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Original Article

Comparison of Seasonal Fatty Acid Composition in Relation to Nutritional Value of Three Commercial Fish Species Caught From Different Zones of Eastern Black Sea

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ABSTRACT

The biochemical composition of fish differs according to seasons and habitat. This study aims to compare seasonal variations in the fatty acid composition of garfish (*Belone euxini*), Mediterranean horse mackerel (*Trachurus mediterraneus*) and red mullet (*Mullus barbatus*), commercially caught from different zones of Eastern Black Sea of Turkey. The results demonstrated significant seasonal variations in the levels of total saturated fatty acids (ΣSFA), monounsaturated fatty acids (ΣMUFA) and polyunsaturated fatty acids (ΣPUFA) in the fish ($p<0.05$). The highest percentage of omega-3 and ΣPUFA fatty acids were observed in autumn for red mullet and Mediterranean horse mackerel, while the highest values of these fatty acids were found in spring for garfish. The highest eicosapentaenoic acid + docosahexaenoic acid (EPA+DHA) levels were obtained for garfish and the lowest for red mullet. Significant seasonal variations were also observed among the three-fish species in values of fatty acids expressed as mg/100g in the edible portion ($p<0.05$). Considering, the highest levels of EPA+DHA, only 145 g of garfish is found enough to meet the weekly requirement of EPA+DHA for winter; although, consumption of approximately 431 g of edible muscle is required for red mullet to meet the same requirement. About 295 g edible muscle of Mediterranean horse mackerel was needed to meet the requisite amount of nutrients in summer. Therefore, this study implies that garfish has a better nutritional value for human consumption due to higher contents of EPA+DHA compared to other two species.

Keywords: Fatty acid, nutritional value, *Mullus barbatus, Belone euxini, Trachurus mediterraneus*

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INTRODUCTION

Fish is known as a good source of beneficial nutrients for human diet. Nutritional value of fish usually relates to its functional properties arise from high contents of PUFAs, particularly omega-3 PUFAs. Fish is rich in essential omega-3 fatty acids, especially high in the amount of EPA and DHA which have a functional role in the health of human beings (Gogus and Smith, 2010). The health benefits of these fatty acids are well investigated in numerous studies (Ozogul and Ozogul, 2007, Gogus and Smith, 2010). They have important functions in normal growth and development. It is also known that they take an important role in the treatment and prevention of various illness particularly cardiovascular diseases. Reports on their role in the preventive role of other diseases such as diabetes, hypertension and cancer commonly exist. They also help neurodevelopment in infants, fat glycemic control, improve visual functions and learning ability (Gordon and Ratliff, 1992; Carlson and Werkman, 1996). European Food Safety Authority (EFSA, 2010) recommends 200-250 mg EPA + DHA for daily consumption to prevent cardiovascular diseases and mortality. Different health authorities have published varying daily amounts of EPA+DHA from 200 mg up to 2 g depending on the past studies and for the intended health benefits (FAO/WHO, 2016). However, it was reported that health benefits of omega 3 was affected by the ratio of omega-6/ omega-3 (n-6 / n-3) in the daily diet and a ratio of 2-5/1 was suggested for the preventive effect of different types of diseases (Simopoulos, 2008).

Besides species peculiarities, fish have seasonal variations of fatty acids composition (Zlatanos and Laskaridis, 2007; Balçik Misir et al., 2014). As a result, the research study on seasonal variations in the fatty acid content of different fish species is of importance as nutritional sources. Moreover, other factors such as nutrition availability, water temperature and sexual maturation have also effect on the lipid contents and fatty acid composition of fish species (Shearer, 1994; Rueda et al., 1997; Görgün and Akpınar, 2007; Llorett et al., 2007).

Garfish (*Belone* euxini, Günther, 1866), Mediterranean horse mackerel (*Trachurus mediterraneus*, Steindachner, 1868) and red mullet (*Mullus barbatus,* Linnaeus, 1758) are commercial fish species and commonly marketed for human consumption in Turkey. Among these species, garfish is a pelagic migratory fish species which is widely distributed in the North-Eastern Atlantic Sea, Mediterranean Sea as well as the Black Sea. They are usually observed in offshore areas with exception of the spawning period when they migrate into coastal regions (FISHBASE, 2016). Bilgin et al. (2014) reported that although garfish has been known as *Belone belone euxini* for many years, this species was accepted as a valid endemic species as *Belone euxini* to Azov Sea, Black Sea and the Marmara Sea. It is a ferocious predator and adults feed on fish species in length smaller than 3 cm, on the other hand juveniles feed on small fish, crustaceans and other aquatic organisms. Garfish reproduce from April to September, intensively in May to August (Samsun et al., 2006). World catch is reported as 1285 tons in 2012 and 232 tons of it represented by Turkish production (FAO, 2014). About 23.1% of Turkish catch was occurred in the Black Sea in the same year (TSI, 2013).

Mediterranean horse mackerel is a high-value marine fish species. It is a semi-pelagic carnivore fish species distributed throughout the Black, Marmara and Mediterranean Seas, and also along the eastern Atlantic coast from Morocco to the English Channel (Turan, 2004). It is most frequently observed within the depths of 20 - 200 meters (šantič et al., 2003). A schooling habit was reported for this species which feeds on other fishes species, particularly anchovies and sardines and also herring larvae and small crustaceans (FISHBASE, 2016). Total world production was reported as 29887 tons in 2012, 82.4% of it was caught from Turkish waters. Majority of Turkish production was represented by the Black Sea (FAO, 2014). Demirel and Yüksek (2013a,b) reported that Mediterranean horse mackerel is a multiple spawner and females spawn about every 6.6 days which accounts approximately 20 times in the spawning period May and August 2009 in Marmara Sea. The spawning peaks in July-August and ends in September. Different spawning period was recorded for this species in the Black Sea in literature. Earliest studies demonstrated that the spawning period was from 15 May to 15 August while later studies reported a spawning period from June to September (Şahin et al., 2009).

Red mullet is a demersal fish species found in the eastern Atlantic Sea along the European and African costs and also in the Mediterranean and Black Seas (FISHBASE, 2016). It feeds on small benthic crustaceans, worms and mollusks usually found at about 100-300 m depths (Haidar, 1970). The world production is reported as 15671 tons in 2012, and 2055 tons are recorded for Turkish production in the same year. About 15.5% of the catch was occurred in Turkish Black Sea (TSI, 2013). Genç (2002) reported that sexual maturity of red mullet is at one year of age and spawns during June-August when water temperatures are 18-25°C; the peak is between 15 June and 15 July.

So far, limited studies exist relating to seasonal variations of the fatty acid profile of these species caught from Black Sea although fatty acid profile of Mediterranean horse mackerel and garfish caught from different seas including the Black Sea have usually been carried out using single sampling time (Ozogul and Ozogul, 2007). Boran and Karaçam (2011) obtained the fat composition of Black Sea horse mackerel and garfish within the range of 8.4-13.3% and 3.2-5.9, respectively with seasonal variations. Other studies reported varying fatty acid values for different months for single sampling times for *B. euxini* and *T. mediterraneus* caught from different seas in different years indicating the seasonal effect on the values of fatty acids (Bayır et al., 2006; Fernandez-Jover et al., 2007; Tzikas et al., 2007; Chuang et al., 2012; Kocatepe and Turan 2012; Merdzhanova et al., 2012; Stancheva et al., 2012). Limited studies exist on seasonal changes in fat content and fatty acid profile of red mullet from Black Sea (Merdzhanova et al., 2012).

