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Research Article

Nutritional Quality, Proximate and Fatty Acid Compositions of Commercially Important Fish from Different Rivers in SE Türkiye: A Comparative Research

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ABSTRACT

Nutritional quality, proximate and fatty acid compositions of fish species from the Khabur, Ambar and Tigris Rivers in SE Türkiye were investigated for the first time. The fish with the lowest total lipids were *Mastacembelus mastacembelus* (0.93%) and *Carasobarbus luteus* (0.99%), and the fish with the highest total lipid was *Chondrostoma regium* from the Tigris River (7.47%). The highest cholesterol content was in *Barbus lacerta* (26.3 mg/100 g) and *Capoeta umbla* (29.98 mg/100g) of the Ambar Stream. However, the Tigris River *Cyprinus carpio* (7.9 mg/100g) and *C. luteus* (7.91 mg/100g) had the lowest cholesterol. The results showed that all species are good sources of ΣSFA and ΣMUFA, specifically C14:0, C16:0, C18:0, C16:1ω7 and C18:1ω9. However, the fish were poor for ω6 and ω3, particularly C20:4ω6, C20:5ω3 and C22:6ω3, probably due to hot water adaptation in summer. Nevertheless, *C. carpio* (Tigris River) and *A. mossulensis* (Khabur River) had relatively high ΣPUFA. Among all the fish, *C. regium* and *A. mossulensis* from the Khabur River were good for protein, and *M. mastacembelus*, *C. luteus, C. carpio* and *C. trutta* from the Tigris River can be recommended as lean fish. Finally, the results could be useful for fisheries industries and they could also guide studies of nutrition and fish physiology.

Keywords: Fish, Nutritional quality, Khabur River, Ambar Stream, Tigris River

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INTRODUCTION

Since the consumption of fish is an important part of a diet that benefits human health and nutrition, studies on the nutritional components of fish have been around for a long time. There are many studies on the fatty acid and proximate composition of both freshwater and marine fish. In most of these studies, the effects of internal and external factors on these biochemical components were investigated. The results of these studies typically show that the fatty acid and proximate composition of fish species differ according to the physiology of the species, seasons, feeding locations, water temperature, water pollution, diet, geographical conditions, ambient temperature, sex and body parts (Citil et al., 2014; Özoğul et al., 2007).

Fatty acids perform many functions in the human body (Bazinet & Layé, 2014; Swanson et al., 2012) and are mainly divided into three groups such as saturated (SFA), monounsaturated (MUFA) and polyunsaturated fatty acids (PUFA). PUFA is the most important group and has great importance for human health (Bazinet & Layé, 2014; Swanson et al., 2012). According to the position of the last double bond relative to the terminal methyl end of the molecule, the PUFA is divided into three classes: ω9, ω3 and ω6. Among them, ω3 and ω6 PUFAs are essential fatty acids that cannot be synthesized in mammals (Zhang et al., 2020). Marine fish con-

tain mainly ω3 PUFAs, while freshwater fish contain relatively high levels of ω9 and ω6, and low levels of ω3, particularly C20:5ω3 (Eicosapentaenoic acid, EPA) and C22:6ω3 (Docosahexaenoic acid, DHA) when compared with marine fish (Özoğul et al., 2007). Freshwater fish are generally characterized by high levels of ω6 PUFA, specifically C18:2ω6 (Linoleic acid, LA) and C20:4ω6 (Arachidonic acid, AA) (Özoğul et al., 2007).

Some studies found that the intake of ingredients containing PUFA plays a significant part in lowering the prevalence of diabetes, reducing the hazard of coronary heart disease, treating high blood pressure and cardiac arrhythmia, lowering the symptoms of rheumatoid arthritis, Alzheimer's and schizophrenia, and reducing most cancers and hyperactivity problems (Bazinet & Layé, 2014; Citil et al., 2014; Tapiero et al., 2002). Since the medicinal effects of C20:5ω3 and C22:6ω3 of fish are known, these fatty acids are used for medicinal purposes such as treating migraines, heart attacks, depression, rheumatic fever, some types of cancer, diabetes, high cholesterol, high blood pressure, and cardiovascular diseases (Bazinet & Layé, 2014; Citil et al., 2014; Swanson et al., 2012; Tapiero et al., 2002). Moreover, C20:5ω3 and C20:4ω6 can also be metabolized to various eicosanoids that act as hormonal agents (Satar et al., 2012; Swanson et al., 2012). Long-chain ω3 PUFA cannot be synthesized by the human body and must be obtained through the diet (Alasalvar et al., 2002; Swanson et al., 2012); therefore ω3 and ω6 PUFAs are considered essential fatty acids (Satar et al., 2012).

Despite the great diversity of the ichthyofauna of the Khabur, Ambar and Tigris Rivers, detailed information on the proximate composition and fatty acid content of fish species in these rivers is lacking. The purpose of this study was to determine and evaluate the profiles of fatty acids and nutrients such as total lipids, crude protein, cholesterol, ash and moisture in the dorsal muscle of eighteen commercially important fish species living in the Khabur, Ambar and Tigris Rivers.

MATERIALS AND METHODS

Sample collection and preparation

For the purposes of this study 12 different species of economically valued and frequently consumed fish (a total of 18 fish species) from SE Türkiye were chosen. The gathering of samples took place in July 2021 and included freshwater fish *Capoeta umbla* (Sarı balık, Şah balığı), *Barbus lacerta* (Benekli bıyıklı balık), *Squalius break* (Tatlısu kefali), *Chondrostoma regium* (Zereke, Karaburun) and *Alburnus mossulensis* (Gümüş balığı) from the Khabur River (Yeşilöz Deresi), taken from under the Khabur II Bridge, near the Khabur Gendarmerie Station, Uludere, Şırnak (37° 22′ 1″ N: 43° 4′ 37″ E, water temperature 22 °C); *Mastacembelus mastacembelus,* (Mezopotamya yılanbalığı), *B. lacerta, C. umbla, Cyprinion macrostomus* (Bunni balığı) and *Capoeta trutta* (Karabalık, Berat) from the Ambar Stream, between Yayvan and Soylu Villages, Kocaköy, Diyarbakır (37° 51′ 6″ N: 40° 32′ 20″ E, water temperature 22 °C); *C. umbla, Cyprinus carpio* (Sazan), *C. trutta, S. break, C. regium, Carasobarbus luteus* (Himri, Karagöz), *Carassius gibelio* (Gibel sazanı) and *Silurus triostegus* (Mezopotamya yayın balığı) from the Tigris River, taken from under the Sadi Bridge, at a distance of 2 km from the center of Diyarbakır (37° 54′ 57.2436″ N: 40° 13′ 32.2320″ E, water temperature 21 °C). Once collected, the fish were transported within 30 minutes to the laboratory on ice with a fish/ice ratio of 1:2 (w/w) in a styrofoam box, and morphometric measurements of wet weight (WW) and length (cm) were calculated. Identification of the fish species was performed by ichthyologists in the Department of Biology, Dicle University, Türkiye. Averages of 20 species of similar size were caught for each species, and 6-8 species of similar size (female) were selected and analyzed. The size of the selected fish was determined by the size of the fish caught at the collection point and sold in the market. The fish were prepared using processes such as gutting, deboning, filleting and washing. From each specimen, the dorsal muscle portion between the dorsal fin and the head was removed and stored frozen at -20 °C for a month until analysis. The characteristics of fish species are given in Table 1.

The care and use of experimental animals complied with Ministry of Agriculture and Rural Affairs of Türkiye fish welfare laws, guidelines and policies as approved by (Communique No: 2008/48).

