Fatty Acid Composition of Muscle Lipids of *Cyprinus carpio* L. Living in Different Dam Lake, Turkey

O. B. Citil, V. Sariyel, M. Akoz

***Abstract*—**In this study, total fatty acid composition of muscle lipids of *Cyprinus carpio* L. living in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake were determined using GC. During this study, for the summer season of July was taken from each region of the land and they were stored in deep-freeze set to -20 degrees until the analysis date. At the end of the analyses, 30 different fatty acids were found in the composition of *Cyprinus carpio* L. which lives in different lakes. *Cyprinus carpio* Suğla Dam Lake of polyunsaturated fatty acids (PUFAs), were higher than other lakes. *Cyprinus carpio* L. was the highest in the major SFA palmitic acid. Polyunsaturated fatty acids (PUFA) of carp, the most abundant fish species in all lakes, were found to be higher than those of saturated fatty acids (SFA) in all lakes. Palmitic acid was the major SFA in all lakes. Oleic acid was identified as the major MUFA. Docosahexaenoic acid (DHA) was the most abundant in all lakes. ω3 fatty acid composition was higher than the percentage of the percentage ω6 fatty acids in all lake. ω3/ω6 rates of *Cyprinus carpio* L. Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake, 2.12, 1.19, 2.15, 2.87, and 2.82, respectively. Docosahexaenoic acid (DHA) was the major PUFA in Eğirdir and Burdur lakes, whereas linoleic acid (LA) was the major PUFA in Altinapa and Suğla Dam Lakes. It was shown that the fatty acid composition in the muscle of carp was significantly influenced by different lakes.

***Keywords*—**Chromatography, *Cyprinus carpio* L., fatty acid composition.

I. Introduction

THE common carp (*Cyprinus carpio* Linnaeus) has been one of the oldest domesticated species of fi sh for food. Culture of carp in China dates back to at least the 5th century BC, although domestication began much later [1]. Common carp dwells in middle and lower reaches of rivers and shallow confined waters. Best growth is obtained at water temperature of 23-30°C [2]. According to the FAO statistics of 2004, production of farmed common carp was ca. 13% (3,387,918 tonnes) of the total global freshwater aquaculture production. Common carp production increased by an average global rate of 9.5% per year between 1985 and 2004 and in the past decade (1993-2004), this has increased to 10.4% per year [3]. Common carp (*Cyprinus carpio*) is one of the most cultured fish in the world. In 2008, the world and the European production was 2 987 433 tons and 144 747 tons, respectively [4]

Fish, both freshwater and marine, are extremely rich source of polyunsaturated fatty acids for human consumption. Polyunsaturated fatty acids are known to diminish the level of blood cholesterol [5].

Fishes have essential unsaturated fatty acids, protein with high biological value, minerals and vitamins that make them distinguished from other creatures [6]. Many clinical and observational studies concerning the role of fatty acids in human health have revealed that saturated and trans fatty acids increase cardiovascular risk while long chain n-3 PUFA (EPA and DHA), which appear to play a multifactorial role in CVD risk, the mechanisms of which have yet to be fully elucidated, have been associated with a reduced risk [7].

Carps represent the largest group of cultured fish constituting around 70% of freshwater aquaculture production. In Europe, the majority of carp production takes place in central Europe where it is produced in ponds using traditional semi-intensive techniques. There are two sources of n-3 High Unsaturated Fatty Acid (HUFA) in carp produced in ponds. The one is the natural feed, plankton and benthos, which is rich in n-3 High Unsaturated Fatty Acid and the other is the n-3 HUFA synthesized by carp from alpha linolenic acid (ALA). It was reported that carps, in contrast to marine fish, are be able to bio-convert ALA to Eicosapentaenoic acid EPA and Docosapentaenoic acid DHA [8]-[11]. It is therefore of interest to understand and maximize the ability of carp to synthesize EPA and DHA from ALA in order to preserve the lipid quality of the fish as human food and for sustainable utilization of feed resources. Carp culture might be capable of becoming net producer of EPA and DHA by selecting fish with high enzyme activities in fatty acid elongation and desaturation.

The carps have also relatively low requirements both for n-3 and n-6 fatty acids (0.5-1%) which can be fulfilled by plant 18 carbon fatty acids [12]. Inclusion of fish meal (5%) and fish oil (0%) in carp culture is also very low [13] and therefore the substitution of fish meal and oil will be considerably easier than for carnivorous aquaculture.

