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Effect of Seasons on Fatty Acid Composition and n-3/n-6 Ratios of Muscle Lipids of Some Fish Species in Apa Dam Lake, Turkey

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Abstract.- This study was designed to determinate the effect of hot and cold seasons on fatty acid composition and n-3/n-6 ratios of *Cyprinus carpio*, *Sander lucioperca*, *Carassius gibelio* and *Leuciscus lepidus* dorsal muscle lipids in Apa Dam Lake, Turkey by gas chromatographic method. Major saturated fatty acid (SFA), monounsaturated fatty acid (MUFA) and polyunsaturated fatty acid (PUFA) were palmitic acid, oleic acid and docosahexaenoic acid (DHA) in *L. lepidus*, *C. gibelio* and *S. lucioperca*, respectively. The total PUFA percentage was higher than the total SFA and MUFA percentages in all species except for *C. gibelio* and *C. carpio* in summer. The total amount of n-3 fatty acids was higher than that of n-6 fatty acids in all species. The highest percentage of total n-3 fatty acids among these species was observed in *S. lucioperca* in winter. Especially, the ratio of n-3/n-6 PUFAs with nutritional importance for human health was 3.19 in winter in *S. lucioperca*. Additionally, the fatty acid composition of these fish species was affected by seasonal differences at statistical significance level ($p<0.05$) with regard to some fatty acids.

Keywords: Polyunsaturated fatty acid, n-3/n-6 ratio, fish muscle lipids, saturated fatty acids, monounsaturated fatty acids.

INTRODUCTION

Shellfish and fish provide an almost unlimited variety of fatty acids with beneficial role in human health. Among the fatty acids, particular emphasis has been given to the n-3 and n-6 polyunsaturated fatty acids (PUFAs), because of their beneficial effects on human health. The increased fish consumption as a source of n-3 PUFA is often associated with decreased mortality from cardiovascular disease (Leaf and Weber, 1988). n-3 PUFAs are beneficial in reducing cholesterol and thus the risk of myocardial infarction (Zyriax and Windler, 2000). If we are to maintain/enhance our health, we must take a proactive approach to ensure our sustained access to essential fatty acids and, in particular, to C 20:5n-3 (eicosapentaenoic acid, EPA), C 22:6n-3 (docosahexaenoic acid, DHA) and C 20:4n-6 (arachidonic acid, AA) (Arts *et al*., 2001). AA, EPA and DHA are important structural components of cell membranes and neural tissues. AA and EPA are also the parent compounds for the production of eicosanoids (Simopoulos, 2002).

Total lipid content, fatty acid proportions and trace mineral compositions of fish depend greatly upon the diet consumed (Alasalvar *et al.*, 2002). Additionally, the fatty acid profiles are influenced by reproduction, spawning, salinity, season and geographical location, as well as diet (Rasoarahona *et al*., 2004; Celik *et al*., 2005; Uysal and Aksoylar, 2005; Guler *et al*., 2007; Özogul *et al*., 2007; Guler *et al*., 2008; Schulz *et al.*, 2008; Kalyoncu *et al*., 2009; Guler *et al*., 2011; Cakmak *et al*., 2012; Harlioğlu, 2012). Freshwater fish contain low level of n-3 PUFA than marine fish (Vlieg and Body, 1988). Freshwater fish have high amounts of C 16 and C 18 fatty acids and the low amounts of C 20 and C 22 fatty acids when compared to marine fish, and these differences are primarily due to the dietary fat (Ackman, 1967). There is generally an increase in highly unsaturated fatty acids at lower temperatures in freshwater fish (Henderson and Tocher, 1987).

No reports have yet been published about the effect of seasons on fatty acid composition of *Cyprinus carpio* L., 1758 (common carp). *Carassius gibelio* (Bloch, 1782) (Prussian carp), *Leuciscus lepidus* Heckel, 1843 and *Sander lucioperca* (L. 1758) (zander) muscle lipids in Apa Dam Lake, Turkey. These fish species have been consumed as food by local people except for hunting ban period in spring. This study is the first report which characterizes and compares these fish species in Apa Dam Lake in terms of their fatty acids, in hot

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and cold seasons of the year.

