtained through percentage calculations. Since the highest amount of crude fat was observed in the Pagellus bogaraveo, it directly affects the EP value. Therefore, when evaluated in terms of the consumable amount, the highest unsaturation is seen in Pagellus bogaraveo, but in terms of the percentage of fat quality, Boops boops appears to be the most valuable. To obtain a more reliable result, the UNSAT-EPR value was calculated. The UNSAT-EPR value is the ratio of the unsaturated fatty acids (UNSAT) in mg/100 g of edible portion to the percentage (%) amount of EP (UNSAT-EPR = EP / %). The aim is to see the effect of the percentage of fatty acids on the mg/100 g of edible portion and to obtain a comparably sized result between the two data. Therefore, the portion size effect of a high percentage of fat can be better interpreted to obtain more reliable results. The UNSAT-PER value is highest in Pagellus bogaraveo with 33.37, and the lowest is in Lithognathus mormyrus with 18.44. The higher the UNSAT-PER value, the greater the effect of unsaturated fatty acids (UNSAT) in the raw fat. It is expected that unsaturation will be higher in fatty acids, and the higher the unsaturation, the better the quality and type of fat. For this purpose, the unsaturation/saturation (UNSAT/SAT) ratio was calculated in Table 2, and it was observed to be approximately between 1.7-2% in all examined fish. The highest ratio was observed in Boops boops with 2.06, and the lowest was in Oblada melanura fish with 1.74.

According to Table 2, the percentage of ω-3 fatty acids varies between 34-43%. The highest percentage of total ω-3 fatty acids was observed in Oblada melanura with 43.33%, while the lowest was observed in Lithognathus mormyrus with 34.77%. In general, it can be said that in all fish, omega (ω-3) fatty acids make up approximately one-third of all fatty components in terms of percentage, and these ratios are at good levels. On the other hand, in terms of EP, the results of omega (ω-3) fatty acids in all fish varied between 641-1367 mg/100 g fresh portion, with the highest being in Pagellus bogaraveo and the lowest in Lithognathus mormyrus. In other words, it can be summarized that 100 g portion of Pagellus bogaraveo meat contains approximately 31367 mg of ω-3 fatty acids. These results show that including the amount of raw fat between the percentage (%) ratio and mg/100 g edible fresh portion (EP) in fatty acid calculations yields different results. Scientific studies show that the higher the total ω-6/3 ratio, the higher the risk of pathogenesis of many diseases, including cardiovascular disease, cancer, inflammatory, and autoimmune diseases (Simopoulos, 2008; Stratev *et al.*, 2017). Therefore, these types of calculations are important for the following reasons. In our study, the total ω-6/3 ratio varied between 0.08-

0.16% on a percentage basis and based on edible weight. The lowest ω-6/3 ratio was calculated in Oblada melanura and the highest in Lithognathus mormyrus. Therefore, it is recommended that the total ω-6/3 ratio does not exceed 4 (Stratev *et al*., 2017). It is stated that the type of fat is more important than the total fat amount in measuring the risk of cardiovascular disease (Stratev *et al*., 2017). It was observed that our results did not pose any health risks as our ω-6/3 ratio was much lower than 4. The n-3/n-6 ratio is a good index to compare the relative nutritional value of fish oil (Küçükgülmez *et al*., 2018). A high n-3/n-6 ratio is of great importance in reducing the risks of coronary heart disease, plasma lipid levels, and cancer (Kinsella *et al*., 1990; Küçükgülmez *et al*., 2018). EPA and DHA are important fatty acids. Their ratios in fish are provided in Tables 1 and 2. The highest EPA was determined in Pagellus bogaraveo as 11.43%, while the lowest was observed in Lithognathus mormyrus as 6.31%. The highest DHA was observed as 30.45 % in Oblada melanura, while the lowest was seen in Lithognathus mormyrus as 22.0%. In terms of EPA, the highest amount was found in Pagellus bogaraveo as 381 mg/100 g edible portion, and the lowest was observed in Lithognathus mormyrus as 116.35 mg/100 g edible portion. Different fatty acid ratios can be obtained in the same fish species depending on the season and region.

