BF-1770
[1-9]

RESEARCH ARTICLE Indian Journal of Animal Research

Sex-based Differences in Fatty Acids and Macro Elements Composition in Garfish, European Barracuda and Anglerfish from Aegean Sea, Türkiye

M.P. Olgunoglu[1], I.A. Olgunoglu[1], E. Artar[1]

ABSTRACT

Background: Fish, owing to its nutritional attributes, serves as a pivotal component of a wholesome diet. The constituents found in fish, specifically macroelements and polyunsaturated fatty acids (PUFA), play a crucial role in promoting human health. This study investigates the fatty acid profiles and macro element contents of economically significant fish species, including garfish (*Belone belone*), European barracuda (*Sphyraena sphyraena*) and anglerfish (*Lophius piscatorius*), with a specific focus on gender-based differences. The research addresses a notable gap in existing literature, providing a comprehensive evaluation of the nutritional quality of these species.

Methods: In February 2023, marine fish species, were obtained from the Aegean Sea located between the western and southwestern shores of Türkiye and the eastern shores of Greece. A total of fifteen samples, representing each fish species and gender within the sampling area, were collected for the analysis of fatty acids and macro elements.

Result: The findings of this study indicate that, regardless of fish species and gender, the major fatty acids in the SFAs, MUFAs and PUFAs classes were palmitic (C16:0), oleic (C18:1n-9) and DHA (C22:6n-3), respectively. The examined species in this study exhibit average macro element levels. While PUFA, EPA and DHA values meet target levels of content for human health and quality food consumption, achieving these levels minimally implies that the studied species lack a rich fatty acid profile compared to those in prior research. Nonetheless, it is concluded that monitoring seasonal variations is essential for a comprehensive understanding of their fatty acid composition.

Key words: Aegea sea, Fatty acid, Gender, Macro element, Marine fish.

INTRODUCTION

Marine fish have gained increasing attention due to their rich sources of health-beneficial nutrients, making fish a vital component of both a healthy and regular diet. (Devadawson *et al*., 2017; Sit *et al*., 2021). The nutrients in fish, particularly polyunsaturated fatty acids (PUFA), play a crucial role in human health, contributing to various aspects from embryological development to the prevention and treatment of conditions such as arthritis, inflammation, autoimmune diseases, type 2 diabetes, hypertension, kidney and skin disorders and cancer in both children and adults. Essential fatty acids like eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA), which cannot be synthesized by the human body, necessitate their intake through diet. Fish lipids provide a valuable supply of both EPA and DHA. The health advantages of these fatty acids have been thoroughly examined in numerous studies. Consequently, the regular inclusion of fish in human nutrition is recommended (Taşbozan and Gökçe, 2017).

Daily recommended intake levels of EPA and DHA vary across countries, ranging from 500 mg/day in France to 1-2 g/day in Norway. In the USA, adult adequate intakes have been established at 1.6 g n-3 fatty acids (ALAs-alpha-linolenic acid) per day for men, 1.1 g/day for women and 17 g n-6 fatty acids (LA- linoleic acid) per day for men (19-50 years of age) and 12 g/day for women (19-50 years of age) (Candela *et al*., 2011; www.nutri-facts.org). In terms of international organizations, the World Health Organization (WHO) recommends a daily consumption range of 0.3-0.5 g, the International Society for the Study of Fatty Acids and Lipids (ISSFAL) advocates for 500 mg/day and the North Atlantic Treaty Organization (NATO) suggests 800 mg/day. Additionally, the American Heart Association and the Academy of Nutrition and Dietetics recommend a weekly intake of two 4-ounce servings of fish, roughly equivalent to 500 mg of EPA and DHA per day (Candela *et al*., 2011; Watters *et al.,* 2012).

The fatty acid profile in marine fish oils is influenced by the composition of fatty acids present in the natural diet of these aquatic species. Consequently, while all fish species contain a variety of fatty acids, including EPA and

[1]Adiyaman University, 02400 Kahta-Adiyaman, Türkiye.

Corresponding Author: M.P. Olgunoglu, Adiyaman University, 02400 Kahta-Adiyaman, Türkiye. Email: mineper@yahoo.com

How to cite this article: Olgunoglu, M.P., Olgunoglu, I.A. and Artar, E. (2024). Sex-based Differences in Fatty Acids and Macro Elements Composition in Garfish, European Barracuda and Anglerfish from Aegean Sea, Türkiye. Indian Journal of Animal Research.

Submitted: 01-02-2024 **Accepted:** 30-04-2024 **Online:**

DHA, the quantities of these substances exhibit significant variation among and within species, as well as in different sections and types of muscle. This variation is attributed to environmental factors such as temperature, salinity, season of capture, life stage, habitat and age. Furthermore, distinctions arise based on whether the fish are herbivorous, omnivorous, or carnivorous (Kuley *et al*. 2008; Akpinar *et al.,* 2009; Olgunoglu, 2017). Additionally, the composition of fish fatty acids closely correlates with their sex, though researchers have not fully unraveled the intricacies of these sex-specific variations (Liu *et al*., 2023).

Minerals play a pivotal role in numerous biochemical reactions within the human body and it is crucial to ensure their consumption aligns with the organism's requirements (Artar *et al.,* 2022). The elements present in fish can be broadly categorized into two groups: macro and micro elements (Karataþ, 2021). Macro elements, which include Magnesium (Mg), Calcium (Ca), Phosphorus (P), Sodium (Na) and Potassium (K) are essential for human health, playing critical roles in biological systems and requiring higher concentrations in the body. For example, Ca, P and Mg contribute to bone health, Na is important for nerve and muscle function and K aids in nerve function and muscle contraction. On the other hand, micro elements such as Iron (Fe), Zinc (Zn), Copper (Cu) and Chromium (Cr), though essential for human life, can have varying effects, either beneficial or harmful, depending on their concentration-often equivalent to less than a teaspoon per person's body weight (Artar *et al*., 2022; Olgunoglu *et al*., 2014). As a result, the consumption of fish or the supplementation of fish oil, whether from freshwater or marine sources, is highly encouraged (Kumaran *et al*., 2012).