MATERIALS AND METHODS

Area and sample collection

The Apa Dam Lake is about 65km south of Konya province in Turkey which was built on the Çarşamba Stream for irrigation and flood prevention purposes. Apa Dam Lake is located in the country of Cumra at 37° 22' 10.66'' North and 32° 29' 42.26'' West, between the Apasaraycik village and Apa town. The dam was first run in 1963 and has a surface area of 12km^2, with an irrigation field of 59704ha, an altitude of 1013m and a depth of 26m. The area around the lake has a terrestrial climate (Anonymous, 1992). *C. carpio*, *S. lucioperca*, *C. gibelio* and *L. lepidus* were collected as the most abundant fish species in this lake. *C. carpio*, *C. gibelio* and *L. cephalus* are cyprinids which are the most widely cultured fish species in the world (Anonymous, 1993) and *S. lucioperca*, percid fish species, is one of the most valuable freshwater carnivorous fish in Europe (Schulz *et al*., 2008).

The seasons chosen for investigation were summer (hot season) and winter (cold season). The fish were purchased after landing from local fisherman in July and January. The temperatures of lake water were 25.5°C and 5.5°C in July and January, respectively. The specimens of each fish species used in this study were of the mostly consumed sizes and almost at the same size and age. Gender differences were ignored. Ten individuals were sampled in each season for all species for total lipid extraction and fatty acid analyses except for *Leuciscus lepidus* in summer (eight individuals). Fish were transported in ice to the laboratory and dorsal muscle tissues (20g) were taken as the samples. The samples were frozen at -26ºC until analyzed. At the beginning of analysis, the samples were allowed to equilibrate to room temperature.

Fatty acid analysis

Total lipid of each fish specimen was extracted with chloroform/methanol separately (2:1 v/v) according to Folch *et al*. (1957). The fatty acids in the total lipid were esterified into methyl esters by saponification with 0.5 N methanolic NaOH and transesterified with 14% BF_3 (v/v) in methanol (Paquot, 1979).

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 HP-88 capillary column (100m, 0.25mm i.d. and 0.2µm) three times for each fish specimen. Injector and detector temperatures were 240ºC and 250ºC, respectively. The oven was programmed at 160ºC initial temperature and 2 min initial time. Thereafter the temperature was increased to 185ºC at 4ºC/min, then increased to 200ºC at 1ºC/min and held at 200ºC for 46.75 min. Total run time was 70 min. Carrier gas used was helium (1mL/min).

Identification of fatty acids were carried out by comparing sample FAME peak relative retention times with those obtained for Alltech (Carolean Industrial Drive, State College, PA, USA) standards. Results were expressed as FID response area relative percentages. Each sample was analyzed three times by GC. Data are offered as mean ± SD.

Data analysis

The results were analysed by t-test, at 0.05 significance level, using a standard computer program SPSS 13.0 (SPSS, 2004).

RESULTS AND DISCUSSION

Table I shows the weights of fishes caught during summer and winter seasons.

Table I.- Mean weight (g) ± SD of fish species caught in Apa Dam Lake in summer and winter seasons.

Species	Winter	Summer
Cyprinus carpio	2105 ± 205 g (n=10)	1920 ± 285 g (n=10)
Carassius gibelio	530 ± 46 g (n=10)	492 ± 85 g (n=10)
Leuciscus lepidus	264 ± 51 g (n=10)	234 ± 70 g (n=8)
Sander lucioperca	382 ± 48 g (n=10)	395 ± 41 g (n=10)

Within the lines, values for samples in different seasons are not significantly different at $p > 0.05$.

Fatty acid composition of *C. carpio*, *C. gibelio*, *L. lepidus* and *S. lucioperca* are presented in