Analysis of fatty acid methyl esters (FAME) and Cholesterol and GC-FID conditions

Total lipid extraction was performed according to the method of Bligh and Dyer (Bligh & Dyer, 1959). Samples containing total muscle lipids were trans-esterified with acidified methanol (Stanley-Samuelson & Dadd, 1983).

Gas Chromatography (Agilent 7820A): GC oven: Thermostat controlled for columns that can operate with an accuracy of ± 0.1 °C. Flame Ionization Detector (FID). Capillary column (silica capillary column, DB-23): 60 m long, 0.25 - 0.32 mm inner diameter, 0.10 - 0.30 μm film thickness. Conditioning of the column: The column was conditioned by the GC-oven temperature program, starting from the ambient temperature, and increased by 3 °C/min, up to a temperature of 10 °C. Conditioning was continued until the baseline became linear without any peaks and with no deviation from the baseline. After the baseline became linear, it was kept at that temperature for one hour. Gas chromatography injector: 10 μL (0.1 μL graduated). Carrier gas: Inert gas nitrogen, (flow rate 1 mL/min). Auxiliary gases: high purity hydrogen (purity ≥ 99.9%) and high purity dry air. Oven temperature: After waiting for 15 minutes at the initial temperature of 165 °C, it was increased to 200 °C with an increase in temperature of 5 °C/min. Injection temperature: 250 °C. Detector temperature: constant, maximum temperature is 260/280 °C. The flow rate of the carrier gas: 1.2 mL/min. Amount of substance injected: 1 μL. Split ratio: 1:20 Optimized by sample. Sample amount: 0.1-0.2 μL. The sample amount was increased up to 10 times when the trace amount of substances was analyzed. After the oven temperature was programmed, the separation was continued at a constant temperature until all the peaks came out. Since the sample contained fatty acids lower than 12 carbons, the injection was done at 100 °C and the temperature was immediately increased to the optimum temperature at a rate of 4-8 °C/min. The program was continued at a constant temperature until all components were separated. The number of trans-isomers of fatty acids with carbon numbers between 10 and 24 was determined using capillary columns of a certain polarity. Capillary column for trans-isomers: Silica coated with cyanopropsilicon, 60 m long, 0.25-0.32 mm inner diameter,

Table 1. The characteristics of fish species from the Khabur River, Ambar Stream and Tigris River.

Fish samples	Mean standard length (cm) mean ± SE	Mean total weight (g) mean ± SE	Sex of fish	Number of samples	Studied part
Khabur River					
Capoeta umbla	28±5.45	250±12.30	Female	7	Dorsal muscle
Barbus lacerta	20±4.10	92±6.40	Female	8	Dorsal muscle
Squalius berak	21±4.20	120±7.90	Female	7	Dorsal muscle
Chondrostoma regium	24±4.90	145±10.45	Female	7	Dorsal muscle
Alburnus mossulensis	19±3.34	73±8.43	Female	8	Dorsal muscle
Ambar Stream					
Mastacembelus mastacembelus	42±6.20	109±9.30	Female	7	Dorsal muscle
Barbus lacerta	24±5.15	103±9.25	Female	7	Dorsal muscle
Capoeta umbla	25±6.24	190±10.34	Female	7	Dorsal muscle
Cyprinion macrostomus	18±4.34	80±8.43	Female	8	Dorsal muscle
Capoeta trutta	25±3.42	150±8.75	Female	7	Dorsal muscle
Tigris River					
Capoeta umbla	33±4.60	420±15.10	Female	7	Dorsal muscle
Cyprinus carpio	42±6.25	910±20.25	Female	7	Dorsal muscle
Capoeta trutta	28±7.20	228±11.50	Female	7	Dorsal muscle
Squalius berak	30±6.40	293±13.15	Female	7	Dorsal muscle
Chondrostoma regium	28±5.30	205±11.10	Female	7	Dorsal muscle
Carasobarbus luteus	25±4.85	250±16.45	Female	7	Dorsal muscle
Carassius gibelio	23±4.34	251±13.30	Female	7	Dorsal muscle
Silurus triostegus	85±10.20	2050±55.40	Female	6	Dorsal muscle

Values are given as mean ± SE (standard error) from 6-8 different fish measurements

0.10-0.30 μm film thickness. The FAMEs were identified using retention times compared with those of standard purified FAMEs (Sigma Chemical Co., St. Louis, MO, USA). Results were expressed as FID response area relative percentages. The proportions and spectra of FAMEs were obtained with Hewlett-Packard 3365 Chem-Station computer program.

Cholesterol determination was made according to the AOAC method (Helrich, 1990). The standard curve for cholesterol quantification was built using cholesterol standards at values of 0.0125, 0.025, 0.05, and 0.1 mg/mL. In order to standardize injection mistakes, a correction factor based on an internal standard called 5a-cholestane (Sigma-Aldrich, MO, USA) was applied. A high-grade toluene solution (Sigma-Aldrich) was used to dilute all standards. To each of the control samples 1 mg of free cholesterol (Sigma-Aldrich) was added, as also to the samples utilized for the recovery test, which were designated with the letter "R." Each set of samples used for validation had three replicates taken out, with a sample size of 1 g. The addition of free cholesterol (Sigma-Aldrich) to sample matrices was used to assess the method's accuracy. Utilizing a dilution of the standard solution, the detection limit was established. Once the response signal was twice as strong as the noise signal and observable during the retention time corresponding to the free cholesterol standard, the cholesterol standard was diluted and subjected to GC analysis. The cholesterol detection threshold was determined by assuming that the cholesterol came from 1 g of fish tissue.

Fish muscle tissue samples were properly weighed to 1 g and deposited in a 125 mL boiling flask; then 2 mL of 50% potassium hydroxide in water and 10 mL of 95% ethanol were added to the flask. For 80 minutes, the mixture was stirred, boiled, and refluxed. After cooling the boiling liquid to room temperature (25°C), 10 mL of high-grade toluene (Sigma-Aldrich) was added. The solution had to be mixed for 30 seconds before being transferred to a 250 mL separatory funnel. To eliminate the aqueous components, at least five washes of toluene extract were conducted. The amounts of wash solutions (1.0 N, 0.5N KOH, and distilled water) were significantly reduced due to the reduction of the toluene solvent used. It was critical to allow the toluene layer to completely separate before discarding the aqueous layer in all washes. To eliminate any moisture connected with the toluene, the mixture of toluene and anhydrous sodium sulfate was shaken. In a 2.0 mL flask, 0.5 mL of crystal-clear toluene solution containing extracted cholesterol was combined with 0.5 mL of internal standard solution before being run through the GC apparatus. The Agilent 7820A gas chromatographic system and the DB-17 capillary column (30 m ×0.250 mm×0.15 mm, Agilent Technologies Inc., CA, USA) were used to measure the cholesterol. Gas chromatography for cholesterol: Oven temperature: 260±5°C. Injection temperature: 280 °C. Detector temperature: 300 °C. Velocity of carrier gas: Helium 20-35 cm/s, Hydrogen 30-50 cm/s. Split ratio: 1:50. Injection volume: 0.5-1 μL. Using a 10 μL micro-injector, 1 μL of hexane was taken, 0.5 μL of air was drawn into it, followed by 0.5-1 μL of the sample. The identification and

retention times of each peak were made by comparing the retention times of cholesterol (Δ-5-cholesten-3β-ol) and the standards analyzed under the same conditions.

Analysis of Proximate Composition

The proximate composition of the fish was determined according to the official method of the AOAC (Helrich, 1990). The nitrogen content was measured by the Kjeldahl method, and the percentage (%) of crude protein was calculated from the nitrogen content. In the Kjeldahl method, the entire organic nitrogen is converted to ammonium sulfate after being digested in concentrated sulfuric acid. Under alkaline circumstances, ammonia is created and then distilled into a boric acid solution. The amount of nitrogen in the borate anions, which represents the amount of crude protein in the sample, is estimated by titrating them with standardized hydrochloric acid. Moisture content (%) was calculated by drying the sample in an oven (WISD/WON105) at 103 °C for 18 hours, and the ash content (%) was calculated by direct analysis in a GC-oven (Prothem/PLF 110/15) at 550 °C for 12 hours.