Since, the place, time, salinity, temperature, food sources, and many other factors directly affect the composition of fish meat, it is natural for some fatty acid contents to differ in different studies. Suárez *et al*. (2021) determined the DHA content as 32.7% and EPA as 7.6%, it was determined as 25.97 and 11.93 in our study, respectively. In Boops boops, DHA was determined as 31.7% and EPA as 4.6% in the same studies. Özoğul *et al*. (2009) examined the lipid content and fatty acid compositions of 34 marine fish species in the Mediterranean. The fatty acid compositions of the fish consisted of 30.10% to 46.88% saturated fatty acids, 11.83% to 38.17% monounsaturated fatty acids, and 20.49% to 49.31% polyunsaturated fatty acids. Many fish species were found contain myristic acid (C14:0, 0.72% to 8.09%), pentadecanoic acid (15:0, 0.05% to 2.35%), palmitic acid (C16:0, 15.97% to 31.04%), palmitoleic acid (C16:1, 1.48% to 19.61%), heptadecanoic acid (C17:0, 0.31% to 1.84%), cis-10-heptadecenoic acid (C17:1, 0.17% to 2.01%), stearic acid (C18:0, 2.79% to 11.20%), oleic acid (C18:1n9, 2.44% to 28.97%), linoleic acid (C18:2n-6, 0.06% to 3.48%), arachidonic acid (C20:4n-6, 0.12% to 10.72%), cis-5,8,11,14,17-eicosapentaenoic acid (C20:5n-3,1.94% to 10%), and cis-4,7,10,13,16,19-docosahexaenoic acid (C22:6n-3, 3.31% to 31.03%). In the study, the DHA value of Lithognathus mormyrus was determined to be 23.7% and EPA was 7.15%. The examined Lithognathus mormyrus had DHA and EPA values of 22.20% and 6.31%, respectively.

3.2. The Lipid Quality Indexes (LQI)

Using the fatty acid results of the samples, the lipid quality index was calculated in Table 2. Lipid quality index is based on important calculations frequently used in studies that determine fatty acids. Atherogenicity index (AI) shows the relationship between the sum of major saturated fatty acids and the sum of major unsaturated classes. Other major saturated (SAT) fatty acids containing C12:0, C14:0 and C16:0, except for C18:0, are considered proatherogenic (they cause the circulation and attachment of lipids to immune system cells) (Gonzalez-Felix, 2016; Omri *et al.*, 2019; Chen and Liu, 2020). Lipids support the attachment of immune and circulatory system cells (proatherogenic) and are anti-atherogenic, inhibiting plaque aggregation and reducing levels of esterified fatty acids, cholesterol, and phospholipids, thus preventing the onset of micro and macro coronary diseases (Ghaeni *et al*., 2013). AI is commonly used for foods such as seaweeds, grains, meat, fish, and dairy products (Chen and Liu, 2020). The AI value in fish ranges from 0.31 to 1.63. The thrombogenic index (TI) indicates the thrombotic potential of fatty acids and their contribution to the formation of blood clots in the bloodstream, with prothrombogenic FAs (C12:0, C14:0, and C16:0) playing a role. The relationship between prothrombogenic (saturated) and antithrombogenic (MU-FAs, n-6 PUFA, and n-3 PUFA) fatty acids characterizes the TI. Therefore, consuming foods or products with low TI values is beneficial for cardiovascular health (CVH) (Chen and Liu, 2020; Garaffo *et al*., 2011; Ghaeni *et al*., 2013). low AI and TI values in Lipids are preferred (Luczynska and Beata Paszczyk, 2019). The lower the AI and TI values, the more beneficial the product is for health, which is associated with the positive effects of MUFA and PUFA on the cardiovascular system (Turan *et al*., 2007; Murzina *et al*., 2022).