Weihrauch et al. (1977) pointed out that researchers report the data of fatty acid values in terms of weight percent of total methyl esters (FAME%). They suggested that relative amounts of component fatty acid esters should be converted to grams fatty acids (as free acid) /100 g of food in order to use these data in nutrient tables. Therefore, for this purpose, conversion factors which defined as the weight of fatty acids in 1 g fat, were derived from several food products. Therefore, they suggested using a formula to calculate fatty acid values in mg/100 g of the edible portion of fish, with the use of the different conversion factors for different parts of organs due to difference in the phospholipid levels. Unfortunately, although nutritional data tables are prepared by using different conversion factors and formulae to give a better evaluation of nutrition in foods (Exler, 2013, Personal Communication), the most reported research in past literature on the fatty acid levels of fish are still given as FAME%.

In our previous studies, we have investigated seasonal variations in the nutritional values of the several commercial fish products such as anchovy, whiting, Atlantic bonito, and shad in terms of their fatty acid values (Tufan et al., 2011; Balçik Misir et al., 2014; Tufan and Köse, 2014). However, there is still lacking information relating to fatty acid values as mg/100 g in the edible portion of Mediterranean horse mackerel, red mullet and garfish from the Black Sea. Therefore, our purpose in the current work was to investigate seasonal changes in lipid content and fatty acid composition of the edible muscle of these fish species caught from different zones of Turkish Black Sea. Moreover, we also aimed to compare the nutritional value of these fish species for different seasons in order to guide for humans, and seafood industry for consumption and marketing.

MATERIAL AND METHOD

Chemicals

The chemicals used in this work was obtained from different companies. These are Merck (Darmstadt, Germany, J.T. Baker (USA) and Sigma-Aldrich (Steinheim, Germany). All the chemicals were analytical grade.

Fish Samples

Three fish species (*M. barbatus*, *B. euxini*, *T. mediterraneus*) were purchased from the local fish market in Trabzon (Eastern Black Sea coast) as seasonally, approximately 2.0 kg from each fish species at each month. They were transferred to the laboratory in ice within 30 mins of purchase. The length and weight measurements of fish were taken at each sampling time and the mean length values were 14.3±3.2 cm for red mullet, 15.1±4.2 cm for Mediterranean horse mackerel and 36.2±7.1 cm garfish. The mean weight values were 28.4±5.3 g, 18.3±7.3 g and 48.3±6.2 g, respectively. Then, the fish were headed, gutted, filleted and skin was removed from the edible muscle. The samples were divided into two groups. One group was used directly for fat content analysis. The rest was kept at frozen storage at -40°C (Sanyo; MDF- U5411, Osaka, Japan) for fatty acid analysis for the following days (within ten days) and defrosted at refrigerator (4±2°C) overnight (7-10 hrs) prior to analysis. The samples were homogenized by a kitchen food processor (Arçelik; K-1631 P Valso Plus, 2.2 L capacity, Turkey) prior to analysis. Triplicated sampling was carried out for each homogenised group each month for the analysis of fat content and fatty acid profile. The results were shown seasonally including mean values of the relating months.

Methods

Analyses of total fat contents

A solvent extractor, Velp SER 148/6 (Velp Scientifica, Milano, Italy) was used to analyse total fat content. Petroleum ether was used as solvent at 130°C. Determination of fat content was carried out gravimetrically and calculated as gram lipids per 100 g wet muscle (Tufan et al., 2013).

Analysis of fatty acid methyl esters (FAME%)

Analysis of FAME % was carried out according to the modified method of Ichihara et al. (1996). Bligh and Dyer method (1959) was used to extract lipid using chloroform: methanol (2:1, v/v). Methyl esters were prepared using transesterification method with 2 M potassium hydroxide (KOH) in methanol and n-hexane according to the method of Ichihara et al. (1996) with few modifications. Ten mg extracted oil were dissolved in 2 mL n-hexane in a tube. Then 4 mL of 2 M methanolic KOH were in added. The tube was vortexed for 2 mins at room temperature. It was centrifuged for 10 mins at 4,000 rpm. Then the hexane layer was used for gas chromatography (GC).

Gas chromatography conditions

Fatty acids were determined using a Shimadzu 2010 GC equipped with an auto sampler (Shimadzu, JAPAN) and a split injector (ratio 1:20), a flame ionization detector (FID). The column was a 100 m SUPELCO (SP™-2380, USA) fused silica capillary column (film 0.20 µm, diameter 0.25 mm). The temperatures of the detector and the injector port were held at 260°C. The injected volume was 1 µL. The column temperature was held at 140°C for 5 mins, then raised to 240°C at 5°C/min, kept at 240°C for 30 mins. Identification of fatty acids was carried out by comparing the retention times of FAME with Supelco™ 37 component FAME mixture (Cat. No. 47885-U). FAME was quantified by using area normalization method. Area composition of each compound was detected and results were expressed as FAME%. For each sample extract, three replicated GC analyses were performed and the results were expressed in GC area % as the mean values±standard deviation (SD). The amount of g fatty acid in edible fish muscle was calculated by the method explained in Greenfield and Southgate (2003), Exler et al. (1975) and Compilers' Toolbox (2016) using the formulae given below;

Fatty acid (FA) content (g FA per 100 g edible fish muscle) = FAME % x FACF x lipid content % (g lipid/100g food) /100 (Eq. 1)

Where FAME is fatty acid methyl esters, FACF: the lipid conversion factor (fatty acid conversion factor, g FA/g lipid) that is reported as 0.90 for fish muscle which contains fat above 5%, if the fat contents are below 5%, the FACF is calculated from the equation: 0.933 – (0.143/TL) for fish muscle, where TL means total lipid content (Weihrauch et al., 1977).

Statistical Analysis

The obtained data were subjected to analysis of variance (ANOVA). Comparisons among means were carried out if significant differences were found, by using Tukey test ($p<0.05$) with the application of JMP 5.0.1 statistical program (SAS Institute Inc., Cary, NC, USA) (Sokal and Rohlf, 1987). The data are expressed as mean±SD of the values obtained from triplicated samples.

RESULTS AND DISCUSSION

Total Lipid

Table 1 demonstrates seasonal changes in total lipid (% wet weight basis) values of three fish species. Total lipid contents of garfish, horse mackerel and red mullet were in the range of 8.3-11.5, 3.9-8.0 and 3.5-7.5%, respectively. The highest lipid values of garfish and red mullet were observed in winter while the highest lipid content of horse mackerel was determined in autumn. Total lipid contents of each fish species varied significantly amongst seasons ($p<0.05$). The seasonal variations were usually attributed to spawning season of the fish and also on the feed availability in the living habitat (Llorett et al., 2007). Therefore, lower fat contents were obtained in the fish muscle during spawning seasons (Kandemir and Polat, 2007). The lowest fat content of red mullet was found in summer as 3.5%. The spawning period of this species was reported as between June-August with a peak of June-July (Genç, 2002). This result supports our findings for red mullet. However, although spawning season of Mediterranean horse mackerel have been reported starting from May which ends in September (particularly a peak in July and August) (Şahin et al., 2009; Demirel and Yüksek, 2013 a,b), the lowest fat content was

Table 1. Total lipid contents of fish species for different seasons (g/100g)

Fish Species	Summer	Autumn	Winter	Spring
Garfish	NA	$9.3\pm2.0^{a}_{A}$	$11.5\pm0.9^{ab}_{A}$	$8.3\pm0.2^{a}_{A}$
Mediterranean horse Mackerel	$6.1\pm0.5^{a}_{A}$	$8.0\pm1.0^{b}_{A}$	$6.6\pm0.6^{a}_{B}$	$3.9\pm0.1^{c}_{B}$
Red mullet	$3.5\pm0.0^{a}_{B}$	$4.6\pm0.5^{b}_{B}$	$7.5\pm0.1^{c}_{C}$	$4.2\pm0.1^{b}_{C}$

$p>0.05$; not significant $p<0.05$; significant; F: female; M: male obtained in spring as 3.9%. This result does not support the effect of spawning season. Therefore, other factors such as feed availability are thought to influence the fat content of this species. For this reason, further study was carried out on wild and reared Mediterranean horse mackerel in sea cages (Tufan et al., 2016). Recently published results confirmed our findings in the work that feeding closely affected the fat contents of this species. The previous study also showed that spawning season did not affect the fat content of this species (Tufan et al., 2016).