In this research, primary objective to investigate gender-based differences in the fatty acid and macro elements (Mg, Ca, P, Na and K) composition of garfish (*Belone belone*), European barracuda *(Sphyraena sphyraena*) and anglerfish (*Lophius piscatorius*) which have economic value in Turkish markets. Notably, a comprehensive review of existing literature has underscored the inadequacy of studies pertaining to the fatty acid and mineral composition of these species. This research seeks to address this gap and contribute valuable insights to the understanding of the nutritional profiles of these economically significant fish.

MATERIALS AND METHODS

Fish samples

In this study conducted in February 2023, marine fish species, including garfish and European barracuda classified as pelagic, as well as anglerfish categorized as demersal, were obtained from the Aegean Sea located between the western and southwestern shores of Türkiye and the eastern shores of Greece. Sampling area is given in Fig 1.

After collection, the fish samples were promptly rinsed with clean seawater, preserved in crushed ice and transported to the laboratory on the same day. In the laboratory, during the gender determination process, the head, fins, scales, skin, gonads and all internal organs, along with muscle tissue, are removed. Subsequently, edible muscle tissue samples undergo washing with distilled water, after which they are placed in labeled polyethylene bags. These bags are then stored at -20°C until they are sent to the Accredited Industrial Services Laboratory of Turkiye in Izmir for analysis of fatty acids and element. Dry ice is used during transportation to ensure low temperatures and preserve sample integrity. In the study, a sample comprising 15 males and 15 females was employed for each species.

Lipid and fatty acid analyses

Lipids were extracted with chloroform/methanol (2:1, v/v), determined according to the method outlined by Bligh and Dyer (1959) and quantified as g/100. The methyl esters of fatty acids in the samples were prepared following IUPAC Methods II.D.19.

The analyses were conducted using a Perkin Elmer Autosystem XL Gas Chromatography equipped with a Flame Ionization Detector (FID) and a Supelco 2330 fused silica capillary column (30 m × 0.25 mm × 0.20 µm film thickness) to determine the fatty acid composition. The following working conditions were meticulously maintained: Sample working conditions on the GC device:

Column temperature program: 2 minutes at 120°C, followed by 10 minutes at 220°C with a 15°C increase, resulting in a total analysis time of 32 minutes.
Injector temperature: 240°C.
Carrier gas: Helium at a flow rate of 0.5 ml/min.
Detector temperature: 260°C.
Hydrogen (H2) flow rate: 45 ml/min.
Air flow rate: 450 ml/min.
Sample injection volume: 2 µl.
Maximum column temperature: 280°C.
Split flow: 50 m.

Lipids nutritional quality indexes

The nutritional quality of the total lipids was evaluated using three indices. The Atherogenicity Index (AI) and Thrombogenicity Index (TI), in accordance with Ulbricht and Southgate (1991), Santos-Silva *et al.* (2002) with modifications and the calculation of Hypocholesterolemic/Hypercholesterolemic ratio (h/H) indices, were performed as follows:

$$AI = [(C12{:}0 + (4 \times C14{:}0) + C16{:}0)] / [MUFA + \Sigma (n-6) + \Sigma (n-3)]$$

$$TI = (C14{:}0 + C16{:}0 + C18{:}0) / [(0.5 \times \Sigma MUFA) + (0.5 \times \Sigma n\text{-}6) + (3 \times \Sigma n\text{-}3) + (\Sigma n\text{-}3/\Sigma n\text{-}6)]$$

$$H/H = [(C18{:}1n\text{-}9 + C18{:}2n\text{-}6 + C18{:}3n\text{-}3 + C20{:}4n6 + C20{:}5n3 + C22{:}5n\text{-}3 + C22{:}6n\text{-}3) / (C14{:}0 + C16{:}0)]$$

Mineral analyses

The mineral content of muscle tissues was determined by Inductively Coupled Plasma-Optical Emission Spectroscopy

(ICP-OES) according to the Association of Official Analytical Chemists analysis method (AOAC, 2012). 0.5 g sample of fish muscle (wet weight) was meticulously weighed and introduced into a teflon digestion vessel, accompanied by 6 ml of concentrated (65%) nitric acid (HNO_3) and 1.5 ml of 30% hydrogen peroxide (H_2O_2). The digestion process was facilitated using a microwave digestion system (Milestone Ethos PLUS). The primary minerals assessed included calcium (Ca), phosphorus (P), potassium (K), sodium (Na) and magnesium (Mg). The concentrations were quantified and expressed as milligrams per kilogram (mg/kg) of wet weight of tissue in organisms.

Statistical analysis

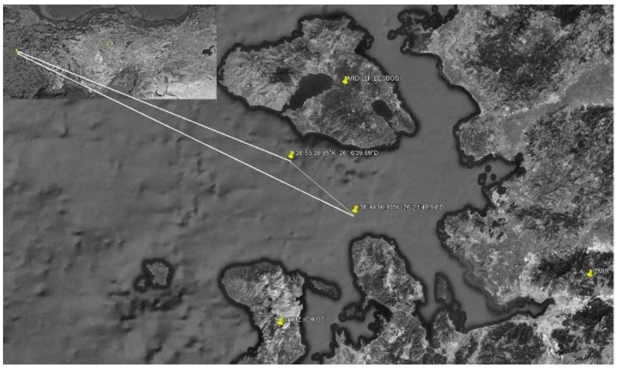
The results of the analysis are expressed as mean ± standard deviation (SD), with all analyses being conducted in triplicate. One-way analysis of variance (ANOVA) tests was applied to the data and mean comparisons were carried out using the independent t-Test and Post hoc test (Duncan) with the SPSS program version 21.0 for Windows. The significance level used was 5% ($p<0.05$).