Statistical Analyses

All data are presented as mean ± standard deviation (SD). For analysis data, a statistical program (SPSS 16.0) was used. Statistical analyses of fatty acid levels and proximate compositions were performed by analysis of variance (ANOVA), and mean comparison was performed by Tukey's test. Means were obtained in triplicate and statistically significant differences were reported at ($P \leq 0.05$).

RESULTS AND DISCUSSION

Proximate composition

The proximate compositions of all fish are presented in Table 2. Although the total lipid contents were similar in a few species, significant differences ($P \leq 0.05$) were observed between the species. For example, in the Ambar Stream, in *M. mastacembelus*, the total lipid level was found to be very low at 0.93%, while in *B. lacerta* and *C. umbla*, it was found to be close to each other and relatively high at 5.58% and 5.74%, respectively. The total lipid content was found to be the highest in *C. umbla* with 6.7% and the lowest in *B. lacerta* with 3.72% in fish from the Khabur River. Among the Tigris River fish, total lipid was found to be the lowest in *C. luteus* with 0.99% and the highest in *C. regium* with 7.47%. There are many studies on the total lipid content of freshwater fish. In most of these studies, the total lipid level showed differences as in the current study. For example, in a study on the Indus River fish, the total lipid levels were reported to vary between 0.85% and 18.32% (Memon et al., 2010). In a study of 20 freshwater fish species collected from Malaysian freshwaters, it was reported that the total lipid content of fish (between 1.17 - 34%) varied widely (Rahman et al., 1995). In another study on freshwater fish from Seyhan Dam Lake, it was reported that *Sander lucioperca* had the lowest total lipid content of 0.39% and *Clarias gariepinus* had the highest as 3.21% (Özoğul et al., 2007). The total lipid level in *C. carpio* fish, which was also examined in the current study, was stated as 0.88% (Özoğul et al., 2007). In another study, the total lipid level of *C. carpio* and *Sander lucioperca* L. collected from Beyşehir Lake was reported as 3.33 and 1.73%, respectively (Öksüz et al., 2019). Another study reported that the total lipid content of the tissue of *M. mastacembelus* (Atatürk Dam), which was also investigated in the current study, changed seasonally from 0.50% to 3.59%, and it was also emphasized that the total lipid level was as low as 0.77% in July (Kaçar et al., 2018). In the present study, the total lipid content of *M. mastacembelus* from the Tigris River was also found to be as low as 0.98% in July. Another study showed that the total lipid content of *S. triostegus*, male and female, collected from the Atatürk Dam changes seasonally from 0.63% to 1.32% and from 0.45% to 1.83%, respectively (Kaçar et al., 2016). Additionally, the same study emphasized that the lipid of female *S. triostegus* decreased to a minimum in July (Kaçar et al., 2016). In the current study, the total lipid level of *S. triostegus* was found to be 2.93%. This result was not in agreement with the findings of *S. triostegus* from Atatürk Dam. Atatürk Dam Lake and the Tigris River conditions differ from each other. This is because fish are exothermic and water temperature is one of the most important abiotic factors affecting the growth and survival of aquatic animals. Any change in optimum water temperature has a marked and direct effect on many of the basic physiological processes, especially lipid content (Fatma & Ahmed, 2020).

Fish are typically divided into four groups according to their total lipid content: lean fish (lipid less than 2%), low-fat fish (lipid 2-4%), medium-fat fish (lipid 4-8%) and high-fat fish (lipid more than 8% by weight) (Ackman, 1994). In the current study, *M. mastacembelus, C. luteus, C. carpio* and *C. trutta* (Tigris River) were lean fish. *C. trutta* (Ambar Stream), *S. berak* (Tigris River), *C. gibelio*, and *S. triostegus* were low-fat fish, and the other species were medium-fat fish.

The cholesterol levels of the Ambar Stream fish were found to be the lowest in *M. mastacembelus* with 11.45 mg/100 g and the highest in *C. umbla* with 29.98 mg/100 g. In the Khabur River fish, the lowest level was detected in *A. mossulensis* with 12.64 mg/100 g and the highest in *B. lacerta* with 20.2 mg/100 g. In the Tigris River fish, the lowest cholesterol content was found in *C. carpio* with 7.9 mg/100 g, and the highest in *C. umbla* with 18.97 mg/100 g. In a study on the cholesterol content of three freshwater fish, the amount of cholesterol was found to be in the range of 40.99-52.79 mg/100 g (Moreira et al., 2001), and the amounts were found to be significantly higher than the cholesterol content of the species in this study. In another study, it was reported that the cholesterol content of fish species living in the Porsuk Dam ranges from 94.68 to 179.84 mg/100g (Donmez, 2009). The lipid and cholesterol content of fish depends on age, spawning period, sex, season, geographical conditions and their nutrients and feeding types (Memon et al., 2010). Age variation and sexual maturity in the same species also cause significant differences in total lipid and cholesterol content (Memon et al., 2010). Fish caught during the spawning season or in waters with scarce food sources have lower lipid and cholesterol content than normal seasons, and reducing PUFA in the diet raises cholesterol content in the fish (Donmez, 2009).

In all studied fish, *C. regium* (Khabur River) had the highest protein content with 20.76% and *C. umbla* (Tigris River) had the lowest with 16.64%. Crude protein levels of the same species in dif-

Table 2. Proximate composition of the dorsal muscle of fish from the Ambar, Khabur and Tigris Rivers (%, wet basis). Cholesterol is mg/100 g of dorsal meat of the fish.

Species	Total Lipid (%)	Crude Protein (%)	Cholesterol (mg/100g)	Moisture (%)	Ash (%)
Ambar Stream fish					
Mastacembelus mastacembelus	0.93±0.02a	17.74±0.35a	11.45±0.26a	80.14±0.45a	1.19±0.03a
Barbus lacerta	5.58±0.08b	19.02±0.56b	26.30±0.35b	74.25±0.40b	1.15±0.02a
Capoeta umbla	5.74±0.09b	17.56±0.36a	29.98±0.42c	75.55±0.38b	1.15±0.02a
Cyprinion macrostomus	4.56±0.07c	18.45±0.55b	22.16±0.39d	75.8±0.41b	1.19±0.03a
Capoeta trutta	2.32±0.05d	18.98±0.48b	16.37±0.35e	77.57±0.47ab	1.13±0.02a
Khabur River fish					
Capoeta umbla	6.70±0.09e	17.92±0.31a	12.94±0.23a	74.22±0.57b	1.16±0.02a
Barbus lacerta	3.72±0.0cd	17.86±0.45a	20.20±0.29d	77.31±0.63ab	1.11±0.03a
Squalis berak	4.16±0.08c	19.32±0.41b	13.64±0.18a	75.33±0.54b	1.19±0.03a
Chondrostoma regium	6.02±0.06b	20.76±0.38c	16.85±0.17e	72.10±0.49c	1.12±0.02a
Alburnus mossulensis	4.27±0.07c	19.91±0.29bc	12.64±0.13a	74.72±0.57b	1.10±0.03a
Tigris River fish					
Squalis berak	2.14±0.05d	17.45±0.21a	17.67±0.22e	79.29±0.65a	1.12±0.06a
Capoeta trutta	1.63±0.07ad	17.39±0.23a	10.15±0.12a	79.68±0.59a	1.30±0.08a
Cyprinus carpio	1.37±0.09ad	17.28±0.32a	7.90±0.08f	80.2±0.73a	1.15±0.07a
Capoeta umbla	5.41±0.11b	16.64±0.14d	18.97±0.19de	76.77±0.66b	1.18±0.08a
Chondrostoma regium	7.47±0.16e	17.76±0.17a	11.87±0.31a	73.63±0.81bc	1.14±0.09a
Carasobarbus luteus	0.99±0.08a	17.75±0.15a	7.91±0.11f	80.15±0.58a	1.11±0.06a
Carassius gibelio	2.81±0.11d	18.61±0.16b	11.15±0.12a	77.45±0.70ab	1.13±0.05a
Silurus triostegus	2.93±0.12d	18.62±0.19b	8.61±0.09f	77.29±0.68ab	1.16±0.09a

