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PROOF

Effects of Seasonal Variations on the Fatty Acid Composition of Total Lipid, Phospholipid and Triacylglicerol in the Dorsal Muscle of Mesopotamian Catfish (*Silurus triostegus* Heckel, 1843) in Tigris River (Turkey)

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Abstract

The seasonal effects on the fatty acid composition of total lipid, triacylglicerol and phospholipid in the dorsal muscle of *Silurus triostegus* were determined by gas chromatographic (GC) method. The total polyunsaturated fatty acids (PUFA) and monounsaturated fatty acids (MUFA) were the most important groups of total lipid and statistically ranged ($P<0.05$) from 33.88% to 55.85% and from 23.37% to 38.71%, respectively. The major fatty acids of total lipid in all seasons were palmitic acid (16:0) in SFA, oleic acid (18:1) in MUFA, linoleic acid (18:2) in n-6 PUFA, and docosahexanoic acid (22:6, DHA) in n-3 PUFA. In the present study, n-3/n-6 ratios of total lipid were 2.47, 1.20, 1.03 and 1.40 in spring, summer, autumn and winter, respectively. It was determined that MUFA and PUFA were the most important groups of triacylglicerol and statistically ranged ($P<0.05$) from 34.09% to 47.02% and from 33.13% to 46.12%, respectively. The main fatty acids of triacylglicerol were palmitic acid in SFA, oleic acid in MUFA and linoleic acid in PUFA. PUFA was the most important group of phospholipid except summer. The total PUFA percentages of the phospholipid statistically ranged ($P<0.05$) from 38.12% to 65.75%. The major fatty acids identified in the phospholipid were palmitic acid in SFA, oleic acid in MUFA, arachidonic acid (20:4, AA) in n-6 PUFA and DHA in n-3 PUFA in all seasons. DHA was very high in winter (30.41%). It was shown that the fatty acid compositions in the muscle of fish were significantly influenced by seasons.

Keywords: Seasonal variation, fatty acid composition, fish, *Silurus triostegus*, n-3/n-6 ratio.

Dicle Nehri'ndeki (Türkiye) Mezopotamya Yayın Balığı'nın (*Silurus triostegus* Heckel, 1843) Dorsal Kasındaki Total Lipit, Fosfolipit ve Triaçilgliserolün Yağ Asit Kompozisyonu Üzerinde Mevsimsel Değişimin Etkileri

Özet

Silurus triostegus'un dorsal kasındaki total lipit, triaçilgliserol ve fosfolipitin yağ asit kompozisyonu üzerindeki mevsimsel etkiler, gaz kromatografisi ile (GC) belirlendi. Total çoklu doymamış yağ asitleri (PUFA) ve tekli doymamış yağ asitleri (MUFA), total lipitin en önemli gruplarıydı ve istatistiksel olarak ($p<0.05$) sırasıyla %33.88'den %55.85'e ve %23.37'den %38.71'e değişti. Bütün mevsimlerde total lipitin en önemli yağ asitleri; doymuş yağ asitlerinde (SFA) palmitik asit (16:0), MUFA'da oleik asit (18:1), n-6 PUFA'da linoleik asit (18:2) ve n-3 PUFA'da dokosahekzaenoik asit (22:6, DHA) idi. Bu çalışmada, total lipitin n-3/n-6 oranları bahar, yaz, sonbahar ve kış mevsimlerinde sırasıyla 2.47, 1.20, 1.03 ve 1.40 idi. MUFA ve PUFA'nın, triaçilgliserolün en önemli grupları olduğu ve istatistiksel olarak ($p<0.05$) sırasıyla %34.09'dan %47.02'ye ve %33.13'den %46.12'ye değiştiği belirlendi. Triaçilgliserolün temel yağ asitleri; SFA'da palmitik asit, MUFA'da oleik asit ve PUFA'da linoleik asitti. PUFA, yaz mevsimi dışında fosfolipitin en önemli grubuydu. Fosfolipitin total PUFA yüzdeleri, istatistiksel olarak ($p<0.05$) %38.12'den %65.75'e değişti. Tüm mevsimlerde, fosfolipitte tayin edilen en önemli yağ asitleri SFA'da palmitik asit, MUFA'da oleik asit, n-6 PUFA'da araşidonik asit (20:4, AA) ve n-3 PUFA'da DHA idi. DHA kış mevsiminde çok yüksek bulundu (%30.41). Balıkların kas dokusundaki yağ asit kompozisyonlarının, mevsimlerden önemli ölçüde etkilendiği gösterildi.