RESULTS AND DISCUSSION

Table 1 presents the percentage values of total lipid content for three fish species from the Aegean Sea, Turkiye. The highest lipid values, 6.20±0.3%, were observed in the edible muscle tissue of female European barracuda, followed by 5.23±0.2% in the male counterparts ($p<0.05$). This was followed by 4.10±0.20% in the tissue of male garfish and 4.00±0.09% in female garfish tissue ($p>0.05$). The lowest values were recorded as 0.62±0.1% in male anglerfish and 0.64±0.1% in female anglerfish, which are demersal ($p>0.05$). Statistical significance in lipid contents was observed regardless of fish species and gender, with a significance level of $p<0.05$ when compared to each other. The results from our study indicate that garfish and European barracuda have lower lipid content compared to the values reported by Tufan *et al*. (2018) as 8.3±0.2-9.3±2.0% and Durmuş (2019) as 8.23%, respectively, for the same species. In contrast, anglerfish showed higher lipid contents than those reported by Prego *et al*. (2012), ranging from 0.322 to 0.342 g/100 g±0.29. Additionally, in a study conducted by Mesa *et al*. (2021) on anglerfish, the lipid content was also reported as 0.6 g/100 g, which is a similar value to that observed in our study. Numerous scientific studies and resources confirm that the lipid content of fish varies significantly among different species and even within the same species. This variability is closely tied to their body composition, with distinctions in lipid compositions of certain fish species influenced by factors such as the spawning period, fish feeding patterns and seasonal fluctuations (Taşbozan and Gökçe, 2017). According to a report by Juszczak and Szymczak (2009), fish are categorized based on their fat content into four groups: lean (up to 2% fat), semi-fat fish (2-7% fat), fatty fish (7-15% fat) and very fat (over 15% fat). Based on the our results, European barracuda and garfish is categorized in the semi-fat fish group, while anglerfish is categorized as a lean fish. The lipid composition in lean or fatty fish is typically influenced by the location and manner in which lipids are stored. For instance, according to a report by Taþbozan and Gökçe (2017), Cod fish are recognized as lean fish, storing lipids exclusively in their liver rather than in their muscle tissues (fillet). In contrast, salmon and trout species accumulate lipids in their muscle tissues and surrounding organs, with minimal storage occurring in their liver. In parallel with this idea, it was thought that the samples we examined in our study accumulated lipids in their muscles at a minimum level.

Fish serves as an excellent alternative to meat because of its rich content of polyunsaturated fatty acids (Kamble *et al*., 2023). People usually consume the muscle of fish. Hence, the fatty acid composition in the muscle tissue of fish species residing in their ecosystem can offer valuable information for the field of nutritional science (Rodriguez *et al*., 2004). The composition of fatty acids in the edible muscle tissues of garfish (*B. belone*), European barracuda (*S. sphyraena*) and anglerfish (*L. piscatorius*) is presented in Table 2.

Twenty-nine fatty acids were identified in the muscle tissue of both sexes across three species. Quantitative differences were determined and classified into saturated fatty acids (SFAs), monounsaturated fatty acids (MUFAs) and polyunsaturated fatty acids (PUFAs). The analysis revealed that total saturated fatty acid (SFA) levels were



(38°55′38.95″ N-26°6′39.69″E/38°44′56.80″N-26°21′48.54″E)

Fig 1: Sampling area.

Table 1: Total lipid contents (g/100g) in edible muscle tissue of garfish, European barracuda and anglerfish from Aegean Sea, Türkiye.

Gender	Garfish	European barracuda	Anglerfish
♂	4.10±0.20^{b}	5.23±0.2^{c}	0.62±0.1^{a}
♀	4.00±0.09^{b}	6.20±0.3^{*c}	0.64±0.1^{a}

Values with distinct superscript letters within the same row indicate significant differences between groups for each sample ($p<0.05$). (*) indicates the difference between males and females in the same species.

higher in males across all species (p>0.05) while total polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) were found to be higher in females compared to males (p>0.05). Additionally, the fatty acid composition in muscle tissues of male fish follows the order SFA>MUFA>PUFA However, this pattern varies in edible muscle tissues of female fish, with garfish and European barracuda showing the sequence MUFA> SFA>PUFA. In the case of anglerfish, the fatty acid arrangement in female muscle tissue remains consistent

Table 2: Fatty acid profiles in edible muscle tissue of garfish, European barracuda and anglerfish from Aegean Sea, Türkiye.

