J Food Sci Technol (July 2016) 53(7):2913–2922
DOI 10.1007/s13197-016-2253-5

ORIGINAL ARTICLE

Effect of seasonal variation on lipid and fatty acid profile in muscle tissue of male and female *Silurus triostegus*

Semra Kaçar[1] · Mehmet Başhan[2] · Seyit Ahmet Oymak[3]

Revised: 9 May 2016 / Accepted: 17 May 2016 / Published online: 21 July 2016

Abstract Fatty acid (FA) compositions of total lipid, phospholipid (PL) and triacylglycerol (TAG) fractions have been determined in muscle tissues of *Silurus triostegus*. The distributions of saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) proportions were found to be different among total lipid, PL and TAG fractions from lipids in muscle tissues of the male and female *S. triostegus* in all seasons. Triacylglycerol contained a lower proportion of PUFA and a higher proportion of MUFA and SFA than PL while PL contained higher proportion of PUFA than proportion of MUFA and SFA compared to TAG. Triacylglycerol and PL fatty acid compositions in muscle tissues of the male and female fish species were found different. The most abundant fatty acids in the investigated seasons were palmitic acid (C16:0), stearic acid (C18:0), oleic acid (C18:1 n-9), palmitoleic acid (C16:1 n-7) and docosahexaenoic acid (C22:6 n-3). It was shown that the total lipid content and FA compositions in muscle tissues of the male and female *S. triostegus* were influenced by reproduction period and season.

Keywords *Silurus triostegus* · Fatty acidphospholipid · Triacylglycerol

✉ Semra Kaçar
semrakacar21@gmail.com

[1] Department of Nutrition and Dietetics, School of Health, Mardin Artuklu University, 47100 Mardin, Turkey

[2] Department of Biology, Faculty of Science, Dicle University, Diyarbakır, Turkey

[3] Department of Biology, Faculty of Science-Literature, Harran University, Şanlıurfa, Turkey

Introduction

Mesopotamia catfish (*Silurus triostegus*), is a species of catfish from the Siluridae family. The *S. triostegus* exists only in the Tigris and Euphrates basins. It is located in Mesopotamia; Syria, Iraq, Iran and Turkey. It was identified that the spawning occurs in May and continues until late June in the *S. triostegus* (Oymak et al. 2001). *Silurus triostegus* is a carnivorous fish and generally feeds on other fish species, amphibians and smaller waterfowl. The catfish is a tasty fish that is a good source of high quality proteins. *Silurus triostegus* also has economic value.

Fish are one of the main sources of animal proteins in the world. The high nutritional value of fish is also attributed to other nutritive materials such as minerals and vitamins In recent years increasing attention has focused on the significance of n-3 PUFAs for human nutrition, particularly eicosapentaenoic acid (EPA, C20:5 n-3) and DHA. The data obtained in epidemiological and experimental studies support the beneficial effects of these n-3 PUFAs in the prevention of cardiovascular diseases (Sidhu 2003), autoimmune disorders, inflammation, hypertension, allergies, arthritis, and cancers (Von Sckacky 2003). Besides, n-3 PUFAs play a vital role in the development and function of the nervous system, photoreception, and the reproductive system (Sidhu 2003).

The FA composition of fish species varies with the geographical location of the catch, diet, feeding, sex, and the state of their reproductive cycle. Furthermore, the seasonal variations of the factors mentioned could be effective in changing the FA composition of fish (Kayhan et al. 2015; Kaçar and Başhan 2015).

The lipid classes referred to as TAG and PL have different functions in organisms. PL is important constituents of membranes and they function as precursors in eicosanoid metabolism, whereas the TAG serve mainly as a depot of lipids used as an energy source (Suloma and Ogata 2012). For this reason, it is necessary to determine the FA composition of TAG and PL fractions of *S. triostegus.*

The present study was undertaken to clarify the influences of spawning and season on the FA composition of total lipid, TAG and PL in the muscles of both the male and female *S. triostegus* in the Atatürk Dam Lake.

Materials and methods

The wild fish were caught from Atatürk Dam Lake (Turkey) in 2 month periods between May 2008 and March 2009, kept in ice and transferred to the laboratory for analyses. The geographic co-ordinates of the study area were 37°38′21.42″ North and 38°36′5.41″ East (Belören).

Fish sex was determined by their gonad. Analyses were done in triplicate for each lot.

The specimens were dissected and a 3-g muscle tissue taken from the dorsal muscle along the lateral line of each fish. Samples of muscle tissues were stored at −30 °C for lipid analysis.

Lipid determination of the fish was carried out by modified Folch et al. (1957) method. The residual chloroform was then removed by N_2. Total lipid content was gravimetrically quantified. The fractions were scraped into reaction vials, and the associated fatty acids were transmethylated by refluxing the fractions in acidified (sulfuric acid) methanol for 2 h at 85 °C (Stanley-Samuelson and Dadd 1983). The fatty acid methyl esters (FAMEs) were extracted with hexane and the resulting solution injected into gas chromatograph (GC).

Gas chromatography conditions

Fatty acids were determined in the form of FAMEs prepared from the extracted lipid. The FAMEs were separated and quantified using gas chromatograph (GC) HP6890 equipped with a flame ionization detector (FID) and an autosampler. The analysis involved the use of column DB–23 capillary column. Oven temperature was programmed from 130 to 230 °C. The injection port and detector temperatures were 270 and 280 °C, respectively. Ultra-pure helium flowing at a rate of 2.8 mL min^{-1} was used for each sample analysis and split injection (1:25) of 1 µL sample was performed. The profiles of individual fatty acids were calculated using an automatic integrator and presented as percentages of total fatty acids according to the peak areas.

All of the data were presented as mean ± standard deviation (SD). Data analyses were performed using SPSS (16.0) software. One-way ANOVA was utilized to compare the data by season. Tukey's test was used to compare the mean values.

Results

Lipid content

The ranges and mean (± SD) length, weight, age, and lipid contents (%) of the male and female *S. triostegus* from the Atatürk Dam Lake used in the present study are shown in Table 1. The total lipid content of the male and female changed seasonally from 0.63 to 1.32 %, and from 0.45 to 1.83 %, respectively (Table 1). The highest lipid content was found in the month of May (the reproduction period) in both sexes. The lipid content in the muscles of the female *S. triostegus* decreased to a minimum in the month of July. The lipid content of the muscle tissue was found higher before the reproduction period (March) in both sexes.

FA composition of total lipid

The FA composition of the total lipid of the muscle tissue of the male and female *S. triostegus* is presented in Table 2. Among the SFAs, the most abundant FAs were myristic acid (C14:0), C16:0, and C18:0. In the females, no

Table 1 Total length, weight, age and total lipid of female and male *S. triostegus*

	Mean standard length (cm)		Mean total weight (g)		Age (year)		Total lipid (%)	
	Female	Male	Female	Male	Female	Male	Female	Male
May-(2008)	480 ± 31.28	380 ± 20.45	776 ± 39.40	462 ± 44.34	5 ± 0.45	4 ± 0.41	1.32 ± 0.51^{a}	1.83 ± 0.24^{a}
July-(2008)	450 ± 30.47	490 ± 30.33	554 ± 37.55	764 ± 31.67	5 ± 0.65	6 ± 0.47	0.63 ± 0.09^{b}	0.66 ± 0.22^{b}
September-(2008)	770 ± 56.54	390 ± 35.56	2738 ± 50.45	500 ± 32.67	8 ± 0.87	4 ± 0.53	0.96 ± 0.10^{c}	0.45 ± 0.10^{c}
November-(2008)	615 ± 34.52	590 ± 27.21	1650 ± 48.59	1382 ± 54.34	6 ± 0.43	5 ± 0.49	0.90 ± 0.09^{c}	0.64 ± 0.10^{b}
January-(2009)	690 ± 40.23	475 ± 47.56	2100 ± 48.44	706 ± 43.48	7 ± 0.73	4 ± 0.57	0.89 ± 0.29^{c}	1.69 ± 0.81^{a}
March-(2009)	670 ± 36.32	600 ± 34.39	2600 ± 67.64	1380 ± 38.44	7 ± 0.83	5 ± 0.58	0.83 ± 0.08^{c}	0.77 ± 0.22^{b}

Superscript letters (a,b,c) denote significant differences ($p < 0.05$) in lipid content among months

Table 2 Seasonal variations of fatty acid composition of total lipid of female and male *S. triostegus* (% of total FA)

