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Seasonal variations on total fatty acid composition of fillets of zander (*Sander lucioperca*) in Beysehir Lake (Turkey)

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Abstract

Seasonal variations on total fatty acid compositions of zander, *Sander lucioperca* in Beysehir Lake, were determined by using GC. Polyunsaturated fatty acids (PUFA) were found to be higher than saturated (SFA) and monounsaturated fatty acids (MUFA) in all seasons. Palmitic acid was the major SFA (57.0–64.0% of total SFA) in all seasons. Oleic acid was identified as the major MUFA (45.0–58.0% of total MUFAs). Docosahexaenoic acid (DHA), linoleic acid (LA), eicosapentaenoic acid (EPA), and arachidonic acid (AA) were the most abundant PUFA. Relating to the total fatty acid composition of zander, the percentages of DHA, LA, AA, and EPA ranged between 17.1–23.3%, 5.40–15.4%, 6.72–9.94% and 4.22–5.93% of total lipid, respectively. The percentages of total ω3 fatty acid were higher than those of total ω6 fatty acid in the fatty acid composition of zander with ω3/ω6 ratios of 1.49, 1.45, 1.22, 0.72 in spring, autumn, winter, and summer, respectively. It was shown that the fatty acid composition and ω3/ω6 fatty acids ratio in the muscle of zander were significantly influenced by spawning and season.

Keywords: Zander; *Sander lucioperca*; Fatty acid composition; Seasonal variations; Beysehir Lake

1. Introduction

Since it was noted that the reduced cardiovascular mortality of Eskimos was related to fish consumption, fish oil has become subject of thorough investigation (Lancet, 1983). During recent years, fish lipids have been focused on as being beneficial for human health (Anon, 1992). The potential health benefits related to fish consumption are due to the presence of proteins, unsaturated essential fatty acids, minerals, and vitamins. Additional health benefits from the consumption of fish or fish oil may be related to polyunsaturated fatty acids (PUFAs), especially ω3 PUFAs (Sidhu, 2003). The composition of fish oils is dominated by two members of the ω3 PUFA family: 20:5 ω3 (eicosapentaenoic acid, known as EPA) and 22:6 ω3 (docosahexaenoic acid, known as DHA). Long chain ω3 PUFAs cannot be readily synthesised by human bodies and mostly are obtained through the diet (Alasalvar, Taylor, Zubcov, Shahidi, & Alexis, 2002). Thus, PUFA, especially the longer-chain ω3 and ω6 PUFA, have been considered essential fatty acids and have been shown to have curative and preventive effects on cardiovascular diseases, neurodevelopment in infants, cancers and fat glycemic control (Conner, 1997; Kinsella, Lokesh, & Stone, 1990). The ω3 fatty acids are always present in fish flesh even in lean fish (Ackman, 2002). Results of clinical and epidemiological research suggest that EPA and DHA, found mainly in fish and seafoods have extremely beneficial properties for the prevention of human coronary artery disease (Leaf & Weber, 1988). The evidence of fish oil's heart protective benefits is strong enough that the American

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heart association (AHA) now urges everyone to eat at least two servings of fish a week, along with other foods rich in alpha linolenic acid. In the fall of 2002 the AHA advised people who already have heart disease to consume about 1 gram a day of the active ingredients in fish oil—EPA and DHA. Additionally, patients needing to lower elevated triglyceride levels are recommended to consume 2–4 g EPA + DHA daily under the guidance of a physician (Kris-Etherton, Harris, & Appel, 2002). Lemaitre et al. (2003) reported that higher blood EPA plus DHA levels was associated with a 70% lower risk of fatal ischemic heart disease in older adults.

The amount of longer-chain ω3 PUFAs differs between species and can be influenced by a number of factors. The fatty acid composition of fish tissue can be affected by diet, size, age, reproductive cycle, salinity, temperature, season and geographical location (Bandarra, Batista, Nunes, Empis, & Christie, 1997; Henderson & Tocher, 1987; Leger, Bergot, Lukuet, Flanzy, & Meurot, 1977; Luzia, Sampaio, Castellucci, & Torres, 2003; Shirai, Suzuki, Tokairin, & Wada, 2001, 2002).