Anahtar Kelimeler: Mevsimsel değişiklik, yağ asit kompozisyonu, balık, *Silurus triostegus*, n-3/n-6 oranı.

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Introduction

Fish oil is of vital importance for human health because of the presence of polyunsaturated fatty acids (PUFAs). Long chain n-3 PUFAs cannot be synthesised by human bodies and mostly are obtained through the diet (Alasalvar *et al.*, 2002). Thus, especially eicosapentaenoic acids (EPA) and docosahexaenoic acids (DHA) have been considered as essential fatty acids. These fatty acids have great importance to humans for prevention of coronary artery disease (Kinsella *et al.*, 1990). DHA is a major component of brain, eye retina and heart muscle. It has been considered as important for brain and eye development and also good cardiovascular health (Ward and Singh, 2005). EPA has also been reported to be useful in brain disorders and cancer treatment (Fenton *et al.*, 2000). Furthermore, arachidonic acid (AA) and EPA can be oxidatively metabolized to a variety of eicosanoids that act as hormonal substances (Whelan *et al.*, 1993).

Result of clinical and epidemiological research suggests that EPA and DHA are mainly in fish and seafoods (Leaf and Weber, 1988). The n-3 fatty acids are always present in fish flesh even in lean fish (Ackman, 2002).

The nutritional importance of fish consumption is closely associated with the n-3 fatty acid content of each species. The quantity and composition of fatty acids from lipids are not only associated with the species, but also depend on diet, temperature, seasonality, age and gender (Ackman, 1989).

Phospholipids (PL) contain a high percentage of PUFAs. The absorption of PUFA is influenced by the lipid form in which these fatty acids are eaten (Carnielli *et al.*, 1998). In particular, the fatty acid composition of the triacylglycerol (TG) strongly reflected that of the diet, implying that TG acts as a nutritional storage site in the fish body (Shirai et al., 2002).

Therefore, it is necessary to establish the fatty acid composition of TG and PL in order to estimate the nutritive value of fish.

Silurus triostegus is found in the Tigris-Euphrates basin (Unlu and Bozkurt, 1996). This species is one of the most abundant freshwater fish in Tigris River, Turkey. *Silurus triostegus* has great economic value. People who live in Southeastern Anatolia consume this fish abundantly. Its daily diet consists of other fish species, amphibians and even the smaller waterfowl. In general, the fatty acid composition of fish lipids is influenced by seasonal variations (Bandarra *et al.*, 1997). Although there are many studies on seasonal variations for many different fish species, no reports have been published about the effects of seasonal variations on the fatty acid composition of this important species in Tigris River. There has been no study on the fatty acid composition of total lipid, TG and PL from *S. triostegus* lipids. In the view of these facts, it is necessary to carry out a study on lipid profile of commonly consumed fish, *S. triostegus*, in this location. The present study was undertaken to clarify the influence of seasonal variations on the fatty acid composition of total lipid, TG and PL in the dorsal meat, and n-3/n-6 fatty acids ratio of *S. triostegus.*