Fatty Acids	May-(2008)		July-(2008)		September-(2008)		November-(2008)		January-(2009)		March-(2009)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
10:00	–	0.11 ± 0.01^{a}*	–	0.11 ± 0.02^{a}	–	0.01 ± 0.01^{b}	–	–	–	–	–	–
12:00	0.08 ± 0.02^{a}	0.13 ± 0.03^{b}	–	0.04 ± 0.02^{c}	0.05 ± 0.03^{c}	0.18 ± 0.03^{d}	–	0.16 ± 0.01^{d}	0.12 ± 0.01^{b}	–	–	–
13:00	0.15 ± 0.01^{a}	0.44 ± 0.04^{b}	0.10 ± 0.03^{a}	0.12 ± 0.01^{a}	0.12 ± 0.07^{a}	0.14 ± 0.03^{a}	–	0.05 ± 0.03^{c}	–	0.01 ± 0.01^{d}	–	–
14:00	3.45 ± 0.33^{a}	4.02 ± 0.40^{a}	2.67 ± 0.26^{b}	2.92 ± 0.22^{b}	1.16 ± 0.11^{c}	1.61 ± 0.25^{c}	1.58 ± 0.10^{c}	2.39 ± 0.22^{b}	2.51 ± 0.23^{b}	2.01 ± 0.20^{d}	3.79 ± 0.34^{a}	2.42 ± 0.29^{b}
15:00	0.57 ± 0.05^{a}	0.74 ± 0.07^{b}	0.46 ± 0.03^{a}	0.53 ± 0.05^{a}	0.56 ± 0.04^{a}	0.70 ± 0.03^{b}	0.57 ± 0.05^{a}	0.51 ± 0.04^{a}	0.70 ± 0.07^{b}	0.47 ± 0.04^{a}	0.82 ± 0.08^{b}	0.24 ± 0.02^{c}
16:00	22.13 ± 1.22^{a}	25.02 ± 1.28^{a}	24.87 ± 1.20^{a}	26.54 ± 1.23^{a}	27.26 ± 1.25^{a}	31.83 ± 1.31^{b}	28.77 ± 1.33^{a}	28.46 ± 1.20^{a}	25.91 ± 1.03^{a}	20.69 ± 1.02^{c}	25.02 ± 1.22^{a}	28.25 ± 1.30^{a}
17:00	0.31 ± 0.03^{a}	0.46 ± 0.04^{b}	0.35 ± 0.02^{a}	0.50 ± 0.03^{b}	0.51 ± 0.05^{b}	0.47 ± 0.03^{b}	0.27 ± 0.02^{a}	0.66 ± 0.05^{b}	0.47 ± 0.04^{b}	0.22 ± 0.01^{c}	0.56 ± 0.05^{b}	1.03 ± 0.12^{d}
18:00	5.63 ± 0.55^{a}	7.37 ± 0.77^{b}	8.13 ± 0.81^{b}	7.26 ± 0.70^{b}	7.99 ± 0.77^{b}	9.25 ± 0.99^{c}	7.07 ± 0.71^{b}	6.62 ± 0.56^{ab}	7.41 ± 0.70^{b}	6.94 ± 0.69^{b}	7.03 ± 0.89^{b}	6.94 ± 0.71^{b}
∑S.F.A	32.32 ± 1.33^{a}	38.29 ± 1.38^{b}	36.58 ± 1.37^{b}	38.02 ± 1.40^{b}	37.65 ± 1.30^{b}	44.19 ± 1.41^{c}	38.26 ± 1.41^{b}	38.85 ± 1.39^{b}	37.12 ± 1.38^{b}	30.34 ± 1.30^{a}	37.22 ± 1.35^{b}	38.88 ± 1.33^{b}
16:1n-7	9.72 ± 0.99^{a}	8.77 ± 0.88^{a}	8.50 ± 0.87^{a}	9.22 ± 0.92^{a}	8.48 ± 0.84^{a}	3.94 ± 0.35^{b}	5.12 ± 0.51^{c}	7.55 ± 0.77^{a}	8.19 ± 0.83^{a}	6.84 ± 0.62^{c}	9.16 ± 0.90^{a}	5.18 ± 0.51^{c}
18:1n-9	22.59 ± 1.23^{a}	23.00 ± 1.20^{a}	25.59 ± 1.20^{a}	23.41 ± 1.23^{a}	25.11 ± 1.22^{a}	18.69 ± 1.08^{b}	17.60 ± 1.07^{b}	20.28 ± 1.22^{b}	18.00 ± 1.08^{b}	23.62 ± 1.29^{a}	26.59 ± 1.26^{a}	22.18 ± 1.19^{a}
20:1n-9	0.78 ± 0.07^{a}	1.00 ± 0.09^{b}	1.23 ± 0.11^{b}	1.38 ± 0.11^{b}	1.14 ± 0.10^{b}	0.64 ± 0.05^{a}	0.29 ± 0.02^{c}	0.68 ± 0.04^{a}	1.02 ± 0.12^{b}	1.41 ± 0.12^{b}	1.46 ± 0.14^{b}	1.03 ± 0.09^{b}
∑M.U.F.A	33.09 ± 1.37^{a}	32.77 ± 1.33^{a}	35.32 ± 1.35^{a}	34.01 ± 1.30^{a}	34.73 ± 1.30^{a}	23.27 ± 1.29^{b}	23.01 ± 1.20^{b}	28.51 ± 1.22^{c}	27.21 ± 1.27^{c}	31.87 ± 1.37^{a}	37.21 ± 1.43^{a}	28.39 ± 1.27^{c}
18:2n-6	3.66 ± 0.39^{a}	3.73 ± 0.33^{a}	2.06 ± 0.20^{a}	2.68 ± 0.22^{a}	2.94 ± 0.29^{a}	2.40 ± 0.28^{a}	2.47 ± 0.13^{a}	2.87 ± 0.27^{a}	2.71 ± 0.27^{a}	3.15 ± 0.31^{a}	3.18 ± 0.31^{a}	2.74 ± 0.25^{a}
18:3n-3	2.97 ± 0.27^{a}	1.97 ± 0.11^{b}	1.68 ± 0.13^{b}	2.24 ± 0.23^{a}	2.24 ± 0.24^{a}	1.41 ± 0.18^{b}	1.54 ± 0.14^{b}	2.65 ± 0.22^{a}	1.68 ± 0.18^{b}	2.28 ± 0.27^{a}	1.77 ± 0.11^{b}	0.94 ± 0.09^{c}
20:2n-6	0.35 ± 0.03^{a}	0.55 ± 0.05^{b}	0.44 ± 0.04^{a}	0.44 ± 0.04^{a}	0.43 ± 0.03^{a}	0.50 ± 0.30^{b}	0.69 ± 0.06^{b}	0.31 ± 0.27^{a}	0.20 ± 0.01^{c}	0.50 ± 0.06^{b}	0.43 ± 0.03^{a}	0.68 ± 0.07^{b}
20:3n-6	0.59 ± 0.05^{a}	0.50 ± 0.04^{a}	0.25 ± 0.02^{b}	0.35 ± 0.12^{b}	0.32 ± 0.04^{b}	0.38 ± 0.07^{b}	0.23 ± 0.02^{b}	0.44 ± 0.02^{ab}	1.15 ± 0.11^{c}	0.55 ± 0.04^{a}	0.35 ± 0.03^{b}	0.53 ± 0.03^{a}
20:4n-6	5.78 ± 0.56^{a}	4.68 ± 0.44^{a}	5.00 ± 0.53^{a}	4.26 ± 0.40^{a}	4.03 ± 0.43^{a}	7.68 ± 0.71^{b}	8.56 ± 0.89^{b}	5.57 ± 0.54^{a}	6.68 ± 0.66^{ab}	7.03 ± 0.70^{b}	5.06 ± 0.50^{a}	6.84 ± 0.63^{b}
20:5n-3	6.92 ± 0.65^{a}	4.63 ± 0.41^{b}	4.41 ± 0.43^{b}	4.82 ± 0.44^{b}	4.42 ± 0.41^{b}	3.26 ± 0.22^{c}	5.68 ± 0.54^{a}	5.50 ± 0.23^{a}	5.85 ± 0.56^{a}	5.58 ± 0.54^{a}	5.45 ± 0.45^{a}	3.84 ± 0.34^{c}
22:5n-3	3.62 ± 0.32^{a}	2.95 ± 0.23^{a}	3.10 ± 0.29^{a}	2.97 ± 0.19^{a}	2.89 ± 0.30^{a}	2.43 ± 0.31^{a}	2.39 ± 0.24^{a}	2.70 ± 0.11^{a}	4.12 ± 0.41^{b}	4.42 ± 0.41^{b}	2.68 ± 0.22^{a}	1.94 ± 0.19^{c}
22:6n-3	10.63 ± 1.01^{a}	9.83 ± 0.99^{a}	11.08 ± 1.11^{a}	10.11 ± 0.98^{a}	10.25 ± 1.09a	14.38 ± 1.04^{b}	17.10 ± 1.07^{b}	12.53 ± 1.12^{a}	13.18 ± 1.12^{a}	14.18 ± 1.05^{b}	6.59 ± 0.67^{c}	15.13 ± 1.16^{b}
∑P.U.F.A	34.52 ± 1.33^{a}	28.84 ± 1.25^{b}	28.02 ± 1.27^{b}	27.87 ± 1.29^{b}	27.52 ± 1.22^{b}	32.44 ± 1.33^{a}	38.66 ± 1.37^{c}	32.57 ± 1.30^{a}	35.57 ± 1.37^{a}	37.69 ± 1.28^{c}	25.51 ± 1.26^{b}	32.64 ± 1.41^{a}
n-3	24.14 ± 1.22^{a}	19.38 ± 1.09^{b}	20.27 ± 1.20^{b}	20.14 ± 1.20^{b}	19.80 ± 1.09^{b}	21.48 ± 1.19^{b}	26.71 ± 1.26^{a}	23.38 ± 1.22^{a}	24.83 ± 1.28^{a}	26.46 ± 1.28^{a}	16.49 ± 1.06^{b}	21.85 ± 1.22^{b}
n-6	10.38 ± 1.00^{a}	9.46 ± 0.99^{a}	7.75 ± 0.77^{b}	7.73 ± 0.76^{b}	7.72 ± 0.67^{b}	10.96 ± 1.02^{a}	11.95 ± 1.04^{a}	9.19 ± 0.98^{a}	10.74 ± 1.12^{a}	11.23 ± 1.11^{a}	9.02 ± 0.99^{a}	10.79 ± 1.10^{a}
n-3/n-6	2.32	2.04	2.61	2.60	2.56	1.95	2.23	2.54	2.31	2.35	1.82	2.02

