Comparison of Farmed and Wild Common Carp (*Cyprinus carpio*): Seasonal Variations in Chemical Composition and Fatty Acid Profile

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Abstract

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Chemical composition and fatty acid profile of fillets from farmed and wild common carp were assessed in the course of four seasons. Ten wild and ten0 farmed fish were collected in the middle month of each season (except summer due to unavailability of wild fish) during the year. Lipid and protein contents of the samples decreased from summer to spring (protein: 17.6 ± 0.3–15.9 ± 1.6; 18.2 ± 0.1–17.9 ± 1.4%, in the farmed and wild carp samples, lipid (5.1 ± 0.2–1.5 ± 0.5; 3.8 ± 0.6–2.8 ± 0.9%, respectively; $P > 0.05$), moisture content of both samples increased in this period (76.7 ± 1.4–81.4 ± 0.4, 75.5 ± 0.6–78.5 ± 0.2 in the farmed and wild carp, respectively). Protein content of wild carp fillet was higher (17.7 ± 0.8% protein vs. and 16.2 ± 1.2%) and moisture content was lower than those of the farmed counterparts (77.65 ± 0.6 vs. and 79.3 ± 0.1, $P < 0.05$). In all seasons, MUFA were higher than SFA and also the PUFA. In the wild carp fillet, PUFA was higher than SFA in winter and spring but in the farmed carp it was higher in all seasons except the spring. Palmitic, oleic, and DHA were the major SFA, MUFA, and PUFA in the wild carp fillet, respectively. In the farmed carp fillet, the major SFA and MUFA were similar to those in the wild one but linoleic acid was the major PUFA in all seasons. ω-3/ω-6 PUFA ratios in the wild carp fillet were higher than in the farmed counterparts.

Keywords: SFA; MFA; PUFA; liquid; protein; fatty acid composition; fillet

The consumption of fish and fish lipids can provide PUFAs especially ω-3 PUFAs (Kmínková *et al.* 2001), moreover, proteins, unsaturated essential fatty acids, minerals, and vitamins can also be provided by them (Ackman 2000). Polyunsaturated fatty acids are known to diminish the level of the blood cholesterol, therefore, they can prevent cardiovascular diseases (Kmínková *et al.* 2001). Long chain ω-3 PUFA cannot be synthesised by humans and must be obtained from the diet (Alasalvar *et al.* 2002). Thus, if we attempt to maintain or enhance our present-day health, we must take a proactive approach to ensure our sustained access to essential fatty acids and, in particular, to eicosapentaenoic acid (EPA), docosahexaenoic acid (DHA), and arachidonic acid (AA).

It has been reported that the type and amount of fatty acids in fish tissues vary mainly with fish feeding, but other factors such as size or age, reproductive status, geographic location, season (Alasalvar *et al.* 2002), and temperature (Leger *et al.* 1977) influence the fat content and composition of fish muscle. It is known that the biochemical contents of marine organisms undergo changes due to seasonal changes (Ackman 1995). The chemical parameters of wild fish are strongly influenced by the sea environmental conditions, which determine the nutrients availability (Izquierdo *et al.* 2003) while in farmed fish the feeding with artificial diets prepares a wide range of nutrients and determines the flesh composition (Periago *et al.* 2005). However, the flesh protein content is less influenced by external feeding since it is mainly dependent on intrinsic factors such as the fish species, variety, and size (Børresen 1992; Shearer, 1994; Huss 1999). It is widely believed that the wild fish acceptability is better than that of farmed fish, generally an important accomplishment is that consumers expect farmed fish to be equivalent or superior to the wild fish (Mairesse *et al.* 2005).

Recently, the differences in the chemical composition between the wild and farmed sea bass, wild and cultured sea bream were reported by Periago *et al.* (2005) and Mnari *et al.* (2007). A review of the literature has revealed some information on the proximate composition of common carp in the Czech Republic (Kmínková *et al.* 2001) and in Turkey (Guler *et al.* 2008).