Materials and Methods

Sampling Procedure

The samples were caught in winter (January), spring (April), summer (July) and autumn (October) from the Tigris River in Turkey. The samples were kept in ice after capturing and transported to the laboratory immediately. The total length and weight of all individuals were measured. All representative fishes ($n = 3$ at each determination) used in the experiments were almost at the same age (2-3 years old) and female. It is well known that female samples are more prone to changes in biochemical composition due to gonad development and spawning. The average for the total length of *S. triostegus* was 24.10 ± 2.66 cm, and the total weight was 155.2 ± 44.96 g. This size and weight of fish are common in the river. From each specimen, an edible portion of the dorsal muscle between dorsal fin and the head was excised. This section was then skinned, deboned and the red muscle was trimmed off. Samples were collected in small pochettes. They were kept maximum 1-2 days at −30 °C prior to analysis. At the beginning of each analysis, the samples were allowed to defrosted to room temperature, and homogenized in chloroform/methanol mixture (2/1 v/v). Autoxidation of unsaturated components was minimized by adding 50 µL of 2% butylated hydroxytoluene in chloroform to each sample during the extraction process.

Lipid Extraction and Lipid Class Analysis

Lipids were extracted by the method of Bligh and Dyer (1959). The PL and TG were fractionated by thin layer chromatography (TLC; 0.25 mm silica gel 60 $F_{254,}$ Merck, Germany). After applying the total lipid extracts, the TLC plates were developed using petroleum ether:diethyl ether:acetic acid (80:20:1 by vol.) and the developed TLC plates were sprayed with 2'7'- dichlorofluorescein (Supelco, USA), and PL and TG fractions were identified by correspondig standards. PL and TG fractions were recovered from the TLC plates by scraping off the appropriate bands. Samples containing muscle lipid were transesterified with acidified methanol (Stanleysamuelson and Dadd, 1983). The fatty acid methyl esters (FAMEs) were extracted from the reaction vials three times with hexane.

Fatty acid methyl esters (FAMEs) were analysed by capillary gas chromatography using a Ati Unicam

GC-610 (ATI Unicam, UK) equipped with a flame ionization detector (FID), a Unicam 4815 recording integrator and a fused silica capillary column (Quadrex 007-23, 30 m x 0.25 mm i.d.; 0.25 µm film thickness, Quadrex Corp., USA). The temperature profiles were as follows: initial temperature, 100 ^{o}C (initial time, 3 min); heating rate, 5 ^{o}C min^{-1}; final temperature, 260 ^{o}C; injection temperature, 230 ^{o}C; detector temperature, 300 ^{o}C and total run time 35 min. The carrier gas was nitrogen (flow rate 1 ml/min) and split ratio was 40:1.

The FAMEs were identified by comparisons of the retention times with those of standard purified fatty acids (Sigma, USA, catalogue number of the FAMEs standard: 18913, 18916, ME10, 47563). Results were expressed as FID response area relative percentages. The amount of fatty acids was given as a percentage.

Statistics Methods

Kruskal-Wallis non-parametric test was used for measurements to evaluate statistical differences across subjects among the four conditions (spring, summer, autumn and winter). When the Kruskal-Wallis test showed a statistical difference, Mann-Whitney U test was used for multiple comparisons to evaluate the statistical significance of the difference between different groups. $P<0.05$ was considered statistically significant in all analyses.

Results and Discussion

Fatty Acid Composition of Total Lipid

Seasonal variations on fatty acid composition of total lipid in *S. triostegus* are presented in Table 1. Nineteen fatty acids in muscle lipids of *S. triostegus* were identified and evaluated. The major fatty acids in the *S. triostegus* in all seasons were palmitic acid (16:0), palmitoleic acid (16:1n-7), stearic acid (18:0), oleic acid (18:1n-9), linoleic acid (18:2n-6), linolenic acid (18:3n-3), AA (20:4n-6), EPA (20:5n-3), docosapentaenoic acid (22:5n-3, DPA) and DHA (22:6n-3). It was observed that the fatty acid composition of *S. triostegus* varied throughout the seasons. Except eicosadienoic acid (20:2n-6), significant differences ($P<0.05$) were observed in all fatty acids between seasons. The total saturated fatty acid (SFA) and monounsaturated fatty acid (MUFA) reached their highest value in summer. The total SFA percentages of the total lipid extracted from *S.*

Table 1. Seasonal variations in fatty acid composition of total lipid of *Silurus triostegus* (FAME%).