Seasonal variations were also obtained for lipid contents of these species (Boran and Karaçam, 2011; Merdzhanova et al., 2012). However, past studies reported much lower fat contents for garfish while higher values obtained for red mullet caught from the Black Sea at different times (Boran and Karaçam, 2011; Chuang et al., 2012; Kocatepe and Turan, 2012; Merdzhanova et al., 2012). Polat et al. (2009) reported that lipid contents of red mullet captured from the north-eastern Mediterranean were 5.8% in autumn, 5.3% in winter and 3.7% in spring. They also observed significant seasonal differences in the lipid contents ($p<0.05$). The differences in lipid contents of these two species reported in past studies might have occurred due to variations in feed sources and availability at different years.

Two different horse mackerel species are known in Black Sea region as *T. mediterraneaus* and *T. trachurus*. In this region, the highest catch is commonly reported for *T. mediterraneus* (Bektas and Belduz, 2008; Kasapoglu, and Duzgunes, 2013). Studies on horse mackerel caught from Black Sea region usually are reported for *T. trachurus* although it is possible that this species might have been misidentified. Our recent study with this species (Tufan et al., 2016) supported the values of fat content while Boran and Karaçam (2011) obtained higher fat contents for *T. trachurus* from this region. Celik (2008) reported much lower values for this species caught from the Mediterranean Sea. Few studies reported lipid composition of Mediterranean horse mackerel caught from other seas. Tzikas et al. (2007) reported much lower lipid values for this species caught from the Aegean Sea with seasonal variations while Saglık and Imre (2001) determined higher lipid content as 10.6% for the same species caught in November. However, the origin of the fish was not stated in their study. Stancheva et al. (2012) found lower lipid value for Black Sea horse mackerel (*T. mediterraneus ponticus*) obtained from Bulgarian Black Sea as 4.2%. The current study also shows that among three fish species studied, garfish contained the highest lipid contents indicating the better nutritional value of this species.

Fatty Acid Methyl Esters (FAME) of Fish Muscle

Table 2 represents fatty acid profiles as FAME% of red mullet, horse mackerel and garfish samples. The highest value of ∑SFA was found for red mullet as 32.9% in spring and the lowest value was obtained for garfish in winter as 28.2%. Although significant differences were observed for individual fatty acid values among species and also among seasons with some exceptions, the changes were usually found insignificant for ∑SFA values. The most abundant SFA was palmitic acid (C16:0) followed by stearic acid (C18:0) in the ranges of 17.3-21.2% and 3.2-7.8%, respectively. Few studies reported fatty acid profile of Mediterranean horse mackerel, garfish and red mullet caught from the Black Sea or different seas. However, limited studies investigated seasonal variation in the fatty acid profile of these species caught from Black Sea since their sampling represented a single month of different years. Therefore, this study is first to report on seasonal values of red mullet and garfish for Turkish Black Sea. Fatty acid values of past studies were in agreement with our findings in terms of C16:0 was the major SFA (Tzikas et al., 2007; Stancheva et al., 2007; Chuang et al., 2012; Kocatepe and Turan 2012). Another seasonal study on the fatty acid profile of Mediterranean horse mackerel was recently published by Tufan et al. (2016) although it was carried later than this work by our research team. In the relating study, the values of ∑SFA were within the range of our findings for wild fish samples, while lower SFA contents were determined for cultured Mediterranean horse mackerel in sea cages (Tufan et al., 2016).

Significant fluctuations were observed among MUFA values (within 16.1-33.0%) of all fish species ($p<0.05$). The highest and lowest values were found in spring for Mediterranean horse mackerel and garfish, respectively. Oleic acid (C18:1n-9) was determined as the main ∑MUFA (9.6-25.6%) for the whole year. Other researchers also reported oleic acid as the main MUFA for these species caught in the Black Sea or other seas (Polat et al., 2009; Chuang et al., 2012; Kocatepe and Turan 2012; Merdzhanova et al., 2012; Tufan et al., 2016). However, Stancheva et al. (2012) reported major MUFA as palmitoleic acid (C16:1) for Black Sea horse mackerel.

With regard to ∑PUFA content, the values obtained for fish species during all seasons were found significantly higher for garfish than other fish species ($p<0.05$). Therefore, the highest ∑PUFA value was attributed to garfish in spring as 49.5%, followed by Mediterranean horse mackerel and red mullet in autumn as 36.2% and 34.2%, respectively. DHA was determined as the main PUFA in all species, followed by EPA for Mediterranean horse mackerel and garfish and by linoleic acid (C18:2n-6) for red mullet. The levels of DHA were determined significantly higher for garfish than other fish species for the whole year ($p<0.05$) as 25.6 and 32.4%. DHA levels of red mullet and Mediterranean horse mackerel were determined as 5.9-15.3% and 11.5-22.3%, respectively. Celik (2008) obtained lower DHA and EPA for Mediterranean horse mackerel and *M. barbatus*, respectively. Chuang et al. (2012), Kocatepe and Turan (2012), and Merdzhanova et al. (2012) also obtained higher values of DHA for garfish than red mullet, however, they obtained lower values of EPA for these species. The findings of Stancheva et al. (2012) also supported our results for DHA values. Tufan et al. (2016) recorded lower DHA values for wild Mediterranean horse mackerel with the exception of winter months. Therefore, this study showed that fatty acid values can also vary at different years.

The n-3⁄n-6 ratio has been suggested to be a useful indicator to compare relative nutritional values of fish oils and a ratio of 1:1-1:5 was recommended (Osman et al., 2001). The results indicated that ∑n3⁄n6 ratio of all the fish samples was higher than the recommended ratio with a range for edible flesh as 1.5-6.8%. The highest n3/n6 ratio was observed of garfish with all seasons indicating better health benefit of this species compared to other species analyzed in this study. The values obtained by Chuang et al. (2012), and Kocatepe and Turan (2012) were higher for garfish and horse mackerel. However, the results of Chuang et al. (2012) for red mullet supported our findings.

Table 2. Fatty acid profile of red mullet, mediterranean horse mackerel and garfish during different seasons (FAME%).