Herbivorous fish, which feed on algae containing large amounts of C18 PUFAs but lesser amounts of C20 and C22 PUFAs (Henderson & Tocher, 1987) are found to be rich in ω6 PUFAs and shorter-chain ω3 PUFAs (Brown, Roberts, & Truswell, 1989). Carnivores, due to their consumption of other fish in which chain elongation and desaturation is completed, were rich in longer-chain ω3 PUFAs but lower in α-linolenic acid. Omnivorous fish have a higher proportion of C18 linolenic acid but a lower proportion of longer-chain ω3 PUFAs (Brown et al., 1989), thus reflecting their diet.

Cold water species have higher levels of longer-chain highly unsaturated ω3 fatty acids in their diets than warm-water species, which have higher levels of ω6 and ω9 fatty acids (Lovell, 1991). Generally a decrease in temperature results in an increase in the degree of unsaturation (Henderson & Tocher, 1987). A possible explanation is that at low temperatures a higher degree of fatty acid unsaturation is needed to maintain flexibility and permeability in membrane phospholipids (Lovell, 1991).

The most important change in total lipid and fatty acid composition of fish is observed during the period of reproduction. In this period, the storage lipids as well as other nutritional compounds such as proteins, vitamins, and minerals in muscle, liver, and visceral organs are mobilized to the gonads in order to ensure maturation (Agren, Muje, Hanninen, Herranen, & Penttila, 1987; Cejas et al., 2003). Therefore, the nutritional quality of muscle may decrease during gonodal maturation (Uysal & Aksoylar, 2005).

The aim of this study was to determine the seasonal variations in total fatty acid composition and ω3/ω6 fatty acids ratio of muscle of zander, *Sander lucioperca*, which is of great commercial importance in Beysehir Lake, the largest freshwater lake in Turkey. Fishing is mostly between July and March.

2. Materials and methods

2.1. Materials

S. lucioperca (zander), used in this study, were obtained seasonally from Beysehir Lake which is the largest freshwater lake (651 km^2) in Turkey. Beysehir Lake is located in central Anatolia and 90 km from the city of Konya (37° 45′ North–31°30′ East). Its average depth is 7–8 m, length about 45 km and width is 14–26 km. It is tectonic/karstic in origin. The water of the lake is used for irrigation and drinking purposes. Zander is one of the most abundant fish in all seasons in this lake and has a great commercial importance for central anatolian peoples.

Zander is a carnivorous fish, and it generally feeds on other fish species rich in fatty acids (Ekmekçi, Erkakan, & Bayrak, 1991). Zander is an important freshwater fish species distributed especially in Eastern and Central Europe, Western Asia, as well as in many other countries in the world. In Turkey, especially in Central Anatolia, zander is a commercial fish species. Zander was implanted into Beysehir Lake between 1978 and 1980 (Erdem, Sarıhan, & Erdem, 1985), and no reports have yet been published about the effects of seasonal variations on the fatty acid composition of this important species in this location.

The seasons chosen for analysis were summer, winter, spring, and autumn. The samples were collected in middle month of each season during 2003. All representative fishes ($n = 3$ at each determination) used in the experiments were of almost the same size and age. After being caught, they were transported on ice to the laboratories, filleted, and then frozen. At the beginning of each analysis, the samples were allowed to equilibrate to room temperature, ground, and homogenized in chloroform/methanol mixture (2/1 v/v).

2.2. Fatty acid analysis

Samples of fillets were extracted by the Folch, Lees, and Sloane Stanley (1957) method were transesterified with BF_3-methanol (Moss, Lambert, & Merwin, 1974).

Fatty acid methyl esters (FAMEs) were analyzed on a HP (Hewlett Packard) Agilent 6890N model gas chromatograph (GC), equipped with a flame ionization detector (FID) and fitted with a DB-23 capillary column (60 m, 0,25 mm i.d. and 0,25 μm). Injector and detector temperatures were 270 and 280 °C, respectively. Column temperature program was 190 °C for 35 min then increasing at 30 °C/min up to 220 °C where it was maintained for 5 min. Carrier gas was helium (2 ml/min) and split ratio was 30:1.

Identification of normal fatty acids was carried out by comparing sample FAME peak relative retention times with those obtained for Alltech standards. Results were expressed as FID response area relative percentages.

2.3. Statistical analysis

Each reported result is the average value of three GC analyses. The results are offered as means ± SD. The results were submitted to analysis of variance (ANOVA), at 0.05 significance level, using SPSS, 10.0. The mean values were compared by Tukey's test.

