Research Article

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Effect of season on the fatty acid composition of the liver and muscle of *Alburnus chalcoides* (Güldenstädt, 1772) from Tödürge Lake (Sivas, Turkey)

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Abstract: Seasonal variations in the liver and muscle fatty acid composition of *Alburnus chalcoides* (Güldenstädt, 1772) from Tödürge Lake (Sivas, Turkey) were determined. The most abundant fatty acids in the investigated seasons and tissues were C16:0, C18:0, C18:1 n-9, C18:1 n-7, C20:4 n-6, C20:5 n-3, and C22:6 n-3. The total saturated fatty acids (SFAs) of the liver and muscle were at the highest in the spring (38.59%) and summer (41.65%), respectively. The total monounsaturated fatty acids (MUFAs) were at the highest in the autumn (51.79%) for liver and in the winter (40.04%) for muscle. The total polyunsaturated fatty acids (PUFAs) were determined to be at the lowest levels in the autumn for the both liver and muscle. The lowest total n-6 PUFA levels were determined as 2.60% and 4.19% in the autumn for the liver and muscle, respectively, while the lowest total n-3 PUFA levels were 14.84% for the liver (autumn) and 22.60% for muscle (spring).

Key words: *Alburnus chalcoides*, liver, muscle, fatty acid composition, season, Tödürge Lake

Introduction

It has been emphasized that fish that are rich in terms of the n-3 and n-6 forms of polyunsaturated fatty acids (PUFAs) are beneficial for human health (Sharma et al., 2010), and it seems that intensive efforts have been focused on eicosapentaenoic acid (C20:5 n-3; EPA), docosapentaenoic acid (C22:5 n-3; DPA), and docosahexaenoic acid (C22:6 n-3; DHA) among the PUFAs in fish tissues, due to their nutritive importance (Szlinder-Richert et al., 2010).

With epidemiological studies, the protective effects of especially the EPA and DHA found in fish tissues on coronary heart diseases have been well documented (Holub and Holub, 2004). Other beneficial effects of these forms of fatty acids have also been proven in neurodegenerative diseases (Lauritzen et al., 2000) and plurimetabolic syndrome, which has a high prevalence in the world population (Lombardo et al., 2007). At the same time, activities such as growth, development, and reproduction in fish require these PUFAs, together with arachidonic acid (C20:4 n-6; ARA) (Sargent et al., 1999).

Exler et al. (1975) indicated that fatty acid patterns in fish have shown remarkable variations between species and individuals of the same population, as well as different fish organs. However, maturity stage, the season, and fishing ground have an important impact in the fluctuations seen in the fatty acid composition

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of fish tissues (Aidos et al., 2002). Among these parameters, the season can be the most important because it also affects the composition of the diets, which are available throughout the seasons (Szlinder-Richert et al., 2010). In this context, Fajmonova et al. (2003) emphasized that the fatty acid composition of fish has been affected by diet to a substantial degree. However, Arzel et al. (1994) documented that in *Salmo trutta* some fatty acids reflect a specific pattern of fatty acid composition, depending on the species and tissue under investigation, instead of reflecting the composition of the diet in a simple manner.

Lipid storage sites found in fish may be different depending on the species under investigation, and lipids can be stored in the muscle, liver, and subcutaneous and mesenteric membranes. For example, while the muscles of mackerel (*Scomber scombrus*) and salmon (*Salmo salar*) function as the main fat depots, this function has been taken over by the liver in the cod (*Gadus morhua*) (van den Thillart et al., 2002). Under conditions like reduced feeding and gonadal maturation, the fats (or the nutrients) are transferred from the depots, such as the liver and muscle, to the tissues that need these compounds (Uysal et al., 2006). Thus, the liver as the main metabolic structure and the muscle as the main edible part of fish are important organs and should be investigated in terms of fatty acid composition.