The highest AI value was calculated for silver fish, and considering AI values, it can be said that the consumption of other fish, except for silver fish, is more appropriate. The FLQ index indicates the quality of the nutrient source of lipids. When calculating FLQ, the rapidly oxidizable EPA and DHA content should be considered to determine the "freshness" of the product (Abrami *et al*., 1992; Senso *et al*., 2007; Murzina *et al*., 2022). The FLQ value in fish has been calculated to range from 28 to 38. The hypocholesterolemic/hypercholesterolemic (H/H) ratio is an index used in the fatty acid profile of lamb meat, first proposed by Santos-Silva *et al*. (2002) (Chen and Liu, 2020). Santos-Silva *et al*. (2002) developed the H/H index as a new index to assess the effect of the fatty acid composition on cholesterol, based on the low PUFA/SFA ratio in lambs due to a high proportion of saturated (SAT) fatty acids (Chen and Liu, 2020). The H/H index, which is a basic research on the regulation of dietary FA and plasma LDL-C, characterizes the relationship between hypokolesterolemic fatty acids (cis-C18:1 and PUFA) and hypercholesterolemic FAs (Dietschy, 1998; Chen and Liu, 2020). As C12:0 was not detected in lambs, Santos-Silva *et al*. (2002) concluded that the formula contained only C14:0 and C16:0 in hypercholesterolemic fatty acids (Chen and Liu, 2020). The H/H index ranges from 2.28 to 2.75. The UI indicates the degree of unsaturation in lipids and is calculated as the sum of the percentages of each unsaturated FA multiplied by the number of double bonds in that FA (Logue, 2000; Chen and Liu, 2020). Unlike UFA and PUFA, different unsaturated fatty acids have different weights in the UI. Overall, it is stated that the UI more comprehensively reflects the ratio of different unsaturation degrees of fatty acids in the composition of total fatty acids in a food component (Chen and Liu, 2020). As an example, it has been reported that the UI values of some algae species generally range from 45 to 368.68, with Gracilaria changii having a UI of 368.68 (Chan and Matanjun, 2017).

Furthermore, the UI values for both individuals were found to range from 225-265, indicating good unsaturation indices (UI) for the species. One of the main purposes of calculating these indices is to obtain more comparable data in terms of the relationship between fatty acids, health, and quality. This allows for more comparable results to be obtained across studies. The polyene index (PI) was used as a measure of PUFA damage (Lubis and Buckle, 1990; Küçükgülmez *et al*., 2018). Simat *et al*. (2015) reported that the decrease in PI values during cold storage of Boops boops was a sign of the degradation of available PUFA and that a decrease in PI was associated with an increase in primary and secondary oxidation products, namely peroxide value (PV) and TBA components. In the scope of our study, it was calculated that the PI values varied between 1.11-0.73 (Simat *et al*., 2015). In our study, the PI value for fish ranged from 1.38-1.92.

Conclusions

Nowadays, food quality and nutrition have become one of the most important topics. Nutrition quality is important for human health. Fish, which is an important alternative food source, is known to have a rich nutrient composition, including essential amino acids, unsaturated fatty acids, vitamins, minerals, and antioxidants, necessary for human life. The need for fish is met through aquaculture and fishing. In this study, the fatty acid contents of five different fish sold in fish markets in Çanakkale were examined and compared with each other. In this study, some fish species from the Sparidae family that are important for human consumption have been investigated. The study examined the fatty acid profiles and quality index parameters of the studied fish species and regions. Quality index parameters contain crucial information for comparison and evaluation purposes. Therefore, this study can provide important information and data, as well as comparable reference values for using in the literature. The highest unsaturation ratio was observed in the gurnard fish. The highest ω-3 fatty acids were determined in the red mullet. It is seen that all fish are rich in EPA and DHA fatty acids. As a result, it is observed that the examined fish species are rich in fatty acids. It is recommended to consume all types of fish throughout the year for the purpose of nutrition quality. Since, fish are also high in protein, minerals, and vitamins, they are included in high-quality foods.

Conflict of Interest

The authors declare that there is not any conflict of interests regarding the publication of this manuscript.

References

Abrami, G., Natiello, F., Bronzi, P., McKenzie, D., Bolis, L., and Agradi, E. 1992. A comparison of highly unsaturated fatty acid levels in wild and farmed eels (Anguilla Anguilla). Comparative Biochemistry and Physiology Part B: Comparative Biochemistry, 101(1–2): 79–81.

Akpinar, N.A., Gorgun, S., and Akpinar, A.E. 2009. A comparative analysis of the fatty acid profiles in the liver and the muscle of male and female Salmo trutta macrostigma. Food Chemistry, 112: 6-8.

AOAC. 1995. Official methods of analysis. Association of official analytical chemists. official methods, 985.14. Gaithersburg, MD.