Carp, *Cyprinus carpio*, is a freshwater fish species and has been known as one of the most widely cultured species all over the world due to its fast growth rate and easy cultivation. *C. carpio* is one of the most abundant freshwater fish in the Caspian Sea, which is the largest brackish water lake (about 13 ppt) and is also cultured in a wide range in Iran. The increased production of common carp has raised concerns over the quality of the cultured fish, in comparison with the wild fish. No reports have yet been published about the differences between the farmed and wild carp and the effects of seasonal variations on the fatty acid composition of this important species.

Two populations of common carp have been studied: A farmed one was obtained from Agricultural & Animal Husbandry Ran Co., Gonbad, Iran and the other one captured in the Caspian Sea. This study may contribute to understanding the nutritional quality of wild and cultured common carp and help to design diets according to their seasonal requirements. Meanwhile, this study may be useful in changing the diet formulation to obtain equivalent qualities of wild and cultured carp flesh.

MATERIAL AND METHODS

Materials. Wild *C. carpio*, used in this study, was obtained seasonally from the Caspian Sea in the north of Iran. The farmed carp was obtained from Agricultural & Animal Husbandry Ran Co. and was cultured in a semi-intensive system. Common carp is an omnivorous species. In the case of the farmed situation, the specimens were fed with natural food and common pellets for omnivorous fish. Pelleted feeding included 6% crude fat from soybean meal, ground corn, cotton seed, and sunflower. The seasons chosen for the analyses were the summer, autumn, winter, and spring (2008). The samples were collected in the middle of the month in each season (except summer due to the unavailability of wild fish in July). All representative fish samples (n = 3 at each determination) used in the experiments were of almost the same size (average length 31 ± 174.4, 30.3 ± 84.6 cm for both samples, respectively) and age (3 years old by scales; Beamish & MacFarlane 1987). Female fish were selected by gonad histology and gonadosomatic index (GSI = (gonadal weight × 100)/ total weight) determination. The reproductive period of carp is in the late of April and July (water temperature should be between 17–23°C) (Abdoli 1999). After having been caught, the specimens were transported in an ice box with maximum temperature 4°C within 6 h to the laboratories, filleted, and then frozen. All samples were treated under the same conditions. At the beginning of each analysis, the samples were permitted to equilibrate to room temperature, ground, and homogenised. The lipid content was analysed according to the procedure of Bligh and Dyer (1959). The fatty acid methyl asters (FAMEs) were separated and quantified using a Shimadzu GC-17 gas chromatograph equipped (Shimadzu, Kozto, Japan) with a flame ionisation detector (250°C) and BPX70 column (50 m × 0.32 mm *i.d.*). Nitrogen was used as the carrier gas, the oven initial temperature was 125°C kept for 1 min, followed by an increase at a rate of 4°C/min to the final temperature of 215°C. The individual FAMEs were identified by the reference to authentic standards and to characterise fish oil well (Cronin *et al.* 1991).

Table 1. Biometric measurements of sampled individuals of wild and farmed Common carp

Date	Standard length (cm)		Weight (g)		Body depth (cm)		GSI (%)	
	wild	farmed	wild	farmed	wild	farmed	wild	farmed
Summer	29.1 ± 1.0	31.0 ± 2.4	481.0 ± 70.3	920.5 ± 202.0	7.68 ± 0.4	11.9 ± 1.3	1.1 ± 0.5	4.3 ± 1.0
Autumn	30.4 ± 1.7	31.9 ± 2.4	594.2 ± 95.1	889.7 ± 231.1	9.33± 0.4	11.2 ± 1.3	6.2 ± 3.6	5.2 ± 3.4
Winter	30.9 ± 1.1	30.5 ± 1.3	639.0 ± 101.2	848.0 ± 102.4	9.35 ± 0.8	10.5 ± 0.8	10.1 ± 3.6	6.6 ± 2.6
Spring	30.7 ± 1.2	30.7 ± 1.0	630.0 ± 71.9	848.8 ± 162.2	8.92 ± 0.3	10.5 ± 0.8	12.1 ± 2.8	15.2 ± 2.6

Protein was determined by Kjeldahl method (with 6.25 nitrogen to protein conversion factor) and the moisture content was estimated by drying at 105 ± 1°C to constant weight (Hernández *et al.* 2003).