Recently, a few studies have focused on the seasonal fatty acid variations in fish living in Turkish freshwaters. Among the species investigated were *Solea solea* (Gökçe et al., 2004), *Sander lucioperca* (Uysal and Aksoylar, 2005; Uysal et al., 2006; Guler et al., 2007), and *Vimba vimba tenella* (Kalyoncu et al., 2009). However, the authors were unable to find any information on the fatty acid composition of *Alburnus chalcoides*. Thus, the main purpose of this study was to determine the fatty acid compositions of the liver and muscle of this species. To the best of the authors' knowledge, this study is the first comprehensive report on the seasonal changes of the fatty acid dynamics of *A. chalcoides*.

Materials and methods

Sample collection

Mature *A. chalcoides* (Güldenstädt, 1772) individuals were collected from Tödürge Lake in the spring, summer, autumn, and winter (Table 1). In each season, 3 fish specimens were used for lipid and fatty acid analyses. One gram each of the liver and muscle samples was extracted for total lipid and fatty acid analyses. The muscle sample was taken directly from the area underneath the dorsal fin. Three replicates were taken of each sample and were immediately placed in chloroform/methanol (2/1, v/v) and stored at –20 °C until analyses.

Fatty acid analyses

The total lipids from the liver and muscles were isolated using the method of Folch et al. (1957). The saponification of the total lipids obtained was carried out using methanol (50%) containing of 5% sodium hydroxide for 1 h. The methyl ester forms of

Table 1. The fork length (cm) and weights (g) of fish used in the fatty acid analyses, according to seasons*.

Season	Length (cm) mean ± SE	Weight (g) mean ± SE	Water temperature (°C)
Spring	15.50 ± 0.76^{ab}	58.98 ± 6.98^{a}	12
Summer	16.83 ± 0.67^{a}	54.29 ± 6.44^{a}	24
Autumn	15.50 ± 0.50^{ab}	50.85 ± 1.73^{a}	19
Winter	14.33 ± 0.44^{b}	44.37 ± 2.41^{a}	6

*Each data is the mean of length and weight of 3 different fish. Values for each sample with different superscript letters in the same column are significantly different at $P \leq 0.05$.

the saponifiable lipids obtained were prepared using the boron trifluoride-methanol method (Moss et al., 1974). The resultant fatty acid methyl esters (FAMEs) were introduced into a HP Agilent 6890N model gas chromatograph (Hewlett Packard, Palo Alto, CA, USA), containing a flame ionization detector and fitted with an HP-88 capillary column (100 m, 0.20 mm i.d., and 0.25 μm) (Agilent Technologies Inc., USA). The gas chromatographic procedure and conditions were carried out according to Cakmak et al. (2011).

Statistical analyses

SPSS 15.0 for Windows (SPSS Inc., Chicago, IL, USA) was used in the statistical analyses of the data obtained from the experiments. The mean values were obtained from 3 experiments and were reported. Comparison of the percentages of fatty acid was carried out by ANOVA and Tukey's test was used in the evaluation between means. Differences between means were indicated as significant at $P \leq 0.05$.

Results and discussion

The seasonal changes found in the fatty acid compositions of the liver and muscle of *A. chalcoides* can be seen in Tables 2 and 3, respectively. In the gas chromatographic analyses, 38 fatty acids were found to be in both the liver and muscle tissues of *A. chalcoides*. There were also remarkable quantitative differences between the individual fatty acids, depending on the season. The fatty acids with the highest percentage in the liver and muscle were C16:0 (palmitic acid), C18:0 (stearic acid), C16:1 n-7 (palmitoleic acid), C18:1 n-7, C18:1 n-9 (oleic acid), C20:4 n-6 (ARA), C20:5 n-3 (EPA), and C22:6 n-3 (DHA).