Fatty Acids	Red mullet				Mediterranean horse mackerel				Garfish		
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
C14:0	2.0±0.1$^{a}_{A}$	2.5±0.3$^{b}_{A}$	2.0±0.0$^{a}_{A}$	2.1±0.0$^{a}_{A}$	2.3±0.1$^{a}_{A}$	2.8±0.1$^{a}_{A}$	2.5±0.1$^{b}_{B}$	3.3±0.2$^{c}_{B}$	3.2±0.6$^{a}_{B}$	3.6±0.1$^{a}_{B}$	2.3±0.1$^{b}_{B}$
C15:0	0.9±0.1$^{a}_{A}$	0.8±0.1$^{a}_{A}$	0.7±0.1$^{a}_{A}$	0.7±0.0$^{a}_{A}$	0.5±0.0$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.4±0.0$^{c}_{B}$	0.2±0.0$^{d}_{B}$	0.8±0.0$^{a}_{A}$	0.7±0.0$^{a}_{A}$A	0.7±0.1$^{a}_{A}$
C16:0	20.8±1.0$^{a}_{A}$	19.3±1.3$^{a}_{A}$	20.2±0.2$^{a}_{A}$	20.7±0.3$^{a}_{A}$	21.2±0.7$^{a}_{A}$	19.6±1.2$^{b}_{A}$	17.7±0.0$^{c}_{B}$	17.3±0.5$^{c}_{B}$	20.3±1.8$^{a}_{A}$	17.4±0.6$^{b}_{A}$	17.3±2.3$^{b}_{B}$
C17:0	1.2±0.1$^{a}_{A}$	0.9±0.1$^{b}_{A}$	0.8±0.0$^{b}_{A}$	0.8±0.1$^{b}_{A}$	0.6±0.0$^{a}_{B}$	0.3±0.0$^{b}_{B}$	0.5±0.2$^{ab}_{B}$	0.2±0.0$^{c}_{B}$	0.5±0.1$^{a}_{B}$	0.6±0.3$^{a}_{A}$	1.0±0.2$^{ab}_{A}$
C18:0	4.7±0.5$^{a}_{A}$	4.8±0.5$^{a}_{A}$	5.4±0.2$^{b}_{A}$	7.1±0.2$^{c}_{A}$	7.1±0.2$^{a}_{B}$	7.3±0.2$^{a}_{B}$	7.8±0.4$^{a}_{B}$	7.6±0.0$^{a}_{A}$	4.9±0.8$^{a}_{A}$	3.2±0.2$^{b}_{C}$	7.7±0.4$^{c}_{B}$
C20:0	0.4±0.0$^{a}_{A}$	0.2±0.0$^{b}_{A}$	0.4±0.0$^{a}_{A}$	0.2±0.0$^{b}_{A}$	0.8±0.0$^{a}_{B}$	0.0±0.0$^{b}_{B}$	0.6±0.2$^{c}_{A}$	0.0±0.0$^{b}_{B}$	2.3±0.2$^{a}_{C}$	2.3±0.1$^{a}_{C}$	3.2±0.4$^{b}_{B}$
C22:0	0.9±0.1$^{a}_{A}$	1.4±0.1$^{b}_{A}$	1.0±0.1$^{c}_{A}$	0.6±0.0$^{d}_{A}$	0.3±0.0$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.1±0.0$^{b}_{B}$	0.1±0.0$^{b}_{B}$	0.3±0.0$^{a}_{B}$	0.2±0.1$^{a}_{B}$	0.1±0.0$^{b}_{B}$
C24:0	0.3±0.0$^{a}_{A}$	0.6±0.3$^{a}_{A}$	0.5±0.0$^{ab}_{A}$	0.7±0.1$^{ab}_{A}$	0.0±0.0$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.4±0.2$^{c}_{A}$	0.0±0.0$^{a}_{B}$	0.5±0.1$^{a}_{C}$	0.2±0.0$^{b}_{C}$	0.3±0.1$^{b}_{A}$
ΣSFA	31.2±1.6$^{a}_{A}$	30.5±2.5$^{a}_{A}$	31.1±0.1$^{a}_{A}$	32.9±0.0$^{b}_{A}$	32.8±0.6$^{a}_{A}$	30.3±0.9$^{b}_{A}$	30.0±0.3$^{b}_{A}$	28.7±0.3$^{c}_{B}$	32.8±2.1$^{a}_{A}$	28.2±0.1$^{b}_{A}$	32.6±1.2$^{a}_{A}$
C14:1	0.1±0.0$^{a}_{A}$	0.3±0.0$^{b}_{A}$	0.4±0.0$^{c}_{A}$	0.5±0.0$^{d}_{A}$	0.0±0.0$^{a}_{B}$	0.0±0.0$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.0±0.0$^{a}_{B}$	0.2±0.0$^{a}_{C}$	0.2±0.0$^{a}_{C}$	0.1±0.0$^{b}_{B}$
C15:1	0.4±0.0$^{a}_{A}$	0.4±0.1$^{a}_{A}$	0.4±0.0$^{a}_{A}$	0.4±0.0$^{a}_{A}$	0.0±0.0$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.1±0.0$^{b}_{B}$	0.1±0.0$^{b}_{B}$	0.2±0.1$^{a}_{C}$	0.1±0.0$^{a}_{B}$	0.2±0.1$^{a}_{B}$
C16:1	1.2±0.1$^{a}_{A}$	1.3±0.3$^{a}_{A}$	0.8±0.1$^{b}_{A}$	0.5±0.1$^{c}_{A}$	3.9±0.1$^{a}_{B}$	4.3±0.7$^{a}_{B}$	4.9±0.0$^{b}_{B}$	5.7±0.3$^{c}_{B}$	4.9±0.2$^{a}_{C}$	5.6±0.2$^{b}_{C}$	3.1±0.1$^{b}_{C}$
C17:1	0.2±0.0$^{a}_{A}$	0.1±0.0$^{b}_{A}$	0.5±0.0$^{c}_{A}$	0.4±0.0$^{d}_{A}$	0.1±0.0$^{a}_{B}$	0.7±0.2$^{b}_{B}$	0.6±0.3$^{b}_{AB}$	0.1±0.0$^{a}_{B}$	0.9±0.2$^{a}_{C}$	0.4±0.1$^{b}_{C}$	0.9±0.1$^{a}_{B}$
C18:1n-9	15.6±1.1$^{a}_{A}$	19.9±1.2$^{b}_{A}$	22.4±0.2$^{c}_{A}$	23.4±0.6$^{c}_{A}$	21.6±0.5$^{a}_{B}$	21.9±1.2$^{a}_{A}$	25.6±0.6$^{b}_{B}$	21.0±2.4$^{a}_{B}$	14.6±0.6$^{a}_{A}$	15.5±1.1$^{a}_{B}$	9.6±0.9$^{b}_{C}$
C20:1	0.5±0.1$^{a}_{A}$	0.3±0.1$^{b}_{A}$	0.4±0.1$^{b}_{A}$	0.3±0.0$^{b}_{A}$	0.9±0.0$^{a}_{B}$	1.1±0.1$^{a}_{B}$	1.3±0.1$^{b}_{B}$	0.1±0.0$^{c}_{B}$	2.1±0.8$^{a}_{C}$	2.4±1.8$^{a}_{C}$	1.1±0.1$^{b}_{B}$
C22:1n-9	0.4±0.1$^{a}_{A}$	0.8±0.1$^{b}_{A}$	0.5±0.0$^{ac}_{A}$	0.4±0.1$^{ac}_{A}$	0.2±0.0$^{a}_{B}$	0.4±0.2$^{a}_{B}$	0.1±0.0$^{b}_{B}$	0.6±0.0$^{c}_{B}$	0.3±0.1$^{a}_{A}$	0.2±0.1$^{a}_{C}$	0.3±0.1$^{a}_{C}$
C24:1	0.3±0.0$^{a}_{A}$	0.4±0.1$^{ab}_{A}$	0.6±0.1$^{bc}_{A}$	0.2±0.0$^{d}_{A}$	0.2±0.0$^{a}_{B}$	0.8±0.0$^{b}_{B}$	0.3±0.1$^{a}_{B}$	0.7±0.0$^{b}_{B}$	0.8±0.2$^{a}_{C}$	0.3±0.2$^{b}_{A}$	0.8±0.1$^{a}_{C}$