Fatty acid compositions	Spring	Summer	Autumn	Winter
12:0	0.13 (0.09)^{a}	0.34 (0.01)^{b}	0.21 (0.89)^{ab}	0.07 (0.09)^{c}
14:0	1.04 (0.07)^{a}	2.02 (0.99)^{c}	1.32 (0.37)^{b}	1.48 (0.12)^{b}
15:0	0.37 (0.03)^{a}	0.27 (0.01)^{ab}	0.45 (0.07)^{ac}	0.11 (0.01)^{b}
16:0	14.50 (3.29)^{a}	17.76 (3.53)^{a}	11.77 (2.59)^{b}	10.53 (1.41)^{b}
17:0	1.25 (0.09)^{a}	1.97 (0.05)^{b}	2.31 (0.86)^{b}	1.45 (0.07)^{a}
18:0	5.28 (0.74)^{a}	5.05 (0.88)^{a}	3.31 (0.91)^{b}	4.20 (0.93)^{ab}
Σ SFA	22.57	27.41	19.37	17.84
16:1n-7	5.72 (0.55)^{ab}	8.15 (1.05)^{b}	8.33 (1.35)^{b}	4.70 (0.95)^{a}
18:1n-9	16.93 (2.95)^{a}	28.66 (4.20)^{b}	19.18 (3.53)^{a}	20.90 (1.40)^{a}
20:1n-9	0.72 (0.03)^{a}	1.90 (0.08)^{b}	1.38 (0.08)^{c}	0.71 (0.09)^{a}
Σ MUFA	23.37	38.71	28.89	26.31
18:3n-3	2.27 (0.85)^{a}	3.08 (0.80)^{a}	1.79 (0.43)^{a}	8.58 (1.08)^{b}
20:5n-3	10.78 (2.27)^{a}	5.91 (1.27)^{b}	5.93 (1.45)^{b}	7.82 (1.83)^{ab}
22:5n-3	7.44 (1.95)^{b}	3.17 (0.94)^{b}	6.09 (1.23)^{ab}	3.95 (0.36)^{ab}
22:6n-3	17.99 (2.03)^{a}	6.31 (0.77)^{b}	12.44 (2.06)^{ab}	12.20 (0.44)^{ab}
Σ n-3	38.48	18.47	26.25	32.55
16:2n-6	1.18 (0.11)^{a}	1.26 (0.09)^{a}	0.73 (0.04)^{ab}	0.54 (0.01)^{b}
18:2n-6	4.54 (1.43)^{a}	8.89 (1.35)^{b}	16.46 (1.74)^{c}	14.06 (1.82)^{c}
18:3n-6	0.67 (0.05)^{a}	0.67 (0.09)^{a}	1.17 (0.09)^{b}	0.70 (0.05)^{a}
20:2n-6	0.56 (0.09)^{a}	0.72 (0.03)^{a}	0.61 (0.01)^{a}	0.86 (0.04)^{a}
20:3n-6	1.03 (0.09)^{ab}	0.81 (0.05)^{a}	1.44 (0.05)^{b}	0.08 (0.01)^{c}
20:4n-6	7.60 (1.03)^{a}	3.06 (0.09)^{b}	5.08 (1.12)^{ab}	7.06 (0.85)^{a}
Σ n-6	15.58	15.41	25.49	23.30
Σ PUFA	54.01	33.88	51.74	55.85
n-3/n-6	2.47	1.20	1.03	1.40

Parantheses represents standart deviations of mean values as SD. SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid. Different letters (a,b,c) in the same row represent significant statistical differences ($p<0.05$).

triostegus statistically ranged (P<0.05) from 17.84% to 27.41%. With regard to the ratio of total SFA content, the highest value was found in summer. Palmitic acid was the major SFA, contributing approximately 59.03-64.79% to the total SFA content of the lipids for *S. triostegus*. Stearic acid was the second major SFA (3.31–5.28%). Similar results for other freshwater fish species have also been reported (Haliloglu et al., 2002; Guler *et al.*, 2007; Cengiz *et al.*, 2010). Ackman *et al.* (1975) pointed out that palmitic acid was a key metabolite in fish and its level was not influenced by diet.