Statistical analysis. All analyses were performed at least in triplicate. In each season, ten samples of both wild and farmed carp were analysed. The average results are given as means ± SD. The results were submitted to analysis of variance (Two-way ANOVA), at 0.05 significance level, using SPSS Version 11.5 (IBM, New York, USA). The mean values were compared by Duncan's test.

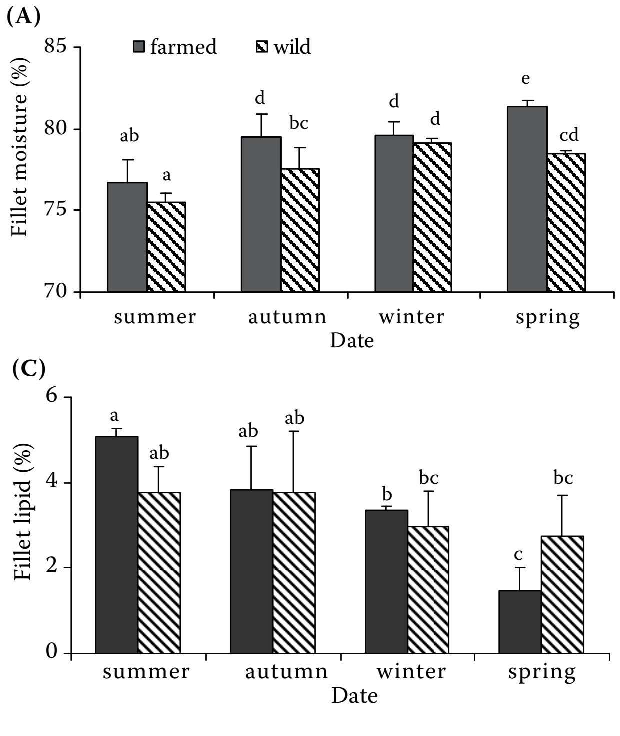
RESULTS

The biometric measurements showed that GSI increased from summer to spring. The values measured in spring indicated that fish were at an advanced maturity stage (Table 1).

Protein content underwent few variations during the experimental period in both farmed and wild carp fillets (Figure 1A), and slightly decreased from summer to spring (spawning season) (17.6–15.9%; 18.2–17.9%, in the farmed and wild carp samples, respectively) ($P > 0.05$).

According to our data, muscular fat of the farmed and wild common carp decreased from summer to spring (5.1–1.5% and 3.8–2.8%, respectively) ($P < 0.05$) (Figure 1B). The moisture content of fillets increased during the sampling period (from summer to spring) (Figure 1C).

Fatty acid composition of the wild and farmed carp captured in different seasons is shown in Tables 2 and 3. The major fatty acids identified in the wild carp were 18:1 (oleic 21.9%), 16:0 (palmitic 14.6%), 22:6 (docosahexanoic acid, DHA 8%), 16:1 (palmitoleic 6.5%), 18:0 (stearic 5.4%), 20:4 (arachidonic 5%), 20:5 (eicosapentaenoic acid 4.4%), 18:2 (linoleic 3.1%) in all seasons, respectively. While in the farmed carp, they were 18:1 (32.1%),



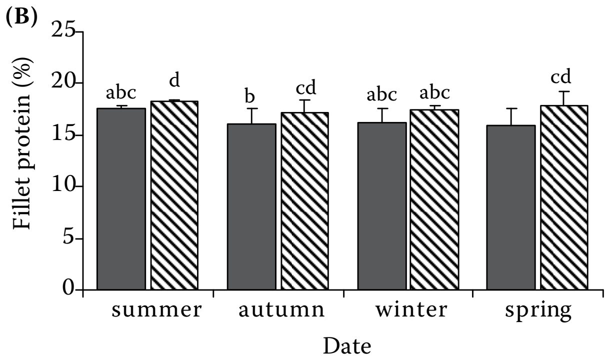


Figure 1. (A) Mean protein, (B) mean lipid and (C) mean moisture percent of farmed and wild common carp (*Cyprinus carpio*) fillet in all seasons. Mean values ($n = 3$) of three independent determinations; bars denote standard deviations of the mean. Different letters show significantly different at $P < 0.05$