C16:0 was the major fatty acid of the SFAs in the liver and muscle. In the liver, the highest percentage of this acid was in the spring (20.57%), and this amount was not different than that for the summer (19.40%) ($P \geq 0.05$). The levels of C16:0 in the muscle tissue were the highest in the summer (19.48%) and the autumn (18.93%) ($P \geq 0.05$). Together with the winter season, this acid showed a decrease in both the liver (16.76%) and muscle tissues (16.06%). C18:0 was the second major fatty acid in the SFAs fraction in *A. chalcoides*. In the liver, the levels of this acid changed from 4.71% (autumn) to 12.30% (spring), while the levels of C18:0 were between 3.05% (autumn) and 8.40% (summer) in the muscle. However, there were no statistical differences between the values for the autumn and the winter periods of C18:0, in both the liver and muscle tissues ($P \geq 0.05$). As can be seen in Tables 2 and 3, other fatty acids of the SFAs fraction were minor compounds, with the exception of C14:0 (myristic acid), C21:0 (heneicosanoic acid) and C22:0 (behenic acid). In the liver, the total SFA amounts were the highest in the spring (38.59%) and the lowest in the winter (28.59%) ($P \leq 0.05$). In the muscle, the highest total SFA amount in the summer period was 41.65%, which decreased to 28.97% in the winter ($P \leq 0.05$). It is well documented that C16:0 and C18:0 were the main components of the SFAs and C16:0 was more stable than C18:0 in the fish tissues (Akpınar et al., 2009). In a study conducted on the fatty acid composition of different tissues of *Salmo trutta labrax*, C16:0 was the main fatty acid of the SFA fraction in the liver and muscle and its level in the liver was higher than that found in the muscle tissue (Aras et al., 2003). Studies carried out on the fillet of *Sander lucioperca* (Guler et al., 2007) and *Cyprinus carpio* (Guler et al., 2008), living in Beyşehir Lake (Turkey), reported that C16:0 was the main SFA in all of the seasons.

In this study, C18:1 n-9 was the predominant fatty acid within the monounsaturated fatty acids (MUFAs) fraction in the liver and muscle of *A. chalcoides*. The percentages of this acid ranged from 13.82% (spring) to 32.96% (autumn) in the liver ($P \leq 0.05$). C18:1 n-9 percentages in the muscle tissue showed significant differences ($P \leq 0.05$) in all of the seasons and the highest level was 22.68% in the winter. C18:1 n-7 and C16:1 n-7 were the other fatty acids with high percentages within the MUFAs. The highest levels of C16:1 n-7 were determined in the autumn for the liver (11.23%) and in the winter for the muscle (9.85%). The percentages of C18:1 n-7 in the liver ranged from 4.17% (summer) to 7.25% (spring), while these values were between 3.56% (autumn) and 6.62% (spring) in the muscles of *A. chalcoides*. In the liver, the total MUFA levels showed significant differences ($P \leq 0.05$) in all of the seasons and had the highest percentage in the autumn (51.79%). However, in the muscle tissue, the total MUFA level, which was the lowest in the summer (21.12%),

Table 2. Seasonal variations of the liver fatty acids of Alburnus chalcoides (%)^{A}.