* The values are means ± SD (standard deviation). Results are expressed as a percentage of total lipid, crude protein, moisture and ash, and mg/100g of cholesterol.
**Means followed by different letters in the same column are significantly different (P≤0.05).

ferent rivers differed slightly. For example, crude protein contents of *B. lacerta* from the Ambar Stream and Khabur River were found to be 19.02% and 17.86%, respectively (*P≤0.05*). The crude protein levels of *C. umbla* from the Ambar Stream, Khabur and Tigris River were 17.56%, 17.92% (*P>0.05*) and 16.64% respectively. *C. regium* from the Khabur and Tigris Rivers had 20.76% and 17.76% of crude protein, respectively (*P≤0.05*). The crude protein content of Indus River fish species was reported to be between 17% and 20.09% (Memon et al., 2010) and the results of the study partly conform with the current study. In another study on five freshwater fish, the crude protein levels were reported to be between 13.93% and 15.41% (Paul et al., 2019) and the results were lower than those in the current study. The crude protein percentages for *C. carpio* and *S. lucioperca*, both of which were taken from Beyşehir Lake, were reported to be 17.40% and 18.97%, respectively (Öksüz et al., 2019). The protein requirements of fish depend on many biological and environmental circumstances (sexual maturity, sex, age, feeding frequency, nutritive conditions, water temperature, non-protein diet amount and dietary protein quality, etc.) (Fatma & Ahmed, 2020).

The findings of our study showed that the moisture content of the Ambar fish was the lowest in *B. lacerta* with 74.25% and the highest in *M. mastacembelus* with 80.14%. Moreover, the moisture content of the Khabur fish varied between 72.10% (*C. regium*) and 77.31% (*B. lacerta*). In the Tigris River fish, the moisture content was the lowest in *C. regium* with 73.63% and the highest in *C. carpio* with 80.20%. However , the ash content was more or less similar (*P>0.05*) in 18 fish species and varied between 1.11% and 1.30% The reason for similar ash content is probably related to the fact that the skeletons of the fish were not used in the ash analysis. However, ash content differs proportionally in some literature. For example, the ash content of eight fish species from the Indus river varied between 0.05% and 4.95% (Memon et al., 2010). The reason for the low level was attributed to the minimal skeleton in small indigenous fish species (Memon et al., 2010). In the same study, the moisture content was found to be between 78.80% and 59.95% (Memon et al., 2010). In another paper on five freshwater fish, the ash content was reported to be between 1.88% and 2.57%, and the moisture content was between 70.82% and 76.11% (Paul et al., 2019). In most studies, significant differences were not observed, and the results are compatible with the current study. In addition, it was noticed that the moisture content of the fish with low total lipid content was high, and an inverse relationship was determined. For example, in *M. mastacembelus* the total lipid content was 0.95% and the moisture was 80.14%; in *C. luteus* the total lipid was 0.99% and the moisture was 80.15%; in *C. carpio* the total lipid level was 1.37% and the moisture content was 80.20%. Similar findings have been highlighted in other studies as well (Memon et al., 2010; Özyurt & Polat, 2006).

Fatty acid composition

The fatty acid compositions of fish taken from the Ambar Stream, the Khabur River and the Tigris River are presented in Tables 3, 4 and 5, respectively. In the analysis, the presence and amount of

37 types of fatty acids from 18 fish species were examined. The predominant fatty acids identified in all fish were C16:0 (Palmitic acid), C16:1ω7 (Palmitoleic acid) and C18:1ω9 (Oleic acid). Moderately detected fatty acids were C14:0 (Myristic acid) and C18:0 (Stearic acid). C16:0 was the primary saturated fatty acid, the level of which was found to be between 32.53% and 40.66% in the Ambar Stream fish, between 26.98% and 33.65% in the Khabur River fish, and between 30.2% and 43.03% in the Tigris River fish. The primary MUFA C16:1ω7 level was found to be between 18.13% and 27.42% in the Ambar Stream fish, between 13.42% and 27.14% in the Khabur River fish, and between 8.08% and 26.92% in the Tigris River fish. The level of C18:1ω9 varied between 12.71% and 24.1% in the Ambar Stream fish, between 19.21% and 36.99% in the Khabur fish, and between 14.51% and 30.66% in the Tigris River fish. Notably, *C. umbla* was collected from the Ambar, Khabur and Tigris Rivers; *B. lacerta* from the Ambar and Khabur Rivers; *C. trutta* from the Ambar and Tigris Rivers and *S. berak* and *C. regium* from the Khabur and Tigris Rivers. When the same species of fish living in different rivers were compared, it was observed that there were some similarities and differences in the levels of fatty acids. For example, the predominant fatty acid profile of *C. umbla* was similar to each other (*P>0.05*) for three rivers except that C18:1ω9. C16:0, C16:1ω7 and C18:1ω9 in *C. umbla* from the Khabur River were found to be 33.65%, 23.24% and 23.11%, respectively. C16:0, C16:1ω7 and C18:1ω9 levels of *C. umbla* in the Ambar Stream were found to be 34.04%, 26.53% and 17.24%, and C16:0, C16:1ω7, C18:1ω9 levels in the Tigris River were found to be 33.71%, 24.43%, and 20.79%, respectively. In the same way, C14:0 and C18:0 were detected in close levels in *C. umbla*. Likewise, the dominant and moderate fatty acid profiles of *B. lacerta* from both the Khabur River and the Ambar Stream were mostly similar except for C16:1ω7 and C18:0. For example, the levels of C16:0, C16:1ω7, C18:1ω9, C14:0, C18:0 in *B. lacerta* from the Ambar Stream were 32.53%, 24.29%, 22.02%, 5.99%, 5.52%, and in *B. lacerta* from the Khabur River the levels were 30.63%, 20.16%, 22.41%, 5.53% and 6.84%, respectively. It was also observed that the fatty acid profile of *C. trutta* was close to each other. The levels of C16:0, C16:1ω7, C18:1ω9, C14:0, C18:0 for *C. trutta* from the Ambar Stream, and Tigris River were 36.32%, 27.42%, 12.71%, 10.72%, 4.71%, and 34.17%, 26.92%, 14.71%, 8.27%, 5.98%, respectively. The levels of C16:0, C16:1ω7, C18:1ω9, C14:0, C18:0 for *S. berak* from the Khabur and Tigris River were also similar. It was only the level of C18:1ω9 that was higher in *S. berak* from the Khabur River than that from the Tigris River (*P≤0.05*). Although C16:0 levels were close to each other in *C. regium* (31.17% for the Khabur River, 33.36% for the Tigris River), differences were observed in the levels of other dominant fatty acids (*P≤0.05*). Consequently, it was observed that the fatty acid profiles of the same fish in different rivers were roughly similar. Minor level differences of the specific fatty acids are possibly due to diet, age, food, water temperature or geographic differences. It is a fact that the same species generally have the same physiological characteristics. It is normal for this similarity to occur because the same species have the same feeding type and prefer similar foods and tastes.