3. Results and discussion

Table 1 shows the lipid content of the fillets of zander investigated from the Beysehir Lake of Turkey. The lipid content ranged from 0.58% to 1.26% in fillets of zander. Similarly, Jankowska, Zakes, Zmijewski, and Szczepkowski (2003) found that contents of fat in the zander muscle tissue was 0.96% and Uysal and Aksoylar (2005) found that total lipid of muscle of zander was between 0.39% and 0.77%.

Seasonal variations on total fatty acid composition of zander are presented in Table 2. We identified and evaluated 35 fatty acids in muscle lipids of zander. The major fatty acids in the zander in all seasons were 22:6 ω3 (DHA), 16:0, 18:1 ω9, 20:4 ω6 (AA), 18:2 ω6, 16:1 ω7, 20:5 ω3 (EPA), and 18:0, respectively.

Palmitic acid was the major SFA, contributing approximately 57.0–64.0% to the total SFA content of the lipids for zander. Similar results for zander (Çelik, Diler, & Küçükgülmez, 2005; Jankowska et al., 2003), and other freshwater fish (Haliloğlu, Aras, & Yetim, 2002; Rahman, Huah, Hassan, & Daud, 1995) have also been reported. Ackman, Eaton, and Linne (1975) pointed out that palmitic acid was a key metabolite in fish and its level was not influenced by diet.

Oleic acid was identified as the major MUFA in the fish (45.0–58.0% of total MUFAs). Oleic acid in muscle tissue of zander was found to be 9.10%, 8.30%, 10.5%, and 11.9% in spring, summer, autumn, and winter, respectively. Similarly, Haliloğlu, Bayır, Sirkecioğlu, Aras, and Atamanalp (2004) found that C18:1 ω9 was the major MUFA in muscle in tissue of rainbow trout (*Oncorhynchus mykiss*) living in freshwater. The high levels of oleic, palmitoleic, and arachidonic acids had been reported as a characteristic property of freshwater fish oils (Andrade, Rubira, Matsushia, & Souza, 1995; Osman, Suriah, & Law, 2001).

PUFAs were found to be a significant constituent 50.2–57.0% of muscle lipid of zander, according to the season. DHA (C22:6 ω3), LA (C18:2 ω6), AA (C20:4 ω6) and EPA (C20:5 ω3) were the predominant PUFAs. The present data showed that DHA (C22:6) was the predominant fatty acid in muscle lipids of zander, and its level showed the most variation during seasons, accounting for 17.1–23.3% of total fatty acids and it was determined at 23.3%, 17.1%, 22.6% and 18.7% in spring, summer, autumn and winter, respectively. Similarly, Jankowska et al. (2003) found that DHA was the predominant fatty acid (24.5%) in muscle lipid tissue of wild zander and in this study, cultured zander fed artificial feed has more total fat (2.87%) than wild zander (0.96%). Sargent (1996) reported that ω3 PUFA, principally DHA, has a role in maintaining the structure and functional integrity of fish cells. In addition, DHA has a specific and important role in neural cell membranes, i.e. the brain and eyes. Moreover, it is considered a desirable property in fish for human nutrition and health.

In the richer feeding period, zander partially preferred to accumulate PUFA rather than SFA and MUFA. In this study, it was found that total PUFA in the fatty acid composition of zander muscle in winter was low where we had hoped that the percentage of total PUFA would be high. The observed decrease in PUFA is likely due to their utilization for gonad maturation. The gonads were not included in the analysis of the material extracted. This conclusion is also supported by the fact that the level of PUFA was lowest both before and just after reproduction (Agren et al., 1987; Cejas et al., 2003). In the same way, Karakaya and Kılıç (1995) reported that zander in Beysehir Lake probably draw near to reproductive period in February.

In the present study, the percentages (in total lipid) of EPA and DHA which have a vital role in human nutrition were between 4.22–5.93% and 17.1–23.3%, respectively, according to the seasons. Thus, among the ω3 series, the zander are good sources of EPA and DHA in all seasons.

