Research Article

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Variations in the fatty acid compositions of the liver and gonad tissue of spiny eel (*Mastacembelus mastacembelus*) from Atatürk Dam Lake

Atatürk Baraj Gölü Dikenli yılan balığının (*Mastacembelus mastacembelus*) gonad ve karaciğer dokusu yağ asidi kompozisyonundaki değişimler

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Abstract

Objective: The aim of the study was to investigate quantitative and qualitative fatty acid profiles of the gonad and liver tissue of female *Mastacembelus mastacembelus* (spiny eel).

Methods: Total lipids were extracted with 5 mL of chloroform-methanol (2:1 v/v). Samples containing gonad and liver lipid were transesterified with acidified methanol. The fatty acid methyl esters were extracted with hexane. Fatty acids were detected by gas chromatography (GC).

Results: The major saturated fatty acids (SFAs) were myristic acid (C14:0), palmitic acid (C16:0) and stearic acid (C18:0) in both gonad and liver tissue. Oleic acid (C18:1 ω-9) and palmitoleic acid (C16:1 ω-7) were the prominent monounsaturated fatty acid (MUFA). The dominant polyunsaturated fatty acids (PUFAs) were linoleic acid (LA, C18:2 ω-6), arachidonic acid (AA, C20:4 ω-6), docosapentaenoic acid (C22:5 ω-3) and docosahexaenoic acid (DHA, C22:6 ω-3). The ratio of ω-3/ω-6 ranged from 1.55 to 3.44 and 1.18 to 2.71 in the gonad and liver tissue, respectively.

Conclusion: The findings of this study will be useful for understanding the seasonal distribution of fatty acid composition in the liver and gonad of spiny eel.

Keywords: *Mastacembelus mastacembelus*; Freshwater fish; Fatty acid; Gonad; Liver.

Özet

Amaç: Bu çalışmanın amacı Atatürk Baraj Gölü’nde yaşayan dişi *Mastacembelus mastacembelus’in gonad ve karaciğer dokusu yağ asidi profilini kalitatif ve kantitatif olarak araştırmaktır.

Yöntem: Total lipidler 5 mL kloroform-metanol (2:1 v/v) çözeltisi ile ekstrakte edildi. Gonad ve karaciğer lipitlerini içeren örnekler asitli metanol ile ester haline getirildi. Yağ asidi metil esterleri hekzan ile ekstrakte edildi. Yağ asitleri gaz kromatografi (GC) ile tespit edildi.

Bulgular: Hem karaciğer hem de gonad dokusunda başlıca doymuş yağ asitleri (DYA) miristik asit (C14:0), palmitik asit (C16:0) ve stearik asit (C18:0) idi. Oleik asit (C18:1 ω-9) ve palmitoleik asit (C16:1 ω-7) belirgin tekli doymamış yağ asitleridir (TDYA). Baskın çoklu doymamış yağ asitleri (CDYA) linoleik asit (LA, C18:2 ω-6), arasideonik asit (AA, C20:4 ω-6), dokosapentaenoik asit (C22:5 ω-3) ve dokosahexaenoik asit (DHA, C22:6 ω-3)’lerdi. ω-3/ω-6 oranı sırasıyla gonad dokusunda 1.55’den 3.44’e, karaciğer dokusunda 1.18’den 2.71’e değişti.

Sonuç: Dikenli yılan balığının karaciğer ve gonad yağ asidi kompozisyonunun mevsimsel dağılımının anlaşılmasi için bu çalışmanın bulguları yararlı olacaktır.

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Introduction

Spiny freshwater eel (M. mastacembelus) of Mastacembelidae family has been detected in the freshwater resources of Turkey [1]. The first registration studies in the literature reported that the freshwater resources of Iran and Syria are the actual habitats of this species [2]. It was identified that the spawning occurs in the end of May and continues until late July in the M. mastacembelus [3].

The concentrations of some heavy metals such as Co, Cd, Cu, Fe, Mn, Ni, Mo, Pb and Zn in muscle, liver, gonad, gill and kidney of M. mastacembelus caught in Atatürk Dam Lake were determined. The levels of heavy metals were within acceptable limits [4].