Means are the averages of 3 replicates

SFA saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids

* Values reported are mean ± standard deviation; means followed by different letters in same line are significantly different ($p < 0.05$) by Tukey's test

significant difference could be observed in ΣSFA with regard to season (with the exception of May). In the males, the highest ΣSFA amounts were found in the month of September after the reproduction period (44.19 %), and the lowest ΣSFA were found in the month of January (30.34 %). In the muscles of the male and female fish, the ratio of MUFA in the FA composition decreased to a minimum level in November (23.01 %) and September (23.27 %), respectively. The total PUFA content of the female *S. triostegus* showed significantly higher levels in May, November, and January, as compared to other seasons (Fig. 1). In the males, the highest levels of this content were found in September, November, and January.

In the present study, C16:0 was the major FA in the muscle lipids of both male and female *S. triostegus*. The maximal C16:0 contents were found in November and September, respectively. Among the MUFAs, C18:1 n-9, and C16:1 n-7 were the predominant FAs.

In November, the concentration of C16:1 n-7 decreased to its lowest value (5.12 %), while this acid did not show a

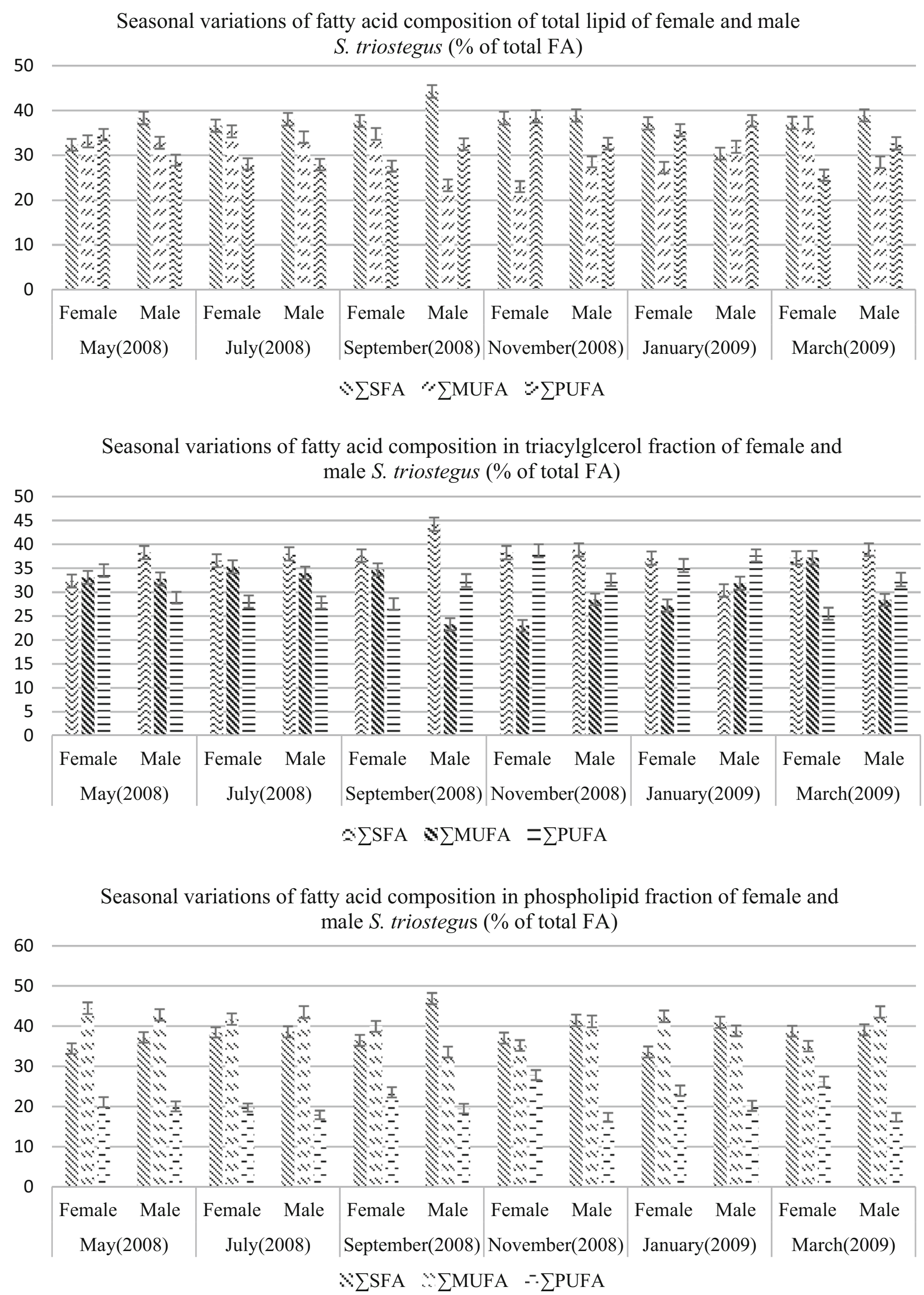

Fig. 1 Seasonal variations of fatty acid composition of total lipid, triacylglycerol and phospholipid fraction of female and male *S. triostegus*

significant difference from other months (8.19–9.72 %) in the female. Males showed the lowest level in the month September (3.94 %). C18:1 n-9 was the major fatty acid in all the seasons in both sexes. In the males and females, no significant differences could be observed in LA regarding the season.

Aracidonic acid (C20:4 n-6, AA), EPA and DHA were the dominant PUFAs. In the present study, the AA percentages increased in the autumn, while the EPA decreased after the reproduction season (in September) in both the sexes. It could be seen that the DHA was the main PUFA in the female *S. triostegus* muscle tissue and had the maximum percentage in November (17.10 %). In March (before the reproduction period), the concentration of this acid decreased to its lowest value (6.59 %). The maximal DHA contents in the male *S. triostegus* were found in March (15.13 %).

The major FAs in the male and female *S. triostegus* in all seasons were C16:0 in SFA; C18:1n-9 in MUFA; and DHA in PUFA. In the males and females, the n-3/n-6 ratios of total lipids were found to be 1.82 (March)-2.61 (July), 1.95 (September)-2.60 (July), respectively.