Fatty acids (%)	Garfish		European barracuda		Anglerfish	
	♂	♀	♂	♀	♂	♀
C8:0	0.23±0.03^{a}	0.25±0.04^{a}	0.15±0.02^{b}	0.09±0.02^{b}	0.17±0.01^{a}	0.22±0.07^{a}
C10:0	0.22±0.07^{a}	0.15±0.01^{a}	0.13±0.01^{ab*}	0.06±0.01^{ab}	0.25±0.12^{b}	0.28±0.13^{b}
C12:0	0.55±0.09^{a}	0.70±0.01^{a}	0.60±0.04^{*b}	0.30±0.01^{b}	0.83±0.11^{c}	0.88±0.12^{c}
C14:0	7.21±1.21^{b}	5.81±0.91^{b}	3.6±0.71^{ab}	6.35±1.01^{ab}	3.83±0.98^{a}	3.87±0.66^{a}
C15:0	1.85±0.01^{a*}	1.33±0.08^{a}	1.26±0.31^{b}	0.94±0.21^{b}	1.54±0.03^{b}	1.71±0.09^{b}
C16:0	23.14±1.01^{a}	20.26±1.61^{a}	26.5±0.97^{*a}	20.16±0.81^{a}	28.31±1.11^{b}	25.89±1.03^{b}
C17:0	2.78±0.62^{a}	1.22±0.23^{a}	1.06±0.06^{a}	1.46±0.21^{a}	1.72±0.01^{a}	1.92±0.22^{a}
C18:0	10.02±1.41^{a}	8.04±1.17^{a}	7.1±1.00^{a}	6.85±1.01^{a}	7.11±1.01^{b}	7.43±1.08^{b}
C20:0	0.99±0.21^{b}	0.48±0.05^{b}	0.33±0.05^{a}	0.25±0.11^{a}	0.41±0.0^{b}	0.91±0.07^{*b}
C22:0	0.34±0.11^{a}	0.30±0.01^{a}	0.14±0.03^{b}	0.19±0.02^{b}	0.58±0.08^{c}	0.69±0.04^{c}
C24:0	1.43±0.24^{ab*}	0.21±0.04^{ab}	0.26±0.06^{a}	0.50±0.08^{a}	0.81±0.14^{b}	1.15±0.11^{b}
ΣSFA	**48.76±6.75^{a}**	**38.75±5.97^{a}**	**41.13±7.60^{a}**	**37.15±5.92^{a}**	**45.56±8.14^{a}**	**44.95±7.30^{a}**
C14:1	0.44±0.07^{a}	0.41±0.01^{a}	0.43±0.08^{a}	0.25±0.01^{a}	0.77±0.01^{b}	0.86±0.06^{b}
C15:1	0.43±0.02^{*ab}	0.17±0.02^{ab}	0.17±0.01^{a}	0.13±0.01^{a}	0.32±0.01^{*ab}	0.16±0.00^{ab}
C16:1	5.54±1.07^{ab}	8.09±0.97^{ab}	8.7±1.01^{ab}	7.82±0.01^{ab}	7.51±0.01^{a}	7.68±0.88^{a}
C17:1	0.48±0.03^{a}	0.48±0.02^{a}	0.57±0.03^{b}	0.55±0.01^{b}	0.48±0.01^{b}	0.64±0.02^{*b}
C18:1 (n-9)	19.14±0.89^{a}	23.46±0.99^{a}	26.37±0.94^{b}	29.2±1.11^{b}	16.37±1.22^{c}	17.23±1.31^{c}
C18:1 (n-7)	0.29±0.04^{ab}	4.07±0.76^{ab*}	0.31±0.22^{a}	0.21±0.01^{a}	1.16±0.37^{ab}	0.2±0.00^{ab}
C20:1 (n-9)	1.25±0.02^{*a}	0.15±0.03^{a}	0.08±0.00^{a}	0.13±0.01^{*a}	0.17±0.02^{a}	0.28±0.01^{*a}
C22:1 (n-9)	0.09±0.01^{a}	0.23±0.03^{*a}	0.21±0.10^{a}	0.10±0.00^{a}	0.16±0.00^{a}	0.22±0.02^{a}
C24:1 (n-9)	1.17±0.14^{b}	2.74±0.80^{b}	0.69±0.02^{a}	0.71±0.02^{a}	2.37±0.58^{b}	2.89±0.55^{b}
ΣMUFA	**28.83±5.98^{a}**	**39.8±7.34^{a}**	**37.53±8.44^{a}**	**39.1±9.27^{a}**	**29.31±5.24^{a}**	**30.16±5.54^{a}**
C18:2 (n-6) (LA)	4.27±1.07^{b}	1.88±0.87^{b}	1.24±0.21^{a}	1.36±0.76^{a}	1.26±0.51^{a}	1.56±0.56^{a}
C18:3 (n-6)	0.08±0.01^{a}	0.56±0.10^{*a}	0.15±0.01^{b}	0.28±0.21^{b}	0.51±0.04^{*b}	0.33±0.02^{b}
C18:3 (n-3) (ALA)	0.3±0.01^{b}	0.6±0.06^{*b}	0.53±0.04^{a}	0.95±0.08^{*a}	0.65±0.08^{a}	0.95±0.11^{a}
C20:2 (n-6)	0.33±0.04^{a}	0.75±0.04^{*a}	0.3±0.03^{a}	0.16±0.02^{*a}	0.33±0.12^{b}	0.36±0.02^{b}
C20:3 (n-6)	0.24±0.01^{a}	0.33±0.03^{a}	0.62±0.32^{ab}	0.90±0.14^{ab}	0.21±0.01^{ab}	0.90±0.04^{*ab}
C20:4(n-6)(ARA)	1.15±0.55^{a}	1.67±0.44^{a}	1.32±0.70^{a}	1.18±0.21^{a}	3.14±0.74^{b}	5.08±1.00^{b}
C20:5 (n-3)(EPA)	2.23±0.97^{a}	1.56±0.81^{a}	2.16±0.21^{ab}	2.69±0.81^{ab}	1.72±0.24^{ab}	1.05±0.08^{ab}
C22:5 (n-3)(DPA)	0.56±0.03^{a}	0.82±0.09^{a}	0.53±0.01^{a}	0.63±0.01^{*a}	0.89±0.01^{b}	0.96±0.21^{b}
C22:6(n-3) (DHA)	11.48±1.41^{a}	12.7±1.11^{a}	14.19±1.21^{b}	15.42±1.37^{b}	14.9±1.21^{b}	13.54±1.01^{b}
ΣPUFA	**20.64±3.60^{a}**	**20.87±3.81^{a}**	**21.04±4.33^{a}**	**23.57±5.06^{a}**	**23.61±4.53^{a}**	**24.73±4.16^{a}**
AI	1.06	0.73	0.71	0.73	0.84	0.77
TI	0.64	0.47	0.48	0.39	0.52	0.53
h/H	1.29	1.64	1.54	1.94	1.21	1.36
PUFA/SFA	0.42	0.54	0.51	0.63	0.52	0.55
Σn-3	14.57	15.68	17.41	19.69	18.16	16.5
Σn-6	6.07	5.19	3.63	3.88	5.45	8.23
n3/n6	2.40	3.02	4.80	5.07	3.33	2.00
DHA+EPA	13.71	14.26	16.35	18.11	16.62	14.59
DHA/EPA	5.15	8.14	6.57	5.73	8.66	12.90

Values with distinct superscript letters within the same row indicate significant differences between groups for each sample (p<0.05). (*) indicates the difference between males and females in same species. Values expressed as %.

with that of male tissue, following the pattern SFA>MUFA>PUFA (Fig 2). However, unsaturated fatty acids were more prevalent than saturated fatty acids (SFA<PUFA + MUFA) for both sexes in all species.

The quantity of PUFA in fish is influenced by their diet (Sahari *et al*. 2009). In the muscle tissue of anglerfish (demersal), polyunsaturated fatty acids (PUFAs), which was the highest, accounted for 24.73% and 23.61% of the total fatty acids in females and males, respectively. Among the three species, European barracuda (21.04-23.57%) and garfish (20.64-20.87%) which both are pelagic had lower PUFA levels ($p>0.05$). It has been reported that the fatty acid composition of fish species varies based on their habitat, with demersal fish having higher percentages of PUFAs than pelagic fish (Saei-Dehkordi *et al*., 2021).

In the investigation conducted by Merdzhanova *et al.* (2012) into the fatty acid composition of fish species in the Bulgarian Black Sea, Turbot demonstrated the highest PUFA value (36.83%), followed by garfish (33.45%), with red mullet exhibiting the lowest amount (21.40%). In our study, we observed that the PUFA values, particularly for garfish, were lower than those reported by the researcher. However, the PUFA values we observed for all three species closely matched the researcher's reported value for Red Mullet, which was approximately 21.40%, the lowest among them.