Fish lipids are characterized by long-chain polyunsaturated fatty acids (LC-PUFAs) with up to six double bonds, such as EPA and DHA [5] that differ from mammalian lipids. These two types of fatty acids are the precursors for the biosynthesis of eicosanoids and docosanoids with multiple health benefits [6].

Major roles of the liver in lipid metabolism include uptake, oxidation, conversation between fatty acids and the supply of polyunsaturated fatty acids to other tissues [7].

Gonads are responsible for secreting the sexual hormones. Lipid content of gonads is dependent upon the reproductive cycle and the sex of the fish [8, 9]. As a rule, the ovaries of fish accumulate higher amount of lipids, particularly triacylglycerols than the testes do, because the provision of energy for the offspring depends mainly on their way of life, feeding level and especially the reproductive ecology of each species.

The fatty acid content in fish tissue is affected by lots of factors such as fishing season, fishing location, fish size, maturity stage and starvation [10–13]. The quantity of total lipids may vary between various tissues and organs and also between different species. Lipid and FA profiles are known to vary even between the tissues of fish. Analysis of the fatty acid profiles of the tissues like muscle, liver and gonad of fish that lives in its natural habitat can yield valuable information [14].

There are only a few researches conducted on the fatty acid profiles of this species [15–17]. However, the fatty acid profiles of gonads according to seasonal variation and liver tissue of M. mastacembelus have not yet been studied. In the present research, we examined the seasonal variations of fatty acid profile of total amount of lipid in female M. mastacembelus in the Atatürk Dam Lake.

Materials and methods

The samples of M. mastacembelus in this study were collected in Atatürk Dam Lake on different seasons from May 2008 to January 2009. Fish sex was determined by their gonad. The specimens were dissected and the organs to be studied were removed. Samples of gonad and liver tissues were stored at −30°C for lipid analysis. Approximately 2 g of gonad and liver samples were cut into small pieces before lipid extraction. For the analysis of FAs, total lipids were transesterified according to Folch et al. [18].

The residual chloroform was then removed by N₂. Samples containing muscle lipid were transesterified with acidified methanol. It was refluxed for a 2 h at 85°C [19]. The fatty acid methyl esters (FAMEs) were extracted with hexane.

Gas chromatography analysis

FAMEs were analysed by capillary gas chromatography (GC, Model 6890; Hewlett Packard Inc, Wilmington, DE, USA) with a flame ionization detector (FID), and Hewlett Packard ChemStation software [20]. A BPX70 capillary column [70% cyanopropyl 30% dimethyl polysilphenylene-siloxane bonded phase, 30 m × 0.32 mm (i.d.) × 0.250 μm film thickness] was used. The flow rates of compressed air and hydrogen were 300 mL/min and 30 mL/min, respectively. The carrier gas was helium at a flow rate of 1.0 mL/min. The injection port temperature was 260°C, the detector temperature 280°C. Split ratio was 1:20. The oven temperature was programmed at initial temperature 130°C and kept constant for a min, and then to rise from 130 to 170°C at a rate of 6.5°C/min, from 170 to 215°C at a rate of 2.75°C/min and kept constant for 12 min, and from 215 to 230°C at a rate of 40°C/min and kept constant for 3 min. Total analysis time was 38.89 min. The chemical structures of the FAs were identified as their methyl esters by comparison of their relative retention times of authentic standards (Sigma-Aldrich Chemicals).
All the analyses were conducted in triplicate, standard deviation (SD) was computed in SPSS (16.0) and the data is presented as mean of triplicate values ± SD.

**Results**

**Fatty acid profile of gonad tissue**

Seasonal variations of total fatty acid composition of *M. mastacembelus* are presented in Table 1. Noticeable changes in percentages of total SFAs with lipid content variation were not observed (33.51%–34.38%). There was a significant amount of C16:0 in gonad tissues compared to other SFAs like C14:0, and C18:0. The ratio of C16:0 decreased to a minimum level in summer (the reproduction, 23.22%). Lauric acid and tridecanoic acid were only found in autumn and summer in low amounts (0.05%, 0.12%), respectively. C15:0 and C17:0 were found in low amounts in the SFA fractions of the investigated gonad. The level of C18:0 was considerably lower in January (4.46%) than in July (8.37%). In addition, monthly variations for total monounsaturated fatty acids (MUFA) observed are ranging from 21.34% (the reproduction, in May) to 35.49% (post reproduction, in September). Total percentage of MUFA decreased at spawning stage to the lowest value (30.55%). C18:1 ω-9 was identified as the major MUFA in gonad tissue. C18:1 ω-9 in gonad tissue of *M. mastacembelus* was found to be 21.34%, 24.01%, 27.29%, and 30.24% in spring, summer, winter and autumn, respectively. This was followed by C16:1 ω-7 and then gondoic acid (C20:1 ω-9). C16:1 ω-7 was the second most abundant MUFA (5.30%–8.64%) in the present study. The proportions of C16:1 ω-7 in the gonad did not differ across the months.