In this study, the proportions of the major FAs in the muscle tissue of the *S. triostegus* varied to depending on the reproduction period, temperature, and season.

FA composition of TAG fraction

The percentages of the FA composition of the TAG fraction of the muscle tissues of the male and female *S. triostegus* are presented in Table 3. Males and females showed the highest ΣSFA amounts in the month of March (before the reproduction period) and September (after the reproduction period), respectively. However, the ΣSFA amounts decreased in the reproduction season (May) in both. The highest ΣMUFA amounts were found in the month of May in both sexes.

ΣMUFA content decreased in March (before the reproduction period) and September (after the reproduction period), respectively in both the sexes. Throughout the year, the PUFAs accounted for 19.76–27.83 % of the TAG fatty acid composition in the females. The seasonal variation of the PUFAs in the male muscles varied from 17.33 to 20.19 % (Fig. 1). The C16:0 percentages in the muscle tissue showed significant differences in all of the seasons, and the highest level was in the post-spawning period (September) in both sexes. C18:1 n-9 was the most abundant of the monoenes in the male and female *S. triostegus*. The DHA content of the female fish in May was significantly lower than in the other months, while in the male fish this acid content was lower in March. The n-3/n-6 ratios of the TAG fractions were found to be 1.48 (September)-2.43 (January) in females and 1.37 (March)-2.41 (November) in males. The major components were C16:0, C16:1 n-7, C18:1 n-9, linoleic acid (C18:2 n-6, LA), linolenic acid (C18:3 n-3, ALA), EPA and DHA in the TAG fraction.

FA composition of PL fraction

The FA composition of the PL fraction of the muscle tissue in the male and female *S. triostegus* is presented in Table 4. The results showed that the percentage of FAs varied among in season female fish species, ranging from 30.16 to 34.43 % SFAs; 22.81 to 28.88 % MUFAs, and 38.48 to 43.24 % PUFAs. The levels of SFAs, MUFAs, and PUFAs in the male muscles were found in the range of 34.28–36.48, 21.18–26.01 and 37.06–42.94 %, respectively.

In the males, the SFA did not show a significant difference regarding the season. The highest SFA was found in the month of November in both the sexes. The maximal MUFA contents of PLs in the male and female *S. triostegus* were found in May and July, respectively. The total PUFAs were also the most flactuated FAs among the seasons in both individuals. In the females, the maximum ΣPUFAs were found in July (the reproduction period), September (after the reproduction period) and January, and the minimum contents were found in March (before the reproduction period). In the males, this content showed lower levels in July (the reproduction period) (Fig. 1). C16:0 was the major SFA in both sexes. The percentages of this acid were higher in July, September, November, and March, than in May and January. The lowest amount of C18:1n-9 was found in September (after the reproduction period) and the highest level was found in May (the reproduction period) in the females. In September, the concentration of this acid decreased to the lowest value in March in the males. In this study, AA showed fluctuations in both individual. EPA content varied between 4.83 % (in September and November) and 9.53 % (in March) in females. Significant differences could not be observed in males (4.96–5.94 %). In females and males, DHA was found to be at the highest level in the n-3 PUFA.

The major FAs in the *S. triostegus* in all the seasons were C16:0 and C18:0 in SFA, C16:1 n-7 and C18:1 n-9 in MUFA, LA, EPA, AA, docosapentaenoic acid (C22:5 n-3), and the DHA in the PUFA. n-3/n-6 ratios of the PL fractions were found to be 2.02 (May)-2.55 (November) in the females and 1.86 (May)-2.26 (November) in the males.

Discussion

Lipid content

Depending on their fat content, fish are classified as lean (up to 2 % fat), medium fat (2–7 % fat), fat (7–15 % fat),

Table 3 Seasonal variations of fatty acid composition in triacylglycerol fraction of female and male *S. triostegus* (% of total FA)