The total MUFA percentages of the total lipid statistically ranged (P<0.05) from 23.37% to 38.71%. Oleic acid was identified as a primary MUFA in the *S. triostegus* for all seasons. The levels of this fatty acid in muscle tissue of *S. triostegus* was 28.66%, 20.90%, 19.18%, and 16.93% in summer, winter, autumn and spring respectively. The highest level of oleic acid was in summer. Similarly Guler *et al.* (2007) found that oleic acid was the major MUFA in muscle tissue of zander, *Sander lucioperca* living in freshwaters of Turkey. Palmitoleic acid was the second major MUFA (4.70-8.33%) in the present study. The high levels of oleic acid and palmitoleic acid have been reported as a characteristic property of freshwater fish oils (Osman *et al.*, 2001).

The total PUFAs were highest in winter, then spring followed by autumn and summer. Calabretti *et al.* (2003) reported that total PUFAs were high in winter and were low in summer for *Oncorhynchus mykiss*. The total PUFA percentages of the total lipid extracted from the *S. triostegus* ranged from 33.88% to 55.85%. DHA was the most abundant n-3 PUFA, statistically ranging (P<0.05) from 34.16 to 47.39%. The proportion of n-6 PUFAs in total fatty acids ranged from 15.41 to 25.49%. AA and linoleic acid were the major n-6 PUFAs. The findings were similar to the fatty acid compositions found in previous study on different species (Bayir *et al.*, 2006).

The n-3/n-6 ratio is a good index for comparing relative nutritional value of fish oils (Pigott and Tucker, 1990). In this study, data show that the n-3/n-6 ratio was 2.47 in spring, 1.40 in winter, 1.20 in summer and 1.03 in autumn. An increase in the human dietary n-3/n-6 fatty acid ratio is essential in the diet to help preventing coronary heart disease by reducing plasma lipids and to reduce cancer risk (Kinsella *et al.*, 1990). According to Guler *et al.* (2007) the ratio of n-3/n-6 fatty acids was 1.49 in spring, 1.45 in autumn, 1.22 in winter and the lowest value (0.72) was in summer in *Sander lucioperca*. A high level of n-6 fatty acids lowered the n-3/n-6 ratio in summer in a freshwater fish *Sander lucioperca*. According to another study**,** the ratio of n-3/n-6 fatty acids of *Vimba vimba tenalla* was 1.4 in spring, 1.5 in summer, 1.2 in autumn and 1.4 in winter (Kalyoncu *et al.*, 2009). Our study has revealed that *S. triostegus* may be a valuable food for human consumption in terms of fatty acids. It is suggested that this fish should be consumed in spring and winter because of its quite nutritious fatty acid composition and ratio.

Fatty Acid Composition of Triacylglycerol

The fatty acid composition of TG in *S. triostegus* are shown in Table 2. It was determined that MUFA and PUFA were the most important groups of triacylglicerol and statistically ranged (P<0.05) from 34.09% to 47.02% and from 33.13% to 46.12%, respectively. MUFA was highest in spring and total PUFA was highest in autumn. The percentage of total SFA was the lowest fatty acid group found in *S. triostegus* throughout the year. Significant differences were observed in the fatty acid composition of TG *(*P<0.05). It was found that palmitic acid in SFA; palmitoleic acid and oleic acid in MUFA were the main fatty acids of TG in the all seasons. Linoleic acid percentage in spring and summer was high in PUFA. Shirai *et al.* (2002) have reported that the main fatty acids of TG in Japanese and Thai catfish were palmitic acid, oleic acid and linoleic acid.