Our investigation reveals that the PUFA values in the examined Aegean Sea fish species are notably lower than those previously reported for some marine fish species, implying a limited richness in polyunsaturated fatty acids.

Palmitic acid (C16:0) was identified as the primary saturated fatty acid (SFA) in the muscle tissues of both sexes across all three species. The fatty acid found at the second-highest level was stearic acid (C18:0). Across all species and genders, C18:1 (n-9) and (DHA) C22:6 (n-3) were typically the most common fatty acids in the MUFA and PUFA groups, respectively.

Merdzhanova *et al.* (2012) in his study, C18:1 (n-9) was identified as the most dominant fatty acid among all MUFAs groups, while C22:6 (n-3) (DHA) was predominant in PUFAs groups for red mullet, turbot and garfish. Regardless of the fish species, the variations in the major fatty acids within the SFAs, MUFAs and PUFAs classes were reported as palmitic (C16:0), oleic (C18:1n-9) and DHA (C22:6 n-3), respectively, by Saei-Dehkordi *et al.* (2021) in their study on the fatty acid profile of seven fish species from the Persian Gulf. Jakhar *et al.* (2012) reported that fish lipids are dominated by saturated fatty acids such as palmitic acid (C16:0), stearic acid (C18:0) and myristic acid (C14:0), while the monounsaturated fatty acid (MUFA) is oleic acid [C18:1 (n-9)]. In a study, Pirestani *et al.* (2010) also reported that oleic acid (C18:1n9) was the most abundant fatty acid among the MUFAs in all fish species from the South Caspian Sea. The FA profile observed in both male and female fish of the three species in our study closely resembles that reported by the researches. At the same time, while some studies (Muhamad and Mohamad, 2012) generally indicate that marine fishes exhibit a higher PUFA content compared to SFAs, with MUFAs registering the lowest levels, our study identified a different pattern. Tufan *et al.* (2018) reported fluctuations in the monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) contents of garfish captured from the Eastern Black Sea. The MUFA contents were as follows: 24.0±2.2 in autumn, 24.7±2.4 in winter and 16.1±0.1 in spring. The PUFA contents were as follows: 41.7±2.3 in autumn, 40.02±0.8 in winter and 49.5±2.8 in spring. The values obtained in our study were found to have higher levels of MUFAs (28.83-39.8%) and lower levels of PUFAs (20.64-20.87%) compared to the values reported by the Tufan *et al.* (2018). These variations can be ascribed to differences in fish diet, season and geographical location, as reported in the literature, where the fatty acid composition of fish species is known to vary with the geographical location of the catch, diet, feeding and the state of their reproductive cycle. Moreover, the seasonal variations of the mentioned factors could be effective in changing the

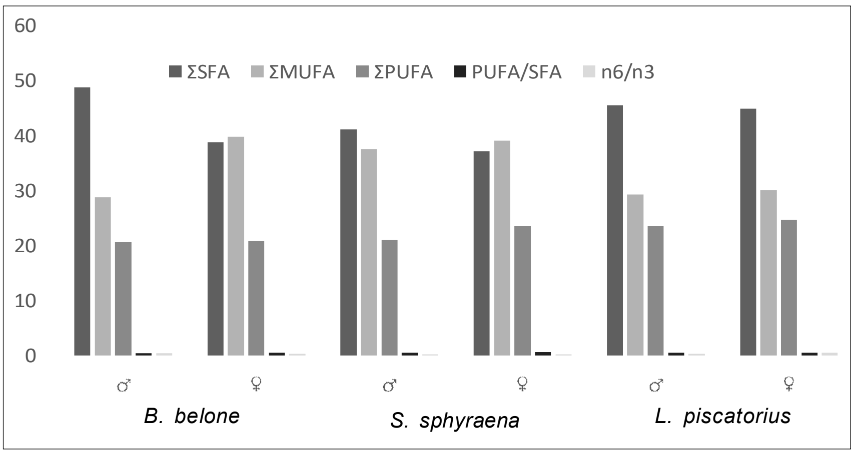


Fig 2: Chart of fatty acids in garfish (*B. belone*), European barracuda (*S. sphyraena*) and anglerfish (*L. piscatorius*) from Aegean Sea, Türkiye.

fatty acid composition of fish (Kaçar *et al*. 2016). Nevertheless, our data are consistent with the study conducted by Taheri *et al*. (2012) on Cobia fish (*Rachycentron canadum*) fillets. The study reported a fatty acid ranking of SFA> MUFA> PUFA, which indicates that unsaturated fatty acids were more abundant than saturated fatty acids (SFA <PUFA + MUFA). The results supporting the findings of our study have also been reported in the studies conducted by Sahari *et al.* (2009) and Pirestani *et al.* (2010). A study by Kaçar *et al.* (2016) reported that SFAs serve as a primary energy reservoir in females, whereas males rely on MUFAs to facilitate gonadal maturation. This observation elucidates the underlying reasons for the higher prevalence of MUFAs in females and SFAs in males within the parameters of our study.

The recommended minimum value for the PUFA/SFA ratio is 0.45 with an estimated optimum dietary value of 1.0±0.2 (Mgbechidinma *et al.* 2023). In other word, foods with total PUFA/SFA coefficient below 0.45 have been considered undesired for human nutrition because of their potential to induce cholesterol increase in the blood (Woloszyn *et al*., 2020). In the current study PUFA/SFA ratio was obtained as less than 1. The lowest value of 0.42 was observed in the muscle tissue of male garfish, while the highest value of 0.63 was detected in the muscle tissue of female European barracuda. The PUFA/SFA ratios obtained in our study were found to be within the range reported by Saglık and İmre (2001) in their study on determining omega-3 fatty acids in fishes from Türkiye, which ranged from a minimum of 0.42 to a maximum of 0.74 for various species.