In most of the studies on freshwater fish, C16:0, C18:0, C16:1ω7 and C18:1ω9 were determined as the dominant component and high levels of these fatty acids have been described as a characteristic of freshwater fish (Aras, 2003; Cengiz et al., 2010; Kaçar et al., 2016, 2018; Kaçar & Başhan, 2016; Memon et al., 2010; Osman et al., 2001; Özoğul et al., 2007; Satar et al., 2012; Vasconi et al., 2015). In one study, the main fatty acids of freshwater fish were highlighted as C16:0 (15.9-20.5%), C16:1ω7 (2.51-10.9%), C18:0 (5.63-14.8%), C18:1ω9 (3.46-15.9%), and C22:6ω3 (6.72-24.8%) (Özoğul et al., 2007). In another study, C16:0 (25.39%), C16:1ω7 (5.63%), C18:0 (5.91%), C18:1ω9 (20.63%) and C22:6ω3 (21.42%) were reported as dominant fatty acids in a freshwater *Salmo trutta labrax* muscle tissue (Aras, 2003). Furthermore, for the freshwater fish Rainbow Trout (*Oncorhynchus mykiss*), the dominant fatty acids detected in the muscle of the fish were C16:0 (21.3%), C16:1ω7 (4.16%), C18:0 (6.79%), C18:1ω9 (22.2%), C18:2ω6 (10.4%) (22.2%) and C22:6ω3 (22.7%) (Haliloğlu et al., 2004). In a paper describing the fatty acid compositions of 9 freshwater fish species from the Tigris River (some of them are the same fish as in the current study, such as *A. mossulensis, C. regium, C. luteus, C. macrostomus* and *S. triostegus*) predominant fatty acids were C16:0, C16:1ω7 and C18:1ω9 as in the current study.

In all studied fish, ω3 and ω6 PUFAs particularly C18:2ω6, C18:3ω6 (γ-Linolenic acid, GLA), C20:4ω6, C20:5ω3 and C22:6ω3 levels were found to be quite low. Among the PUFAs, C18:2ω6 had the highest level, with 5.91% for *A. mossulensis*. The level of C20:4ω6, C20:5ω3 and C22:6ω3 was determined to be below 1%. On the contrary, a high content of C20:4ω6 (between 0.75-12.27%), C20:5ω3 (between 0.65-20.15%) and C22:6ω3 (between 0.72-26.89%) was reported in some freshwater fish such as *C. regium, B. rajonorum, C. luteus, Leuciscus lepidus, Acanthobrama marmid, C. macrostomus, and S. triostegus* (Cengiz et al., 2010). In a study conducted on the seasonal fatty acid composition of *C. carpio* from Beysehir Lake, the levels of C18:2ω6 (8.82%), C20:4ω6 (6.99%), C20:5ω3 (4.72%) and C22:6ω3 (11.03%) were reported high in the summer season (Guler et al., 2008). However, as in the present paper, some studies reported that the levels of C20:4ω6 and C20:5ω3 components in freshwater fish were below 1% (Citil et al., 2014; Kaçar et al., 2018; Łuczyńska et al., 2014; Paul et al., 2019). Interestingly, another study revealed that *C. carpio,* also used in the current study, contained very different C20:5ω3 levels in two different dam lakes (Işıklı and Karacaören Dam lakes 0.56% and 20.91%, respectively) (Citil et al., 2014). This shows that even in the same species, the level of C20:5ω3 may differ significantly due to environmental conditions. PUFA levels of fish typically decrease in the summer season (Kaçar et al., 2016; Satar et al., 2012) and fish living in cold waters accumulate more ω3 PUFAs to respond to their physiological requirements (Özoğul et al., 2007). All fish examined in the current study were collected in July during the hottest month of the year. The breeding period of the studied fish is between April and June. It is estimated that the PUFA levels of the fish may decrease after spawning and breeding. Species diversity is the most important cause of variation in fatty acid profiles of fish. Moreover, fatty acid compositions of fish with high species diversity may differ due to many factors. Living in aquatic environments with different ecological conditions, differences in feeding components, particularly whether a species is herbivorous, omnivorous or carnivorous are consid-

Table 3. Fatty acid composition of the total lipid from dorsal muscle of the Ambar Stream fish (%, fatty acids).

Fatty acids (%)	*Mastacembelus mastacembelus*	*Barbus lacerta*	*Capoeta umbla*	*Cyprinion macrostomus*	*Capoeta trutta*
C4:0	nd	nd	nd	nd	0.07±0.01
C6:0	0.10±0.02a	nd	nd	0.05±0.01a	0.07±0.02a
C8:0	0.05±0.01a	0.07±0.02a	0.16±0.04b	0.08±0.02a	0.05±0.01a
C10:0	nd	nd	nd	nd	nd
C11:0	nd	nd	nd	nd	nd
C12:0	0.75±0.07a	0.66±0.06a	0.15±0.02b	0.13±0.02b	0.19±0.03b
C13:0	0.07±0.01a	nd	nd	0.05±0.01a	0.15±0.02b
C14:0	6.56±0.05a	5.99±0.06a	9.54±0.08b	6.32±0.05a	10.72±0.20b
C15:0	0.86±0.07a	0.59±0.05a	0.65±0.06a	0.76±0.07a	1.34±0.11b
C16:0	33.68±0.61a	32.53±0.78a	34.05±0.60a	40.66±0.71b	36.32±0.47ab
C17:0	0.91±0.07a	0.49±0.03b	0.24±0.02c	1.12±0.09a	0.54±0.06b
C18:0	7.62±0.25a	5.52±0.21b	3.04±0.19c	6.22±0.37ab	4.71±0.10bc
C20:0	0.36±0.03a	0.29±0.03a	0.12±0.01b	0.16±0.02b	0.24±0.03a
C21:0	nd	nd	nd	nd	nd
C22:0	0.22±0.02a	0.05±0.01b	nd	nd	0.06±0.01b
C23:0	nd	nd	nd	nd	nd
C24:0	0.14±0.03a	0.06±0.01b	0.05±0.01b	nd	nd
C14:1ω5	0.31±0.02a	0.25±0.02a	0.26±0.02a	0.25±0.03a	nd
C15:1ω5	nd	nd	nd	nd	nd
C16:1ω7	18.44±0.33a	24.29±0.28b	26.53±0.31c	18.13±0.22a	27.42±0.44c
C17:1ω7	0.98±0.09a	1.75±0.08b	1.73±0.08b	1.13±0.10ab	1.15±0.11ab
C18:1ω9	24.10±0.37a	22.02±0.28a	17.24±0.19b	22.06±0.21a	12.71±0.13c
C20:1ω9	1.65±0.12a	1.21±0.10a	1.98±0.12a	1.44±0.09a	2.20±0.10b
C22:1ω9	nd	nd	nd	nd	nd
C24:1ω9	0.23±0.06a	0.05±0.01b	0.10±0.03c	nd	nd
C18:2ω6-cis	1.06±0.05a	1.55±0.09a	1.05±0.07a	0.51±0.03b	0.38±0.04b
C18:2ω6-trans	0.22±0.03a	0.11±0.02b	0.06±0.01c	0.10±0.01b	0.38±0.03d
C18:3ω3	nd	0.07±0.01a	0.14±0.02b	nd	nd
C18:3ω6	0.57±0.03a	0.65±0.05a	0.93±0.08a	0.20±0.01b	nd
C20:2ω6	0.08±0.01a	0.08±0.01a	0.07±0.01a	nd	nd
C20:3ω3	0.09±0.02a	0.14±0.02a	nd	0.07±0.01a	0.10±0.03a
C20:3ω6	nd	nd	nd	nd	nd
C20:4ω6	nd	nd	nd	nd	nd
C20:5ω3	nd	0.48±0.03a	0.52±0.04a	nd	nd
C22:2ω6	0.74±0.06a	0.65±0.04a	0.91±0.09b	0.95±0.09b	1.15±0.15b
C22:6ω3	nd	0.10±0.02a	0.08±0.01a	nd	nd
∑SFA	**51.32±1.34a**	**46.25±1.12b**	**48±1.32c**	**55.55±1.56d**	**54.46±1.47d**
∑MUFA	**45.70±1.10a**	**49.57±1.12b**	**47.77±1.17b**	**43.01±1.05c**	**43.48±1.06c**
∑PUFA	**2.76±0.13a**	**3.83±0.17b**	**3.76±0.21b**	**1.83±0.09c**	**2.01±0.10a**
∑ω6	**2.67±0.11a**	**3.04±0.21b**	**3.02±0.23b**	**1.76±0.12c**	**1.91±0.11c**
∑ω3	**0.09±0.03a**	**0.79±0.05b**	**0.74±0.05b**	**0.07±0.04a**	**0.10±0.02a**
ω6 / ω3	**29.67**	**3.85**	**4.08**	**25.14**	**19.10**