Here is a large body of evidence that n-3 highly unsaturated fatty acids, especially EPA and DHA are beneficial for human health. EPA and DHA have many different functions and actions in human body, e.g.: influencing the physical nature of cell membranes, membrane-protein-mediated responses, being eicosanoid precursors, cell signaling and gene expression in many different cell types [14]. EPA and DHA have been shown to have beneficial effect in a range of cardiovascular risk factors, which result in primary cardiovascular prevention, reduction in total and cardiovascular mortality [15].

Beneficial effect of EPA and DHA is generally recognized, however, there have been several concerns about safety of fish

F. O.B. Citil, S. V. Sariyel and T. M. Akoz are with the Department of Veterinary, Karapinar Aydoganlar Vocational School of Higher Education, Selcuk University, Karapinar/Konya 42400, Turkey (phone: +90332-755-6896; fax: +90332-755-6300; e-mail: ozcancitil@gmail.com, vahdet@selcuk.edu.tr, makoz@selcuk.edu.tr).

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consumption mainly due to potential hazard of contaminants (mercury, PCB, dioxines). Mozaffarian & Rimm [16] conducted an extensive meta-study and concluded that the benefits of fish intake exceed the potential risks of possible harmful effect of pollutants.

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 [17], [18].

In general, the fatty acid composition of fish lipids is influenced by seasonal change, the type of food available, and gonad development [19], [20]. Although there are many studies on the seasonal changes of many different fish species, no reports have yet been published about the effects of only July variations on the fatty acid composition of this important species in the Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake. There have been no studies on the fatty acid composition of total lipid, *Cyprinus carpio* lipids. In light of these facts, it seems necessary to carry out a lipid profile study of *Cyprinus carpio* in this location. The present study was undertaken to clarify the effects of only one season variation on the fatty acid composition of total lipid, as well as the n-3/n-6 fatty acids ratio in the dorsal meat of *Cyprinus carpio*. Therefore, the nutritional quality of muscle of fish may change among in the lake [21]. The aim of this study was to comparison the of July variations in total fatty acid composition of muscle of *Cyprinus carpio*, which is of great commercial importance in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake, freshwater lake in Turkey. Fishing is only july.

II. Materials and Methods

Cyprinus carpio, used in this study, were obtained from local fisherman in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake, seasonally.

The seasons chosen for analysis were for the summer season of July. Ten individuals were sampled in only one season for Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake for total lipid extraction and fatty acid analyses. All fish were almost of the same size (average weight 1.000 kg) and age (over 2-y-old). Fish were transported in ice to the laboratory and dorsal muscle tissues were taken as samples. The samples were frozen at −26◦C until analyses. At the beginning of analysis, the samples were allowed to equilibrate at room temperature.

Total lipids of fish were extracted with chloroform: methanol (2:1 v/v) according to [22]. The fatty acids in the total lipid were esterified into methyl esters by saponification with 0.5 N methanolic NaOH and transesterified with 14% BF3 (v/v) in methanol [23].

The resultant fatty acid methyl esters were separated and stored at -20°C. At the beginning of each analysis, the samples were allowed to equilibrate to room temperature and analyzed using a gas liquid chromatograph (Shimadzu 15-A), equipped with a dual flame ionization detector and a 1.8 m 3 mm internal diameter packed glass column containing GP 10% SP-2330 on 100/120 Chromosorb WAW, Cat. No. 11851. Column temperature was 190°C for 31 min, and then rose progressively at 30°C/min up to 220°C where it was maintained for 10 min at 220°C. The carrier gas was nitrogen (2 mL/min). The injector and detector temperatures were 235 and 245°C, respectively.

Conditions were chosen to separate fatty acids of carbon chain length from 8 to 24. The fatty acids were identified by comparison of their retention times with known external standard mixtures (Alltech), quantified by Shimadzu Class-Vp software, and expressed as percentage distribution of fatty acid methyl esters. Each of the experiments was repeated three times.

FAME peak relative retention times with those obtained for Alltech (Carolean Industrial Drive, State College, Pa., U.S.A.) standards. Results were expressed as FID response area relative percentages. The results are given as mean ± standard deviation in Table I.

III. Results and Discussions

Table I shows the lipid content of the fillets of *Cyprinus carpio* investigated from the Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake of Turkey. The lipid content 0.64, 0.73, 0.97 and 1.13, respectively in fillets of *Cyprinus carpio*. Previous research has shown that the total lipid content of common carp about 1% in summer [24].