The concentration of PUFA varied seasonally from 26.90% (in September, post reproduction) to 35.49% (in May, prior to reproduction). The relative concentration of ω-3 PUFA varied seasonally, ranging from 17.80% (in May, prior to reproduction) to 27.50% (in May). The maximum level of ω-6 was found in January (11.51%). Highly unsaturated fatty acids like AA and DHA are dominant PUFAs. In our study, C18:2 ω-6 (2.23%–4.12%), AA (2.74–7.27%) and

**Table 1:** The seasonal variation of fatty acid in gonad of *M. mastacembelus* (% of total FA).

| Fatty acids | May (2008) | July (2008) | September (2008) | January (2009) |
|-------------|------------|-------------|-----------------|----------------|
| C12:0       | –          | 0.12 ± 0.01 | 3.18 ± 0.32b    | 1.61 ± 0.12c   |
| C13:0       | 2.00 ± 0.28a | 1.85 ± 0.18a | 6.05 ± 0.22     | 0.70 ± 0.21    |
| C14:0       | 23.52 ± 0.99a | 23.22 ± 1.02a | 24.06 ± 1.21a   | 26.38 ± 1.00b  |
| C15:0       | 7.43 ± 0.51a | 8.37 ± 0.50a | 5.32 ± 0.33b    | 4.46 ± 0.44b   |
| C16:0       | 33.51 ± 1.22a | 34.38 ± 1.30a | 34.05 ± 2.76a   | 34.06 ± 3.03a  |
| C16:1 ω-7   | 8.64 ± 0.24a | 5.30 ± 0.12a | 7.41 ± 0.45a    | 7.82 ± 0.69a   |
| C18:0       | 21.34 ± 1.01a | 24.01 ± 1.28a | 30.24 ± 1.31a   | 27.29 ± 1.89b  |
| C20:0       | 0.95 ± 0.25a | 1.24 ± 0.33a | 1.12 ± 0.27a    | 1.44 ± 0.52a   |
| C20:1 ω-9   | 30.93 ± 2.09a | 30.55 ± 1.06a | 38.77 ± 1.90b   | 36.55 ± 2.56a  |
| C18:2 ω-6   | 3.06 ± 0.44a | 2.23 ± 0.24a | 2.41 ± 0.34a    | 4.12 ± 0.43a   |
| C18:3 ω-3   | 1.11 ± 0.12a | 0.91 ± 0.26a | 1.27 ± 0.46a    | 2.28 ± 0.85a   |
| C20:2 ω-6   | 0.44 ± 0.20a | 0.44 ± 0.02a | 0.85 ± 0.52a    | 0.66 ± 0.26a   |
| C20:3 ω-6   | 0.49 ± 0.02a | 0.72 ± 0.28a | 0.26 ± 0.04a    | 0.89 ± 0.18a   |
| C20:4 ω-6   | 4.00 ± 0.68a | 7.27 ± 0.98a | 2.74 ± 0.55a    | 5.84 ± 0.27a   |
| C20:5 ω-3   | 2.18 ± 0.47a | 1.69 ± 0.33a | 3.04 ± 0.29a    | 0.76 ± 0.25a   |
| C22:5 ω-3   | 6.38 ± 0.85a | 5.61 ± 0.52a | 4.98 ± 0.46a    | 4.16 ± 0.44a   |
| C22:6 ω-3   | 17.83 ± 1.05a | 16.03 ± 1.62a | 11.35 ± 1.32b   | 10.60 ± 1.36a  |
| ΣPUFA       | 35.49 ± 2.33a | 34.09 ± 2.98a | 26.90 ± 2.56b   | 29.31 ± 2.78b  |
| Σ ω-3       | 27.50 ± 1.23a | 24.24 ± 1.05a | 20.64 ± 0.95b   | 17.80 ± 1.27b  |
| Σ ω-6       | 7.99 ± 0.27a | 10.66 ± 0.96a | 6.26 ± 0.45a    | 11.51 ± 0.88b  |
| ω-3/ω-6     | 3.44 ± 0.30a | 2.27 ± 0.21a | 3.30 ± 0.40a    | 1.55 ± 0.39a   |