Table II. Thirty seven fatty acids in these fish samples were identified and evaluated. Major saturated fatty acid (SFA) was C 16:0 (palmitic acid) in all species. In these species, palmitic acid was higher in summer than in winter. Other predominant SFAs were C 18:0 (stearic acid) and C 14:0 (myristic acid) in all species. Celik *et al*. (2005), Guler *et al*. (2007) and Özogul *et al*. (2007) have reported that major SFA was palmitic acid and other predominant SFA was stearic acid for *S. lucioperca* in Turkey. Özogul *et al*. (2007), Guler *et al*. (2008), Donmez (2009) and Kalyoncu *et al*. (2010) have also reported that primary SFA was palmitic acid and the other was stearic acid in *C. carpio*. Crexi *et al*. (2009) have stated that palmitic acid was the most abundant SFA and the others were myristic acid and stearic acid in carp crude oils obtained by fishmeal and ensilage process. Izci (2010) and Bulut (2010) have also obtained the same results for *C. gibelio* from Egirdir Lake and Seyitler Dam Lake (Turkey), respectively. Cengiz *et al*. (2010) have found that palmitic acid was major SFA and the others were stearic acid and myristic acid in *L. lepidus*. In the present study, palmitic acid and stearic acid were affected by seasonal differences in *C. carpio*, *S. lucioperca* and *L. lepidus*. In *C. gibelio* and *S. lucioperca*, myristic acid was affected by seasonal differences. Total SFA was significantly higher in summer than in winter in all species. Similarly, Guler *et al*. (2007) has observed that total SFA was higher in summer than in winter for zander. In previous studies, total SFA was 27.84% in wild *S. lucioperca* (Jankowska *et al*., 2003), 26.60-29.60% and 36.49% in *C. carpio* (Guler *et al*., 2008; Donmez, 2009), 23.34-25.99% in *C. gibelio* (Bulut, 2010), 32.92% in *Carassius carassius* (Donmez, 2009) and 25.20% in *L. lepidus* (Izci, 2010). In this study, total SFA was 26.46-34.24% in *S. lucioperca*, 26.73-34.18% in *C. carpio*, 26.76-30.44% in *C. gibelio* and 24.53-31.75% in *L. lepidus*.

The predominant monounsaturated fatty acid (MUFA) was C 18:1n-9 (oleic acid), it was followed by C 16:1n-7 (palmitoleic acid) in all species, in agreement with *S. lucioperca* (Jankowska *et al*., 2003; Celik *et al*., 2005; Guler *et al*., 2007; Özogul *et al*., 2007), *C. carpio* (Özogul *et al*., 2007; Guler *et al*., 2008; Crexi *et al*., 2009; Donmez, 2009; Kalyoncu *et al*., 2010), *C. gibelio* (Bulut, 2010), *C. carassius* (Donmez, 2009) and *L. lepidus* (Cengiz *et al*., 2010). In *C. gibelio* and *S. lucioperca*, oleic acid was significantly higher in summer than in winter, while in *C. carpio*, *S. lucioperca* and *L. lepidus* palmitoleic acid was significantly higher in winter than in summer. In terms of total MUFA, only *C. gibelio* was affected by seasonal differences. In previous studies, total MUFA was 31.27-34.56% in *C. gibelio* (Bulut, 2010), 32.21% in *C. carassius* (Donmez, 2009), 28.30-41.10%, 13.80%, 31.92% and 38.59-48.09% in *C. carpio* (Özogul *et al*., 2007; Guler *et al*., 2008; Donmez, 2009; Kalyoncu *et al*., 2010), 20.30%, 13.80% and 21.36% in *S. lucioperca* (Jankowska *et al*., 2003; Celik *et al*., 2005; Özogul *et al*., 2007) and 15.02% in *L. lepidus* (Cengiz *et al*., 2010). In the present study, total MUFA was 22.40-23.87% in *S. lucioperca*, 36.10-37.15% in *C. carpio*, 27.29-38.89% in *C. gibelio* and 29.30-36.86% in *L. lepidus*.

S. lucioperca is rich with regard to PUFA (51.14-41.89%), especially DHA (22.75- 12.94%) and EPA (9.42- 6.10%). These results match with Uysal and Aksoylar (2005), who have reported that EPA, DHA and AA were the most abundant PUFA in zander muscle lipids from Egirdir Lake, Turkey. In the present study, especially in winter, DHA was predominant fatty acid in *S. lucioperca*, *C. gibelio* and *L. lepidus*. Similarly, DHA was major PUFA in *S. lucioperca* (Jankowska *et al*., 2003; Celik *et al*., 2005; Guler *et al*., 2007; Özogul *et al*., 2007), *C. gibelio* (Bulut, 2010), *C. carassius* (Donmez, 2009) and *L. lepidus* (Cengiz *et al*., 2010). EPA and DHA possess extremely beneficial properties for the prevention of human coronary artery disease (Leaf and Weber, 1988). In this study, DHA and total PUFA were higher in winter than in summer in all species except for *L. lepidus* and seasonal differences was observed in *C. gibelio* and *S. lucioperca* with regard to total PUFA and DHA. EPA was higher in winter than in summer and affected by seasonal differences in *C. gibelio*, *C. carpio* and *S. lucioperca*. Total PUFA was higher than total MUFA and SFA for *L. lepidus* and *S. lucioperca* in both summer and winter, while total PUFA was higher than total MUFA and SFA in winter for *C. gibelio* and *C. carpio*. Higher levels of oleic acid increased the total MUFA in these species