Table 2. Seasonal variations on total fatty acid composition of fillets of wild carp (*Cyprinus carpio*) in the Caspian Sea

Fatty acids (%)	Summer	Autumn	Winter	Spring
C 14:0	2.02 ± 0.06^{c}	1.76 ± 0.31^{bc}	1.35 ± 0.53^{ab}	1.66 ± 0.45^{bc}
C 15:0	1.14 ± 0.03^{c}	1.02 ± 0.29^{bc}	0.80 ± 0.01^{b}	0.96 ± 0.03^{bc}
C 16:0	16.18 ± 0.36^{ab}	12.99 ± 6.50^{a}	16.16 ± 1.79^{ab}	14.56 ± 4.92^{a}
C 18:0	5.54 ± 0.03^{bc}	5.36 ± 0.57^{bc}	5.78 ± 0.77^{c}	5.05 ± 1.56^{abc}
C 20:0	0.45 ± 0.03^{a}	0.38 ± 0.03^{a}	–^{b}	0.26 ± 0.01^{ab}
Σ SFA	25.33	21.51	24.09	22.49
C 14:1ω5	0.35 ± 0.01^{b}	0.50 ± 0.17^{c}	0.02 ± 0.04^{a}	0.21± 0.05^{b}
C 16:1ω7	6.15 ± 0.13^{ab}	7.02 ± 0.97^{b}	5.99 ± 0.14^{ab}	6.45 ± 2.01^{ab}
C 18:1ω9	25.11 ± 0.43^{bc}	22 ± 3.67^{c}	22.07 ± 0.84^{c}	19.05 ± 1.39^{c}
C 20:1ω9	1.23 ± 0.01^{a}	0.97 ± 0.59^{a}	1.64 ± 0.44^{a}	1.44 ± 0.25^{a}
Σ MUFA	32.84	30.49	29.72	27.15
C 18:2ω6	2.19 ± 0.12^{c}	3.92 ± 1.78^{c}	3.72 ± 1.38^{c}	1.99 ± 1.26^{c}
C 18:3ω3	0.33 ± 0.02^{b}	0.78 ± 0.72^{b}	0.57 ± 0.09^{b}	0.45 ± 0.17^{b}
C 20:2ω6	0.6 ± 0.03^{abc}	0.33 ± 0.37^{a}	0.6 ± 0.03^{abc}	0.78 ± 0.06^{c}
C 20:3ω3	–	–	–	–
C 20:4ω6	3.3 ± 0.04^{ab}	5.00 ± 1.21^{bc}	6.20 ± 0.97^{c}	5.5 ± 1.17^{bc}
C 20:5ω3	4.15 ± 0.07^{c}	4.62 ± 1.4^{c}	3.95 ± 0.53^{bc}	4.75 ± 0.23^{c}
C 22:6ω3	5.98 ± 0.11^{c}	6.08 ± 2.42^{c}	11.61 ± 1.54^{d}	9.81 ± 0.63^{d}
Σ PUFA	16.55	20.73	26.65	23.28
ω3	10.46	11.48	16.13	15.01
ω6	6.09	9.25	10.52	8.27
ω3/ω6	1.72	1.24	1.53	1.81
Σ USFA/Σ SFA	1.95	2.38	2.34	2.24

aAverage of three lots analysed; values reported are means ± SD; $^{a-c}$values for each sample with different letters in the same fraction are significantly different at $P < 0.05$

16:0 (17%), 18:2 (15.3%), 18:0 (5.3%), 16:1 (5.2%), 20:4 (3.2%), 22:6 (2.9%), 18:3 (linolenic 2.6%), 20:5 (2%) in all seasons, respectively.