Given values are means ± SD (means are the average of three replicates) followed by different letters in same line are significantly different (p < 0.05) by Tukey’s test. SFA, Saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. *a,b,c,d*Values (p < 0.05) by Tukey’s test. SFA, Saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. *a,b,c,d*Values denote significant differences between seasons.
DHA (10.60–17.83%) were the most obvious PUFA in the gonad tissue of *M. mastacembelus* in all seasons. In wild *M. mastacembelus*, EPA and DHA percentages in gonad total lipids were similar between the prior reproduction and reproduction seasons. However, AA percentage of total lipid in gonad the prior to reproduction season was lower than that during the reproduction season. It is clear that DHA was the main PUFA and its level decreased from 17.83% in May to 10.60% in January. The proportion of DHA was nearly two times higher at the pre-spawning stage than at the post-spawning stage. In winter, low level of DHA decreased the PUFA content in gonad tissue. C22:5 ω-3 and AA were found to be the second major PUFAs, that the gonad had during pre-spawning and spawning season the highest level across the months (6.38%, 7.27%), respectively. A relatively higher PUFAs of C22:5 ω-3 occurred in all seasons with an average of 5.28%. The major ω-3 PUFA were DHA and C22:5 ω-3 while the major ω-6 PUFA was AA. In the gonads of females, the ratio of PUFA in fatty acid composition decreased to the minimum level in September (26.90%, post reproduction) and significantly increased in May (35.49%, prior to reproduction).

In this study, the saturated fatty acid (SFA) contents were generally much higher than the PUFA in autumn and winter 34.05%, 34.06%, respectively. The highest PUFA values were determined in the hot seasons which also include reproduction period for *M. mastacembelus*.

Our results show that the ω3/ω-6 ratios vary for gonad tissue according to season, being lower in winter (1.55) and raising up to 3.44 in spring (Table 1).

**Fatty acid profile of liver tissue**

Total fatty acid profiles in fish liver were compared and listed in Table 2. Total percentages of SFAs are found 38.61%–44.56%. There were no seasonal changes in total SFA values for liver samples between September (39.23%) and January (40.28%). The highest concentrations of SFA were C16:0 (20.97%–29.73%), C18:0 (6.28%–15.38%). There were also small amounts of C15:0, C17:0. Fluctuations in total MUFA were observed, ranged between 19.94% and 27.85%, in which the highest value was found in January while the lowest value was found in May. The monoene with the highest concentration was C18:1 ω-9, 19.34% (in January) and the lowest concentration was 14.24% (in May, prior to reproduction). The higher