The well-established benefits of omega-3 fatty acids include supporting human growth, health and immune function (Prakash *et al*., 2023). In another study involving 34 assorted marine fish species from the Mediterranean Sea, it was shown that the EPA and DHA values in fish ranged between 1.94% and 10.0% and 3.31% and 31.03%, respectively. These values were reported to be at the target levels for optimal well-being and the consumption of quality food (Taşbozan and Gökçe, 2017). In our study, when comparing EPA and DHA values between species and genders ($p<0.05$), the lowest EPA value was observed in the female anglerfish muscle tissue, at 1.05±0.08%; the highest EPA value, at 2.69±0.8%, was detected in the female European barracuda muscle tissue. The highest DHA value, at 15.42±1.37%, was observed in the female European barracuda muscle tissue, while the lowest value, at 11.48±1.41%, was observed in the male garfish muscle tissue. However, these values are close to the minimum levels of EPA and DHA reported in the previous study, leading to the conclusion that the species in our study do not exhibit a rich EPA+DHA content

The ratio of n3/n6 is widely reported to range from 0.24 to 4.1 for different fish species and used as an index for assessing the nutritional quality of fisheries products (Hosseini *et al*., 2014; Khosroshahi *et al*., 2016; Dagtekin *et al*., 2018). In the current study, for male and female muscle tissue of garfish and anglerfish, the total n-3/n-6 ratio were within the range reported for some different fish species while the ratio was higher (4.80-5.07) in European barracuda. The h/H ratio and the AI and TI indexes assess the nutritional quality of food by reflecting fatty acid fractions and their potential impact on cardiovascular health. While no specific maximum or minimum amounts are considered optimal for human health, higher h/H ratios and AI and TI indexes below 1 (one) are generally preferred in lipid profiles for preventing cardiovascular disorders (16,32,35). TI value obtained in this study (0.39-0.64) was lower than risky value in the muscle tissue of all species and genders. The AI value, except in the male tissue of garfish, was found to be slightly below 1, which is generally preferred in lipid profiles. The h/H ratio was found between 1.21-1.94 in this study. However, a higher h/H value is more favorable for human health, as it indicates that the oil in the product is well-suited for nutrition (Bayraklı, 2023).

Seafood and its derivatives serve as significant sources of essential macronutrients, including sodium, potassium, phosphorus, calcium and magnesium. Potassium is directly associated with sodium in intercellular and intracellular fluids. These elements play crucial roles in physiological processes, regulating fluid balance, membrane potential and muscle contraction (Matloob, 2023). The macro element contents in the edible muscle tissues of garfish, European barracuda and anglerfish is presented in Table 3.

Table 3: Macro element contents (mg/kg) in edible muscle tissue of garfish, European barracuda and anglerfish from Aegean Sea, Türkiye.

		Mg	Ca	P	Na	K
Garfish	♀	376.5±45.30^{b}	211.2±29.50^{a}	2113±335.38^{ab}	1199±145.67^{b}	3784±505.54^{c*}
	♂	338.2±40.70^{b}	389.0±54.40^{a}	1897±300.67^{ab}	1128±137.05^{b}	2852±381.02^{c}
E. barracuda	♀	458.6±55.20^{c}	182.2±25.50^{b}	2931±464.56^{b}	802.6±97.50^{a}	4921±738.40^{b}
	♂	391.1±54.70^{c}	393.6±47.4^{b*}	2220±351.87^{b}	723.7±87.90^{a}	3885±519.0^{b}
Anglerfish	♀	234.5±28.20^{a}	159.4±22.3^{b}	1830±222.34^{a}	1322±209.53^{a*}	2457±328.25^{a}
	♂	221.1±26.90^{a}	439.2±61.4^{b*}	1754±213.11^{a}	838.5±132.90^{a}	2044±139.48^{a}
		According to FAO the concentration range of macro elements in fish muscles, mg/100 g Stoyanova (2018)				
		4.5-452	19-881	68-550	30-134	19-502

Values with distinct superscript letters within the same column indicate significant differences between groups for each sample ($p<0.05$). (*) indicates the difference between males and females in the same species.

The order of mean concentrations of macro elements in the muscle tissue of garfish were as follows:
In females: K>P>Na>Mg>Ca
In males: K>P>Na>Ca>Mg

Except for K, there were no observed statistically significant variations in the concentrations of macro elements between genders ($p>0.05$).

The mean concentrations of macro elements in the muscle tissue of European Baracuda followed the following order.
In females: K>P>Na>Mg>Ca
In males: K>P>Na>Ca>Mg

With the exception of Ca, no statistically significant variations in the concentrations of macro elements were observed between genders.

In the muscle of anglerfish, the macro elements exhibited the following order of mean concentrations.
In female: K>P>Na>Mg>Ca
In males: K>P>Na>Ca>Mg

Except for Ca and Na, the variation in macro element concentrations between genders was not found to be statistically significant ($p>0.05$).

As a result, when comparing all the species examined in this study, it was determined that the macro elements K, P and Na were the most abundant in the tissues of both female and male specimens. In all examined specimens, Ca exhibited higher concentrations in male muscle tissues compared to Mg, whereas in female muscle tissues, Mg surpassed Ca in concentration.

K> P> Na> Mg> Ca

In the study conducted by Stoyanova (2018), the macroelement contents in the muscles of marine fish species such as *Scomber scombrus*, *Sprattus sprattus*, *Trachurus mediterraneus ponticus* and *Pomatomus saltatrix* were reported in the following order:

K> P> Na> Mg> Ca.

The same researcher also reported that fish muscles can contain high amounts of P, ranging from 2202.31±0.81 to 2436.68±24.74 mg/kg, Ca ranging from 130.09±0.67 to 195.96±3.93 mg/kg, K ranging from 2635.63±13.58 to 3384.81±43.12 mg/kg, Na ranging from 527.99±19.73 to 833.76±21.40 mg/kg, Mg ranging from 204.29±1.35 to 336.86±28.20 mg/kg.

The results obtained in the study are consistent with data reported by the researcher and are also mostly within the levels reported by FAO. Unfortunately, there is insufficient data regarding the levels of fatty acids and macro elements in the examined species in this study. Consequently, the present results were compared only with recently published data for other marine species. The findings have not been compared with freshwater fish due to the fact that a majority of freshwater organisms have evolved distinct mechanisms for tissue osmoregulation, adapting to the varying concentrations of ions present in the surrounding water, sediments and food sources (Matloob, 2023).