DISCUSSION

Previous studies reported on some portion of muscular lipids which was spent on the energy requirements and complete maturation of genital products (Abramova & Balykin 1997; Komova 2001). Çelik (2008) reported that protein fluctuations were observed in chub mackerel, *Scomber japonicus,* and horse mackerel, *Trachurus trachurus,* in all seasons.

In all cases, the wild fish were found to have a higher protein content than their farmed counterparts (about 17.7% protein vs. 16.2%), probably because of their significantly lower moisture content. Wild sea bream also showed higher muscle protein levels, which was probably due to their significantly lower fat content (Grigorakis *et al.* 2002). Periago *et al.* (2005) reported similar protein contents of wild and farmed sea bass.

Many fish species tend to reduce their food intake during sexual maturation, so the final stages of gonadal growth are dependent upon the mobilisation and re-allocation of endogenous reserves. In the White Sea bream (*Diplodus sargus*), muscular lipid was highly mobilised during the spawning period, presumably in support of the reproductive effort (Pérez *et al.* 2007). Similarly, other studies reported on the decrease of the lipid content in the spawning season for common carp (Kmínkova *et al.* 2001) and mackerel, *Trachurus mediterraneus* (Tzikas *et al.* 2005). Çelik (2008) found that the lipid contents of the chub mackerel, *Scomber japonicus*, and horse mackerel, *Trachurus trachurus*, were lower in winter than in autumn and spring. The fat content is influenced by species,

Table 3. Seasonal variations on total fatty acid composition of fillets of farmed carp (*Cyprinus carpio*)

Fatty acids (%)	Summer	Autumn	Winter	Spring
C 14:0	1.01 ± 0.02[a]	1.02 ± 0.4[a]	0.97 ± 0.2[a]	1.3 ± 0.18[a]
C 15:0	0.36 ± 0.01[a]	0.37 ± 0.01[a]	0.45[a]	0.55 ± 0.05[a]
C 16:0	16.08 ± 0.21[ab]	14.98 ± 0.86[a]	16.16 ± 1.79[a]	21.23 ± 1.26[b]
C 18:0	3.69 ± 0.04[a]	4.25 ± 0.81[ab]	5.06 ± 1.44[abc]	8.32 ± 0.15[d]
C 20:0	0.34 ± 0.38[a]	0.22 ± 0.79[ab]	–[b]	0.32 ± 0.07[a]
Σ SFA	21.48	20.84	22.64	31.72
C 14:1ω5	0.05[a]	0.26 ± 0.04[b]	0.05 ± 0.04[a]	0.29 ± 0.1[b]
C 16:1ω7	5.33 ± 0.07[a]	5.08 ± 0.8[a]	5.02 ± 0.94[a]	5.5 ± 0.55[ab]
C 18:1ω9	37.23 ± 0.48[a]	31.76 ± 7.05[ab]	29.77 ± 4.94[b]	30.64 ± 3.27[b]
C 20:1ω9	1.34 ± 0.01[a]	1.09 ± 0.6[a]	1.43 ± 0.18[a]	1.67 ± 0.77[a]
Σ MUFA	43.95	38.19	36.27	38.1
C 18:2ω6	18.68 ± 0.23[a]	16.55 ± 6.86[a]	15.69 ± 2.02[ab]	10.48 ± 2.79[b]
C 18:3ω3	3.58 ± 0.03[a]	2.68 ± 0.95[a]	3.18 ± 0.91[a]	1.1 ± 0.12[b]
C 20:2ω6	0.39 ± 0.01[ab]	0.47 ± 0.24[abc]	0.48 ± 0.03[abc]	0.69 ± 0.06[bc]
C 20:3ω3	–	–	–	–
C 20:4ω6	1.14 ± 0.04[a]	3.51 ± 2.28[ab]	4.52 ± 2.59[bc]	3.20 ± 1.05[ab]
C 20:5ω3	1.17 ± 0.02[a]	2.45 ± 1.7[abc]	2.42 ± 1.02[a]	1.68 ± 2.62[ab]
C 22:6 ω3	1.35 ± 0.15[a]	3.05 ± 1.4[abc]	4.78 ± 3.26[bc]	2.40 ± 2.48[ab]
Σ PUFA	26.31	28.71	31.07	19.75
ω3	6.1	8.18	10.38	5.18
ω6	20.21	20.53	20.69	14.37
ω3/ω6	0.3	039	0.5	0.36
Σ USFA/Σ SFA	3.27	3.21	2.97	1.82