Fatty Acids	May-(2008)		July-(2008)		September-(2008)		November-(2008)		January-(2009)		March-(2009)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
10:00	0.11 ± 0.01^{a*}	0.40 ± 0.04^{b}	0.23 ± 0.02^{c}	0.18 ± 0.01^{c}	–	0.41 ± 0.03^{b}	–	0.31 ± 0.03^{d}	0.23 ± 0.03^{c}	–	–	0.22 ± 0.01^{c}
12:00	0.11 ± 0.01^{a}	0.27 ± 0.02^{b}	0.17 ± 0.02^{c}	0.12 ± 0.01^{a}	0.15 ± 0.01^{c}	0.50 ± 0.04^{d}	0.26 ± 0.02^{b}	–	–	0.21 ± 0.01^{b}	–	–
13:00	0.26 ± 0.02^{a}	0.46 ± 0.03^{b}	0.33 ± 0.03^{ab}	0.28 ± 0.02^{a}	–	–	–	0.76 ± 0.06^{c}	–	–	0.18 ± 0.07^{d}	–
14:00	5.21 ± 0.52^{a}	2.93 ± 0.21^{b}	3.76 ± 0.31^{b}	3.84 ± 0.37^{b}	1.41 ± 0.11^{c}	4.57 ± 0.45^{a}	3.35 ± 0.39^{b}	4.67 ± 0.47^{a}	3.57 ± 0.31^{b}	2.97 ± 0.23^{b}	3.90 ± 0.33^{b}	3.25 ± 0.39^{b}
15:00	0.79 ± 0.07^{a}	0.62 ± 0.05^{a}	0.71 ± 0.06^{a}	0.71 ± 0.07^{a}	0.30 ± 0.02^{b}	1.64 ± 0.11^{c}	0.33 ± 0.01^{b}	0.71 ± 0.07^{a}	0.64 ± 0.05^{a}	1.07 ± 0.10^{c}	0.72 ± 0.06^{a}	1.12 ± 0.12^{c}
16:00	22.64 ± 1.25^{a}	25.72 ± 1.23^{b}	26.10 ± 1.22^{b}	27.13 ± 1.20^{b}	30.71 ± 1.33^{c}	32.61 ± 1.33^{c}	27.33 ± 1.27^{b}	28.22 ± 1.26^{b}	22.58 ± 1.20^{a}	29.04 ± 1.34^{b}	28.26 ± 1.31^{b}	27.72 ± 1.27^{b}
17:00	0.53 ± 0.04^{a}	0.88 ± 0.07^{b}	0.35 ± 0.03^{c}	0.38 ± 0.03^{c}	0.20 ± 0.01^{d}	0.98 ± 0.08^{b}	0.74 ± 0.06^{b}	0.98 ± 0.09^{b}	0.55 ± 0.04^{a}	0.91 ± 0.10^{b}	0.47 ± 0.03^{a}	0.98 ± 0.11^{b}
18:00	4.73 ± 0.41^{a}	5.88 ± 0.55^{a}	6.76 ± 0.56^{a}	5.93 ± 0.56^{a}	3.65 ± 0.33^{b}	6.16 ± 0.61^{a}	5.00 ± 0.51^{a}	5.78 ± 0.56^{a}	5.95 ± 0.56^{a}	6.72 ± 0.63^{a}	5.18 ± 0.51^{a}	5.77 ± 0.57^{a}
∑S.F.A	34.38 ± 1.33^{a}	37.16 ± 1.33^{a}	38.41 ± 1.30^{a}	38.57 ± 1.38^{a}	36.42 ± 1.38^{a}	46.87 ± 1.40^{b}	37.01 ± 1.35^{a}	41.43 ± 1.44^{a}	33.52 ± 1.37^{a}	40.92 ± 1.39^{a}	38.71 ± 1.35^{a}	39.06 ± 1.36^{a}
16:1n-7	13.59 ± 1.03^{a}	10.92 ± 1.01^{a}	10.62 ± 0.99^{a}	10.39 ± 1.10^{a}	9.19 ± 0.91^{a}	9.27 ± 0.92^{a}	10.60 ± 1.01^{a}	9.46 ± 0.99^{a}	12.28 ± 1.10^{a}	6.67 ± 0.65^{b}	10.04 ± 0.92^{a}	9.44 ± 0.73^{a}
18:1n-9	29.69 ± 1.27^{a}	30.30 ± 1.35^{a}	29.80 ± 1.28^{a}	31.80 ± 1.38^{a}	30.50 ± 1.33^{a}	23.57 ± 1.27^{b}	24.28 ± 1.22^{b}	30.92 ± 1.29^{a}	28.74 ± 1.30^{a}	31.12 ± 1.30^{a}	23.33 ± 1.28^{b}	31.26 ± 1.35^{a}
20:1n-9	1.18 ± 0.11^{a}	1.56 ± 0.11^{a}	1.31 ± 0.13^{a}	1.30 ± 0.16^{a}	0.22 ± 0.02^{b}	0.68 ± 0.06^{c}	0.26 ± 0.01^{b}	0.76 ± 0.07^{c}	1.40 ± 0.13^{a}	1.00 ± 0.95^{a}	1.61 ± 0.17^{a}	2.81 ± 0.23^{d}
∑M.U.F.A	44.46 ± 1.44^{a}	42.78 ± 1.45^{a}	41.73 ± 1.40^{a}	43.49 ± 1.49^{a}	39.91 ± 1.36^{a}	33.52 ± 1.36^{b}	35.14 ± 1.34^{b}	41.14 ± 1.48^{a}	42.42 ± 1.44^{a}	38.79 ± 1.34^{a}	34.98 ± 1.31^{b}	43.51 ± 1.44^{a}
18:2n-6	4.17 ± 0.41^{a}	4.60 ± 0.45^{a}	2.60 ± 0.22^{b}	2.61 ± 0.22^{b}	6.23 ± 0.65^{a}	3.08 ± 0.35^{ab}	5.46 ± 0.45^{a}	3.22 ± 0.30^{ab}	3.47 ± 0.33^{ab}	2.77 ± 0.21^{b}	4.94 ± 0.40^{a}	3.65 ± 0.34^{ab}
18:3n-3	3.22 ± 0.33^{a}	1.58 ± 0.15^{b}	2.02 ± 0.20^{b}	1.97 ± 0.17^{b}	0.94 ± 0.08^{c}	3.07 ± 0.38^{a}	2.28 ± 0.27^{b}	1.79 ± 0.17^{b}	3.61 ± 0.36^{a}	1.02 ± 0.14^{c}	1.86 ± 0.16^{b}	1.04 ± 0.13^{c}
20:2n-6	0.33 ± 0.03^{a}	0.10 ± 0.03^{b}	0.27 ± 0.02^{a}	0.30 ± 0.04^{a}	2.19 ± 0.22^{c}	0.32 ± 0.05^{a}	0.20 ± 0.02^{a}	0.20 ± 0.01^{a}	0.42 ± 0.04^{d}	0.51 ± 0.03^{d}	0.26 ± 0.02^{a}	0.91 ± 0.09^{e}
20:3n-6	0.29 ± 0.03^{a}	0.66 ± 0.07^{b}	0.61 ± 0.06^{b}	0.45 ± 0.04^{c}	0.42 ± 0.04^{c}	0.68 ± 0.06^{b}	0.34 ± 0.03^{a}	0.30 ± 0.03^{a}	0.33 ± 0.02^{a}	0.25 ± 0.02^{a}	0.45 ± 0.04^{c}	0.59 ± 0.06^{b}
20:4n-6	2.34 ± 0.21^{a}	2.88 ± 0.24^{a}	2.62 ± 0.20^{a}	2.22 ± 0.27^{a}	0.65 ± 0.05^{b}	2.12 ± 0.28^{a}	2.90 ± 0.26^{a}	1.36 ± 0.15^{c}	2.75 ± 0.30^{a}	2.83 ± 0.20^{a}	3.21 ± 0.33^{a}	2.16 ± 0.22^{a}
20:5n-3	4.65 ± 0.45^{a}	2.24 ± 0.25^{b}	3.40 ± 0.33^{ab}	3.22 ± 0.33^{ab}	5.02 ± 0.52^{a}	3.70 ± 0.34^{ab}	5.80 ± 0.55^{a}	2.20 ± 0.27^{b}	4.51 ± 0.41^{a}	3.95 ± 0.45^{a}	6.02 ± 0.65^{a}	2.12 ± 0.26^{b}
22:5n-3	1.99 ± 0.29^{a}	1.43 ± 0.13^{b}	2.15 ± 0.22^{a}	1.71 ± 0.17^{a}	1.08 ± 0.10^{b}	1.06 ± 0.11^{b}	2.30 ± 0.26^{a}	1.42 ± 0.10^{b}	2.59 ± 0.27^{a}	1.35 ± 0.14^{b}	3.15 ± 0.34^{c}	1.89 ± 0.17^{a}
22:6n-3	4.12 ± 0.41^{a}	6.56 ± 0.65^{a}	6.09 ± 0.66^{a}	5.45 ± 0.45^{a}	7.04 ± 0.70^{b}	5.49 ± 0.56^{a}	8.55 ± 0.88^{b}	6.84 ± 0.66^{a}	6.28 ± 0.66^{a}	7.51 ± 0.72^{b}	6.32 ± 0.48^{a}	4.97 ± 0.45^{a}
∑P.U.F.A	21.11 ± 1.27^{a}	20.05 ± 1.23^{a}	19.76 ± 1.00^{a}	17.93 ± 1.07^{a}	23.57 ± 1.28^{a}	19.52 ± 1.20^{a}	27.83 ± 1.22^{b}	17.33 ± 1.12^{a}	23.96 ± 1.30^{a}	20.19 ± 1.25^{a}	26.21 ± 1.27^{b}	17.33 ± 1.07^{a}
n-3	13.98 ± 1.03^{a}	11.81 ± 1.01^{a}	13.66 ± 1.04^{a}	12.35 ± 1.15^{a}	14.08 ± 1.10^{a}	13.32 ± 1.10^{a}	18.93 ± 1.08^{b}	12.25 ± 1.01^{a}	16.99 ± 1.13^{b}	13.83 ± 1.18^{a}	17.35 ± 1.07^{b}	10.02 ± 1.07^{a}
n-6	7.13 ± 0.71^{a}	8.24 ± 0.89^{a}	6.10 ± 0.65^{a}	5.58 ± 0.55^{b}	9.49 ± 0.99^{c}	6.20 ± 0.67^{a}	8.90 ± 0.87^{a}	5.08 ± 0.45^{b}	6.97 ± 0.63^{a}	6.36 ± 0.67^{a}	8.86 ± 0.88^{a}	7.31 ± 0.77^{a}
n-3/n-6	1.96	1.43	2.23	2.21	1.48	2.14	2.12	2.41	2.43	2.17	1.95	1.37

Means are the averages of 3 replicates

SFA saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids

* Values reported are mean ± standard deviation; means followed by different letters in same line are significantly different ($p < 0.05$) by Tukey's test

Table 4 Seasonal variations of fatty acid composition in phospholipid fraction of female and male *S. triostegus* (% of total FA)