ΣMUFA	18.7±1.4$^{a}_{A}$	23.5±1.3$^{b}_{A}$	26.0±0.1$^{c}_{A}$	26.1±0.8$^{c}_{A}$	26.9±0.5$^{a}_{B}$	29.3±1.9$^{a}_{B}$	33.0±0.6$^{b}_{B}$	28.3±2.0$^{a}_{A}$	24.0±2.2$^{a}_{B}$	24.7±2.4$^{a}_{A}$	16.1±0.1$^{b}_{C}$
C18:2n-6	7.9±0.4$^{a}_{A}$	7.6±0.8$^{a}_{A}$	7.2±0.6$^{a}_{A}$	5.2±0.3$^{b}_{A}$	2.5±0.1$^{a}_{B}$	2.6±0.1$^{a}_{B}$	2.5±0.0$^{a}_{B}$	3.1±0.0$^{b}_{B}$	2.7±0.0$^{a}_{A}$	2.4±0.1$^{b}_{B}$	3.1±0.3$^{c}_{C}$
C18:3n-6	0.1±0.0$^{a}_{A}$	0.1±0.0$^{a}_{A}$	0.4±0.2$^{b}_{A}$	0.2±0.0$^{bc}_{A}$	0.1±0.0$^{a}_{A}$	0.1±0.0$^{a}_{A}$	0.1±0.0$^{a}_{B}$	0.1±0.0$^{a}_{B}$	0.4±0.1$^{a}_{B}$	0.2±0.1$^{a}_{A}$	0.8±0.1$^{b}_{A}$
C18:3n-3	0.3±0.0$^{a}_{A}$	0.2±0.0$^{b}_{A}$	1.8±0.1$^{b}_{A}$	0.4±0.1$^{a}_{A}$	0.9±0.1$^{a}_{B}$	0.7±0.1$^{a}_{B}$	0.5±0.0$^{b}_{B}$	0.6±0.1$^{a}_{A}$	0.2±0.1$^{a}_{A}$	0.0±0.0$^{b}_{C}$	0.1±0.0$^{b}_{C}$
C18:3n-4	1.2±0.0$^{a}_{A}$	1.5±0.4$^{ab}_{A}$	2.1±0.3$^{c}_{A}$	1.4±0.2$^{ab}_{A}$	0.7±0.0$^{a}_{B}$	0.5±0.1$^{b}_{B}$	1.1±0.1$^{c}_{B}$	0.9±0.2$^{c}_{A}$	0.4±0.1$^{a}_{C}$	0.2±0.1$^{b}_{C}$	0.2±0.0$^{b}_{C}$
C20:3n-3	0.1±0.0$^{a}_{A}$	0.8±0.1$^{b}_{A}$	2.0±0.1$^{ac}_{A}$	1.4±0.1$^{d}_{A}$	0.1±0.0$^{a}_{A}$	0.2±0.0$^{b}_{B}$	0.1±0.0$^{a}_{B}$	0.1±0.0$^{a}_{B}$	0.2±0.1$^{a}_{A}$	0.1±0.0$^{a}_{C}$	0.1±0.0$^{a}_{B}$
C20:2	0.4±0.0$^{a}_{A}$	0.8±0.3$^{b}_{A}$	0.9±0.1$^{bc}_{A}$	1.5±0.1$^{d}_{A}$	0.3±0.0$^{a}_{A}$	0.3±0.0$^{a}_{B}$	0.5±0.0$^{b}_{B}$	0.4±0.0$^{c}_{B}$	0.9±0.2$^{a}_{B}$	1.1±0.1$^{a}_{A}$	1.2±0.2$^{a}_{A}$
C22:2	0.1±0.0$^{a}_{A}$	0.6±0.0$^{b}_{A}$	0.7±0.1$^{bc}_{A}$	0.3±0.0$^{d}_{A}$	0.1±0.0$^{a}_{A}$	0.0±0.0$^{b}_{B}$	0.0±0.0$^{b}_{B}$	0.1±0.0$^{a}_{B}$	0.6±0.1$^{a}_{B}$	0.7±0.1$^{a}_{A}$	0.6±0.1$^{a}_{A}$
C20:4n-6	0.4±0.0$^{a}_{A}$	0.3±0.2$^{ab}_{A}$	0.5±0.1$^{b}_{A}$	0.5±0.1$^{b}_{A}$	0.9±0.1$^{a}_{B}$	0.2±0.0$^{b}_{B}$	0.1±0.0$^{b}_{B}$	0.8±0.4$^{a}_{A}$	1.2±0.2$^{a}_{B}$	1.6±0.8$^{a}_{C}$	1.5±0.2$^{ab}_{C}$
C20:5n-3	7.2±0.3$^{a}_{A}$	5.3±0.9$^{b}_{A}$	5.9±0.0$^{b}_{A}$	6.8±0.6$^{b}_{A}$	5.7±0.4$^{a}_{B}$	5.0±0.1$^{a}_{A}$	6.0±0.2$^{b}_{A}$	8.0±0.3$^{c}_{B}$	5.0±0.1$^{a}_{B}$	4.8±0.4$^{a}_{A}$	4.5±0.4$^{a}_{B}$
C22:5n-3	0.1±0.0$^{a}_{A}$	0.2±0.1$^{ab}_{A}$	0.5±0.1$^{c}_{A}$	0.3±0.1$^{ab}_{A}$	1.4±0.2$^{a}_{B}$	0.2±0.0$^{b}_{A}$	0.2±0.0$^{b}_{B}$	0.1±0.0$^{c}_{B}$	3.1±0.2$^{a}_{C}$	2.8±0.2$^{a}_{B}$	3.6±0.4$^{a}_{C}$
C22:5n-6	1.1±0.0$^{a}_{A}$	2.0±0.2$^{b}_{A}$	1.8±0.2$^{c}_{A}$	1.5±0.1$^{c}_{A}$	1.2±0.2$^{a}_{A}$	1.7±0.1$^{b}_{A}$	2.5±0.1$^{c}_{B}$	2.0±0.1$^{d}_{B}$	0.9±0.1$^{a}_{A}$	0.7±0.1$^{a}_{B}$	1.4±0.2$^{b}_{A}$
C22:6n-3	15.3±0.7$^{a}_{A}$	8.7±2.7$^{b}_{A}$	9.8±0.6$^{c}_{A}$	5.9±0.2$^{d}_{A}$	22.3±0.7$^{a}_{B}$	15.2±3.1$^{b}_{B}$	11.5±0.2$^{c}_{B}$	11.7±0.7$^{c}_{B}$	26.1±2.2$^{a}_{C}$	25.6±0.7$^{a}_{C}$	32.4±1.1$^{b}_{C}$
ΣPUFA	34.2±1.5$^{a}_{A}$	28.1±1.6$^{b}_{A}$	33.6±0.1$^{a}_{A}$	25.4±1.8$^{b}_{A}$	36.2±1.4$^{a}_{A}$	26.7±2.8$^{b}_{A}$	25.1±0.2$^{b}_{B}$	27.9±1.3$^{b}_{A}$	41.7±2.3$^{a}_{B}$	40.2±0.8$^{a}_{B}$	49.5±2.8$^{b}_{C}$
EPA+DHA	22.5±0.4$^{a}_{A}$	14.0±1.8$^{b}_{A}$	15.7±0.3$^{bc}_{A}$	12.7±0.4$^{bd}_{A}$	28.0±0.6$^{a}_{B}$	20.2±1.6$^{b}_{B}$	17.5±0.2$^{c}_{BC}$	19.7±0.5$^{cd}_{A}$	31.1±1.2$^{a}_{C}$	30.4±1.1$^{a}_{C}$	36.9±0.8$^{b}_{D}$
∑n3	23.0±1.1$^{a}_{A}$	15.2±4.2$^{b}_{A}$	20.0±0.6$^{c}_{A}$	14.8±1.2$^{b}_{A}$	30.4±1.3$^{a}_{B}$	21.3±3.2$^{b}_{B}$	18.3±0.0$^{bc}_{A}$	20.5±1.0$^{bc}_{B}$	34.6±2.0$^{a}_{B}$	33.3±0.9$^{a}_{C}$	40.7±0.9$^{b}_{B}$
∑n6	9.5±0.4$^{a}_{A}$	10.0±1.1$^{a}_{A}$	9.9±0.6$^{b}_{A}$	7.4±0.5$^{ac}_{A}$	4.7±0.0$^{a}_{B}$	4.6±0.3$^{a}_{B}$	5.2±0.2$^{a}_{B}$	6.0±0.3$^{ab}_{B}$	5.2±0.3$^{a}_{B}$	4.9±0.8$^{a}_{B}$	6.8±0.4$^{b}_{C}$
∑n3/∑n6	2.4	1.5	2.0	2.0	6.5	4.6	3.5	3.4	6.7	6.8	6.0