Average of three lots analysed; values reported are means ± SD; [a,b]values for each sample with different letters in the same fraction are significantly different at $P < 0.05$

season, geographical regions, age, and maturity (Piggot & Tucker 1990). According to Panetsos (1978) classification (moderately fat fish: 3–8% lipid), the wild and farmed common carp seem to be moderately fat fish (3.3% lipid).

Muscle fat levels of the farmed and wild fish did not show significant differences ($P > 0.05$). Periago *et al.* (2005) observed similar muscle fat contents in the farmed and wild sea bass. On the contrary, some studies on other fish species showed a higher muscle fat content in the farmed than in the wild counterparts (Alasalvar *et al.* 2002; Grigorakis *et al.* 2002; Cejas *et al.* 2003; Olsson *et al.* 2003; Rodríguez *et al.* 2004; Periago *et al.* 2005; Mnari *et al.* 2007).

Similarly, Komova (2001) found that the moisture content of *Abramis brama* (Cyprinidae), increased from summer to spring. According to Love (1976), the process of spending protein in non-fatty fish is accompanied by an increase in the moisture content, which is in index emaciation level. Thus, in immature cod, *Gadus morhua*, coming from the North Sea, the moisture content is constant in all periods. In fish spawning for the first time, the moisture content increases during the spawning season and then returns to the initial level (Abramova & Balykin 1997). The same results were reported with mackerel, *Trachurus mediterraneus* and Walleye Pollack, *Theragra chalcogramma*, (Abramova & Balykin 1997; Tzikas *et al.* 2005). The inverse relationship between the fat and water contents described by Love (1970) is also observed in the farmed and wild common carp. The present data indicated that the moisture content of the wild carp was lower than that of the farmed carp ($P < 0.05$).

The fatty acid profile had a higher degree of unsaturation in winter. Palmitic, palmitoleic, oleic, arachidonic, eicosapentaenoic, and docosahexanoic fatty acids were found to be the major fatty acids in common carp, smelt, sucker, rainbow trout, and lake trout muscles (Kmínková *et al.* 2001). The major fatty acids of the carp have been reported to be 18:1ω9 (oleic), 16:0 (palmitic), 16:1 (palmitoleic), 22:6ω3 (docosahexanoic acid), 18:2ω6 (linoleic), 20:4ω6 (arachidonic), 18:0 (stearic), and 20:5ω3 (eicosapentaenoic acid), in all seasons, respectively (Guler *et al.* 2008). Chub mackerel and horse mackerel exhibited seasonal fluctuations in their fatty acid composition. The fatty acid profile of the two species revealed a higher degree of unsaturation during winter (Çelik 2008).

Palmitic acid was the primary saturated fatty acid (SFA) in carp in all seasons. Similar results for carp (Kolakowska *et al.* 2000; Guler *et al.* 2008) and other fish species have also been reported in the literature (Çelik *et al.* 2005). In general, fish fillet is relatively low in SFA (< 30%), except for certain species (Guler *et al.* 2008). Similar results were specified in this study for all seasons (24.2 and 23.4% in farmed and wild fish, respectively). Guler *et al.* (2008) found that the carp has a low SFA content (26.6–29.6%) in all seasons.