CONCLUSION

In the current study, the fatty acid profiles and macro element contents of garfish, European barracuda and anglerfish were determined. The investigation also explored gender-based differences. Given the limited existing literature on the macro element and fatty acid composition of these species, this study aimed to fill the gap and provide an evaluation of these macroelements and fatty acids in the context of human health.

Results from this study suggest that the examined species are characterized by average levels of macroelement contents. However, although PUFA, EPA and DHA values appear to be at optimal thresholds for human well-being and nutritious food consumption, the fact that meeting these levels at a minimum suggests that the species in our study do not possess a rich fatty acid profile compared to species in previous studies. Nonetheless, it is concluded that monitoring seasonal variations is essential for a comprehensive understanding of their fatty acid composition.

Conflict of interest

The authors declare that they have no conflict of interest regarding the publication of this article.

REFERENCES

Akpinar, M.A., Görgün S., Akpinar, A.E. (2009). A comparative analysis of the fatty acid profiles in the liver and muscles of male and female *Salmo trutta macrostigma*. Food Chemistry. 112: 6-8.

AOAC, (2012). Official Methods of Analysis of AOAC International, 19th ed. AOAC International, Gaithersburg, MD, USA, Official Method 2008.01. Revised October 2013.

Artar, E., Olgunoglu, M.P., Olgunoglu, I.A. (2022). Mineral contents and fatty acids compositions of fillets of female and male pangas (*Pangasius hypophthalmus*, Sauvage 1878) cultured in Turkey. Progress in Nutrition. 24, N. 3: e2022056. DOI: 10.23751/pn.v24i3.12382.

Bayraklı, B. (2023). A study on fatty acid composition and quality indicators of anchovy (*Engraulis encrasicolus*) oils from different factories. Marine Science and Technology Bulletin. 12(4): 522-529. https://doi.org/10.33714/masteb.1356285.

Bligh, E.C. and Dyer, W.J.A. (1959). Rapid method of total lipid extraction and purification. Canadian Journal of Biochemistry and Physiology. 37: 913-917.

Candela, C.G., López, L.M.B., Kohen, V.L. (2011). Importance of a balanced omega 6/omega 3 ratio for the maintenance of health: Nutritional recommendations. Nutrición Hospitalaria. 26(2): 323-329.

Dagtekin, G.B.B., Balcık, M.G., Kutlu, S., Bastürk, O. (2018). Comparison of biochemical, fatty acids and quality indexes of prussian carp (*Carassius gibelio*) caught from Lake Çıldır on different seasons. MedFAR. 1(1): 2-14.

Devadawson, C., Jayasinghe, C., Sivakanesan, R. (2017). Fatty acid compositions and atherogenic and thrombogenic indices of commonly consumed marine, brackish and fresh water fishes. Indian Journal of Animal Research. B-586: 1-6. https://doi.org/10.18805/ijar.v0iOF.7254.

Durmuþ, M. (2019). Fish oil for human health: omega-3 fatty acid profiles of marine seafood species. Food Science and Technology 39 (Suppl. 2): 454-461. doý: https://doi.org/10.1590/fst.21318.

Hosseini, H., Mahmoudzadeh, M., Rezaei, M. (2014). Effect of different cooking methods on minerals, vitamins and nutritional quality indices of kutum roach (*Rutilus frisii kutum*). Food Chemistry. 148: 86-91. http://dx.doi.org/10.1016/j.foodchem.2013.10.012.

IUPAC, (1979). Standard methods for analysis of oils, fats and derivatives, 6th Edition (Fifth Edition Method II.D.19) 96-102. Pergamon Pres, Oxford.

Jakhar, J.K., Pal, A.K., Reddy, A.D., Sahu, N.P., Venkateshwarlu, G., Vrdia, H.K. (2012). Fatty acids composition of some selected Indian fishes. African Journal of Basic and Applied Sciences. 4(5): 155-160. doý: 10.5829/idosi.ajbas.2012.4.5.6627.

Juszczak, L.P., Szymczak, K.K. (2009). Fatty acid profiles and fat contents of commercially important fish from Vistula Lagoon. Polish Journal of Food Nutrition Science. 59(3): 225-229.

Kaçar, S., Baþhan M., Oymak, S.A. (2016). Effect of seasonal variation on lipid and fatty acid profile in muscle tissue of male and female *Silurus triostegus*. Journal of Food Science Technology. 53(7): 2913-2922. doi: 10.1007/s13197-016-2253-5.

Kamble, P.A., Gore, S.B., Relekar, S.S., Telvekar, P.A., Rathod, R.H., Belsare, S.S., Tandale, A.T., Meshre, S.D. (2023). Development of fish cracker from Indian major carp, *Labeo catla*. Bhartiya Krishi Anusandhan Patrika. 38(2): 167-171. doi: 10.18805/BKAP617.

Karataþ, T. (2021). Comparison of micro and macro element contents of commercial fish species sold in the Erzurum province. Eastern Anatolian Journal of Science. 7(2): 16-22.

Khosroshahi, N.K., Hosseini, H., Rezaei, M., Khaksar, R., Mahmoudzadeh, M. (2016). Effect of different cooking methods on minerals, vitamins and nutritional quality indices of rainbow trout (*Oncorhynchus mykiss*). International Journal of Food Properties. 19: 2471-2480. https://doi.org/10.1080/10942912.2015.10 39028 34.

Kuley, E., Özogul, F., Özogul, Y., Olgunoglu, I.A. (2008). Comparison of fatty acid and proximate compositions of the body and claw of male and female blue crabs (*Callinectes sapidus*) from different regions of the Mediterranean coast. International Journal of Food Sciences and Nutrition. 59(7-8): 573-580.

Kumaran, R, Ravi, V, Gunala, B, Murugan, S, Sundramanickam, A. (2012). Estimation of proximate, amino acids, fatty acids and mineral composition of mullet *(Mugil cephalus*) of Parangipettai, Southeast Coast of India. Advances in Applied Science Research. 3(4): 2015-201.

Liu, J., Zhang, F., Ma, Q., Wei, Y., Liang, M., Xu, H. (2023). Sex Differences in fatty acid composition of Chinese tongue sole (*Cynoglossus semilaevis*) tissues. Fishes. 8: 421. https://doi.org/10.3390/fishes8080421.