Fatty acids	Spring mean ± SE	Summer mean ± SE	Autumn mean ± SE	Winter mean ± SE
C8:0^{C}	0.03 ± 0.07^{a}	0.03 ± 0.01$^{a, B}$	0.01 ± 0.01^{a}	0.02 ± 0.01^{a}
C10:0	0.06 ± 0.00^{a}	0.03 ± 0.01^{a}	0.01 ± 0.00^{a}	0.03 ± 0.01^{a}
C11:0	0.05 ± 0.03^{a}	0.09 ± 0.01^{b}	0.09 ± 0.00^{b}	0.15 ± 0.00^{c}
C12:0	0.12 ± 0.01^{ab}	0.17 ± 0.03^{b}	0.15 ± 0.03^{b}	0.06 ± 0.12^{a}
C13:0	0.05 ± 0.01^{a}	0.06 ± 0.01^{a}	0.01 ± 0.00^{b}	0.05 ± 0.01^{a}
C14:0	1.19 ± 0.19^{a}	1.54 ± 0.17^{a}	3.25 ± 0.09^{b}	2.61 ± 0.16^{c}
C15:0	0.51 ± 0.08^{a}	0.26 ± 0.05^{b}	0.19 ± 0.01^{b}	0.31 ± 0.08^{b}
C16:0	20.57 ± 0.29^{a}	19.40 ± 0.41^{a}	17.19 ± 0.32^{b}	16.76 ± 0.21^{b}
C17:0	1.68 ± 0.10^{a}	1.57 ± 0.24^{a}	0.77 ± 0.13^{b}	0.56 ± 0.02^{b}
C18:0	12.30 ± 0.30^{a}	8.62 ± 0.14^{b}	4.71 ± 0.17^{c}	4.79 ± 0.22^{c}
C19:0	0.41 ± 0.07^{a}	0.20 ± 0.03^{b}	0.07 ± 0.00^{c}	0.10 ± 0.03^{bc}
C20:0	0.24 ± 0.03^{a}	0.86 ± 0.08^{ab}	1.35 ± 0.13^{b}	0.96 ± 0.02^{b}
C21:0	0.29 ± 0.04^{a}	0.77 ± 0.09^{b}	1.42 ± 0.09^{c}	1.15 ± 0.11^{c}
C22:0	0.80 ± 0.11^{a}	1.21 ± 0.13^{a}	1.18 ± 0.08^{a}	0.82 ± 0.05^{a}
C24:0	0.31 ± 0.06^{ac}	0.16 ± 0.02^{bd}	0.38 ± 0.01^{a}	0.24 ± 0.03^{cd}
Σ SFA	**38.59 ± 0.30^{a}**	**34.93 ± 0.22^{b}**	**30.77 ± 0.33^{c}**	**28.59 ± 0.26^{c}**
C14:1 n-5	0.15 ± 0.02^{ad}	0.08 ± 0.01^{ab}	0.05 ± 0.02^{b}	0.16 ± 0.03^{d}
C15:1 n-5	0.11 ± 0.01^{a}	0.08 ± 0.01^{ab}	0.05 ± 0.02^{b}	0.07 ± 0.04^{ab}
C16:1 n-7	4.92 ± 0.08^{a}	6.23 ± 0.14^{a}	11.23 ± 0.21^{b}	10.91 ± 0.19^{b}
C17:1 n-8	0.77 ± 0.13^{a}	1.04 ± 0.09^{a}	1.29 ± 0.20^{a}	0.96 ± 0.10^{a}
C18:1 n-9	13.82 ± 0.70^{a}	18.86 ± 0.17^{b}	32.96 ± 0.76^{c}	25.80 ± 0.28^{d}
C18:1 n-7	7.25 ± 0.08^{a}	4.17 ± 0.13^{b}	4.36 ± 0.17^{b}	5.74 ± 0.11^{c}