*Values are means ± SD (standard deviation) for 3 replicates. Results were expressed as a percentage of total fatty acid methyl esters. **The mean values of different characters on the same line vary significantly ($P \leq 0.05$). (Results are expressed as % fatty acids of total lipids). Abbreviations: SFA - saturated fatty acid; MUFA - monounsaturated fatty acid; PUFA - polyunsaturated fatty acid; nd - not detected.

ered to be the most important reasons for proximate and fatty acid variations. The season when fish are caught, as well as the size and reproductive status of individuals of the same species living in a certain area, also affect the variations. Additionally, the level of ω3 fatty acids, especially C20:5ω3 and C22:6ω3 are high in fish living in cold climates and vice versa (Çelik et al., 2005). Another reason for the low rate of ω3 and ω6 PUFAs accumulation in the fish of the current study may be related to the low level of

Table 4. Fatty acid composition of the total lipid from dorsal muscle of the Khabur River fish (%, fatty acids).

Fatty acids (%)	*Capoeta umbla*	*Barbus lacerta*	*Squalius berak*	*Chondrostoma regium*	*Alburnus mossulensis*
C4:0	0.05±0.01	nd	nd	nd	nd
C6:0	nd	nd	nd	nd	0.07±0.02
C8:0	0.16±0.02a	0.10±0.02a	0.16±0.03a	0.06±0.01b	0.22±0.04c
C10:0	nd	0.12±0.02a	0.20±0.03b	0.05±0.01c	0.13±0.03a
C11:0	nd	0.06±0.01	nd	nd	nd
C12:0	0.10±0.02a	1.61±0.05b	0.96±0.03c	0.52±0.03d	1.22±0.05b
C13:0	nd	0.08±0.02a	0.06±0.01a	0.15±0.03b	nd
C14:0	8.21±0.12a	5.53±0.11b	3.95±0.07c	7.08±0.08ab	3.17±0.04c
C15:0	0.47±0.04a	0.68±0.06a	0.51±0.05a	0.84±0.08b	0.45±0.04a
C16:0	33.65±0.66a	30.63±0.61b	28.89±0.56c	31.17±0.59b	26.98±0.49d
C17:0	0.56±0.06a	0.66±0.07a	0.59±0.06a	0.50±0.05a	0.61±0.08a
C18:0	4.86±0.16a	6.84±0.14b	7.51±0.19b	4.46±0.14a	5.98±0.29ab
C20:0	0.11±0.03a	0.35±0.04b	nd	0.24±0.03ab	0.38±0.03b
C21:0	nd	nd	nd	nd	nd
C22:0	nd	0.10±0.04a	0.09±0.02a	0.07±0.01a	0.11±0.03a
C23:0	nd	nd	nd	nd	0.41±0.04
C24:0	nd	nd	nd	0.05±0.01a	0.10±0.02b
C14:1ω5	0.25±0.04a	2.30±0.10b	0.18±0.04a	0.20±0.04a	0.11±0.02c
C15:1ω5	nd	nd	nd	nd	nd
C16:1ω7	23.24±0.44a	20.16±0.40b	13.42±0.37c	27.14±0.54d	14.70±0.31c
C17:1ω7	1.56±0.12a	1.14±0.13a	0.69±0.08b	2.07±0.15c	1.06±0.09a
C18:1ω9	23.11±0.47a	22.41±0.45a	36.99±0.81b	19.21±0.39c	34.21±0.78d
C20:1ω9	0.12±0.02a	1.49±0.07b	nd	1.04±0.07b	0.94±0.06ab
C22:1ω9	nd	nd	nd	0.06±0.01a	0.14±0.03b
C24:1ω9	nd	0.11±0.03	nd	nd	nd
C18:2ω6-cis	0.80±0.07a	3.06±0.16b	3.60±0.17b	2.03±0.11c	5.91±0.18d
C18:2ω6-trans	0.06±0.01a	0.16±0.03b	0.13±0.03b	0.08±0.02a	0.11±0.03b
C18:3ω3	0.08±0.01a	nd	nd	0.10±0.02a	nd
C18:3ω6	1.13±0.04a	0.74±0.05b	0.59±0.04b	0.65±0.06b	1.15±0.09a
C20:2ω6	0.05±0.01a	0.12±0.03b	0.19±0.03b	0.15±0.02b	0.37±0.04c
C20:3ω3	nd	0.29±0.03	nd	nd	nd
C20:3ω6	nd	nd	nd	0.10±0.02a	0.10±0.03a
C20:4ω6	0.10±0.03a	0.14±0.04a	0.05±0.01b	0.08±0.01b	0.13±0.03a
C20:5ω3	0.30±0.04a	0.28±0.04a	0.07±0.02b	0.87±0.07c	0.68±0.05c
C22:2ω6	0.67±0.04a	0.52±0.03a	0.62±0.04a	0.65±0.05a	0.30±0.03b
C22:6ω3	nd	nd	0.20±0.03a	0.10±0.03b	0.08±0.01b
∑SFA	**48.17±1.21a**	**46.76±.1.18b**	**42.92±1.14c**	**45.19±1.13b**	**39.35±1.09d**
∑MUFA	**48.28±1.30a**	**47.61±1.27a**	**51.28±1.39b**	**49.72±1.40c**	**51.16±1.45b**
∑PUFA	**3.19±0.08a**	**5.31±0.09b**	**5.45±0.10b**	**4.81±0.08b**	**8.83±0.18c**
∑ω6	**2.81±0.06a**	**4.74±0.11b**	**5.18±0.14b**	**3.74±0.09c**	**8.07±0.21d**
∑ω3	**0.38±0.03a**	**0.57±0.05a**	**0.27±0.02a**	**1.07±0.09b**	**0.76±0.08c**
ω6 / ω3	**7.39**	**8.32**	**19.19**	**3.50**	**10.62**

*Values are means ± SD (standard deviation) for 3 replicates. Results were expressed as a percentage of total fatty acid methyl esters. **The mean values of different characters on the same line vary significantly ($P \leq 0.05$). (Results are expressed as % fatty acids of total lipids). Abbreviations: SFA - saturated fatty acid; MUFA - mono-unsaturated fatty acid; PUFA - polyunsaturated fatty acid; nd - not detected.

C18:3ω3 and C18:2ω6 that enable the synthesis of C22:6ω3, C20:4ω6 and C20:5ω3. The higher concentration of ω6 fatty acids in freshwater fish could be attributed to dietary precursors such as freshwater algae, insect larvae and crustacean that are rich in C18:2ω6 and C18:3ω6 (Kaçar & Başhan, 2016; Steffens, 1997). However, because of the absence of both D12 and D15 desaturase, fish cannot convert C18:1ω9 to C18:2ω6 and further to C18:3ω3 (Tian et al., 2016). Thus, fish are considered to have an

Table 5. Fatty acid composition of the total lipid from dorsal muscle of the Tigris River fish (%, fatty acids).