Matloob, M.H. (2023). Determination of selected macro and microelements in muscle tissue of freshwater fish in Iraq. Iranian Journal of Fisheries Sciences. 22(4): 745-770. doi: 10.22092/ijfs.2023.129752.

Merdzhanova, A., Stancheva, M., Makedonski, L. (2012). Fatty acid composition of Bulgarian Black Sea fish species. Annals of Chemistry. 23(1): 41-46.

Mesa, M.D., Gil, F., Olmedo, P., Gil, A. (2021). Nutritional ımportance of selected fresh fishes, shrimps and mollusks to meet compliance with nutritional guidelines of n-3 LC-PUFA intake in Spain. Nutrients. 13: 465. https://doi.org/10.3390/nu13020465.

Mgbechidinma, C.L., Zheng, G., Baguya, E.B., Zhou, H., Okon, S.U., Zhang, C. (2023). Fatty acid composition and nutritional analysis of waste crude fish oil obtained by optimized milder extraction methods. Environmental Engineering Research. 28(2): 220034. https://doi.org/10.4491/eer.2022.034.

Muhamad, N.A. and Mohamad, J. (2012). Fatty acids composition of selected Malaysian fishes. Sains Malaysiana. 41(1): 81-94.

Olgunoglu, İ.A. (2017). Review on Omega-3 (n-3) Fatty acids in fish and seafood. Journal of Biology, Agriculture and Healthcare. 7(12): 37-45.

Olgunoglu, M.P., Olgunoglu, I.A., Goçer, M. (2014). Seasonal variation in major minerals (Ca, P, K, Mg) and proximate composition in flesh of Mesopotamian Catfish (*Silurus triostegus* Heckel, 1843) from Turkey. Annual Research and Review in Biology. 4(16): 2628-2633.

Pirestani, S., Sahari, M.A., Barzegar, M., (2010). Fatty Acids changes during frozen storage in several fish species from South Caspian Sea. Journal of Agriculture Science Technology. 12: 321-329.

Prakash, B., Rama Rao, S.V., Raju, M.V.L.N., Paul, S.S., Kannan, A., Praduman, Y., Santosh, P.K. (2023). Flaxseed oil for omega 3 fatty acids enrichment in eggs and performance in laying chickens. Asian Journal of Dairy and Food Research. doi: 10.18805/ajdfr.DR-2060.

Prego, R., Pazos, M., Medina, I., Aubourg, S.P. (2012). Comparative chemical composition of different muscle zones in angler (*Lophius piscatorius*). Journal of Food Composition and Analysis. 28(2): 81-87. https://doi.org/10.1016/j.jfca.2012.10.002.

Rodriguez, C., Acosta, C., Badia, P., Cejas, J.R., Santamaria, F.J., Lorenzo, A. (2004). Assessment of lipid and essential fatty acids requirements of black seabream (*Spondyliosoma cantharus*) by comparison of lipid composition in muscle and liver of wild and captive adult fish. Comparative Biochemistry and Physiology. 139: 619-629.

Saei-Dehkordi, S.S., Fallah, A., Karimi-Dehkordi, S. (2021). Fatty acid profile, lipid and cholesterol content and nutritional lipid quality of seven fish species from the Persian Gulf Journal of Nutrition Fasting and Health. 9(4): 277-287. doi: 10.22038/JNFH.2021.57506.1333.

Saglık, S. and Imre, S. (2001). 3-Fatty acids in some fish species from Turkey. Journal of Food Scýence. 66(2): 210-212.

Santos-Silva, J., Bessa, R. J., Santos-Silva, F. (2002). Effect of genotype, feeding system and slaughter weight on the quality of light lambs. Livestock Production Science. 77(2-3): 187-194. https://doi.org/10.1016/S0301-6226(02)00059-3.

Sahari, M.A., Nazemroaya, S., Rezaei, M. (2009). Fatty acid and biochemical changes in Mackerel (*Scomberomorus commerson*) and Shark (*Carcharhinus dussumieri*) fillets during frozen storage. American-Eurasian Journal of Sustainable Agriculture. 3(3): 519-527.

Sit, G., Jana, A., Chanda, A. (2021). A study on fish diversity, marketing and economics in fish markets at Kharagpur, West Bengal, India. Bhartiya Krishi Anusandhan Patrika. 36(2): 112-119. doi: 10.18805/BKAP310.

Stoyanova, S. (2018). Investigation of macroelements in the muscle of four marine fish species. International Journal of Fisheries and Aquatic Studies. 6(2): 219-222.

Taheri, S., Motallebi, A.A., Fazlara, A., Aghababyan, A., Aftabsavar, Y. (2012). Changes of fatty acid profiles in fillets of Cobia (*Rachycentron canadum*) during frozen storage. Iranian Journal of Fisheries Sciences. 11(1): 204-213.

Taþbozan, O. and Gökçe, M.A. (2017). Fatty Acids in Fish. In Fatty Acids; [Catala, A. (Ed.)]; InTech. https://doi.org/10.5772/68048.

Tufan, B., Balçık M.G., Köse, S. (2018). Comparison of seasonal fatty acid composition in relation to nutritional value of three commercial fish species caught from different zones of Eastern Black Sea. Aquatic Sciences and Engineering. 33(1): 11-19.

Watters, C., Iwamura, S., Ako, H., Deng, D.F. (2012). Nutrition considerations in aquaculture: The Importance of omega-3 fatty acids in fish development and human health. Foods and Nutrition. FN-11. Published by the College of Tropical Agriculture and Human Resources (CTAHR).

Ulbricht, T.L.V., Southgate, D.A.T. (1991). Coronary heart disease: Seven dietary factors. The Lancet. 338(8773): 985-992. https://doi.org/10.1016/0140-6736(91)91846-M.

Woloszyn, J., Haraf, G., Okruszek, A., Werenska, M., Goluch, Z., Teleszko, M. (2020). Fatty acid profiles and health lipid indices in the breast muscles of local Polish goose varieties. Poultry Science. 99: 1216-1224. https://doi.org/10.1016/j.psj.2019 .10.026.

www.nutri-facts.org. 19/01/2024. https://www.nutri-.facts.org/content/dam/nutrifacts/pdf/Nutrients-pdf/Essential_Fatty_Acids.pdf.