| Fatty acids | May (2008) | July (2008) | September (2008) | January (2009) |
|------------|------------|-------------|------------------|----------------|
| C13:0      | 0.06 ± 0.03 | -           | -                | -              |
| C14:0      | 1.57 ± 0.51 | 1.78 ± 0.24 | 2.08 ± 0.23      | 1.18 ± 0.15    |
| C15:0      | 0.38 ± 0.10 | 0.60 ± 0.26 | 0.76 ± 0.02      | 0.59 ± 0.13    |
| C16:0      | 20.97 ± 1.26 | 29.73 ± 1.63 | 29.71 ± 1.85     | 29.26 ± 1.88   |
| C17:0      | 0.25 ± 0.02 | 0.30 ± 0.08 | 0.40 ± 0.18      | 0.86 ± 0.32    |
| C18:0      | 15.38 ± 0.99 | 12.15 ± 0.56 | 6.28 ± 0.63      | 8.39 ± 0.63    |
| ΣSFA       | 38.61 ± 2.38 | 44.56 ± 2.07 | 39.23 ± 2.34     | 40.28 ± 3.49   |
| C16:1 ω-7  | 4.43 ± 0.44 | 4.39 ± 0.25 | 4.30 ± 0.36      | 7.14 ± 0.84    |
| C18:1 ω-9  | 14.24 ± 1.41 | 18.92 ± 1.52 | 15.56 ± 1.68     | 19.34 ± 1.88   |
| C20:1 ω-9  | 1.27 ± 0.22 | 1.49 ± 0.65 | 1.25 ± 0.28      | 1.37 ± 0.69    |
| ΣMUFA      | 19.94 ± 1.36 | 24.80 ± 1.40 | 21.11 ± 1.22     | 27.85 ± 1.58   |
| C18:2 ω-6  | 2.07 ± 0.14 | 2.05 ± 0.52 | 1.22 ± 0.28      | 3.39 ± 0.36    |
| C18:3 ω-3  | 0.66 ± 0.31 | 0.55 ± 0.18 | 0.18 ± 0.03      | 1.29 ± 0.63    |
| C20:2 ω-6  | 0.46 ± 0.10 | 0.48 ± 0.20 | 0.40 ± 0.15      | 0.77 ± 0.16    |
| C20:3 ω-6  | 0.69 ± 0.03 | 0.59 ± 0.01 | 0.35 ± 0.10      | 0.85 ± 0.22    |
| C20:4 ω-6  | 7.88 ± 1.02 | 8.63 ± 0.28 | 10.38 ± 1.35     | 9.66 ± 1.52    |
| C20:5 ω-3  | 1.01 ± 0.25 | 0.92 ± 0.10 | 0.71 ± 0.16      | 0.73 ± 0.19    |
| C22:5 ω-3  | 5.16 ± 0.52 | 3.65 ± 0.32 | 5.75 ± 0.21      | 3.01 ± 0.38    |
| C22:6 ω-3  | 23.33 ± 1.09 | 13.68 ± 1.00 | 20.57 ± 1.84     | 12.09 ± 1.88   |
| ΣPUFA      | 41.26 ± 2.44 | 30.55 ± 3.33 | 39.56 ± 2.50     | 31.79 ± 1.55   |
| Σ ω-3      | 30.16 ± 1.22 | 18.8 ± 1.09 | 27.21 ± 1.47     | 17.12 ± 1.49   |
| Σ ω-6      | 11.10 ± 0.96 | 11.75 ± 0.46 | 12.35 ± 0.34     | 14.67 ± 0.67   |
| ω-3/ω-6    | 2.71 ± 0.07 | 1.60 ± 0.10 | 2.20 ± 0.94      | 1.18 ± 0.48    |

Given values are means ± SD (means are the average of three replicates) followed by different letters in same line are significantly different (p < 0.05) by Tukey’s test. SFA, Saturated fatty acids; MUFA, monounsaturated fatty acids; PUFA, polyunsaturated fatty acids. a,b,c Values denote significant differences between seasons.
amount of C18:1 ω-9 in *M. mastacembelus* may arise from its dominance in the diet. The C16:1 ω-7 content showed variations in the range of 4.30% (in autumn) to 7.14% (in winter) of the total MUFAs. The other monoene was C20:1 ω-9 (1.25%–1.49%).

AA was the major ω-6 PUFA in the liver tissue in our study followed by C18:2 ω-6. AA (7.88%–10.38%), C22:5 ω-3 (3.01%–5.75%) and DHA (12.09%–23.33%) were the most obvious PUFA in *M. mastacembelus* in all seasons. In addition, the variation in its percentage is widely ranged during different seasons. The DHA amounts were higher than EPA amounts in all seasons.

It was determined that the relative proportions of PUFA, ω-3 and ω-6 fatty acids decreased to minimum level during spawning, and increased in spring (in May). C18:3 ω-6 and C20:3 ω-6 were found to be at low amounts in the ω-6 PUFA fractions of the investigated liver tissue. Compared to the total ω-3 PUFA (17.12%–30.16%) the amount of ω-6 PUFAs was lower and only ranged from 11.10% to 14.67% in liver of *M. mastacembelus* in all seasons. The values of total ω-3 decreased significantly from May to July. There were no seasonal changes between May and January in total ω-6 values for liver samples. Significant differences were observed in total percentages of PUFA, SFA and MUFA. The results indicated that the ω-3/ω-6 ratios were 1.18, 1.60, 2.20, and 2.71 in January, July, September and May, respectively.