±SD, n: 3, Different superscript lowercase letters (a, b, c) in the same row represent significant differences among the seasons for the same fish species ($p<0.05$), Different subscript uppercase letters (A, B, C) in the same row represent significant differences among fish species for the same season ($p<0.05$)
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid

Table 3 Seasonal variations in fatty acid composition of red mullet, Mediterranean horse mackerel and garfish (mg per 100g of edible muscle)

Fatty Acids	Red mullet				Mediterranean horse mackerel				Garfish		
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
C14:0	105.7±12.6$^{a}_{A}$	138.0±1.6$^{a}_{A}$	89.5±1.8$^{b}_{A}$	63.8±1.9$^{c}_{A}$	203.3±6.9$^{a}_{B}$	148.8±6.3$^{b}_{A}$	114.6±8.0$^{c}_{B}$	127.8±3.4$^{c}_{B}$	267.8±47.3$^{a}_{C}$	369.2±12.0$^{b}_{B}$	171.8±10.6$^{c}_{BC}$
C15:0	33.6±2.6$^{a}_{A}$	49.6±4.0$^{b}_{A}$	28.9±1.7$^{a}_{A}$	27.6±1.7$^{a}_{A}$	6.8±2.1$^{a}_{B}$	21.3±0.1$^{b}_{B}$	6.1±0.6$^{a}_{B}$	27.4±0.9$^{bc}_{A}$	67.0±0.0$^{a}_{C}$	72.5±0.0$^{a}_{C}$	53.2±10.7$^{b}_{C}$
C16:0	801.2a±55.1$^{a}_{A}$	363.±115.5$^{b}_{A}$	898.6±12.6$^{ac}_{A}$	651.0±30.2$^{d}_{A}$	1414.5±84.6$^{a}_{B}$	1053.3±1.3$^{b}_{AB}$	603.8±7.3$^{c}_{AB}$	1166.9±39.5$^{bd}_{B}$	1699.1±153.9$^{a}_{C}$	1804.4±62.4$^{a}_{C}$	1315.0±172.0$^{b}_{C}$
C17:0	35.8±2.7$^{a}_{A}$	52.4±3.4$^{b}_{A}$	36.8±3.9$^{a}_{A}$	36.8±3.2$^{a}_{A}$	20.6±2.2$^{a}_{B}$	32.4±9.6$^{b}_{B}$	8.4±0.0$^{c}_{B}$	33.2±1.1$^{b}_{A}$	37.7±29.6$^{a}_{A}$	58.7±31.6$^{a}_{A}$	72.2±16.1$^{b}_{C}$
C18:0	199.9±20.5$^{a}_{A}$	367.5±10.7$^{b}_{A}$	309.6±9.5$^{bc}_{A}$	147.4±14.2$^{d}_{A}$	526.6±13.6$^{a}_{B}$	464.7±23.4$^{a}_{B}$	266.0±0.6$^{b}_{B}$	391.5±9.6$^{c}_{B}$	405.9±65.1$^{a}_{BC}$	334.7±15.8$^{a}_{A}$	581.5±26.9$^{a}_{C}$
C20:0	7.0±1.6$^{a}_{A}$	26.1±0.8$^{b}_{A}$	8.9±0.8$^{a}_{A}$	13.0±0.8$^{c}_{A}$	3.2±0.0$^{a}_{B}$	34.9±10.7$^{b}_{AB}$	0.8±0.1$^{c}_{B}$	45.1±1.2$^{bd}_{B}$	188.3±17.8$^{a}_{C}$	238.1±10.4$^{b}_{C}$	239.4±26.9$^{b}_{C}$
C22:0	57.1±35.2$^{a}_{A}$	66.5±8.6$^{ab}_{A}$	27.5±1.5$^{ac}_{A}$	26.8±2.3$^{ac}_{A}$	7.1±0.2$^{a}_{B}$	7.7±0.4$^{a}_{B}$	4.0±0.1$^{b}_{B}$	15.3±1.7$^{c}_{B}$	25.1±0.0$^{a}_{C}$	20.7±10.4$^{a}_{C}$	7.6±0.0$^{b}_{C}$
C24:0	23.8±12.8$^{a}_{A}$	32.7±2.7$^{bc}_{A}$	32.1±3.5$^{b}_{A}$	8.5±1.2$^{d}_{A}$	3.6±0.1$^{a}_{B}$	22.2±9.3$^{b}_{AB}$	0.8±0.2$^{c}_{B}$	2.5±0.7$^{ad}_{A}$	37.7±5.9$^{a}_{AC}$	20.7±17.9$^{b}_{AB}$	19.0±5.4$^{b}_{AC}$
ΣSFA	1264.1±105$^{a}_{A}$	2096.7b±9.2 $^{b}_{A}$	1431.9±0.8$^{a}_{A}$	974.9±51.0$^{c}_{A}$	2185.7±68.4$^{a}_{B}$	1785.3±17.1$^{b}_{B}$	1004.5±9.1$^{c}_{B}$	1809.7±32.1$^{b}_{B}$	2728.6±177.6$^{a}_{C}$	2919.0±12.0$^{a}_{C}$	2459.7±91.4$^{ab}_{C}$
C14:1	11.4±8.6$^{a}_{A}$	25.6±1.2$^{b}_{A}$	20.0±1.9$^{b}_{A}$	2.3±0.2$^{c}_{A}$	2.2±0.2$^{a}_{B}$	8.9±1.0$^{b}_{B}$	1.2±0.1$^{a}_{B}$	1.6±0.1$^{a}_{AB}$	16.7±0.0$^{a}_{AC}$	20.7±0.0$^{a}_{AC}$	7.6±0.0$^{b}_{C}$