Fatty Acids	May-(2008)		July-(2008)		September-(2008)		November-(2008)		January-(2009)		March-(2009)	
	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male	Female	Male
14:00	1.84 ± 0.18^{a}*	2.16 ± 0.21^{a}	1.26 ± 0.12^{b}	1.69 ± 0.11^{a}	0.86 ± 0.05^{c}	0.81 ± 0.07^{c}	1.20 ± 0.10^{b}	1.42 ± 0.14^{b}	0.85 ± 0.07^{c}	1.20 ± 0.10^{b}	0.54 ± 0.05^{c}	1.37 ± 0.13^{b}
15:00	0.48 ± 0.04^{a}	0.91 ± 0.07^{b}	0.59 ± 0.03^{a}	0.81 ± 0.08^{b}	0.42 ± 0.04^{a}	0.51 ± 0.06^{a}	0.36 ± 0.03^{c}	0.52 ± 0.05^{a}	0.38 ± 0.02^{c}	0.49 ± 0.04^{a}	0.66 ± 0.05^{a}	0.68 ± 0.06^{a}
16:00	20.73 ± 1.20^{a}	20.94 ± 1.21^{a}	24.38 ± 1.27^{a}	22.33 ± 1.20^{a}	24.10 ± 1.23^{a}	22.39 ± 1.23^{a}	25.30 ± 1.29^{a}	25.00 ± 1.33^{a}	20.39 ± 1.25^{a}	23.87 ± 1.22^{a}	24.89 ± 1.28^{a}	25.37 ± 1.20^{a}
17:00	0.54 ± 0.05^{a}	0.52 ± 0.05^{a}	0.20 ± 0.02^{b}	0.27 ± 0.01^{b}	0.21 ± 0.01^{b}	0.14 ± 0.01^{c}	0.27 ± 0.02^{b}	0.27 ± 0.02^{b}	0.52 ± 0.04^{a}	0.55 ± 0.04^{a}	0.66 ± 0.05^{a}	0.67 ± 0.05^{a}
18:00	7.22 ± 0.76^{a}	10.48 ± 1.01^{b}	7.25 ± 0.73^{a}	11.38 ± 1.11^{b}	8.27 ± 0.81^{a}	10.43 ± 1.10^{b}	7.30 ± 0.70^{a}	9.14 ± 0.99^{b}	8.02 ± 0.80^{a}	10.07 ± 1.03^{b}	6.50 ± 0.45^{a}	7.72 ± 0.77^{a}
∑S.F.A	30.81 ± 1.30^{a}	35.01 ± 1.33^{a}	33.68 ± 1.36^{a}	36.48 ± 1.38^{a}	33.86 ± 1.33^{a}	34.28 ± 1.34^{a}	34.43 ± 1.38^{a}	36.35 ± 1.39^{a}	30.16 ± 1.31^{a}	36.18 ± 1.36^{a}	33.25 ± 1.34^{a}	35.81 ± 1.30^{a}
16:1n-7	5.08 ± 0.45^{a}	4.83 ± 0.43^{a}	2.27 ± 0.22^{b}	3.88 ± 0.40^{b}	3.77 ± 0.38^{b}	2.56 ± 0.23^{b}	5.58 ± 0.52^{a}	3.61 ± 0.34^{b}	4.28 ± 0.49^{a}	3.05 ± 0.30^{b}	4.67 ± 0.44^{a}	2.72 ± 0.22^{b}
18:1n-9	23.22 ± 1.23^{a}	20.07 ± 1.20^{a}	20.40 ± 1.22^{a}	21.45 ± 1.22^{a}	18.44 ± 1.08^{a}	20.96 ± 1.28^{a}	19.95 ± 1.09^{a}	21.63 ± 1.23^{a}	21.73 ± 1.27^{a}	19.54 ± 1.09^{a}	22.52 ± 1.20^{a}	17.56 ± 1.07^{a}
20:1n-9	0.58 ± 0.04^{a}	0.34 ± 0.03^{b}	0.61 ± 0.06^{a}	0.68 ± 0.05^{a}	0.60 ± 0.05^{a}	0.75 ± 0.05^{c}	0.67 ± 0.06^{a}	0.76 ± 0.06^{c}	0.89 ± 0.07^{c}	0.93 ± 0.09^{c}	1.00 ± 0.10^{c}	0.90 ± 0.08^{c}
∑M.U.F.A	28.88 ± 1.29^{a}	25.24 ± 1.22^{a}	23.28 ± 1.22^{b}	26.01 ± 1.25^{a}	22.81 ± 1.20^{b}	24.27 ± 1.23^{a}	26.20 ± 1.26^{a}	26.00 ± 1.26^{a}	26.90 ± 1.27^{a}	23.52 ± 1.28^{b}	28.19 ± 1.28^{a}	21.18 ± 1.21^{b}
18:2n-6	2.94 ± 0.21^{a}	3.45 ± 0.31^{a}	1.13 ± 0.10^{b}	3.59 ± 0.34^{a}	1.71 ± 0.15^{b}	1.87 ± 0.12^{b}	2.14 ± 0.21^{a}	2.41 ± 0.22^{a}	3.32 ± 0.30^{a}	2.46 ± 0.23^{a}	1.22 ± 0.11^{b}	2.64 ± 0.22^{a}
18:3n-3	1.31 ± 0.12^{a}	1.47 ± 0.14^{a}	1.57 ± 0.15^{a}	1.32 ± 0.11^{a}	0.79 ± 0.07^{b}	1.10 ± 0.10^{a}	1.24 ± 0.16^{a}	1.55 ± 0.15^{a}	1.40 ± 0.14^{a}	1.10 ± 0.18^{a}	0.60 ± 0.05^{b}	0.86 ± 0.07^{b}
20:2n-6	0.43 ± 0.03^{a}	0.57 ± 0.04^{a}	0.54 ± 0.04^{a}	0.27 ± 0.02^{b}	0.48 ± 0.03^{a}	0.60 ± 0.05^{a}	0.43 ± 0.04^{a}	0.58 ± 0.04^{a}	0.41 ± 0.04^{a}	0.55 ± 0.03^{a}	0.22 ± 0.02^{b}	0.32 ± 0.01^{b}
20:3n-6	0.79 ± 0.07^{a}	1.52 ± 0.11^{b}	0.68 ± 0.06^{a}	0.52 ± 0.03^{c}	0.43 ± 0.04^{c}	0.63 ± 0.05^{a}	0.38 ± 0.03^{c}	0.52 ± 0.04^{c}	0.62 ± 0.05^{a}	0.65 ± 0.05^{a}	0.36 ± 0.03^{c}	0.71 ± 0.07^{a}
20:4n-6	9.17 ± 0.91^{a}	8.09 ± 0.84^{a}	11.75 ± 1.01^{b}	7.69 ± 0.73^{a}	10.9 ± 1.01^{b}	10.30 ± 1.01^{b}	8.11 ± 0.81^{a}	8.00 ± 0.80^{a}	9.49 ± 0.92^{a}	9.34 ± 0.91^{a}	10.17 ± 1.01^{b}	10.05 ± 1.00^{b}
20:5n-3	6.37 ± 0.63^{a}	5.12 ± 0.51^{a}	6.92 ± 0.67^{a}	5.58 ± 0.55^{a}	4.83 ± 0.44^{a}	5.65 ± 0.45^{a}	4.83 ± 0.46^{a}	5.54 ± 0.48^{a}	6.52 ± 0.65^{a}	4.96 ± 0.49^{a}	9.53 ± 0.98^{b}	5.94 ± 0.54^{a}
22:5n-3	3.60 ± 0.31^{a}	3.51 ± 0.33^{a}	5.46 ± 0.55^{b}	3.32 ± 0.30^{a}	5.30 ± 0.54^{b}	3.25 ± 0.29^{a}	3.99 ± 0.33^{a}	3.21 ± 0.31^{a}	5.82 ± 0.45^{b}	3.78 ± 0.35^{a}	4.80 ± 0.49^{a}	3.94 ± 0.43^{a}
22:6n-3	15.69 ± 1.05^{a}	15.36 ± 1.05^{a}	14.92 ± 1.06^{a}	14.77 ± 1.04^{a}	18.80 ± 1.12^{b}	17.96 ± 1.21^{b}	18.18 ± 1.08^{b}	15.76 ± 1.05^{a}	15.26 ± 1.05^{a}	17.39 ± 1.20^{b}	11.58 ± 1.11^{c}	18.48 ± 1.08^{b}
∑P.U.F.A	40.30 ± 1.45^{a}	39.09 ± 1.39^{a}	42.97 ± 1.40^{a}	37.06 ± 1.36^{a}	43.24 ± 1.43^{a}	41.36 ± 1.40^{a}	39.30 ± 1.39^{a}	37.57 ± 1.38^{a}	42.84 ± 1.38^{a}	40.23 ± 1.44^{a}	38.48 ± 1.34^{a}	42.94 ± 1.35^{a}
n-3	26.97 ± 1.25^{a}	25.46 ± 1.05^{a}	28.87 ± 1.22^{a}	24.99 ± 1.13^{a}	28.72 ± 1.28^{a}	27.96 ± 1.25^{a}	28.24 ± 1.29^{a}	26.06 ± 1.22^{a}	29.00 ± 1.30^{a}	27.23 ± 1.20^{a}	26.51 ± 1.25^{a}	29.22 ± 1.31^{a}
n-6	13.33 ± 1.03^{a}	13.63 ± 1.03^{a}	14.10 ± 1.05^{a}	12.07 ± 1.00^{a}	13.52 ± 1.01^{a}	13.40 ± 1.15^{a}	11.06 ± 1.11^{a}	11.51 ± 1.01^{a}	13.84 ± 1.04^{a}	13.00 ± 1.03^{a}	11.97 ± 1.10^{a}	13.72 ± 1.11^{a}
n-3/n-6	2.02	1.86	2.04	2.07	2.12	1.93	2.55	2.26	2.09	2.09	2.20	2.12

Means are the averages of 3 replicates

SFA saturated fatty acids, *MUFA* monounsaturated fatty acids, *PUFA* polyunsaturated fatty acids

* Values reported are mean ± standard deviation; means followed by different letters in same line are significantly different ($p < 0.05$) by Tukey's test

and very fat (over 15 % fat) (Rahman et al. 1995). According to the classification provided by Rahman et al. (1995), the catfish ex-amined was lean fish. The average fat content of the fish examined was 0.92 % in the female and 1.00 % in the male. It is known that the species, geographical origin, and season, change the lipid content of fish (Bayir et al. 2010). The values of fat content of the freshwater fish reported in the literature were similar. Catfish (*S. glanis*) from the Adana Seyhan Dam Lake contained 0.54 % (Ozogul et al. 2007), and the same species from Greece had 3.5 % fat (Aggelousis and Lazos 1991). Olgunoğlu et al. (2014) also reported seasonal variation of lipid content in the *S. triostegus* in the Atatürk Dam Lake. In their study, the total lipid contents were 4.22, 4.35, 4.35, and 6.56 % in summer, spring, autumn and winter, respectively. According to Mosa et al. (2012), the lipid content of the *S. triostegus* in the Tigris River was 7.71 %.