July variations on total fatty acid composition of *Cyprinus carpio* are presented in Table I. We identified and evaluated 27 fatty acids in muscle lipids of *Cyprinus carpio*. The major fatty acids in the *Cyprinus carpio* in all lakes were 22:6 n3 (DHA), 16:0, 18:1 n9, 20:4 n6, 18:2 n6, 16:1 n7, 20:5 n3 (EPA), and 18:0, respectively.

Palmitic acid was the major SFA, contributing approximately 60–69% to the total SFA content of the lipids for *Cyprinus carpio*. Similar results for zander [25] and other freshwater fish [26] have also been reported. Ackman et al. [27] 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. Oleic acid in muscle tissue of *Cyprinus carpio* was found to be 16.58%, 15.59%, 12.06%, and 9.36% in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake, respectively. Similarly, [28] found that C18:1 n9 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 [29].

PUFAs were found to be a significant constituent 41.69–45.82% of muscle lipid of *Cyprinus carpio*, according to the all lakes. DHA (C22:6 n3), LA (C18:2 n6), AA (C20:4 n6) and EPA (C20:5 n3) were the predominant PUFAs. The present data showed that DHA (C22:6) was the predominant fatty acid in muscle lipids of *Cyprinus carpio*, and its level showed the most variation during all lakes, accounting for 10.10–14.56% of total fatty acids and it was determined at 10.10%, 11.19%, 12.56% and 14.56% in Burdur Lake, Altinapa Dam Lake, Eğirdir Lake and Suğla Dam Lake, respectively. Similarly, [30] found that DHA was the predominant fatty acid (11.0%) in muscle lipid tissue of *Cyprinus carpio* and in this study, cultured *Cyprinus carpio* fed artificial feed has more total fat (1.09%) than *Cyprinus carpio* (4.45%). Sargent [31] reported that n3 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.

TABLE I
FATTY ACID COMPOSITION OF *CYPRINUS CARPIO*

(%) Fatty acids	Suğla Dam Lake	Apa Dam Lake	Eğirdir Lake	Burdur Lake
C 8:0	0.02 ± 0.01	0.01 ± 0.00	0.03 ± 0.00	0.06 ± 0.01
C 12:0	0.07 ± 0.03	0.07 ± 0.01	0.08 ± 0.02	0.13 ± 0.16
C 14:0	2.28 ± 0.49	2.31 ± 0.40	1.78 ± 0.52	3.47 ± 0.55
C 16:0	17.77 ± 0.54	16.97 ± 0.46	19.38 ± 0.38	22.24 ± 0.18
C 18:0	4.30 ± 0.14	4.70 ± 0.63	5.46 ± 0.83	8.53 ± 0.42
C 19:0	0.03 ± 0.02	0.03 ± 0.02	0.02 ± 0.03	0.04 ± 0.97
C 20:0	0.18 ± 0.05	0.26 ± 0.08	0.13 ± 0.11	0.11 ± 0.96
C 21:0	1.28 ± 0.29	1.38 ± 0.20	1.42 ± 0.31	2.44 ± 0.27
C 24:0	0.01 ± 0.00	0.01 ± 0.00	0.01 ± 0.01	0.02 ± 0.69
Σ SFA	**27.37 ± 1.28**	**27.53 ± 0.64**	**28.31 ± 0.89**	**37.04 ± 0.34**
C 14:1ω5	0.31 ± 0.16	0.26 ± 0.03	0.38 ± 0.05	0.11 ± 0.86
C 16:1ω7	7.63 ± 2.36	9.10 ± 0.72	11.27 ± 0.86	5.21 ± 2.18
C 18:1ω9	16.58 ± 4.10	15.59 ± 0.41	12.06 ± 0.35	9.36 ± 0.68
C 20:1ω9	1.22 ± 0.36	1.19 ± 0.10	0.94 ± 1.01	0.77 ± 0.78
C 22:1ω9	0.02 ± 0.01	0.03 ± 0.01	0.03 ± 0.03	0.02 ± 0.02
C 24:1ω9	0.01 ± 0.01	0.01 ± 0.00	0.01 ± 0.02	0.00 ± 0.00
Σ MUFA	**26.81 ± 6.68**	**27.34 ± 0.93**	**24.69 ± 0.68**	**15.47 ± 2.34**
C 18:2ω6	1.61 ± 1.12	7.28 ± 3.35	3.22 ± 0.44	2.10 ± 0.53
C 18:3ω3	4.50 ± 1.30	6.00 ± 0.67	5.83 ± 0.36	8.20 ± 0.21
C 20:2ω6	0.59 ± 0.32	1.20 ± 0.36	2.02 ± 0.43	1.96 ± 0.67
C 20:4ω6	5.47 ± 2.22	5.58 ± 0.66	7.10 ± 0.74	6.23 ± 0.59
C 20:5ω3	9.34 ± 1.56	8.61 ± 1.16	6.15 ± 2.97	7.82 ± 0.61
C 22:2ω6	0.06 ± 0.03	0.08 ± 0.04	0.10 ± 0.11	0.22 ± 0.12
C 22:4ω6	0.81 ± 0.09	0.90 ± 0.11	1.13 ± 0.89	1.31 ± 0.95
C 22:5ω6	1.88 ± 0.61	1.61 ± 0.54	2.01 ± 0.56	3.05 ± 0.18
C 22:5ω3	6.77 ± 0.27	2.51 ± 0.46	3.77 ± 0.96	3.27 ± 0.63
C 22:6ω3	14.56 ± 6.05	11.19 ± 3.36	12.66 ± 0.65	10.10 ± 0.84
Σ PUFA	**45.82 ± 7.95**	**45.13 ± 0.73**	**41.69 ± 1.18**	**45.08 ± 1.76**
Rumenik Asit (CLA)	0.52±0.01	0.47±0.02	0.56 ± 0.03	0.68 ± 0.33
Trans10-cis12 (CLA)	0.13±0.02	0.09±0.01	0.14 ± 0.04	0.14 ± 0.28
Σ ω3	35.32 ± 6.29	28.42 ± 3.96	28.41 ± 0.84	29.39 ± 0.63
Σ ω6	10.50 ± 2.12	8.71 ± 3.80	12.58 ± 0.68	14.87 ± 0.25
ω3/ω6	3.36 ± 0.25	3.26 ± 0.38	2.26 ± 0.47	1.98 ± 0.16