Bauchot, M.L., and Hureau, J.C. 1986. *Sparidae* In: Fishes of the North Eastern Atlantic and the Mediterranean, Vol. II pp: 883-907. Paris: UNESCO.

Bauchot ML. 1987. Poissons osseux. Fiches FAO d'identification pour les besoins de la pêche. (rev. 1). Méditerranée et Mer Noire. Zone de pêche, 37: 891-1421.

Bligh, E.G., and Dyer, W.J. 1959. A rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology, 37: 911-917.

Chan, P. T., and Matanjun, P. 2017. Chemical composition and physicochemical properties of tropical red seaweed, Gracilaria changii. Food Chemistry, 221: 302–310.

Chen, J., and Liu, H. 2020. Nutritional indices for assessing fatty acids: A Mini-Review. International Journal of Molecular Sciences, 21(16): 5695. doi: 10.3390/ijms21165695.

Costa, R. G., Mesquita, T. V. U., Queiroga, R. D. C. R. D. E., Medeiros, A. N. D., Carvalho, F. F. R. D., and Beltrão Filho, E. M. 2008. Características químicas e sensoriais do leite de cabras Moxotó alimentadas com silagem de maniçoba. Revista Brasileira De Zootecnia, 37(4): 694–702.

Dağtekin, B. B., Misir, G. B., and Kutlu, S. 2018. Comparison of biochemical, fatty acids and lipid quality indexes of Prussian Carp (*Carassius gibelio*) caught from Lake Çıldır on different seasons. Mediterranean Fisheries and Aquaculture Research, 1(1): 2–14.

Dietschy, J.M. 1998. Dietary fatty acids and the regulation of plasma low density lipoprotein cholesterol concentrations. The Journal of Nutrition, 128: 444–448.

Fischer, ML, Bauchot ML, Schneider M. 1987. Fiches FAO d'identification des espèces pour les besoins de la peches, Vol. II, Mediterranèe et mer Noire. Zone de pêche, 37. Rome: Commission des Communautès Europèennes and FAO.

Fricke, R, Bilecenoğlu M and Sarı HM. 2007. Annotated checklist of fish and lamprey species of Turkey, including a red list of threatened and declining species. Stuttg Beitr Naturkunde Ser A (Biologie), 706: 1-69.

Froese, R., and Pauly, D. (Eds.) 2020. FishBase. World Wide Web electronic publication. Retrieved on March 9, 2020, from http://www.fishbase.org

Froese, R. and Pauly, D. (Eds.) 2019. FishBase. World Wide Web electronic publication. Retrieved on August 8, 2019 from http://www.fishbase.org.

Garaffo, M. A., Vassallo-Agius, R., Nengas, Y., Lembo, E., Rando, R., and *et al*. 2011. Fatty acids profile, atherogenic (IA) and thrombogenic (IT) health lipid indices, of raw roe of blue fin tuna (*Thunnus thynnus* L.) and Their Salted Product "Bottarga". Food and Nutrition Sciences, 2(7): 736–743.

Ghaeni, M., and Ghahfarokhi, K. N. 2013. Fatty acids profile, atherogenic (IA) and thrombogenic (IT) health lipid indices in Leiognathusbindus and Upeneussulphureus. Journal of Marine Science: Research and Development, 3(4): 1-3.

Göğüş, A. K. and Kolsarıcı, N., 1992. Su ürünleri teknolojisi ders kitabı, Ankara Üniversitesi Ziraat Fakültesi Yayınları: 1243, Ankara, 1992. (In Turkish).

Golani, D., Öztürk, B., and Başusta, N. 2006. *Fishes of the Eastern Mediterranean*. Turkish Marine Research Foundation (TÜDAV). González-Félix, M. L., Maldonado-Othón, C. A., and Perez-Velazquez, M. 2016. Effect of dietary lipid level and replacement of fish oil by soybean oil in compound feeds for the shortfin corvina (*Cynoscion parvipinnis*). Aquaculture, 454: 217–228.

Gorgun, S., and Akpinar, M. A. 2007. Liver and muscle fatty acid composition of mature and immature rainbow trout (*Oncorhynchus mykiss*) fed two different diets. Biologia, Bratislava, 62(3): 351-355.