C20:1 n-9	0.14 ± 0.01^{a}	0.96 ± 0.03^{b}	1.80 ± 0.14^{c}	2.03 ± 0.11^{c}
C22:1 n-9	0.02 ± 0.00^{a}	0.02 ± 0.01^{a}	0.02 ± 0.00^{a}	0.04 ± 0.03^{a}
C24:1 n-9	0.05 ± 0.01^{a}	0.08 ± 0.04^{a}	0.04 ± 0.01^{a}	0.04 ± 0.01^{a}
Σ MUFA	**27.21 ± 0.32^{a}**	**31.50 ± 0.27^{b}**	**51.79 ± 0.24^{c}**	**45.73 ± 0.17^{d}**
C18:2 n-6	2.88 ± 0.12^{a}	1.02 ± 0.06^{b}	0.96 ± 0.04^{b}	1.93 ± 0.15^{c}
C18:3 n-6	0.48 ± 0.04^{a}	0.11 ± 0.01^{b}	0.09 ± 0.01^{b}	0.22 ± 0.03^{c}
C20:2 n-6	0.14 ± 0.03^{a}	0.02 ± 0.05^{a}	0.16 ± 0.08^{a}	0.41 ± 0.09^{b}
C20:3 n-6	0.08 ± 0.01^{a}	0.05 ± 0.02^{ac}	0.02 ± 0.00^{c}	0.03 ± 0.01^{c}
C20:4 n-6	7.08 ± 0.50^{a}	3.06 ± 0.14^{b}	0.97 ± 0.01^{c}	4.81 ± 0.30^{d}
C22:2 n-6	0.03 ± 0.01^{a}	0.01 ± 0.00^{a}	0.03 ± 0.02^{a}	0.04 ± 0.04^{a}
C22:4 n-6	0.10 ± 0.02^{a}	0.35 ± 0.04^{ab}	0.30 ± 0.08^{a}	0.66 ± 0.17^{b}
C22:5 n-6	0.23 ± 0.04^{a}	0.12 ± 0.01^{ab}	0.07 ± 0.01^{b}	0.21 ± 0.06^{ab}
Σ n-6 PUFA	**11.02 ± 0.19^{a}**	**4.62 ± 0.11^{b}**	**2.60 ± 0.15^{c}**	**8.25 ± 0.18^{d}**
C18:3 n-3	1.07 ± 0.04^{a}	0.31 ± 0.05^{b}	0.37 ± 0.02^{b}	0.70 ± 0.05^{c}
C20:3 n-3	0.03 ± 0.01^{a}	0.04 ± 0.01^{a}	0.20 ± 0.03^{b}	0.06 ± 0.01^{a}
C20:5 n-3	5.52 ± 0.33^{a}	7.49 ± 0.51^{b}	7.06 ± 0.16^{b}	6.84 ± 0.46^{b}
C22:3 n-3	0.03 ± 0.01^{a}	0.01 ± 0.00^{a}	0.25 ± 0.05^{b}	0.05 ± 0.01^{a}
C22:5 n-3	4.53 ± 0.01^{a}	3.69 ± 0.02^{b}	1.74 ± 0.19^{c}	1.90 ± 0.23^{c}
C22:6 n-3	12.07 ± 0.15^{a}	17.33 ± 1.03^{b}	5.27 ± 0.21^{c}	7.86 ± 0.14^{d}
Σ n-3 PUFA	**23.21 ± 0.19^{a}**	**28.95 ± 0.16^{b}**	**14.84 ± 0.12^{c}**	**17.43 ± 0.20^{d}**
Σ PUFA	**34.23 ± 0.28^{a}**	**33.57 ± 0.24^{a}**	**17.44 ± 0.14^{b}**	**25.68 ± 0.21^{c}**