The percentages of PUFA, such as AA, and DPA, were low in TG in spring and summer. The findings were similar to the fatty acid compositions levels in previous studies on different species (Shirai *et al.*, 2002). Palmitic acid and palmitoleic acid were highest in summer. Oleic acid and EPA were highest in spring and winter respectively. The high levels of oleic acid in winter have been reported in Japanese catfish (Shirai *et al.*, 2002).

The fatty acid composition of TG showed higher percentages of palmitic acid and oleic acid, which were consumed for energy production (Shirai *et al.*, 2002).

Fatty Acid Composition of Phospholipid

The fatty acid composition of PL in *S. triostegus* which were captured in different seasons are given in Table 3. No significant differences were observed in pentadecanoic acid (15:0), oleic acid, eicosenoic acid (20:1n-9), hexadecadienoic acid (16:2n-6) of phospholipid between seasons. PUFA was the most important group of fatty acids in *S. triostegus*. It was observed that the fatty acid composition of *S. triostegus* varied througout the seasons. The major fatty acids identified in the *S. triostegus* were palmitic acid, stearic acid, oleic acid, linoleic acid, AA, EPA, DPA and DHA acid in all seasons. Similar results for other fish species have also been reported in the literature (Maia *et al.*, 1995; Inhamuns and Franco, 2001; Almeida *et al.*, 2008).

The total SFA percentages of the PL extracted from the *S. triostegus* statistically ranged (P<0.05) from 21.31% to 41.05%. With regard to the ratio of total SFA content, the highest value was found in summer. Palmitic acid was the primary saturated fatty acid for *S. triostegus* in all seasons (14.71-27.47%). Palmitic acid was highest in summer.

Table 2. Seasonal variations in fatty acid composition of triacylglicerol of *Silurus triostegus* (%FAME).

Fatty acid compositions	Spring	Summer	Autumn	Winter
12:0	0.59 (0.07)^{a}	0.16 (0.01)^{b}	0.16 (0.08)^{b}	0.18 (0.01)^{b}
14:0	1.47 (0.51)^{a}	2.71 (0.31)^{b}	1.50 (0.30)^{a}	1.91 (0.45)^{ab}
15:0	0.27 (0.08)^{a}	0.18 (0.03)^{a}	0.81 (0.06)^{b}	1.00 (0.06)^{b}
16:0	11.63 (2.08)^{ab}	18.10 (1.61)^{bc}	10.41 (0.91)^{a}	15.05 (2.10)^{b}
17:0	1.26 (0.05)^{a}	1.88 (0.57)^{a}	4.43 (0.96)^{b}	3.84 (0.75)^{b}
18:0	4.63 (1.48)^{a}	4.40 (0.29)^{a}	2.48 (0.79)^{b}	4.77 (1.23)^{a}
Σ SFA	19.85	27.43	19.79	26.75
16:1n-7	7.09 (0.80)^{a}	14.56 (1.96)^{c}	9.51 (0.50)^{ab}	12.18 (1.16)^{bc}
18:1n-9	37.96 (2.05)^{a}	22.84 (2.18)^{b}	23.69 (2.13)^{b}	21.84 (2.55)^{b}
20:1n-9	1.97 (0.08)^{a}	0.55 (0.01)^{b}	0.89 (0.01)^{bc}	1.07 (0.03)^{ac}
Σ MUFA	47.02	37.95	34.09	35.09
18:3n-3	3.70 (0.08)^{a}	3.52 (0.09)^{a}	1.62 (0.05)^{b}	3.20 (0.14)^{a}
20:5n-3	1.64 (0.61)^{a}	6.64 (0.32)^{bc}	2.90 (0.45)^{ab}	8.63 (1.74)^{c}
22:5n-3	0.80 (0.03)^{a}	2.37 (0.22)^{b}	8.41 (0.46)^{c}	6.71 (1.02)^{c}
22:6n-3	1.33 (0.02)^{a}	6.04 (0.96)^{b}	9.88 (1.05)^{c}	7.98 (0.98)^{bc}
Σ n-3	7.47	18.57	22.81	26.52
16:2n-6	0.50 (0.03)^{a}	1.55 (0.11)^{b}	2.14 (0.74)^{bc}	2.26 (0.81)^{c}
18:2n-6	17.99 (1.75)^{a}	10.68 (0.29)^{ab}	3.42 (1.48)^{b}	5.16 (0.32)^{b}
18:3n-6	1.46 (0.44)^{a}	0.76 (0.01)^{ab}	0.61 (0.01)^{b}	0.60 (0.01)^{b}
20:2n-6	2.36 (0.85)^{a}	0.52 (0.03)^{b}	1.02 (0.68)^{a}	0.53 (0.35)^{b}
20:3n-6	1.67 (0.29)^{a}	0.45 (0.02)^{a}	5.19 (0.35)^{b}	0.36 (0.01)^{a}
20:4n-6	1.68 (0.33)^{a}	2.09 (0.38)^{a}	10.93 (1.65)^{b}	2.73 (0.37)^{a}
Σ n-6	25.66	16.05	23.31	11.64
Σ PUFA	33.13	34.62	46.12	38.16
n-3/n-6	0.29	1.16	0.98	2.28