Table II.- **Fatty acid composition of muscle of fish species caught in Apa Dam Lake in summer and winter seasons (Values are % of total fatty acid expressed as mean ± standard deviation).**

Fatty acids (%)	*Cyprinus carpio*		*Carassius gibelio*		*Leuciscus lepidus*		*Sander lucioperca*	
	Winter (n=10)	Summer (n=10)	Winter (n=10)	Summer (n=10)	Winter (n=10)	Summer (n=8)	Winter (n=10)	Summer (n=10)
C 8:0	0.03 ± 0.02	0.03 ± 0.02	0.01 ± 0.01	0.05 ± 0.05	0.03 ± 0.03	0.06 ± 0.01	0.05 ± 0.03	0.02 ± 0.01
C 10:0	0.04 ± 0.04	0.03 ± 0.02	0.10 ± 0.06	0.15 ± 0.11	0.11 ± 0.09	0.10 ± 0.04	0.09 ± 0.03	0.02 ± 0.01 *
C 11:0	0.04 ± 0.04	0.02 ± 0.01	0.01 ± 0.01	0.02 ± 0.02	0.03 ± 0.03	0.06 ± 0.04	0.04 ± 0.03	0.01 ± 0.00 *
C 12:0	0.17 ± 0.05	0.11 ± 0.08	0.04 ± 0.02	0.11 ± 0.02 *	0.09 ± 0.01	0.13 ± 0.03 *	0.04 ± 0.02	0.28 ± 0.06 *
C 13:0	0.05 ± 0.02	0.03 ± 0.02	0.02 ± 0.01	0.01 ± 0.01	0.03 ± 0.01	0.07 ± 0.04	0.02 ± 0.01	0.04 ± 0.03
C 14:0	1.39 ± 0.33	1.57 ± 0.79	0.95 ± 0.32	1.73 ± 0.63 *	1.65 ± 0.39	1.55 ± 0.10	1.07 ± 0.09	2.27 ± 0.44 *
C 15:0	0.26 ± 0.08	0.39 ± 0.05 *	0.28 ± 0.08	0.55 ± 0.11 *	0.36 ± 0.12	0.46 ± 0.06	0.29 ± 0.07	0.56 ± 0.19 *
C 16:0	17.89 ± 1.67	22.06 ± 2.75 *	16.08 ± 2.34	17.55 ± 0.82	14.75 ± 1.82	17.31 ± 0.40 *	18.80 ± 0.46	21.40 ± 0.98 *
C 17:0	0.46 ± 0.14	0.22 ± 0.10 *	0.82 ± 0.18	0.94 ± 0.17	1.00 ± 0.45	1.11 ± 0.06	0.78 ± 0.24	0.38 ± 0.25 *
C 18:0	4.82 ± 0.35	7.95 ± 1.92 *	7.46 ± 0.64	7.55 ± 2.73	5.25 ± 1.99	9.30 ± 2.00 *	4.77 ± 0.18	7.80 ± 1.53 *
C 19:0	0.04 ± 0.01	0.35 ± 0.18 *	0.15 ± 0.06	0.29 ± 0.11 *	0.20 ± 0.08	0.30 ± 0.02 *	0.15 ± 0.09	0.32 ± 0.09 *
C 20:0	0.38 ± 0.06	0.17 ± 0.02 *	0.07 ± 0.01	0.22 ± 0.14 *	0.36 ± 0.08	0.29 ± 0.16	0.12 ± 0.02	0.18 ± 0.03 *
C 21:0	0.17 ± 0.02	0.31 ± 0.18	0.20 ± 0.08	0.74 ± 0.23 *	0.22 ± 0.10	0.64 ± 0.21 *	0.09 ± 0.04	0.50 ± 0.20 *
C 22:0	0.98 ± 0.31	0.92 ± 0.43	0.55 ± 0.11	0.52 ± 0.13	0.44 ± 0.17	0.36 ± 0.03	0.14 ± 0.06	0.45 ± 0.17 *
C 24:0	0.01 ± 0.00	0.02 ± 0.01	0.02 ± 0.01	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.01	0.01 ± 0.01	0.01 ± 0.00
∑ SFA †	26.73 ± 1.41	34.18 ± 5.25 *	26.76 ± 2.57	30.44 ± 1.61 *	24.53 ± 3.09	31.75 ± 2.00 *	26.46 ± 0.37	34.24 ± 1.85 *
C 14:1n-5	0.18 ± 0.07	0.15 ± 0.06	0.33 ± 0.15	0.54 ± 0.19	0.67 ± 0.37	0.27 ± 0.02	0.30 ± 0.07	0.36 ± 0.10
C 15:1n-5	0.21 ± 0.11	0.19 ± 0.06	0.42 ± 0.09	0.48 ± 0.20	0.38 ± 0.09	0.46 ± 0.11	0.45 ± 0.19	0.22 ± 0.06 *
C 16:1n-7	10.43 ± 2.12	4.58 ± 1.52 *	7.44 ± 1.17	6.31 ± 2.15	10.78 ± 2.74	4.49 ± 0.33 *	7.63 ± 1.09	4.18 ± 2.03 *
C 17:1n-8	0.90 ± 0.23	0.13 ± 0.06 *	0.85 ± 0.15	0.94 ± 0.15	1.19 ± 0.39	0.71 ± 0.08 *	0.89 ± 0.14	0.37 ± 0.27 *