The main characteristic difference in freshwater fish is the higher levels of C-16 and C-18 acids and the lower levels of C-20 and C-22 acids when compared to marine fish, and these differences are mainly due to the dietary fat (Ackman, 1967); however freshwater fish contain relatively large amounts of EPA and DHA (Wang, Miller, Perren, & Addis, 1990). It should be pointed out that the PUFA contents in the fish studied in this work were higher than those reported by Uysal and Aksoylar (2005) from zander inhabiting Eğirdir Lake, which is the second largest freshwater lake in Turkey. The discrepancy was primarily caused by a higher DHA content. The results obtained in this study show shorter (C:18) chain ω3 acids in the food to be elongated and desaturated in the zander body, whereby longer-chain PUFAs, mainly DHA, are formed. The results demonstrate that zander is highly capable of transforming native forms of 18ω3 into long-chain acids, as a result of which the muscle has a high DHA content. Similar results were obtained by Xu, Fontaine, Melard, and Kestemont (2001) who analysed dietary effects on fatty acid composition in muscles and liver of *Perca fluviatilis*; they found

Table 1
Lipid values determined in spring, summer, autumn and winter for the zander species investigated

Seasons	Lipids (% wet weight basis)
Spring	0.62
Summer	0.8
Autumn	0.58
Winter	1.26

Table 2
Seasonal variations on total fatty acid composition of zander (*Sander lucioperca*) in Beysehir Lake[*]

Fatty acids	Spring	Summer	Autumn	Winter
C8:0	–	0.06 ± 0.12^{a}[**]	–	–
C10:0	–	–	–	0.01 ± 0.18
C12:0	0.03 ± 0.2^{a}	0.14 ± 0.15^{a}	0.12 ± 0.11^{a}	0.07 ± 0.11^{a}
C13:0		0.01 ± 0.52^{a}	0.02 ± 0.2^{a}	0.07 ± 0.1^{a}
C14:0[***]	0.65 ± 0.19^{a}	0.67 ± 0.17^{a}	0.89 ± 0.25^{a}	1.45 ± 0.67^{b}
C15:0	0.20 ± 0.2^{a}	0.18 ± 0.17^{a}	0.25 ± 0.15^{b}	0.30 ± 0.2^{b}
C16:0	14.4 ± 0.89^{a}	17.9 ± 2.85^{b}	16.5 ± 0.87^{b}	14.2 ± 1.63^{a}
C17:0	0.49 ± 0.12^{a}	0.60 ± 0.11^{a}	0.63 ± 0.11^{a}	0.72 ± 0.57^{a}
C18:0	4.76 ± 0.66^{a}	6.21 ± 0.36^{b}	5.29 ± 0.78^{a}	4.08 ± 0.21^{c}
C19:0	0.06 ± 0.2^{a}	0.01 ± 0.2^{a}	0.08 ± 0.2^{a}	0.11 ± 0.15^{a}
C20:0	0.03 ± 0.2^{a}	0.15 ± 0.14^{a}	0.10 ± 0.11^{a}	–
C21:0	0.03 ± 0.2^{a}	–	0.12 ± 0.18^{a}	–
C24:0	3.82 ± 0.63^{a}	2.02 ± 0.22^{b}	3.28 ± 0.75^{a}	3.86 ± 0.45^{a}
∑SFA	24.4	27.9	27.3	24.8
C14:1 ω5	0.11 ± 0.2^{a}	0.17 ± 0.15^{a}	0.31 ± 0.15^{a}	0.42 ± 0.47^{a}
C15:1 ω6	0.24 ± 0.2^{a}	0.47 ± 0.66^{a}	0.21 ± 0.16^{a}	0.17 ± 0.18^{a}
C16:1 ω7	6.75 ± 1.51^{a}	2.31 ± 1.01^{b}	3.40 ± 0.64^{b}	7.18 ± 1.58^{a}
C17:1 ω8	0.85 ± 0.2^{a}	0.71 ± 0.41^{a}	0.82 ± 0.17^{a}	0.52 ± 0.32^{a}
C18:1 ω9	9.10 ± 2.4^{a}	8.30 ± 0.42^{a}	10.53 ± 1.13^{b}	11.9 ± 0.43^{c}
C18:1 ω7	2.90 ± 0.5^{a}	2.07 ± 0.45^{b}	2.81 ± 0.27^{a}	3.43 ± 0.18^{c}
C20:1 ω9	0.27 ± 0.2^{a}	0.08 ± 0.2^{a}	0.15 ± 0.17^{a}	–
C24:1 ω9	–	0.21 ± 0.29^{a}	0.08 ± 0.11^{a}	–
∑MUFA	20.2	14.3	18.3	23.6
C16:2 ω4	0.92 ± 0.58^{a}	0.83 ± 0.41^{a}	0.70 ± 0.17^{a}	0.70 ± 0.44^{a}
C18:2 ω6	5.40 ± 0.74^{a}	15.4 ± 2.82^{b}	7.73 ± 3.13^{a}	7.54 ± 1.92^{a}
C18:3 ω6	0.88 ± 0.24^{a}	1.02 ± 0.64^{a}	1.14 ± 0.2^{a}	2.11 ± 0.89^{b}
C18:3 ω3	0.32 ± 0.2^{a}	0.11 ± 0.16^{a}	0.24 ± 0.4^{a}	0.62 ± 0.48^{b}
C20:2 ω6	–	0.18 ± 0.15^{a}	0.06 ± 0.2^{b}	–
C20:3 ω6	–	–	0.10 ± 0.15^{a}	–
C20:3 ω3	–	0.08 ± 0.15^{a}	0.11 ± 0.16^{a}	0.06 ± 0.17^{a}
C20:4 ω6	9.94 ± 1.29^{a}	6.72 ± 0.36^{b}	9.67 ± 1.85^{a}	8.68 ± 1.38^{a}
C20:5 ω3	5.93 ± 0.46^{a}	4.22 ± 0.84^{b}	5.67 ± 0.19^{a}	5.54 ± 0.31^{a}
C22:3 ω3	–	0.30 ± 0.44^{a}	0.24 ± 0.36^{a}	–
C22:4 ω6	1.64 ± 0.14^{a}	0.93 ± 0.12^{b}	1.52 ± 0.68^{a}	1.80 ± 0.40^{a}
C22:5 ω3	2.53 ± 0.24^{a}	1.81 ± 0.36^{b}	2.31 ± 0.41^{a}	2.42 ± 0.25^{a}
C22:5 ω6	3.36 ± 1.28^{a}	8.28 ± 3.95^{b}	0.99 ± 0.98^{a}	2.04 ± 2.19^{a}
C22:6 ω3	23.3 ± 3.4^{a}	17.1 ± 3.63^{b}	22.6 ± 1.28^{a}	18.7 ± 3.94^{b}
∑PUFA	54.2	57.0	53.1	50.2
Unknown	1.19	0.77	1.34	1.36
ω3	32.0	23.6	31.2	27.4
ω6	21.5	33.0	21.4	22.3
ω3/ω6	1.49	0.72	1.45	1.22