Parantheses represents standart deviations of mean values as SD. SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid. Different letters (a,b,c) in the same row represent significant statistical differences (p<0.05).

Table 3. Seasonal variations in fatty acid composition of phospholipid of *Silurus triostegus* (%FAME)

Fatty acid compositions	Spring	Summer	Autumn	Winter
12:0	0.23 (0.01)^{a}	0.41 (0.05)^{b}	0.22 (0.01)^{a}	0.25 (0.06)^{a}
14:0	1.29 (0.04)^{a}	1.67 (0.07)^{a}	0.51 (0.03)^{b}	0.30 (0.01)^{b}
15:0	0.37 (0.02)^{a}	0.68 (0.04)^{a}	0.46 (0.05)^{a}	0.21 (0.01)^{a}
16:0	15.56 (1.71)^{a}	27.47 (2.30)^{b}	22.71 (1.65)^{b}	14.71 (1.56)^{a}
17:0	1.42 (0.10)^{a}	0.38 (0.01)^{b}	0.85 (0.04)^{ab}	0.24 (0.01)^{b}
18:0	5.01 (0.62)^{a}	10.44 (1.06)^{b}	3.70 (0.55)^{a}	5.60 (0.21)^{a}
Σ SFA	23.88	41.05	28.45	21.31
16:1n-7	2.24 (0.51)^{a}	4.61 (0.13)^{b}	4.54 (0.25)^{b}	2.06 (0.05)^{a}
18:1n-9	14.33 (2.29)^{a}	15.81 (1.37)^{a}	9.24 (3.79)^{a}	10.35 (2.94)^{a}
20:1n-9	0.79 (0.04)^{a}	0.41 (0.05)^{a}	0.42 (0.04)^{a}	0.53 (0.03)^{a}
Σ MUFA	17.36	20.83	14.20	12.94
18:3n-3	2.59 (0.53)^{a}	0.89 (0.09)^{b}	0.63 (0.06)^{b}	1.97 (0.41)^{a}
20:5n-3	7.33 (1.64)^{a}	4.92 (0.79)^{b}	4.19 (2.01)^{b}	8.26 (1.09)^{a}
22:5n-3	7.45 (1.29)^{a}	4.65 (0.88)^{b}	11.34 (4.80)^{c}	10.89 (1.07)^{ac}
22:6n-3	17.77 (2.64)^{a}	13.90 (1.92)^{a}	14.35 (5.88)^{a}	30.41 (5.55)^{b}
Σ n-3	35.14	24.36	30.51	51.53
16:2n-6	0.33 (0.9)^{a}	0.50 (0.01)^{a}	0.49 (0.04)^{a}	0.37 (0.06)^{a}
18:2n-6	10.87 (8.35)^{a}	3.79 (0.45)^{b}	1.99 (0.66)^{c}	3.44 (1.73)^{b}
18:3n-6	0.23 (0.01)^{a}	0.44 (0.01)^{b}	0.36 (0.02)^{ab}	0.45 (0.03)^{b}
20:2n-6	1.47 (0.19)^{a}	0.92 (0.16)^{b}	0.28 (0.07)^{c}	0.62 (0.01)^{bc}
20:3n-6	0.41 (0.19)^{a}	0.55 (0.17)^{a}	11.55 (1.81)^{b}	3.42 (0.26)^{a}
20:4n-6	10.31 (1.28)^{a}	7.56 (0.47)^{ab}	12.17 (2.69)^{a}	5.92 (1.39)^{b}
Σ n-6	23.62	13.76	26.84	14.22
Σ PUFA	58.76	38.12	57.35	65.75
n-3/n-6	1.49	1.77	1.14	3.62