C 18:1n-9	23.86 ± 1.73	30.39 ± 8.19	17.72 ± 1.93	28.87 ± 5.63 *	22.75 ± 1.83	22.64 ± 6.54	12.53 ± 2.03	17.99 ± 4.99 *
C 20:1n-9	0.45 ± 0.10	1.63 ± 0.15 *	0.49 ± 0.22	1.70 ± 0.15 *	1.01 ± 0.44	0.59 ± 0.19	0.56 ± 0.06	0.68 ± 0.50
C 22:1n-9	0.06 ± 0.02	0.07 ± 0.03	0.02 ± 0.01	0.04 ± 0.02	0.07 ± 0.04	0.13 ± 0.05	0.03 ± 0.02	0.05 ± 0.01
C 24:1n-9	0.01 ± 0.00	0.01 ± 0.01	0.02 ± 0.01	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.00	0.02 ± 0.01
∑ MUFA †	36.10 ± 3.23	37.15 ± 9.57	27.29 ± 2.80	38.89 ± 8.02 *	36.86 ± 5.58	29.30 ± 5.98	22.40 ± 2.61	23.87 ± 7.59
C 18:2n-6	11.24 ± 5.27	6.89 ± 1.85	4.15 ± 1.44	5.36 ± 1.40	5.79 ± 0.87	7.98 ± 0.32 *	2.31 ± 0.43	5.95 ± 2.77 *
C 18:3n-6	0.03 ± 0.02	0.27 ± 0.10 *	0.08 ± 0.06	0.18 ± 0.06 *	0.07 ± 0.05	0.27 ± 0.21 *	0.06 ± 0.02	0.24 ± 0.02 *
C 18:3n-3	3.09 ± 1.43	4.48 ± 2.29	2.54 ± 1.03	3.66 ± 0.67 *	4.61 ± 1.93	4.76 ± 0.79	2.13 ± 0.10	5.19 ± 3.92
C 20:2n-6	0.13 ± 0.05	0.58 ± 0.24 *	0.17 ± 0.04	0.77 ± 0.24 *	0.33 ± 0.11	0.73 ± 0.11 *	0.17 ± 0.02	0.47 ± 0.17 *
C 20:3n-6	0.06 ± 0.03	0.06 ± 0.02	0.04 ± 0.02	0.04 ± 0.01	0.03 ± 0.02	0.15 ± 0.13 *	0.02 ± 0.02	0.08 ± 0.01 *
C 20:3n-3	0.03 ± 0.01	0.09 ± 0.03 *	0.02 ± 0.01	0.05 ± 0.01 *	0.02 ± 0.01	0.08 ± 0.01 *	0.01 ± 0.01	0.06 ± 0.01 *
C 20:4n-6	5.18 ± 0.49	3.45 ± 2.38	6.67 ± 0.70	3.97 ± 1.63 *	4.66 ± 0.76	4.27 ± 0.55	6.85 ± 0.49	5.48 ± 1.97
C 20:5n-3	5.44 ± 1.00	2.93 ± 1.60 *	7.21 ± 0.70	4.52 ± 0.74 *	6.73 ± 0.74	7.89 ± 2.52	9.42 ± 0.90	6.10 ± 2.02 *
C 22:2n-6	0.01 ± 0.01	0.05 ± 0.02 *	0.02 ± 0.01	0.09 ± 0.04 *	0.02 ± 0.01	0.06 ± 0.01 *	0.03 ± 0.01	0.04 ± 0.01
C 22:3n-3	0.12 ± 0.05	0.30 ± 0.15 *	0.18 ± 0.18	0.18 ± 0.12	0.25 ± 0.17	0.31 ± 0.08	0.91 ± 0.08	0.71 ± 0.52
C 22:4n-6	0.62 ± 0.22	0.50 ± 0.37	1.01 ± 0.26	0.65 ± 0.33	0.67 ± 0.15	0.50 ± 0.12	0.73 ± 0.09	0.71 ± 0.29
C 22:5n-6	0.77 ± 0.15	0.59 ± 0.44	1.53 ± 0.08	0.82 ± 0.35 *	0.97 ± 0.32	0.40 ± 0.02 *	2.03 ± 0.54	1.41 ± 0.83
C 22:5n-3	2.54 ± 0.27	1.99 ± 1.18	4.44 ± 0.11	2.37 ± 0.81 *	3.61 ± 0.56	3.14 ± 0.49	3.72 ± 0.16	2.51 ± 0.78 *
C 22:6n-3	7.91 ± 1.02	6.49 ± 4.76	17.89 ± 0.96	8.01 ± 3.85 *	10.85 ± 4.50	8.41 ± 3.79	22.75 ± 0.77	12.94 ± 6.51 *
∑ PUFA †	37.17 ± 4.51	28.67 ± 9.37	45.95 ± 0.35	30.67 ± 6.91 *	38.61 ± 3.34	38.95 ± 7.92	51.14 ± 2.54	41.89 ± 6.09 *
∑ n-3	19.13 ± 1.83	16.28 ± 6.71	32.28 ± 0.87	18.79 ± 4.79 *	26.07 ± 2.26	24.59 ± 7.50	38.94 ± 1.79	27.51 ± 5.87 *
∑ n-6	18.04 ± 5.45	12.39 ± 2.75 *	13.67 ± 0.71	11.88 ± 2.24	12.54 ± 1.27	14.36 ± 0.48 *	12.2 ± 0.82	14.38 ± 0.74 *
n-3/n-6	1.06 ± 0.38	1.31 ± 0.26	2.36 ± 0.18	1.58 ± 0.16 *	2.08 ± 0.14	1.71 ± 0.47	3.19 ± 0.11	1.91 ± 0.40 *