**Discussion**

**Fatty acid profile of gonad tissue**

Fatty acids serve as major energy sources for metabolic activities of fish during spawning [21], embryonic development and growth [22, 23]. The most abundant SFA C16:0 is noted to be the predominant source of potential metabolic energy in fish during growth stage, particularly during egg production in female fish [22]. The C16:0 and C18:1 ω-9 fatty acids were released during catabolic period to yield energy [24]. High amounts of acids were consumed during fish growth and development and they were easily becoming catabolic through the mitochondrial metabolism [25].

The high value detected for both C16:0 and C18:1 ω-9 in all seasons determines a requirement for energy metabolism during the course of gonad development. C18:1 ω-9 was the basic fatty acid in MUFA fraction in all seasons. Similar conclusion was obtained by Shirai and Wada [26] and Cejas et al. [27]. The dominance of C16:0 in fish lipid has been reported by other authors [10–13].

The amount of PUFAs in the gonads of female *M. mastacembelus* decreased after the reproduction. DHA and EPA are needed to maintain the fluidity of the biomembrane and DHA plays an important role during vitellogenesis [28]. AA was the most abundant ω-6 PUFA. Its biological importance is similar to that of EPA and DHA. In fact, it is considered as the precursor of several eicosanoids that are produced in the ovarian tissue. Therefore, it plays an important role for ovulation process [29, 30]. PUFAs are necessary for the homeostasis in the fish body. AA can be converted to prostaglandins and it stimulates ovarian steroidogenesis [31]. EPA and DHA accelerate growth more than C18:3 ω-3 [32] and the deficiency in ω-3 PUFA causes shock syndrome [33].

AA is the principle prostaglandin precursor involved in spawning activity of fish including sperm production and its level decreases through the mobilization [34]. Thus, prostaglandins play an important role in fish reproduction [35]. The wild *M. mastacembelus*, contained higher DHA and AA percentages in the spawning season than those in the post-reproduction season (Table 1). These results suggest that *M. mastacembelus* also need AA and DHA to develop the eggs after ovulation.

**Fatty acid profile of liver tissue**

Lipids and fatty acids are accumulated primarily in liver and then they are assimilated or converted to other forms. In this study, C16:0 level was found high in the liver. This result is consistent with the anabolism of fatty acids, which suggests that C16:0 can be biosynthesized in fish through a conventional pathway which is catalyzed by cytosolic fatty acid synthetase [36].

The increase in total SFA might be a result of the increase in temperatures, which might be a physiological adaptation to an extreme cold environment together with a decrease in total PUFA. C18:1 ω-9 was identified as the primary MUFA in *M. mastacembelus* for all seasons. Görgün and Akpınar [37] also found similar results for freshwater fish. C16:1 ω-7 was the second most abundant MUFA in the present study. The high levels of C18:1 ω-9 and C16:1 ω-7 were reported to be a characteristic of freshwater fish [38].

In liver tissue, DHA and AA were dominant PUFAs. Similar results were reported by Aras et al. [39] and Uysal et al. [40], who analysed fatty acids in fish without
seasonal distinction and found high proportions of the DHA and AA in the liver tissue.

**Comparison of fatty acid composition of gonad and liver tissue**

Our study revealed substantial differences in the amounts of individual fatty acids in tissues of fish. SFAs were the most indicative fatty acids, followed by PUFAs and finally by MUFAs in liver tissue. In gonad tissue, SFA, MUFA and PUFA percentages were similar in spring and summer. However, MUFAs were the most typical fatty acids, followed by SFAs and finally by PUFAs in autumn and winter.