In the present study, the highest concentration of lipids was recorded in spring when compared to other seasons in both genders. The lipid content in the muscles of the female decreased to a minimum in the spawning period; however, in the males, the lowest lipid content was found in the post-spawning period. The lipids mobilized from the muscles to the gonads for the development of the gonads in the reproduction period. In this study, the total lipid contents of the muscle were remarkably affected seasonally; especially during the reproduction period.

FA composition of total lipid

The FA profile of the male and female fish from this study was similar to the other studies (Cengiz et al. 2010; Hali-loğlu et al. 2004).

In the present study, the SFAs were found to be in higher amounts than in the MUFAs and PUFAs in July, September, November and March in both sexes. However, PUFAs was high in January. This result is in agreement with Cengiz et al. (2010) study of the Tigris River. It was reported that the SFAs and MUFAs were used as an energy source, whereas the PUFAs were used as a structural function.

High levels of MUFA and SFA are regularly reported in freshwater fish of both temperate (Aggelousis and Lazos 1991) and tropical waters (Rahman et al. 1995). Therefore, in this study, the SFAs were dominant in the total lipid.

It was pointed out that C16:0 is a key metabolite in fish, and its level is not remarkably influenced by diet (Ackman et al. 1975). The high levels of C18:1 n-9, C16:1 n-7 and AA have been reported as a characteristic property of freshwater fish oils (Ackman 1967). C18:1 n-9 was dominant in the MUFAs.

All fish lack Δ^{12} and Δ^{15} desaturases, and so cannot form LA and ALA from C18:1 n-9. Therefore, LA and ALA are essential FAs in the diets. These FAs can be further desaturated and elongated to form the physiologically essential C20 and C22 PUFA, AA, EPA and DHA. Ackman (1967) reported that freshwater fish have high proportions of C18 PUFAs. The high level of AA is most probably due to the lower oxygen solubility in warmer waters (Smith and Miller 1980). However, in some fish (Aggelousis and Lazos 1991; Jankowska et al. 2004), the ratio of this FA is generally low. The maximal AA contents in the male and female *S. triostegus* were found in November and September, respectively. In this study, the AA content of the muscle tissue differed according to the season. The eicosanoids derived from the AA have negative cardiovascular effects such as vasoconstrictions and platelet aggregation. The consumption of AA in diets must be decreased (Nordoy et al. 2001). The low ratio of AA increases the nutritional value of the fish.

The most important factor affecting the quality of fish meat is the percentage of n-3 FAs such as EPA and DHA. DHA is a major component of the brain, the retina, and heart muscles, and plays a vital role in brain and eye development. The eicosanoids derived from EPA have positive effects, such as vasodilation and antiaggregation (Reilly et al. 1998). In particular, the high ratio of DHA shows the nutritional value of this fish. In this study, C20 PUFAs' decreased in the spawning period. In this period, these components may be used in gonad maturation and gamete formation because, fish require EPA, DHA and AA for normal growth, development, and reproduction (Rodriguez et al. 2004).

Females use the SFAs as an energy source, while males use MUFAs for gonad maturation. However, the n-3 and n-6 FAs (LA and ALA) which are stored for gonad maturation would have mobilized during vitellogenesis in the females (Cejas et al. 2003; Medford and Mackay 1978). Sargent and Henderson (1995) reported that MUFAs are catabolized to in order to supply metabolic energy during gonad development.

In this study, DHA and PUFAs were higher in the cold seasons than the hot ones. Especially, DHA would appear to be good candidates for ensuring constant fluidity at the relevant body temperature because of their low melting points (Hall et al. 2002).

Cengiz et al. (2012) found that n-3/n-6 ratio ranged from 1.03 to 2.47 in *S. triostegus*. Ackman (1967) found that this ratio ranged from 1.7 to 3.5 in the freshwater species. Therefore, our findings are in accordance with earlier studies. An increase in the diet n-3/n-6 ratio is essential in the diet to help prevent coronary heart disease by reducing plasma lipids and to decrease cancer risk (Kinsella et al. 1990). In this study, the highest n-3/n-6 ratios of total lipids were recorded in the summer for the male and female *S. triostegus*. The lowest levels were measured in the autumn for the male *S. triostegus,* and spring for the female *S. triostegus*. It has been observed that the n-3/n-6 ratio and FA composition in muscles of the male and female *S. triostegus* vary by both months and seasons throughout the year.

FA composition of TAG fraction

TAGs are one of the universal forms of stored lipids used mainly for various energetic needs. In an overwhelming majority of fish, TAGs are a dominant fraction of neutral lipids (Henderson and Tocher 1987; Vlieg and Body 1988).

According to Henderson and Tocher (1987), the MUFA levels were the highest group and PUFAs were the lowest in the TAG fraction, which can be a possible result of the accumulation of depot lipids in the form of MUFA and SFAs.

In the present study, MUFA was the dominant FA class except for in March (before the reproduction period) followed by SFA and PUFA throughout the year in the female fish. The MUFA content of the male fish showed significantly high levels in summer and spring (the reproduction period).

As in most other freshwater fish, MUFAs and SFAs were the dominant groups in the *S. triostegus* muscle TAGs. These SFA and MUFAs are generally abundant in fish from warm or temperate regions, whereas PUFA show high levels in fish from cold regions (Dey et al. 1993). The high PUFA contents in TAG in the pre-spawning period suggest that there is an important spawning influence on the FA metabolism in the female *S. triostegus.*

No significant difference could be observed in the total SFA with regard to the reproduction period and season.

C16:0, C18:1 n-9, and C16:1 n-7 were found accumulated in the TAG (Ackman 1967). Our data is consistent with this result. In the present study, C16:0, C18:1 n-9, and C16:1 n-7 acids were higher in the TAG fractions than in the PL fractions. Since diet is the main factor affecting tissue FA composition in fish, the high MUFA ratios in May and July are probably related to the increasing feeding activity in both sexes.

The n-3 to n-6 PUFA ratio shown in the study is consistent with that determined in the *S. triostegus* in the Tigris River (Cengiz et al. 2012).

The n-3/n-6 ratios were found to be high in the muscle of the *S. triostegus* and may be a valuable food for human consumption.

FA composition of PL fraction

The total PLs from the fish tissues are characteristically rich in PUFA (Gunstone et al. 1978; Henderson and Tocher 1987).

DHA is a FA characteristic of fish, and is principally of the endogenous origin. It has been reported that the major PUFA in PLs is DHA (Gunstone et al. 1978).

The PUFA content decreased in males during spawning period. Cengiz et al. (2012) found that the same data for the *S. triostegus* from the Tigris River. This suggests that the PUFAs may be used in the reproduction period. Because FAs are not only the major source of metabolic energy in fish for growth, they are also the major source of metabolic energy for reproduction (Tocher 2003).

AA was the major n-6 PUFA in this study. Both the male and female *S. triostegus* contained AA, which is a precursor for prostaglandin and thromboxane biosynthesis (Bell et al. 1994). Through its conversion to lipoxygenase metabolites, AA mediates a great variety of physiological functions including osmoregulation, cardiovascular functions, neural control, and the functionality of the reproductive systems (Sorbera et al. 1998).