Oleic acid was identified as a primary MUFA in the carp ïn all seasons (32.1 and 21.9% in farmed and wild fish, respectively). According to some reports, this fatty acid is known to prevent cardiovascular diseases (Chong & Ng 1991; Peterson *et al.* 1994). Kim and Lee (1986), Csengeri and Farkas (1993), Kolakowska *et al.* (2000) found similar results in the carp and Haliloğlu *et al.* (2004) also found similar results with other freshwater fishes. Palmitoleic acid was the second most abundant MUFA (5.2 and 6.5% in farmed and wild fish, respectively) in the present study. The high levels of oleic, palmitoleic, and arachidonic acids had been reported as a characteristic property of freshwater fish oils (Andrade *et al.* 1995). Guler *et al.* (2008) found oleic acid and palmitoleic to be a primary and secondary MUFA in the carp in all seasons (15.1–20.3 and 5.1–13.2%, respectively). The previous research showed similar results in carp muscle during the four seasons (Kmínková *et al.* 2001). Oleic acid was significantly higher in the farmed carp than in the wild one. The higher amounts of oleic acid in other cultured fishes has been reported (Alasalvar *et al.* 2002).

One of the marked differences between the farmed and wild fish is the higher level of 18:2n-6 present in the farmed fish (about 15.3% vs. 3.1%). Linoleic acid is not a normal constituent of the marine food chain. This fatty acid is contained in plant oils which are used in the feeding of farmed fish and are accumulated largely unchanged in the lipids of marine fish because of their reduced capacity for the chain elongation and desaturation (Grigorakis *et al.* 2002). It has been reported that lower concentrations have to be present in the wild populations than in the farmed ones of species such as wild and cultured gilthead sea bream (Grigorakis *et al.* 2002), wild and farmed halibut (Olsson *et al.* 2003), and black seabream (Rodríguez *et al.* 2004). This result suggests that unsaturated activity in these fish species is low to produce appreciable amounts of 20:4n-6 from dietary 18:2n-6.

PUFA content in wild carp muscle was 16.3–26.7% in all seasons and generally much higher than SFA in winter and spring, while in the farmed carp it was 19.8–31.1% in all seasons and higher than SFA in all cases except spring. The findings showed that the farmed fish contained higher levels because of a higher level of 18:2n-6 in them. MUFA contents of carp fillets were higher than those of SFA and PUFA in all seasons. PUFA contents in carp muscle have been reported to be in a very wide range: 11.6–15.7% of total fatty acids (Bieniarz *et al.* 2000) to 32.3–34.5% (Guler *et al*, 2008). In Guler *et al.* (2008) research, the PUFA contents of carp muscle were generally much higher than SFA contents in spring, summer, and autumn, 37.8, 42.8, and 35.9%, respectively. MUFA contents of carp fillets were higher than those of SFA in spring, autumn, and winter, 35.7, 37.3, and 41.1%, respectively. According to the results of Kmínková *et al.* (2001), MUFA contents of carp fillets were higher than those of SFA and PUFA in all seasons, while PUFA contents were lower than those of SFA. Our data showed that a high level of oleic acid increased MUFA content in all seasons. The reason for the observed results is likely the feeding habits of the fish. The percentages of PUFA, such as EPA and DHA, in fish muscle are dependent on diet (Sargent 1997). Variations in fatty acid composition might be related to the changes in nutritional habits of the fish (Norrobin *et al.* 1990). Other factors such as the size or age, reproductive status, geographic location, season, and temperature may influence the fatty acid composition of the fish muscle (Leger *et al.* 1977; Alasalvar *et al.* 2002).

In our study, 18:2 (3.1%), 20:5 (4.4%), 20:4 (5%), and 22:6 (8%) were the most obvious PUFA in the wild carp and 18:2 (15.3%), 20:4 (3.2%), 22:6 (2.9%)