Freshwater fish species accumulate depot lipids composed mainly of SFA and MUFA [41]. C16:0 and C18:0 were also predominant fatty acids within the SFA in the liver and gonad tissue. However, liver tissue contained higher amounts of SFA than the gonad tissue of the fish. The gonad tissues contain more of mono unsaturated lipids than liver tissue does. The result of this study revealed that the most abundant individual fatty acids were C16:0, C18:1 ω-9 and DHA in the gonad and liver tissues. These values were similar to the values found in the other freshwater species [11, 39, 42, 43]. Several studies indicated that C16:0 is the predominant source of potential metabolic energy during egg production in female fish. Additionally, PUFA is an important source of metabolic energy during reproduction and C18:1 ω-9 plays a crucial role in gonad development [44]. Among the PUFAs of *M. mastacembelus*, DHA was the major ω-3FA in the tissues. This result supports also the findings of Sargent et al. [45] and Tanako et al. [46]. Generally, examined fatty acids of the fish in this study indicated a higher unsaturated rather than saturated acid content. There were significant differences between the tissues with regard to ω-6 and ω-3 PUFA. In addition, this study has supported the fact that gonad and liver tissues contain higher ω-3 PUFA levels than ω-6 PUFAs. The fatty acid composition of freshwater fish is characterized by high proportions of ω-6 PUFA, especially C18:2 ω-6 and AA.

There was also a significant difference between the PUFA profiles of the tissues throughout the season. For example, total ω-3 PUFAs were higher in liver tissue than in gonad tissue prior to reproduction. DHA levels in liver were higher than those in ovaries in all seasons except summer. PUFAs, such as DHA, EPA and C22:5 ω-3 that are necessary for gonadal maturation as well as subsequent embryogenesis were selectively transferred to the ovaries also where they are conserved.

In conclusion, the study revealed that the fatty acid compositions of the liver and gonad tissues of *M. mastacembelus* are influenced by seasonality.

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**References**

1. Fricke R, Bilecenoglu M, Sari HM. Annotated checklist of fish and lamprey species (Gnathostoma and Petromyzontomorphi) of Turkey, including a Red List of threatened and declining species. Stutt Beir Naturk A 2007;706:1–172.
2. Eschmeyer WN. Catalog of fishes, Species of fishes M-Z. Special Publication of the Center for Biodiversity Research and Information, California Academy of Sciences, San Francisco 1998;2:959–1820.
3. Oymak SA, Kirakaya ŞG, Doğan N. Growth and reproduction of Mesopotamian spiny eel (*Mastacembelus mastacembelus* Banks & Solander, 1794) in Atatürk Dam Lake (Şanlıurfa). Turkey J Appl Ichthyol 2009;24:488–90.
4. Karadede H, Cengiz El, Ünlü E. Investigation of the heavy metal accumulation in Mastacembelus simack (Walbum, 1972) from the Atatürk Dam Lake: IX. Turkish Symposium on Aquatic products, 1997; September 17–19. Egridir- Turkey.
5. Jittrepotch N, Ushio H, Ohshima T. Oxidative stabilities of triacylglycerol and phospholipids fractions of cooked Japanese sardine meat during low temperature storage. Food Sci 2006;99:360–7.
6. Güner S, Dincer B, Alemdag N, Colak A, Tufekci M. Proximate composition and selected mineral content of commercially important fish species from the Black Sea. J Sci Food Agr 1998;8:337–42.
7. Rincon-Sanchez AR, Hernandez A, Lopez ML, Mendoza-Figueroa T. Synthesis and secretion of lipids by long-term cultures of female rat hepatocytes. Biol Cell 1992;76:131–8.
8. Newsome EG, Leduc G. Seasonal change of fat content in the yellow perch (*Perca flavescens*) of two laurentian lakes. J Fish Res Board Can 1975;32:2214–21.
9. Vuorela R, Kaitaranta J, Linko RR. Proximate composition of fish roe in relation to maturity. Can Inst F Sci Tec J 1979;12:186–8.
10. Kayhan H, Başhan M, Kaçar S. Seasonal variations in the fatty acid composition of phospholipids and triacylglycerols of brown trout. Eur J Lipid Sci Tech 2015;117:738–44.
11. Kaçar S, Başhan M. Seasonal variations on the fatty acid composition of phospholipid and triacylglycerol in gonad and liver of *Mastacembelus simack*. J Am Oil Chem Soc 2015;92:1313–20.
12. Kaçar S, Başhan M. Comparison of lipid contents and fatty acid profiles of freshwater fish from the Ataturk Dam Lake. Turk J Biochem 2016;41:150–6.
1. Kaçar S, Başhan M, Oymak AS. Effect of seasonal variation on lipid and fatty acid profile in muscle tissue of male and female Silurus triostegus. J Food Sci Tech Mys 2016;53:2913–22.