^{A}: The average of the 3 lots analyzed; ^{B}: The values reported are means ± SE; ^{C}(a – b – c – d): values for each sample with different superscript letters in the same fraction are significantly different at $P \leq 0.05$; Σ SFA: total saturated fatty acid; Σ MUFA: total monounsaturated fatty acid; Σ n-6 PUFA: total n-6 polyunsaturated fatty acid; Σ n-3 PUFA: total n-3 polyunsaturated fatty acid; and Σ PUFA: total polyunsaturated fatty acid.

Table 3. Seasonal variations of the muscle fatty acids of Alburnus chalcoides (%)[A].

Fatty acids	Spring mean ± SE	Summer mean ± SE	Autumn mean ± SE	Winter mean ± SE
C8:0[C]	0.01 ± 0.00^{a}	0.09 ± 0.02$^{b, B}$	0.01 ± 0.01^{a}	0.01 ± 0.00^{a}
C10:0	0.02 ± 0.00^{a}	0.13 ± 0.03^{b}	0.02 ± 0.00^{a}	0.01 ± 0.00^{a}
C11:0	0.02 ± 0.00^{a}	0.35 ± 0.05^{b}	0.26 ± 0.03^{b}	0.12 ± 0.01^{a}
C12:0	0.13 ± 0.04^{a}	0.33 ± 0.04^{b}	0.18 ± 0.02^{a}	0.13 ± 0.02^{a}
C13:0	0.02 ± 0.00^{a}	0.29 ± 0.09^{b}	0.05 ± 0.01^{a}	0.02 ± 0.00^{a}
C14:0	2.16 ± 0.12^{a}	2.65 ± 0.08^{b}	5.63 ± 0.14^{c}	2.94 ± 0.10^{d}
C15:0	0.45 ± 0.04^{a}	1.25 ± 0.10^{b}	0.42 ± 0.11^{a}	0.42 ± 0.05^{a}
C16:0	15.75 ± 0.19^{a}	19.48 ± 0.27^{b}	18.93 ± 0.32^{b}	16.06 ± 0.44^{a}
C17:0	0.77 ± 0.13^{a}	2.20 ± 0.17^{b}	0.91 ± 0.00^{a}	0.65 ± 0.15^{a}
C18:0	5.06 ± 0.25^{a}	8.40 ± 0.23^{b}	3.05 ± 0.15^{c}	3.92 ± 0.53^{c}
C19:0	0.14 ± 0.03^{a}	0.79 ± 0.12^{b}	0.16 ± 0.06^{a}	0.13 ± 0.04^{a}
C20:0	0.95 ± 0.10^{a}	2.36 ± 0.08^{b}	3.02 ± 0.21^{c}	1.57 ± 0.10^{d}
C21:0	1.22 ± 0.13^{ac}	2.44 ± 0.02^{bc}	3.32 ± 0.18^{b}	2.07 ± 0.44^{c}
C22:0	0.71 ± 0.02^{a}	0.72 ± 0.01^{a}	0.91 ± 0.05^{b}	0.72 ± 0.02^{a}
C24:0	0.21 ± 0.00^{a}	0.21 ± 0.00^{a}	0.79 ± 0.08^{b}	0.21 ± 0.01^{a}
Σ SFA	**27.58 ± 0.22^{a}**	**41.65 ± 0.37^{b}**	**37.62 ± 0.35^{c}**	**28.97 ± 0.19^{d}**
C14:1 n-5	0.17 ± 0.01^{a}	0.74 ± 0.09^{b}	0.15 ± 0.03^{a}	0.16 ± 0.02^{a}
C15:1 n-5	0.11 ± 0.00^{a}	0.23 ± 0.03^{b}	0.09 ± 0.01^{a}	0.08 ± 0.00^{a}