and 18:3 (2.6) were the most obvious PUFA in the farmed counterparts in all seasons. Kim and Lee (1986) reported that LAω6 (3.9%), EPA (6%), DHA (5%), LnAω3 (6%), and AA (3.5%) were the most obvious PUFA in carp. Similarly, Guler *et al.* (2008) reported that LAω6 (3.6–10.5%), EPA (4.1–5.7%), AA (4.38–6.99%), and DHA (4.9–11%) were the most obvious PUFA in the carp in all seasons. Kmínková *et al.* (2001) found that LAω6 (6.1–7.5%), linolenic acid (2.49–5.4%), EPA (1.9–4.1%), AA (0.7–1.8%), and DHA (0.8–3.7%) were the most obvious PUFA in the carp in all seasons. The present results showed significantly higher values of AA, EPA, and DHA in the wild specimens ($P < 0.05$). Higher levels of arachidonic acid in the wild carp (Grigorakis *et al.* 2002) and other species (Alasalvar *et al.* 2002) have also been observed in other fish species. Sargent *et al.* (2002) reported that AA is a precursor of prostaglandin and thromboxane which will influence the blood clot formation and its attachment to the endothelial tissue during wound healing. Apart from that, this fatty acid also plays a role in the growth. Kmínková *et al.* (2001) found AA at 1.3% and Guler *et al.* (2008) at 5.6% in the carp.

The percentages of EPA + DHA in the farmed and wild carp were 4.8% and 12.6%, respectively, in all seasons, the highest values having been obtained in winter. Kim and Lee (1986) found that EPA + DHA amounted to 11.1%, Csengeri and Farkas (1993) found them at 15.3%, Kmínková *et al.* (2001) at 2.9–6.9%, and Guler *et al.* (2008) at 8.4–15.9% in the carp. According to our results, n-3 PUFA (about 13.3 vs. 7.5% in the wild and farmed fish, respectively) and n-3/n-6 ratio (about 1.6 vs. 0.4 in the wild and farmed fish, respectively) revealed their higher levels in the wild carp while n-6 PUFA were found in higher levels in the farmed counterparts (about 19% vs. 8.5%). These results were shown in a previous study on the gilthead sea bream (Grigorakis *et al.* 2002).

The increase in the dietary ω3/ω6 fatty acid ratio in favour of ω3 fatty acids also seems to be effective in preventing the shock syndrome and cardiomyopathy (Bell *et al.* 1991). The ratio of ω3/ω6 PUFAs in total lipids of freshwater fishes changes mostly between 0.5 and 3.8, whereas with marine fishes it is 4.7–14.4. In a previous study, the average of this ratio in the carp was near 1 in winter, spring, and summer, and decreased to 0.5 in autumn. This was explained by a decreasing value of the ω3 PUFA from 18.9 to 11.8 in autumn (Guler *et al.* 2008). In our study, this ratio was more than 1 in the wild carp and less than 0.5 in the farmed carp and it slightly fluctuated during the seasons. Although the ratio in the carp from the Caspian Sea was higher than in the farmed carp, it was lower than in other marine species.

The ratio of unsaturated (USFA) vs. saturated fatty acids is of a great importance in edible fat. The value of more than 0.35 is usually believed to be beneficial (Kmínková *et al.* 2001). In our study, these values in the farmed and wild carp muscles were 2.8 and 2.2, respectively, thus from this point of view, the carp fat is beneficial for human nutrition. Kmínková *et al.* (2001) found that this ratio was 2.3 during the 4 seasons.

This study has shown that the wild carp provides the consumer with much higher levels of AA, DHA, EPA, ω3 PUFA, and n-3/n-6 ratio. Increased intakes of n-6 fatty acids have infavourable effects on human health, so the supply has been suggested (Grigorakis *et al.* 2002) of diets for farmed fish to decrease this factor which would maximise their n-3/n-6 ratio or at least approach the ratios found in wild species.

Seasonal fluctuations of fatty acid profile have shown that PUFA, ω3, and ω6 PUFA increased in winter. These results seem to have been obtained because of the temperature variation, food availability or reproductive status. In some cases (such as SFA), we could not observe any regular trend in variations during the four seasons. PUFA produce oxidation carbonyl and alcohol compounds which cause the typical aroma of fish. Because of that, the production of farmed fish with fatty acid profiles similar to those of their wild counterparts might help in the production of fish with similar taste characteristics (Grigorakis *et al.* 2002).

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