2. Rodríguez C, Acosta C, Badia P, Cejas JR, Santamaria FJ, Lorenzo A. 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. Comp Biochem Phys 2004;139B:619–29.

3. Harlıoğlu AG, Yılmaz Ö. Fatty acid composition, cholesterol and fat soluble vitamins of wild-caught freshwater spiny eel, Mastacembelus simack (Walbaum, 1792). J Appl Ichthyol 2011;27:1123–7.

4. Olgunoğlu IA. Determination of the fundamental nutritional components in fresh and hot smoked spiny eel (Mastacembelus mastacembelus, Bank and Solander, 1794). Sci Res Essays 2011;6:4448–53.

5. Taşbozan O, Gökçe MA, Çelik M, Tabakoğlu ŞS, Küçükgülmez A, Başusta A. Nutritional composition of Spiny eel (Mastacembelus mastacembelus) caught from the Atatürk Dam Lake in Turkey. J Appl Bioi Sci 2013;7:78–82.

6. Folch J, Lees M, Stanley A. Simple method for the isolation and purification of total lipids from animal tissues. J Biol Chem 1957;226:497–509.

7. Stanoe-Samuelson DW, Dadd RH. Long-chain polyunsaturated fatty acids: patterns of occurrence in insects. J Food Sci Technol 1983;13:549–58.

8. Keskın C, Kaçar S. Fatty acid composition of root and shoot samples of some Astragalus L. (Fabaceae) taxa growing in the East and Southeast of Turkey. Turk J Biol 2013;37:122–8.

9. Tocher DR, Fraser AJ, Sargent JR, Gamble JC. Fatty acid composition of phospholipids and neutral lipids during embryonic and early larval development in Atlantic herring (Clupea harengus L.). Lipids 1985;20:69–74.

10. Henderson RJ, Sargent JR, Hopkins CC. Changes in the content and fatty acid composition of lipid in an isolated population of the capelin, Mallotus villosus, during sexual maturation and spawning. Mar Biol 1984;78:255–63.

11. Sargent JR, Henderson RJ, Tischer DR. The lipids. In: Halver JE, editor. Fish nutrition, 3rd ed. USA: Elsevier, 2002:181–257.

12. Görgün S, Akmnar MA. Effect of season on the fatty acid composition of the liver and muscle of Alburnus alburnoides (Guldenstadt, 1772) from Todurge Lake (Sivas, Turkey). Turk J Zool 2012;36:691–8.

13. Andrade AD, Rubira AF, Matsushita M, Souza NE. Omega-3 fatty acids in freshwater fish from South Brazil. J Am Oil Chem Soc 1995;72:1207–10.

14. Aras NM, Haliloğlu HI, Ayik Ö, Yetim H. Comparison of fatty acid profiles of different tissues of mature trout (Salmo trutta salar), (Pallas, 1811) caught from Kazandere Creek in the Çoruh Region, Erzurum, Turkey. Turk J Vet Anim Sci 2003;27:311–6.

15. Uysal K, Yerlikaya A, Aksoylar MY, Yöntem M, Ulupinar M. Variations in fatty acids composition of pikeperch (Sander lucioperca) liver with respect to gonad maturation. Ecol Freshwat Fish 2006;15:441–5.

16. Kozlóva TA, Khotimchenko SV. Lipids and fatty acids of two pelagic cottid fishes (Comphoropria spp.) endemic to Lake Baikal. Comp Biochem Physiol B 2000;126:477–85.

17. Silverland C, Norberg B, Haux C. Fatty acid composition of ovulated eggs from wild and cultured turbot (S. Maximus) in relation to yolk and globose lipids. Mar Biol 1996;125:269–78.

18. Czesny S, Dabrowski K, Christensen JE, Eenennaam JV, Doroshov S. Discrimination of wild and domestic origin of sturgeon ova based on lipids and fatty acid analysis. Aquaculture 2000;189:145–53.

19. Huynh MD, Kitts DD, Hu C, Trites AW. Comparison of fatty acid profiles of spawning and non-spawning Pacific herring, Clupea harengus pallasi. Comp Biochem Physiol B 2007;146:504–11.

20. Sargent JR, McEvoy LA, Bell JG. Requirements presentation and evaluation of 19 species of fish from Black Sea and Marmara Sea. Lipids 1999;34:291–7.