C16:1 n-7	9.11 ± 0.19^{a}	5.02 ± 0.26^{b}	7.98 ± 0.31^{c}	9.85 ± 0.22^{a}
C17:1 n-8	1.15 ± 0.08^{a}	0.62 ± 0.06^{b}	1.21 ± 0.12^{a}	1.21 ± 0.05^{a}
C18:1 n-9	19.65 ± 0.59^{a}	10.10 ± 0.37^{b}	20.30 ± 0.61^{c}	22.68 ± 0.33^{d}
C18:1 n-7	6.62 ± 0.11^{a}	3.89 ± 0.27^{b}	3.56 ± 0.18^{b}	5.12 ± 0.20^{c}
C20:1 n-9	1.11 ± 0.35^{a}	0.44 ± 0.03^{b}	0.98 ± 0.10^{ab}	0.88 ± 0.05^{ab}
C22:1 n-9	0.02 ± 0.00^{a}	0.04 ± 0.01^{a}	0.05 ± 0.01^{a}	0.04 ± 0.01^{a}
C24:1 n-9	0.04 ± 0.01^{a}	0.05 ± 0.01^{a}	0.12 ± 0.03^{b}	0.03 ± 0.00^{a}
Σ MUFA	**37.97 ± 0.38^{a}**	**21.12 ± 0.26^{b}**	**34.43 ± 0.19^{c}**	**40.04 ± 0.22^{d}**
C18:2 n-6	4.88 ± 0.49^{a}	2.54 ± 0.16^{bc}	2.22 ± 0.20^{b}	3.44 ± 0.25^{c}
C18:3 n-6	0.35 ± 0.02^{a}	0.19 ± 0.06^{ab}	0.11 ± 0.04^{b}	0.25 ± 0.09^{ab}
C20:2 n-6	0.18 ± 0.06^{abc}	0.18 ± 0.01^{abc}	0.08 ± 0.02^{b}	0.31 ± 0.05^{c}
C20:3 n-6	0.05 ± 0.01^{a}	0.18 ± 0.04^{b}	0.08 ± 0.02^{a}	0.04 ± 0.01^{a}
C20:4 n-6	5.49 ± 0.22^{a}	2.50 ± 0.30^{b}	1.06 ± 0.11^{c}	3.54 ± 0.17^{d}
C22:2 n-6	0.02 ± 0.00^{a}	0.04 ± 0.01^{a}	0.02 ± 0.01^{a}	0.02 ± 0.01^{a}
C22:4 n-6	0.57 ± 0.27^{a}	0.21 ± 0.08^{a}	0.43 ± 0.01^{a}	0.39 ± 0.11^{a}
C22:5 n-6	0.33 ± 0.12^{a}	0.17 ± 0.02^{a}	0.24 ± 0.03^{a}	0.13 ± 0.01^{a}
Σ n-6 PUFA	**11.84 ± 0.24^{a}**	**6.00 ± 0.11^{b}**	**4.19 ± 0.15^{c}**	**8.12 ± 0.13^{d}**
C18:3 n-3	1.46 ± 0.15^{a}	0.86 ± 0.03^{b}	0.86 ± 0.09^{b}	1.22 ± 0.07^{a}
C20:3 n-3	0.03 ± 0.01^{a}	0.22 ± 0.08^{b}	0.27 ± 0.04^{b}	0.02 ± 0.00^{a}
C20:5 n-3	9.24 ± 0.13^{a}	13.62 ± 0.70^{b}	12.85 ± 0.46^{b}	10.77 ± 0.15^{c}
C22:3 n-3	0.03 ± 0.01^{a}	0.05 ± 0.00^{a}	0.10 ± 0.01^{b}	0.03 ± 0.02^{a}
C22:5 n-3	3.31 ± 0.18^{a}	3.44 ± 0.02^{a}	2.51 ± 0.17^{b}	2.82 ± 0.07^{b}
C22:6 n-3	8.53 ± 0.27^{a}	13.06 ± 0.10^{b}	7.18 ± 0.88^{c}	8.04 ± 0.60^{ac}
Σ n-3 PUFA	**22.60 ± 0.12^{a}**	**31.25 ± 0.18^{b}**	**23.77 ± 0.29^{c}**	**22.88 ± 0.10^{d}**
Σ PUFA	**34.44 ± 0.26^{a}**	**37.25 ± 0.21^{b}**	**27.96 ± 0.33^{c}**	**31.00 ± 0.14^{d}**