Fatty acids	*Squalis berak*	*Capoeta trutta*	*Cyprinus carpio*	*Capoeta umbla*	*Chondrostoa regium*	*Carasobarbus luteus*	*Carassius gibelio*	*Silurus triostegus*
C4:0	0.05±0.01a	0.09±0.01a	0.03±0.01a	nd	0.06±0.01a	nd	nd	nd
C6:0	0.07±0.02a	0.07±0.01a	0.06±0.01a	nd	0.07±0.01a	0.09±0.01a	0.09±0.02a	0.07±0.01a
C8:0	0.28±0.04a	0.21±0.03a	0.12±0.02b	0.06±0.01c	0.16±0.03b	0.54±0.04d	0.10±0.03b	0.07±0.01c
C10:0	0.07±0.01a	0.07±0.01a	0.03±0.01b	nd	0.05±0.01ab	nd	nd	nd
C11:0	nd	nd	nd	nd	nd	nd	nd	nd
C12:0	0.55±0.07a	0.24±0.04b	0.43±0.05a	0.14±0.03c	0.24±0.03b	0.07±0.01d	0.80±0.08e	0.40±0.05a
C13:0	0.09±0.02a	0.16±0.04b	0.10±0.03a	nd	0.10±0.02a	0.07±0.01a	0.15±0.04b	0.50±0.07c
C14:0	4.88±0.21a	8.27±0.30b	4.68±0.22a	8.39±0.35b	6.62±0.23ab	3.68±0.12a	4.86±0.27a	5.19±0.12ab
C15:0	1.07±0.08a	1.90±0.07a	1.52±0.05a	0.70±0.04b	1.28±0.06a	0.91±0.04a	1.35±0.05a	0.84±0.04ab
C16:0	30.26±0.50a	34.17±0.66b	35.65±0.75c	33.71±0.52b	33.66±0.69b	43.03±0.72d	30.20±0.57a	33.53±0.62b
C17:0	0.94±0.09a	0.49±0.05b	2.22±0.10c	0.31±0.04b	0.94±0.06a	0.70±0.05a	1.50±0.08ac	0.71±0.05ab
C18:0	6.74±0.45a	5.98±0.32a	10.91±0.15b	3.31±0.11c	5.24±0.15a	6.68±0.21a	7.55±0.19a	10.19±0.20b
C20:0	0.22±0.04a	0.20±0.03a	0.55±0.06b	0.12±0.02c	0.27±0.03a	0.10±0.03c	nd	0.32±0.03ab
C21:0	nd	nd	nd	nd	nd	nd	nd	nd
C22:0	0.06±0.01a	0.10±0.03b	0.34±0.05c	nd	0.07±0.02a	nd	0.12±0.03b	0.09±0.02b
C23:0	nd	nd	nd	nd	nd	nd	nd	nd
C24:0	nd	0.11±0.03a	0.12±0.03a	0.05±0.01b	0.06±0.01b	nd	nd	nd
C14:1ω5	0.23±0.07a	0.19±0.04a	0.49±0.05b	0.69±0.04b	0.85±0.07c	nd	0.67±0.06b	0.13±0.02a
C15:1ω5	0.09±0.02a	nd	0.13±0.03a	nd	nd	nd	0.24±0.03b	0.08±0.01a
C16:1ω7	15.85±0.21a	26.92±0.26b	9.67±0.19c	24.43±0.26d	22.74±0.32e	8.08±0.13c	11.60±0.16d	15.25±0.15a
C17:1ω7	1.04±0.06a	2.13±0.09b	0.94±0.05a	1.61±0.07a	1.06±0.05a	0.47±0.03c	1.24±0.05a	0.58±0.04c
C18:1ω9	30.66±0.67a	14.51±0.45b	21.92±0.49c	20.79±0.52c	22.16±0.54c	28.81±0.61a	29.13±0.70a	28.19±0.65a
C20:1ω9	nd	2.29±0.09a	1.35±0.06b	1.83±0.07b	1.45±0.06b	1.71±0.08b	3.34±0.16c	1.97±0.08ab
C22:1ω9	nd	nd	nd	nd	nd	nd	nd	nd
C24:1ω9	0.08±0.02a	nd	0.14±0.03b	nd	nd	nd	nd	nd
C18:2ω6-cis	3.59±0.10a	0.37±0.05b	3.47±0.09a	1.36±0.06c	0.53±0.07b	1.58±0.09c	3.72±0.09a	0.71±0.05b
C18:2ω6-trans	0.25±0.04a	0.07±0.01b	0.43±0.06a	0.09±0.02b	0.25±0.05a	0.21±0.04a	0.40±0.05a	0.71±0.06c
C18:3ω3	0.07±0.01a	nd	nd	0.09±0.02a	nd	nd	nd	nd
C18:3ω6	1.01±0.08a	0.18±0.04b	2.47±0.09c	0.72±0.05a	0.96±0.08a	1.10±0.05a	nd	0.25±0.04b
C20:2ω6	0.28±0.03a	0.05±0.01b	1.35±0.08c	0.06±0.01b	0.11±0.03b	0.17±0.03ab	0.52±0.04a	nd
C20:3ω3	0.10±0.03a	0.08±0.02a	0.34±0.04b	0.09±0.02a	nd	0.36±0.05b	0.50±0.06b	nd
C20:3ω6	0.10±0.03a	nd	nd	nd	nd	nd	0.07±0.01a	nd
C20:4ω6	0.10±0.02a	nd	0.09±0.01a	0.50±0.06b	nd	nd	0.22±0.04c	nd

Table 5. Continue.

Fatty acids	*Squalis berak*	*Capoeta trutta*	*Cyprinus carpio*	*Capoeta umbla*	*Chondrostoa regium*	*Carasobarbus luteus*	*Carassius gibelio*	*Silurus triostegus*
C20:5ω3	0.12±0.04a	0.18±0.03a	0.11±0.06a	0.27±0.07b	nd	nd	0.12±0.03a	nd
C22:2ω6	0.57±0.06a	0.75±0.07a	0.59±0.05a	0.59±0.06a	0.57±0.05a	0.47±0.04a	0.63±0.06a	0.83±0.07a
C22:6ω3	0.06±0.01a	nd	0.24±0.03b	nd	nd	0.20±0.03b	0.20±0.04b	nd
∑SFA	**45.28±1.15a**	**52.06±1.46b**	**56.76±1.49c**	**46.79±1.25a**	**48.82±1.35d**	**55.87±1.50c**	**46.72±1.34a**	**51.91±1.41b**
∑MUFA	**47.95±1.32a**	**46.04±1.21b**	**34.64±1.12c**	**49.35±1.33a**	**48.26±1.34a**	**39.07±1.13d**	**46.22±1.20b**	**46.20±1.23b**
∑PUFA	**6.25±0.12a**	**1.68±0.09b**	**9.09±0.19c**	**3.77±0.09d**	**2.42±0.07e**	**4.09±0.11d**	**6.38±0.15a**	**2.50±0.08e**
∑ω6	**5.90±0.11a**	**1.42±0.06b**	**8.40±0.18c**	**3.32±0.09d**	**2.42±0.08e**	**3.53±0.10c**	**5.56±0.15a**	**2.50±0.09e**
∑ω3	**0.35±0.03a**	**0.26±0.02a**	**0.69±0.05b**	**0.45±0.04c**	**nd**	**0.56±0.04c**	**0.82±0.07d**	**nd**
ω6 / ω3	**16.86**	**5.46**	**12.17**	**7.38**	**-**	**6.30**	**6.78**	**-**

*Values are means ± SD (standard deviation) for 3 replicates. Results were expressed as a percentage of total fatty acid methyl esters. **The mean values of different characters on the same line vary significantly ($P \leq 0.05$). (Results are expressed as % fatty acids of total lipids). Abbreviations: SFA - saturated fatty acid; MUFA - monounsaturated fatty acid; PUFA - polyunsaturated fatty acid; nd - not detected.

absolute requirement for the essential fatty acid ω6 and ω3 PUFAs that must be provided in the diet (Tian et al., 2016). Furthermore, fish accumulate ω3 PUFAs in their bodies by consuming zooplankton and phytoplankton or through consuming smaller fish (Balıkçı, 2021). Therefore, the level of ω3 PUFA in fish muscle is based on nourishment and their variations may be due to differences in the fish's dietary habits (Balıkçı, 2021).