In the richer feeding period, *Cyprinus carpio* 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 *Cyprinus carpio* 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 [32].

In the present study, the percentages (in total lipid) of EPA and DHA which have a vital role in human nutrition were between 1.61–3.05% and 10.10–14.56%, respectively, according to the seasons. Thus, among the n3 series, the *Cyprinus carpio* 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 [33] however freshwater fish contain relatively large amounts of EPA and DHA. It should be pointed out that the PUFA contents in the fish studied in this work were higher than those reported by [34] 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 n3 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 *Cyprinus carpio* is highly capable of transforming native forms of 18n3 into long-chain acids, as a result of which the muscle has a high DHA content. Similar results were obtained by [35] which analysed dietary effects on fatty acid composition in muscles and liver of *Perca fluviatilis*; they found high DHA contents. Similarly, [25] 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 (18n3) PUFA to be transformed into more unsaturated long-chain PUFA.

There are close relationships between the fish lipid composition and the diets of fish [36]. *Cyprinus carpio* is not 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 n3 PUFAs, but lower in a-linolenic acid. In our study, PUFA levels of *Cyprinus carpio* in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake were found to be high (41.69–45.82%), and a-linolenic acid level was found to be low (4.50–8.20%). However the linolenic acid (C18:3n6), presumably an intermediate between linoleic (C18:2n6) and arachidonic acid (C20:4n6), is relatively high.

The n3/n6 ratio is a good index for comparing relative nutritional value of fish oils [37]. It is important for human health to increase the consumption of fish or fish products, which are rich in PUFAs of the n3 family and poorer in PUFAs of the n6 family [38]. The present data show that the n3/n6 ratio was 1.98 in Burdur Lakes, 2.26 in Eğirdir Lake, 3.26 in Apa Dam Lake and that the lowest value 3.36 was in Suğla Dam Lake. A high level of x6 fatty acids lowered the n3/n6 ratio in Suğla Dam Lake.

IV. Conclusions

This study has shown that the *Cyprinus carpio* is suitable item in the human diet during the fishing period in the Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake of Turkey when the levels of EPA, DHA and n3/n6 ratio are considered. This condition can be regarded as an explanation for the fact that the *Cyprinus c*arpio in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake are richer in n3 fatty acids, taking into consideration with the fatty acid profile of the fish. As a consequence, when human health is taken into account, the *Cyprinus carpio* in Suğla Dam Lake, Altinapa Dam Lake, Eğirdir Lake and Burdur Lake appears to be quite nutritious in terms of fatty acid composition and ratio.

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