[A]: The average of the 3 lots analyzed; [B]: The values reported are means ± SE; [C](a – b – c – d): values for each sample with different superscript letters in the same fraction are significantly different at $P \leq 0.05$; Σ SFA: total saturated fatty acid; Σ MUFA: total monounsaturated fatty acid; Σ n-6 PUFA: total n-6 polyunsaturated fatty acid; Σ n-3 PUFA: total n-3 polyunsaturated fatty acid; and Σ PUFA: total polyunsaturated fatty acid.

increased during the autumn (34.43%), and had the highest levels in the winter (40.04%). Zlatanos and Laskaridis (2007) reported that C18:1, C18:1 n-7, and C16:1 were the most abundant fatty acids in all of the seasons investigated within the MUFA fraction, in the muscles of *Sardina pilchardus*, *Spicara smaris*, and *Engraulis encrasicolus* from the Mediterranean. In a similar study, Rasoarahona et al. (2005) investigated the seasonal changes in the fatty acid compositions in *Oreochromis niloticus*, *O. macrochir*, and *Tilapia rendalli*, which are tilapia species, and reported similar findings. Steffens (1997) pointed out that C18:1 n-9 is the characteristic MUFA of fish tissues.

C18:2 n-6 levels were between 0.96% (autumn) and 2.88% (spring) in the liver of *A. chalcoides*. However, in the muscle, the level was between 2.22% (autumn) and 4.88% (spring) ($P \leq 0.05$), slightly higher than that in the liver. C20:4 n-6 (ARA) was one of the dominant fatty acids among the n-6 form of the PUFAs in both the liver and muscle, depending on the seasons investigated. In the liver, the highest level of ARA was 7.08% in the spring, and this level decreased during the summer (3.06%) and the autumn (0.97%), and increased to 4.81% in the winter. The muscle of *A. chalcoides* also showed the same fluctuation pattern (see Table 3) and there were significant seasonal variations in terms of this acid in both tissues ($P \leq 0.05$). At the same time, the lowest level of the total n-6 form of the PUFA was in the autumn, at 2.60% for the liver and 4.19% for the muscle, and they increased together in the winter. Guler et al. (2011) investigated the seasonal changes in the fatty acid composition of *S. lucioperca* and *Cyprinus carpio* from Altinapa Dam Lake and found that C18:2 n-6 and C20:4 n-6 were the principal n-6 PUFAs of the muscles of the species investigated. Similar results were reported in some studies carried out in fish species living in Turkish freshwater from different regions (Gökçe et al., 2004; Uysal and Aksoylar, 2005; Guler et al., 2007).

In this study, C20:5 n-3 (EPA) and C22:6 n-3 (DHA) had the highest percentages in both the liver and the muscle of *A. chalcoides*. In the liver, EPA levels fluctuated between 5.52% (spring) and 7.49% (summer). In the muscles of *A. chalcoides*, the levels of this acid ranged from 9.24% in the spring to 13.62% in the summer. DHA levels in the liver were 12.07% in the spring, 17.33% in the summer, 5.27% in the autumn, and 7.86% in the winter. However, DHA levels in the muscle were 8.53% in the spring, 13.06% in the summer, 7.18% in the autumn, and 8.04% in the winter. The total n-3 form of the PUFA was lowest in the autumn for the liver (14.84%) and in the spring for the muscle (22.60%).

All of the data obtained in this study showed that there is a tendency towards decreasing levels in the autumn, especially in the ARA and DHA amounts, together with the total PUFA amounts. At the same time, the levels of these important PUFAs increased in the winter in all of the tissues investigated. These fluctuations observed in the total PUFAs, and its individual fatty acids, showed an inverse relation between the total SFAs and its individual fatty acids. The major increases seen in ARA and DHA amounts, together with the total PUFAs in the winter, could be related to the decrease in water temperature (Table 1). To adapt to lower water temperatures, fish have the ability of changing the fatty acid composition of their biological membranes, and PUFAs play a critical and leading role in this progress, due to their lower melting point (Kozlova and Khotimchenko, 2000; Logue et al., 2000; Uysal et al., 2008). At the same time, the reproduction period is another important factor, in which the most remarkable changes in the fatty acid composition of fish have been observed and the quality of flesh may be decreased in terms of fatty acids (Agren et al., 1987; Cesaj et al., 2003; Uysal and Aksoylar, 2005). Sushchik et al. (2007) investigated the seasonal fluctuations in the fatty acid composition of *Thymallus arcticus* and they found that the spawning phenomenon was the main factor causing fluctuations in the seasonal fatty acid compositions of the fish fillet. One study revealed that the reproduction period for *A. chalcoides* from Tödürge Lake was between May and the end of June (Unver, 1998). However, depending on the drastic changes seen in the climatic conditions in Tödürge Lake, the reproduction period of this species may be postponed or moved forward from the usual timing.

According the data obtained in our study, it may be concluded that the variations in the major PUFAs involved in ARA and DHA can be a consequence of the complex relationship between water temperature and the reproduction period. Another important point is that DHA and ARA may play an important role in the reproduction period of *A. chalcoides* living in Tödürge Lake. To the best of our knowledge, this is the first report on the fatty acid dynamics of *A. chalcoides*. The results obtained in the present study suggest that *A. chalcoides* may be a satisfactory fish species in terms of feeding with the n-3 form of PUFAs throughout all of the seasons.

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