C15:1	18.5±2.4$^{a}_{A}$	27.6±0.6$^{b}_{A}$	17.8±0.5$^{a}_{A}$	11.3±1.3$^{d}_{A}$	5.3±1.1$^{a}_{B}$	6.6±0.1$^{a}_{B}$	5.1±0.7$^{a}_{B}$	1.2±0.1$^{b}_{B}$	12.6±5.9$^{a}_{AC}$	10.4±0.0$^{a}_{C}$	11.4±5.4$^{a}_{AC}$
C16:1	52.1±11.4$^{a}_{A}$	50.8±7.6$^{a}_{A}$	23.3±2.6$^{b}_{A}$	36.3±1.6$^{c}_{A}$	307.0±53.4$^{a}_{B}$	292.3±0.0$^{a}_{B}$	200.5±10.8$^{b}_{B}$	212.3±4.1$^{b}_{B}$	405.9±17.8$^{a}_{BC}$	583.1±23.9$^{a}_{C}$	231.8±5.4$^{b}_{BC}$
C17:1	4.3±0.9$^{a}_{A}$	35.7±1.6$^{b}_{A}$	15.6±1.9$^{c}_{A}$	5.0±0.5$^{a}_{A}$	47.8±11.0$^{a}_{B}$	36.3±16.0$^{a}_{A}$	2.1±0.1$^{b}_{B}$	7.0±0.6$^{c}_{A}$	75.3±59.2$^{a}_{C}$	44.9±6.0$^{b}_{A}$	64.6±5.4$^{ac}_{C}$
C18:1n-9	824.5±49.9$^{a}_{A}$	1513.9±13.6$^{b}_{A}$	1015.4±24.8$^{c}_{A}$	487.9±35.6$^{d}_{A}$	1578.5±87.0$^{a}_{B}$	1518.4±35.7$^{a}_{A}$	733.4±82.7$^{b}_{B}$	1187.4±28.4$^{c}_{B}$	1222.0±47.3$^{a}_{BC}$	1600.8±115.4$^{b}_{A}$	725.9±69.9$^{c}_{B}$
C20:1	14.3±4.1$^{a}_{A}$	28.5±10.0$^{b}_{A}$	12.9±0.9$^{a}_{A}$	16.3±2.4$^{ac}_{A}$	76.0±3.6$^{a}_{B}$	78.6±8.4$^{a}_{B}$	3.2±0.1$^{b}_{B}$	50.9±2.7$^{c}_{B}$	175.8±71.0$^{a}_{C}$	248.4±186.6$^{b}_{C}$	83.6±10.7$^{c}_{C}$
C22:1n-9	32.1±6.0$^{a}_{A}$	35.0±2.7$^{a}_{A}$	16.5±2.3$^{b}_{A}$	13.4±2.1$^{b}_{A}$	25.6±11.1$^{a}_{A}$	8.5±0.4$^{b}_{B}$	19.4±0.1$^{ac}_{A}$	13.6±0.7$^{ad}_{A}$	20.9±5.9$^{a}_{A}$	24.2±6.0$^{a}_{AC}$	19.0±5.4$^{a}_{A}$
C24:1	16.8±4.6$^{a}_{A}$	39.5±7.4$^{b}_{A}$	6.9±0.7$^{c}_{A}$	8.5±1.1$^{c}_{A}$	55.8±2.5$^{a}_{B}$	16.2±5.0$^{b}_{B}$	25.9±0.6$^{c}_{B}$	13.2±1.1$^{b}_{B}$	62.8±17.8$^{a}_{B}$	34.5±21.5$^{ab}_{A}$	60.8±10.7$^{ac}_{C}$
ΣMUFA	974.0±55.1$^{a}_{A}$	1756.6±6.1$^{b}_{A}$	1128.4±35.6$^{ac}_{A}$	581.0±44.4$^{d}_{A}$	2098.2±140.3$^{a}_{B}$	1965.8±36.9$^{a}_{A}$	990.8±70.5$^{b}_{B}$	1487.2±30.2$^{c}_{B}$	1992.0±183.5$^{a}_{BC}$	2567.0±250.4$^{b}_{B}$	1204.7±5.4$^{c}_{A}$
C18:2n-6	314.7±33.8$^{a}_{A}$	488.8±43.7$^{ab}_{A}$	227.2±11.8$^{c}_{A}$	247.8±11.4$^{c}_{A}$	188.2±10.3$^{a}_{B}$	147.3±2.8$^{b}_{B}$	106.8±1.7$^{c}_{B}$	138.5±5.2$^{a}_{B}$	226.0±0.0$^{a}_{C}$	248.4±10.4$^{a}_{C}$	235.6±21.5$^{a}_{A}$
C18:3n-6	4.5±1.1$^{a}_{A}$	26.3±11.7$^{b}_{A}$	8.0±0.9$^{ac}_{A}$	2.8±0.0$^{d}_{A}$	3.8±0.1$^{a}_{A}$	3.7±1.3$^{a}_{B}$	1.9±0.6$^{b}_{B}$	4.0±0.5$^{a}_{AB}$	29.3±5.9$^{a}_{B}$	24.2±12.0$^{a}_{A}$	60.8±10.7$^{b}_{C}$
C18:3n-3	6.9±1.7$^{a}_{A}$	121.3±4.2$^{b}_{A}$	15.4±6.4$^{c}_{A}$	7.8±0.1$^{c}_{A}$	51.0±5.2$^{a}_{B}$	28.0±0.3$^{b}_{B}$	19.6±5.0$^{b}_{A}$	48.3±2.8$^{a}_{B}$	12.6±5.9$^{a}_{C}$	3.5±1.0$^{b}_{C}$	3.8±1.4$^{b}_{B}$
C18:3n-4	32.8±24.4$^{a}_{A}$	133.2±6.0$^{b}_{A}$	60.1±4.2$^{c}_{A}$	4.4±0.2$^{d}_{A}$	14.7±1.1$^{a}_{B}$	3.4±0.3$^{b}_{B}$	1.8±0.3$^{c}_{B}$	5.0±0.2$^{bd}_{A}$	29.3±5.9$^{a}_{A}$	24.2±6.0$^{a}_{C}$	15.2±0.0$^{b}_{C}$