[*] Average of three lots analysed.
[**] Values reported are means ± S.D.
[***] [abc] Values for each sample with different superscript letters in the same fraction are significantly different at $P < 0.05$.

high DHA contents. Similarly, Jankowska et al. (2003) found higher DHA concentrations in zander and they found that the zander meat content of DHA, a fatty acid originating in the fish, was high and independent of the food DHA contents; this shows a potential of (18ω3) PUFA to be transformed into more unsaturated long-chain PUFA.

There are close relationships between the fish lipid composition and the diets of fish (McKenzie et al., 2000). Zander is a carnivorous fish and carnivores due to their consumption of other fish in which chain elongation and desaturation is completed were rich in long chain ω3 PUFAs, but lower in α-linolenic acid. In our study, PUFA levels of zander in Beysehir Lake were found to be high (50.2–57.0%), and α-linolenic acid level was found to be low (0.11–0.62%). However the γ-linolenic acid (C18:3*n*−6), presumably an intermediate between linoleic (C18:2*n*−6) and arachidonic acid (C20:4*n*−6), is relatively high.

The ω3/ω6 ratio is a good index for comparing relative nutritional value of fish oils (Piggott & Tucker, 1990). It is important for human health to increase the consumption of fish or fish products, which are rich in PUFAs of the ω3 family and poorer in PUFAs of the ω6 family (Sargent, 1997). The present data show that the ω3/ω6 ratio was

1.49 in spring, 1.45 in autumn, 1.22 in winter and that the lowest value 0.72 was in summer. A high level of ω6 fatty acids lowered the ω3/ω6 ratio in summer.

This study has shown that the zander is suitable item in the human diet during the fishing period in the Beysehir Lake of Turkey when the levels of EPA, DHA and ω3/ω6 ratio are considered. This condition can be regarded as an explanation for the fact that the zander in Beysehir Lake are richer in ω3 fatty acids, taking into consideration with the fatty acid profile of the fish. As a consequence, when human health is taken into account, the zander from Beysehir Lake appears to be quite nutritious in terms of fatty acid composition and ratio.

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