Parantheses represents standart deviations of mean values as SD. SFA: saturated fatty acid; MUFA: monounsaturated fatty acid; PUFA: polyunsaturated fatty acid. Different letters (a,b,c) in the same row represent significant statistical differences (p<0.05).

The total MUFA percentages of the PL ranged from 12.94% to 20.83%. Oleic acid was identified as a primary MUFA in the *S. triostegus* for all seasons (9.24-15.81%). Similar results for other fish species have also been reported in the literature (Maia et al., 1995; Inhamuns and Franco, 2001; Almeida et al., 2008).

The total PUFAs were highest in winter, then spring, followed by autumn and summer. The total PUFA percentages of the phospholipid statistically ranged ($P<0.05$) from 38.12% to 65.75%. For all seasons, it was found that the predominant fatty acids were DHA, DPA, EPA, AA and linoleic acid in PUFA. In *S. triostegus*, the level of DHA was lowest in summer whereas DHA was very high in winter.

Inhamuns and Franco (2001) has reported that in the phospholipids there is a high level of polyunsaturated fatty acids, including primarily DHA, AA, linolenic acid, and EPA.

Farkas (1984) has noted that one of the main changes at the level of fatty acid composition is an increase in DHA at low temperatures.

There is no doubth that increases in the PUFA content of phospholipids occur for adaptation to low environmental temperatures.

The physical properties of the membrane are determined by the phospholipids and the fatty acid composition of phospholipid. The degree of unsaturation of the fatty acids is important for determining the fluidity of the membrane and providing the correct environment for membrane functions. In fish and other poikilotherm species the degree of unsaturation of membrane fatty acids is also important for the processs of adaptation to different environmental temperatures (Bell et al., 1986).

The PLs are generally considered to be structural or functional lipids, being incorporated to a larger extent in the membrane structure of cell and subcellular particles. The triacylglycerols are more often storage lipids and reflect the fatty acid composition of the diet to a greater extent than do the phospholipids. It can be seen that the effect of changing environment on the fatty acid composition of the PL is as great as in the case of salmon, and considerably greater in the case of sweet smelt, than it is on the triacylglycerol composition (Kondo and Yanagısawa, 2005).

Cold temperatures are normally associated with an increased unsaturation degree in body fat, in particular with a conversion of saturated fatty acids of the biological membrane phospholipids typical of the warm season into the corresponding mono- and dienic fatty acids typical of the cold season (Kemp and Smith, 1970; Smith and Kemp, 1971). Moreover, the adaptation of lipid metabolism during the cold season implies a concentration increase of long-chain PUFAs in the membrane phospholipids (Hazel, 1984). This seasonal lipid adaptation is fundamental for animal survival. In fact, the correlation between environmental temperature and PUFA content allows the preservation of membrane fluidity and, as a consequence, the normal physiological functions of the membranes themselves, independently of the surrounding temperature (Hazel, 1984).

This study has shown that the *S. triostegus* is a desirable item in the human diet in the Tigris River, Turkey when the levels of n-3/n-6 ratio are considered. As a consequence, when human health is taken into account, the *S. triostegus* from Tigris River appears to be quite nutritious in terms of fatty acid composition and ratio.

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