Kallianiotis A., Torre M., and Argyri A. 2005. Age, growth, mortality, reproduction, and feeding habits of the striped seabream, *Lithognathus mormyrus* (Pisces: Sparidae), in the coastal waters of the Thracian Sea, Greece. Scientia Marina 69 (3): 391–404. DOI: 10.3989/scimar.2005.69n3391.

Kalyoncu, L., and Yay, M. 2017. Seasonal differences in the total fatty acid profile of 6 fish species from the Marmara Sea. Journal of Science and Technology, 10(1), 112-123.

Kinsella, J. E., Lokesh, B., and Stone, R. A. 1990. Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanisms. The American Journal of Clinical Nutrition, 52(1): 1–28.

Kizilkaya, B., and ÜCyol, N. 2022. Investigation and Comparison of the Suitability and Usability of Fatty Acids and the Lipid Quality Index Parameters in Waste Skin and Bones of Some Cultured Fish. Research in Marine Sciences, 7(2): 3-16.

Kobya, O. 2017. Doğu Karadeniz Bölgesi'ndeki izmarit balığının (*Spicara flexuosa*, Rafinesque 1810) biyokimyasal kompozisyonu ve et kalitesinin belirlenmesi (Yüksek lisans tezi). Recep Tayyip Erdoğan Üniversitesi, Fen Bilimleri Enstitüsü, Rize.

Küçükgülmez, A., Yanar, Y., Çelik, M., and Ersor, B. 2018. Fatty acids profile, Atherogenic, thrombogenic, and polyene lipid indices in golden grey mullet (*Liza aurata*) and gold band goatfish (*Upeneus moluccensis*) from Mediterranean Sea. Journal of Aquatic Food Product Technology, 27(8): 912–918.

Leaf A, Kang JX, Xiao YF, Billman GE. (2003). Clinical prevention of sudden cardiac death by n-3 polyunsaturated fatty acids and mechanism of prevention of arrhythmias by n-3 fish oils. Circulation, 107(21): 2632-2634.

Logue, J., de Vries, A., Fodor, E., and Cossins, A. 2000. Lipid compositional correlates of temperature-adaptive interspecific differences in membrane physical structure. Journal of Experimental Biology, 203(14): 2105–2115.

Lubis, Z., and Buckle, K. A. 1990. Rancidity and lipid oxidation of dried-salted sardines. International Journal of Food Science and Technology, 25(3): 295–303.

Łuczyńska, J., and Paszczyk, B. 2019. Health risk assessment of heavy metals and lipid quality indexes in freshwater fish from Lakes of Warmia and Mazury Region, Poland. International Journal of Environmental Research and Public Health, 16(19): 1-21.

Micale V, Genovese L, Guerrera MC, Laurà R, Maricchiolo G, Muglia U. 2011. The reproductive biology of *Pagellus bogaraveo*, a new candidate species for aquaculture. The Open Marine Biology Journal, 5: 42-46.

Murzina, S. A., Voronin, V. P., Ruokolainen, T. R., Artemenkov, D. V., and Orlov, A. M. 2022. Comparative analysis of lipids and fatty acids in beaked redfish *Sebastes mentella* Travin, 1951 collected in wild and in commercial products. Journal of Marine Science and Engineering, 10(1): 59. https://doi.org/10.3390/jmse10010059.

Nelson, J. S. 2006. Fishes of the World (4th ed). John Wiley & Sons, Inc.

Omri, B., Chalghoumi, R., Izzo, L., Ritieni, A., Lucarini, M., and *et al*. 2019. Effect of Dietary Incorporation of Linseed Alone or Together with Tomato-Red Pepper Mix on Laying Hens' Egg Yolk Fatty Acids Profile and Health Lipid Indexes. Nutrients, 11(4): 813.

Özoğul, Y., Özogul, F., Çiçek, E., Polat, A., & Kuley, E. (2009). Fat content and fatty acid compositions of 34 marine water fish species from the Mediterranean Sea. International Journal of Food Sciences and Nutrition, 60(6), 464-475. doi: 10.1080/09637480701838175.

Paruğ, Ş.Ş., and Cengiz, Ö. 2020. The maximum length record of the blackspot seabream (*Pagellus bogaraveo* Brünnich, 1768) for the Entire Agean Sea and Turkish Territorial Waters. Turkish Journal of Agriculture-Food Science and Technology, 8(10): 2125-2130.