* Within the lines, values in winter and summer seasons in a species of fish are significantly different ($p < 0.05$)
† **SFA**, saturated fatty acid; **MUF**, monounsaturated fatty acid; **PUFA**, polyunsaturated fatty acid.

in summer. These results match with Jankowska *et al*. (2003), Guler *et al*. (2007) and Özogul *et al*. (2007) who have reported that PUFA was higher than total SFA and total MUFA in zander. Similarly, Bulut (2010) have also reported that *C. gibelio* had high PUFA content (40.93%) compared to SFA (23.34%) and MUFA (31.27%) in winter. In the present study, primary PUFA was DHA in all species except for *C. carpio*. In *C. carpio*, predominant PUFA was C 18:2n-6 (linoleic acid). In common carp, linoleic acid was predominant PUFA in spring and autumn but DHA was major PUFA and others PUFA were EPA, AA and linoleic acid in summer and winter (Guler *et al*., 2008). Rasoarahona *et al*. (2004) have stated that AA, DHA, EPA and C 22:5n-3 (docosapentaenoic acid, DPA) were present in appreciable amounts in *C. carpio*. Kalyoncu *et al*. (2010) have found that DHA, linoleic acid and EPA were the highest levels among the PUFAs in common carp. DHA, AA, EPA, linoleic acid and DPA were the most abundant PUFA in *L. lepidus* (Cengiz *et al*., 2010).