Table 3. Seasonal variations in fatty acid composition of red mullet, Mediterranean horse mackerel and garfish (mg per 100g of edible muscle) (Continued)

Fatty Acids	Red mullet				Mediterranean horse mackerel				Garfish		
	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring
C20:3n-3	$63.1 \pm 16.7^{a}_{A}$	$143.2 \pm 17.4^{b}_{A}$	$60.0 \pm 7.6^{a}_{A}$	$37.5 \pm 0.7^{c}_{A}$	$36.9 \pm 9.5^{a}_{AB}$	$67.1 \pm 6.2^{b}_{B}$	$32.1 \pm 5.5^{a}_{B}$	$36.8 \pm 1.4^{a}_{A}$	$12.6 \pm 5.9^{a}_{C}$	$6.9 \pm 6.0^{b}_{C}$	$7.6 \pm 0.0^{b}_{C}$
C20:2	$32.5 \pm 14.3^{a}_{A}$	$63.2 \pm 9.3^{b}_{A}$	$66.0 \pm 3.2^{b}_{A}$	$12.3 \pm 1.5^{c}_{A}$	$21.1 \pm 2.1^{a}_{B}$	$28.2 \pm 2.1^{a}_{B}$	$14.8 \pm 0.8^{b}_{B}$	$18.0 \pm 1.4^{b}_{B}$	$71.1 \pm 17.8^{a}_{C}$	$117.3 \pm 6.0^{b}_{C}$	$87.4 \pm 16.1^{a}_{AC}$
C22:2	$24.1 \pm 2.1^{a}_{A}$	$49.4 \pm 4.4^{b}_{A}$	$13.0 \pm 0.8^{c}_{A}$	$4.4 \pm 0.5^{d}_{A}$	$2.1 \pm 0.2^{a}_{B}$	$2.7 \pm 0.0^{a}_{B}$	$2.4 \pm 0.1^{a}_{B}$	$4.2 \pm 0.4^{b}_{A}$	$50.2 \pm 11.8^{a}_{C}$	$75.9 \pm 6.0^{b}_{C}$	$45.6 \pm 10.7^{a}_{C}$
C20:4n-6	$14.0 \pm 8.8^{a}_{A}$	$36.0 \pm 5.1^{b}_{A}$	$20.2 \pm 3.7^{a}_{A}$	$11.2 \pm 0.8^{c}_{A}$	$11.4 \pm 2.7^{a}_{A}$	$6.8 \pm 0.5^{b}_{B}$	$27.2 \pm 14.5^{c}_{A}$	$47.9 \pm 3.6^{d}_{B}$	$96.3 \pm 17.8^{a}_{B}$	$165.6 \pm 82.2^{ab}_{C}$	$110.2 \pm 16.1^{ac}_{C}$
C20:5n-3	$219.1 \pm 39.2^{a}_{A}$	$395.2 \pm 2.4^{b}_{A}$	$296.0 \pm 24.4^{bc}_{A}$	$223.9 \pm 10.2^{a}_{A}$	$361.0 \pm 10.8^{a}_{B}$	$357.0 \pm 14.0^{a}_{AB}$	$280.6 \pm 9.9^{c}_{A}$	$315.5 \pm 22.8^{ab}_{B}$	$418.5 \pm 11.8^{a}_{C}$	$493.4 \pm 36.3^{ab}_{C}$	$338.2 \pm 26.9^{c}_{B}$
C22:5n-3	$9.0 \pm 5.5^{a}_{A}$	$33.4 \pm 9.6^{b}_{A}$	$13.7 \pm 3.3^{a}_{A}$	$4.6 \pm 0.8^{c}_{A}$	$13.1 \pm 3.0^{a}_{A}$	$12.5 \pm 0.3^{a}_{B}$	$5.1 \pm 0.1^{b}_{B}$	$76.0 \pm 9.8^{c}_{B}$	$255.3 \pm 17.8^{a}_{B}$	$293.3 \pm 21.5^{b}_{C}$	$273.6 \pm 32.2^{ac}_{C}$
C22:5n-6	$81.2 \pm 7.2^{a}_{A}$	$123.2 \pm 14.2^{b}_{A}$	$63.5 \pm 3.0^{c}_{A}$	$34.2 \pm 1.2^{d}_{A}$	$124.4 \pm 10.0^{a}_{B}$	$146.8 \pm 7.3^{ac}_{AB}$	$68.4 \pm 3.0^{c}_{A}$	$66.4 \pm 9.7^{c}_{B}$	$75.3 \pm 11.8^{a}_{A}$	$75.9 \pm 6.0^{a}_{C}$	$102.6 \pm 16.1^{b}_{B}$
C22:6n-3	$362.1 \pm 11.1^{a}_{A}$	$659.3 \pm 42.0^{b}_{A}$	$257.7 \pm 8.9^{c}_{A}$	$476.3 \pm 22.1^{d}_{A}$	$1094.5 \pm 219.6^{a}_{B}$	$685.1 \pm 9.5^{b}_{A}$	$407.4 \pm 23.1^{c}_{B}$	$1229.0 \pm 39.4^{d}_{B}$	$2180.4 \pm 183.5^{a}_{C}$	$2653.1 \pm 76.3^{b}_{B}$	$2458.9 \pm 80.6^{c}_{C}$
ΣPUFA	$1164.0 \pm 233^{a}_{A}$	$2272.5 \pm 6.0^{b}_{A}$	$1100.8 \pm 78.2^{a}_{A}$	$1067.2 \pm 46.6^{a}_{A}$	$1922.2 \pm 202.7^{a}_{B}$	$1488.6 \pm 13.4^{b}_{B}$	$968.1 \pm 44.3^{c}_{A}$	$1989.6 \pm 74.5^{a}_{B}$	$3456.9 \pm 189.4^{a}_{C}$	$4181.7 \pm 83.7^{b}_{C}$	$3739.5 \pm 215.0^{ac}_{B}$
EPA+DHA	$581.2 \pm 25.1^{a}_{A}$	$1054.5 \pm 22.2^{b}_{A}$	$553.7 \pm 16.7^{a}_{A}$	$700.2 \pm 16.5^{c}_{A}$	$1455.5 \pm 113.2^{a}_{B}$	$1042.1 \pm 11.7^{b}_{A}$	$688.0 \pm 16.5^{c}_{AB}$	$1544.5 \pm 33.1^{a}_{B}$	$2598.9 \pm 97.5^{a}_{C}$	$3146.5 \pm 66.3^{b}_{B}$	$2797.1 \pm 53.4^{ac}_{B}$
∑n3	$660.2 \pm 173^{a}_{A}$	$1352.4 \pm 43.2^{b}_{A}$	$642.8 \pm 50.6^{a}_{A}$	$750.1 \pm 33.9^{ac}_{A}$	$1556.5 \pm 229.0^{a}_{B}$	$1149.7 \pm 2.2^{b}_{A}$	$744.8 \pm 33.5^{c}_{A}$	$1705.6 \pm 73.4^{ad}_{B}$	$2879.4 \pm 183.5^{a}_{C}$	$3450.2 \pm 197.5^{b}_{B}$	$3082.1 \pm 311.7^{bc}_{B}$
∑n6	$414.4 \pm 45.3^{a}_{A}$	$674.3 \pm 42.1^{b}_{A}$	$318.9 \pm 23.6^{c}_{A}$	$296.0 \pm 13.7^{cd}_{A}$	$327.8 \pm 24.1^{a}_{AB}$	$304.6 \pm 9.1^{a}_{B}$	$204.3 \pm 10.1^{b}_{B}$	$256.8 \pm 0.7^{b}_{AB}$	$426.9 \pm 165.7^{a}_{A}$	$514.1 \pm 92.8^{ab}_{AC}$	$509.3 \pm 69.9^{b}_{A}$
∑n3/∑n6	1.60	2.0	2.0	2.5	4.7	3.8	3.6	6.6	6.7	6.7	6.1

±SD, n: 3, Different superscript lowercase letters (a, b, c.) in the same row represent significant differences among the seasons for the same fish species ($p<0.05$), Different subscript uppercase letters (A, B, C) in the same row represent significant differences among fish species for the same season ($p<0.05$).
SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid, DHA: socosahexaenoic acid

Human consume generally fish muscle. Therefore, the fatty acid content of the fish muscle of fish species living in their ecosystem can provide precious data to nutritional science (Rodriguez et al., 2004). However, despite of various research studies on the fat content, and the fatty acid profile of different fish species, only limited reports exist on the calculated values in terms of how much of these values can relate to edible portion of the analysed fish (Testi et al., 2006). Total FAME % is commonly used to report fatty acid content of fish species in past studies. Therefore, this study provides additional information on fatty acid contents as mg of fatty acids per 100 g of edible muscle shown in Table 3. Because of seasonal changes in fat content and FAME %, considerable variations ($p<0.05$) were also accounted for the fatty acid levels calculated as mg per 100 g of the edible portion. The highest EPA and DHA values were found as 493.4 and 2653.1 mg per 100g, respectively for garfish in winter.

Some health institutions recommended the daily level of n-3 PUFA and EPA + DHA intake rates as 0.2-0.45g and 0.5-1.0g. These levels vary depending on the amount of other fatty acids such as arachidonic linoleic, and a-linolenic acids (Gogus and Smith, 2010; Candela et al., 2011). The lowest n-3 PUFA was found for red mullet in spring and the highest for garfish in winter with a significant variation among seasons ($p<0.05$) as 642.8 and 3450.2 mg per 100 g of the edible fish portion, respectively. Kocatepe and Turan (2012) obtained the lower amount of n-3 PUFA for garfish and red mullet as 310 mg and as 110 mg in January.

Several health agencies have indicated that 4550 mg of EPA + DHA is adequate for a normal adult to meet their weekly needs. (Testi et al., 2006). In this study, the highest EPA+DHA levels were accounted as 3146.5 mg/100 g of the edible portion for garfish as in winter and the lowest for red mullet as 553.7 mg/100 g in spring with significant changes among the seasons ($p<0.05$). Thus, using the highest EPA+DHA levels, only 145 g of garfish is enough in winter to cover weekly requirement of EPA+DHA although about 431 g of edible fish muscle requires being consumed from red mullet in winter for the same requirement. The highest EPA+DHA content was obtained in summer for Mediterranean horse mackerel. Therefore, about 295 g was estimated to cover recommended the weekly requirement of EPA+DHA for the relating month for this species. Polat et al. (2009) reported lower amount of EPA+DHA for red mullet captured from the north-eastern Mediterranean Sea, so higher amount of edible muscle requires to be consumed to cover the weekly recommended value.

CONCLUSION

This study demonstrated that significant seasonal changes in lipid contents and fatty acid compositions for three fish species living in different sea zones (pelagic, semi-pelagic and demersal) of Turkish Black Sea. The results also showed that there were significant differences among the species in the values of lipid and fatty acid profile with some exceptions. The results indicated that the highest total PUFA, omega-3, EPA and DHA were observed for garfish. One of the reasons might have been attributed to high levels of fat content in the muscle of garfish. Therefore, although about 431 g of edible muscle requires being consumed from red mullet, only 145 g of garfish is enough in winter to cover weekly requirement of EPA+DHA. So, this study indicates that this species is a better nutritional source than other fish species analyzed in terms of contributing to health benefit for human consumption.

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