Santini, F., Carnevale, G., and Sorenson, L. 2014. First multi-locus timetree of seabreams and porgies (Percomorpha: Sparidae). *Italian Journal of Zoology*, *81*, 55-71. https://doi.org/10.1080/11250003.2013.878960

Santos-Silva, J., Bessa, R. J. B., and Santos-Silva, F. 2002. Effect of genotype, feeding system and slaughter weight on the quality of light lambs. II. Fatty acid composition of meat. Livestock Production Science, 77: 187–194.

Schmidt EB, Arnesen H, de Caterina R, Rasmussen LH, Kristensen SD. 2005. Marine n-3 polyunsaturated fatty acids and coronary heart disease: Part I. Background, epidemiology, animal data, effects on risk factors and safety. Thrombosis Research, 115(3), 163-170.

Senso, L., Suárez, M., Ruiz-Cara, T., and García-Gallego, M. 2007. On the possible effects of harvesting season and chilled storage on the fatty acid profile of the fillet of farmed gilthead sea bream (Sparus aurata). Food Chemistry, 101(1): 298–307.

Shahidi, F. and Botta, J.R., 1994. Sea foods: chemistry, processing technology and quality. Blackie Academic and Professional. Chapman and Hall.

Silva, D. A., Rocha Júnior, V. R., Ruas, J. R. M., Santana, P. F., Borges, L. A., and *et al*. 2019. Chemical and fatty acid composition of milk from crossbred cows subjected to feed restriction. Pesquisa Agropecuária Brasileira, 54:1-10.

Šimat, V., Bogdanović, T., Poljak, V., and Petričević, S. 2015. Changes in fatty acid composition, atherogenic and thrombogenic health lipid indices and lipid stability of bogue (*Boops boops* Linnaeus, 1758) during storage on ice: Effect of fish farming activities. Journal of Food Composition and Analysis, 40: 120–125.

Simopoulos, A. P. 2008. The importance of the omega-6/omega-3 fatty acid ratio in cardiovascular disease and other chronic diseases. Experimental Biology and Medicine, 233(6): 674–688.

Spedicato MT, Greco S, Sophronidis K, Lembo G, Giordano D, Argyri A. 2002. Geographical distribution, abundance and some population characteristics of the species of the genus *Pagellus* (Osteichthyes: Perciformes) in different areas of the Mediterranean. Scientia Marina, 66 (Suppl 2): 65-82.

Steffens, W. 1997. Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. Aquaculture, 151(1-4): 197-119.

Stratev, D., Popova, T., Zhelyazkov, G., Vashin, I., Dospatliev, L., and Valkova, E. 2017. Seasonal changes in quality and fatty acid composition of black mussel (*Mytilus galloprovincialis*). Journal of Aquatic Food Product Technology, 26(7): 871–879.

Suárez, M. D., Sáez, M. I., Rincón-Cervera, M. Á., Hidalgo, L., and Guil-Guerrero, J. L. 2021. Discarded fish on the Spanish Mediterranean coast: influence of season on fatty acids profiles. Mediterranean Marine Science, 22(2): 232-245.

Turan, H., Sönmez, G., and Kaya, Y. 2007. Fatty acid profile and proximate composition of the thorn backray (*Raja clavata* L. 1758) from the Sinop coast in the Black Sea. Journal of Fisheries Sciences, 1(2): 97–103.

Ulbricht, T. and Southgate, D. 1991. Coronary heart disease: Seven dietary factors. Lancet, 338: 985–992.

Weihrauch, J. L., Posati, L. P., Anderson, B. A., and Exler, J. 1977. Lipid conversion factors for calculating fatty acid contents of foods. Journal of the American Oil Chemists' Society, 54(1): 36–40.

Wheeler, A. 1997. Pocket Guide to Saltwater Fishes of Britain and Europe. Parkgate Books Ltd. 102 p. – ISBN: 1855853647

Zlatanos, S. and Laskaridis, K. 2007. Seasonal variation in the fatty acid composition of three Mediterranean fish-sardine (*Sardina pilchardus*), anchovy (*Engraulis encrasicolus*) and picarel (*Spicara smaris*). Food Chemistry, 103: 725-728.