S. lucioperca had a higher level of DHA and therefore a high level of total n-3 fatty acids in winter (38.94%) and summer (27.51%) which was higher than those reported by other authors (Celik *et al*., 2005; Guler *et al*., 2007). The amount of n-3 fatty acids in winter was similar to those reported by Jankowska *et al*. (2003) on the muscle fatty acid composition of wild *S. lucioperca* with 38.84%. *C. gibelio* had also the high percentage of total n-3 fatty acids (32.28%) in winter. Bulut (2010) has found that total of n-3 fatty acids was 27.81% for *C. gibelio* in winter. In the present study, seasonal variations were observed in *C. gibelio* and *S. lucioperca* for total n-3 fatty acids. Total of n-3 fatty acids was higher than total of n-6 fatty acids in all species. Similarly, total of n-3 fatty acids was higher than total of n-6 fatty acids in *S. lucioperca* (Jankowska *et al*., 2003; Celik *et al*., 2005; Özogul *et al*., 2007), *C. carpio* (Özogul *et al*., 2007; Crexi *et al*., 2009; Donmez, 2009; Kalyoncu *et al*., 2010), *L. lepidus* (Cengiz *et al*., 2010), *C. gibelio* (Bulut 2010) and *C. carassius* (Donmez, 2009). In this study, for total n-6 fatty acids, seasonal variations were observed in *C. carpio*, *S. lucioperca* and *L. lepidus*. n-3/n-6 fatty acid ratio was higher in winter than in summer for all species except for *C. carpio* and seasonal variations was observed in *C. gibelio* and *S. lucioperca* for n-3/n-6 ratio. The highest level of n-3/n-6 ratio was observed for *S. lucioperca* in winter. In freshwater fish, the n-3/n-6 ratio varies between 1 and 4 (Valfré *et al*., 2003). In present study, n-3/n-6 ratio in winter was 3.19, 2.36, 2.08 and 1.06 for *S. lucioperca*, *C. gibelio*, *L. lepidus* and *C. carpio*, respectively. This ratio of *C. carpio* is relatively low in comparison with other species. However, Guler *et al*. (2007) have determined the same ratio for *C. carpio* in winter.

The n-3/n-6 ratio has been suggested to be useful indicator for comparing relative nutritional values of fish oils (Piggot *et al*., 1990). An increase in the human dietary n-3/n-6 ratio is essential to prevent coronary heart disease by reducing plasma lipids (Kinsella *et al*., 1990). Seafood is the best source of n-3 fatty acids including EPA and DHA. Thus, when fish is suggested as a means of improving health, both the fat content and the PUFA composition must be considered. Although it is generally recognized that PUFA composition may vary among fish species, little attention has been paid to the composition of different species when selecting fish for diet. For this reason fatty acid composition of different fish species must be compared (Pirestani *et al*., 2010). The ratio of n-3/n-6 PUFAs contents ranged from 2.67 to 12.61 in selected 12 marine fish species living in Turkish waters (Bayir *et al*., 2006). Only n-3/n-6 ratio of *S. lucioperca* (3.19) in winter from Apa Dam Lake is in this range. Therefore, *S. lucioperca* will be come into prominence for local people who cannot consume marine fish.

CONCLUSIONS

The results of analysis showed that seasonal variations affected fatty acid composition of *L. lepidus*, *C. gibelio*, *C. carpio* and *S. lucioperca* in Apa Dam Lake. The richest sources of PUFA were *S. lucioperca* and *C. gibelio* in winter. In addition, the highest n-3/n-6 ratios were also observed in *S. lucioperca* and *C. gibelio* in winter. Therefore, these species are economically important fish considering n-3 fatty acids and n-3/n-6 ratios.

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