EPA was the FA at the second highest amount in the n-3 PUFA of the male and female fish muscle tissues. High levels of EPA and DHA were reported by another study of the *S. triostegus* (Cengiz et al. 2012). This study has shown that *S. triostegus* was generally rich in n-3 PUFAs, which correlates with the findings of Cengiz et al. (2012).

The n-3 to n-6 PUFA ratio found in the present experiment was similar to that reported by Cengiz et al. (2012) in catfish in Tigris River. No significant differences were observed in n-3/n-6 ratio with respect to the season in both sexes.

Conclusion

In conclusion, we found that total lipid and FA compositions of total lipid, TAG and PLs of the female and male *S. triostegus* were affected by some endogenous factors, especially reproduction, and exogenous factors, especially diet. In perspective of nutritional value of *S. triostegus*, our results would suggest that *S. triostegus* is an effective source of n-3 FAs, especially DHA in the diet and reveal that this fish species is a good functional food with potential health benefits in disease prevention.

Acknowledgments This study was financed by the Dicle University Scientific Research Foundation (DUAPK-08-FF-07).

References

Ackman RG (1967) Characteristics of the fatty acid composition and biochemistry of some freshwater fish oils and lipids in composition with marine oils and lipids. Comp Biochem Physiol 22:907

Ackman RG, Eaton CA, Linne BA (1975) Differentiation of freshwater characteristics of fatty acids in marine specimens of the Atlantic Sturgeon (*Acipenser oxyrhynchus*). Fish Bull 73:838–845

Aggelousis G, Lazos ES (1991) Fatty acid composition of the lipids from eight freshwater fish species from Greece. J Food Comp Anal 4:68–76

Bayır A, Sirkecioglu AN, Aras NM, Aksakal E, Haliloglu HI, Bayır M (2010) Fatty acids of neutral and phospholipids of three endangered trout: *Salmo trutta caspius* Kessler, *Salmo trutta labrax* Pallas and *Salmo trutta macrostigma* Dumeril. Food Chem 119:1050–1056

Bell JG, Tocher DR, McDonald FM, Sargent JR (1994) Effect of supplementation with (20:3n-6), (20:4n-6) and (20:5n-3) on the production of prostaglandin-e and prostaglandin-f on the 1-series, 2-series and 3-series in turbot (*Scophthalmus maximus*) brain astroglial cells in primary culture. Biochim Biophys Acta 1211:335–342

Cejas JR, Almansa E, Villamandos JE, Badia P, Bolanos A, Lorenzo A (2003) Lipid and fatty acid composition of ovaries from wild fish and ovaries and eggs from captive fish of White Sea bream (*Diplodus sargus*). Aquaculture 216(1–4):299–313

Cengiz Eİ, Unlü E, Bashan M (2010) Fatty acid composition of total lipids in muscle tissues of nine freshwater fish from the River Tigris (Turkey). Turk J Biol 34:433–438

Cengiz EI, Unlü E, Bashan M, Satar A, Uysal E (2012) 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). Turk J Fish Aquat Sci 12:33–39

Dey I, Buda C, Wiik H, Halver JE, Farkas T (1993) Molecular and structural composition of phospholipid membranes in livers of marine and freshwater fish in relation to temperate. Proc Nat Acad Sci USA 90:7498–7502

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

Gunstone FD, Wijesundera RC, Scrimgeour CM (1978) Component acids of lipids from marine and freshwater species with special reference to furan-containing acids. J Sci Food Agric 29:539–550

Haliloğlu HI, Bayır A, Sirkecioğlu N, Aras NM, Atamanalp M (2004) Comparison of fatty acid composition in some tissue of rainbow trout (*Oncorhynchus mykiss*) living in seawater and freshwater. Food Chem 86:55–59

Hall JM, Parrish CC, Thompson RJ (2002) Eicosapentaenoic acid regulates scallop (*Plactopecten magellanicus*) membrane fluidity in response to cold. Biol Bull 202:201–203

Henderson RJ, Tocher DR (1987) The lipid composition and biochemistry of freshwater fish. Prog Lipid Res 26:281–347

Jankowska B, Zakes Z, Zmijewski T, Ulikowski D, Kowalska A (2004) Impact of diet on the fatty acids profile of European catfish (*Silurus glanis* L.). Arch Pol Fish 12:99–110

Kaçar S, Başhan M (2015) Seasonal variations on the fatty acid composition of phospholipid and triacylglycerol in gonad and liver of *Mastacembelus simack*. J Am Oil Chem Soc 92(9):1313–1320

Kayhan H, Başhan M, Kaçar S (2015) Seasonal variations in the fatty acid composition of phospholipids and triacylglycerols of brown trout. Eur J Lipid Sci Tech 117(5):738–744

Kinsella JE, Lokesh B, Stone RA (1990) Dietary n-3 polyunsaturated fatty acids and amelioration of cardiovascular disease: possible mechanisms. Am J Clin Nutr 52(1):1–28

Medford BA, Mackay WC (1978) Protein and lipid content of gonads, liver and muscle of Northern pike (*Esox lucius*) in relation to gonad growth. J Fish Res Board Can 35:213–219

Mosa AA, Radeef AF, Ibrahim KS (2012) Determination of some chemical compositions in muscle of different fish species from Tigris River in North of Iraq. Al-Mustansiriyah J Sci 23(2):91–102

Nordoy A, Marchioli R, Arnesen H, Videbaek J (2001) N-3 polyunsaturated fatty acids and cardiovascular diseases. Lipids 36:127–129

Olgunoğlu MP, Olgunoğlu IA, Göçer M (2014) Seasonal variation in major minerals (Ca, P, K, Mg) and proximate composition in flesh of Mesopotamian Catfish (*Silurus triostegus* Heckel, 1843) from Turkey. Annu Res Rev Biol 4:2628–2633

Oymak SA, Solak K, Ünlü E (2001) Some biological characteristics of *Silurus triostegus* Heckel, 1843 from Atatürk Dam Lake (Turkey). Turk J Zool 25:139–148

Ozogul Y, Ozogul F, Alagoz S (2007) Fatty acids profiles and fat contents of commercially important seawater and freshwater fish species of Turkey: a comparative study. Food Chem 103:217–223

Rahman SA, Huah TS, Hassan O, Daud NM (1995) Fatty acid composition of some Malaysian freshwater fish. Food Chem 54:45–49

Reilly MP, Lawson JA, Fitzgerald GA (1998) Eicosanoids and isoeicosanoids: indices of cellular function and oxidant stress. J Nutr 128:434–438

Rodriguez C, Acosta C, Badia P, Cejas JR, Santamaria FJ, Lorenzo A (2004) Assessment of lipid and essential fatty acids requirements of black sea bream (*Spondyliosoma cantharus*) by comparison of lipid composition in muscle and liver of wild and captive adult fish. Comp Biochem Phys 139B:619–629

Sargent JR, Henderson RJ (1995) Marine n-3.polyunsaturated fatty acids. In: Hamilton RJ (ed) Developments in oils and fats. Blackie Academic and Professional, London, pp 32–65

Sidhu KS (2003) Health benefits and potential risks related to consumption of fish or fish oil. Regul Toxicol Pharm 38(3):336–344

Smith MW, Miller NGA (1980) In animals and environmental fitness. In: Giles R (ed) Pergamon Press, Oxford, UK

Sorbera LA, Zanuy S, Carrielo M (1998) A role for polyunsaturated fatty acids and prostaglandins in oocyte maturation in the sea bass (*Dicentrarchus labrax*). In: Vandry H, Tonon MC, Roubos EW, Loof A (eds) Trends in comparative endocrinology and neurobiology: from molecular to integrative biology. Ann NY Acad Sci, vol 839. New York Academy of Sciences, New York, pp 535–537

Stanley-Samuelson DW, Dadd RH (1983) Long-chain polyunsaturated fatty acids: patterns of occurrence in insects. J Food Sci Technol 13:549–558

Suloma A, Ogata HY (2012) Lipid and fatty acid composition of commercially important tropical freshwater fish gonads: guidelines for specific broodstock diet. Turk J Fish Aquat Sci 12:743–749

Tocher DR (2003) Metabolism and functions of lipids and fatty acids in teleost fish. Fish Sci 11:107–184

Vlieg P, Body DR (1988) Lipid contents and fatty acid composition of some New Zealand freshwater finfish and Marine finfish, shellfish and roes. N Z J Mar Freshw Res 22:151–162

Von Sckacky C (2003) The role of omega-3 fatty acids in cardiovascular disease. Curr Atheroscler Rep 5:139–145