Several studies have reported that zooplankton and phytoplankton abundance is highest in spring and lowest in winter (Balıkçı, 2021). Naturally, zooplankton and phytoplankton diets provide physiologically essential PUFAs such as C22:6ω3 and C20:5ω3 (Balıkçı, 2021). The low ω3 PUFA content of the species studied in the summer is probably due to lower consumption of freshwater phytoplankton and zooplankton compared to other seasons. The quantity of planktonic organisms in the rivers during the summer can affect post-spawning fatty acid profiles and the post-ovulation interval raises the possibility of low fatty acid levels. In order to understand the relationship between the fatty acid levels of fish and their diets, the planktonic levels of the collection regions should be investigated. Additionally, it is well-known that during the summer when fish are active and need more energy, they directly reduce their fat reserves by using the fat that has been deposited.

In the comparison of ∑SFA, ∑MUFA and ∑PUFA levels of the Ambar Stream fish, there were some significant differences ($P \leq 0.05$). The highest ∑SFA level was found in *C. macrostomus* with 55.55%, and the lowest ∑SFA level was found in *B. lacerta* with 46.25%. However, the highest ∑MUFA level was in *B. lacerta* with 49.57% and the lowest ∑MUFA was detected in *C. macrostomus* with 43.01%. The ∑PUFA level varied between 1.83% and 3.83% and the highest ratio of ω6/ω3 was observed in *M. mastacembelus* with 29.67. For the fish of the Khabur River, the ∑SFA level ranged from 39.35% (*A. mossulensis*) to 48.17% (*C. umbla*). Their ∑MUFA levels were between 47.61% (*B. lacerta*) and 51.28% (*S. berak*). The highest ∑PUFA level was detected in *A. mossulensis* with 8.83% and the lowest in *C. umbla* with 3.19%. The highest ratio of ω6/ω3 was found in *S. berak* (19.19). In the Tigris River fish, ∑SFA levels were high in *C. carpio* (56.76%) and *C. luteus* (55.87%), whereas in *S. berak* (45.28%), *C. umbla* (46.79%) and *C. gibelio* (46.72%) the ∑SFA were low. The lowest ∑MUFA level was in *C. carpio* with 34.64% and the highest in *C. umbla* with 49.35%. The ∑PUFA levels varied between 1.68% (*C. trutta*) and 9.09% (*C. carpio*). The highest ratio of ω6/ω3 was found in *S. berak* with 16.86. Omega-3 fatty acids were not detected in *C. regium* and *S. triostegus*. In general, fatty acid composition and ω6/ω3 ratio of fish depends upon the composition of consumed feed (Guler et al., 2008). In consequence, ∑SFA and ∑MUFA levels were significantly higher than ∑PUFA levels in all 18 fish species. This is characteristic of freshwater fish living in warm waters (Kaçar et al., 2016; Kayhan et al., 2015). In many studies, it has been reported that levels of the ∑SFA, ∑MUFA and ∑PUFA differed according to season, habitat or species. For instance, in a study on 9 wild-caught freshwater fish, ∑SFA (27% - 36.2%), ∑MUFA (21.83% - 50.53%) and ∑PUFA (19.43% - 45.60%) were reported at high levels (Zhang et al., 2020). Similarly, in a paper on the fatty acid composition of the muscle lipids of five dam fish species from Türkiye, the ∑SFA, ∑MUFA and ∑PUFA levels were

found to be high, (24.95% and 35.34%), (26.08% and 38.17%) and 30.73% and 47.71%, respectively (Citil et al., 2014). In the muscle tissue of *S. trutta labrax* from Kazandere Creek, it was reported that ∑SFA was 37.21%, ∑MUFA was 26.76%, ∑PUFA (ω6) was 28.85%, and ∑PUFA (ω3) was 3.98% (Aras, 2003). In another article about Brazilian freshwater fish both from farms and wildlife habitats, results of 18.76% for ∑PUFA and 38.83% for ∑SFA for farmed fish, and 12.02% for ∑PUFA and 41.86% for ∑SFA for wild fish were reported (Moreira et al., 2001). Like the studies above, it was emphasized in some other studies (particularly in cold freshwater fish), that the ∑PUFA levels were higher than the current study (Cengiz et al., 2010; Kaçar & Başhan, 2016; Kayhan et al., 2015; Özoğul et al., 2007). However, in the studies on fish collected in warm freshwaters, it was reported that the ∑PUFA levels were low. For example, in a study about the fatty acid profile of male and female *S. triostegus* from Atatürk Dam Lake, the ∑SFA (36.58% for females and 38.02% for males) was found to be higher than the ∑MUFA and ∑PUFA in July; however, the ∑PUFA (35.57% for female and 37.69% for male) level was high in January (Kaçar et al., 2016). Naturally, levels of ∑PUFA in fish muscle are mostly dependent on dietary precursors and environmental temperatures (Aras, 2003; Guler et al., 2017; Sargent, 1997). Variations in fatty acid profiles especially in PUFAs might be related to the changes in the nutritional habits of the fish and the temperature of their habitats. For example in some studies on cultured fish, the ω3 PUFA was generally lower than that of wild fish possibly due to the lack of components originating from phytoplankton and aquatic organisms in cultured diets (Guler et al., 2017). It is well known that fish tend to accumulate PUFAs in cold waters and SFAs in warm waters (Kaçar et al., 2016). The results and fish samples of the present study were obtained in July (the hottest month of south Anatolia) and it is both normal and possible for the fish to have low PUFAs, and high MUFAs and SFAs levels.

CONCLUSION

The results of this informative study show that 18 species of freshwater fish are good sources of ∑SFA and ∑MUFA, specifically C14:0, C16:0, C18:0, C16:1ω7 and C18:1ω9. However, fish (mainly consumed in summer when there is no fishing ban and water levels are low enough to be fished) were observed to be poor in terms of ω6 and ω3, particularly C20:4ω6, C20:5ω3 and C22:6ω3. Consumption of those fish in the summer will now no longer offer a good deal of gain as regards ∑PUFA. Nevertheless, *C. carpio* (Tigris River) and *A. mossulensis* (Khabur River) had relatively high ∑PUFA levels compared to other fish due to their partly higher C18:2ω6 and C18:3ω6 levels. Among all the fish, *C. regium* and *A. mossulensis* from the Khabur River were discovered to be good sources of protein, and *M. mastacembelus, C. luteus, C. carpio* and *C. trutta* from the Tigris River may be recommended for consumption as a lean fish category. *C. umbla* and *B. lacerta* from the Ambar Stream were high in cholesterol, while *C. carpio*, *C. luteus* and *S. triostegus* from the Tigris River were low in cholesterol. As a result, the data may be useful to the food and fisheries industries and they may guide studies regarding the nutritional quality, physiology and biochemistry of fish.

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Ethical Approval: Animal care and experiments were carried out in accordance with national and /or international guidelines.

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