African Journal of Food Science Vol. 4(8) pp. 522 - 530, August 2010
Available online http://www.academicjournals.org/ajfs
ISSN 1996-0794 ©2010 Academic Journals

Full Length Research Paper

Total lipid content, fatty acid and mineral compositions of muscles and liver in wild and farmed sea bass (*Dicentrarchus labrax*)

A. Mnari Bhouri[1*], I. Bouhlel[1], L. Chouba[2], M. Hammami[3], M. El Cafsi[4] and A. Chaouch[1]

[1]Laboratory of Physiology, 05/UR-09/05 "« Physiologie et Ecophysiologie des Organismes Aquatiques", Faculty of Medicine, Monastir, Tunisia.
[2]Institut National des Sciences et Techniques de la Mer, port de pêche 2060, La Goulette, Tunis, Tunisia.
[3]Laboratory of Biochemistry, UR03/ES08 "Human Nutrition and Metabolic Disorders" Faculty of Medicine, Monastir, Tunisia.
[4]Département de Biologie, Faculté des Sciences de Tunis, Campus Universitaire, Al Manar Tunis, Tunisia.

Accepted 29 June, 2010

The fatty acid and mineral compositions in the dorsal and ventral muscles and liver of wild and farmed sea bass (*Dicentrarchus labrax*) were evaluated. The farmed animals showed a significant higher fat content ($p < 0.05$) than the wild ones, for all studied samples. The percentages of SFA and PUFA as well as the n-6/n-3 were higher ($p < 0.05$) in the muscle in wild compared with farmed sea bass. However, in liver, SFA and MUFA were concentrated in wild fish. Among n-3 PUFA both fish were good sources of EPA and DHA. The results revealed also that levels of trace elements varied depending on different tissues in both fish ($p < 0.05$). Potassium, calcium and magnesium were concentrated in muscles compared with liver, in both fish, whereas iron, zinc, copper and manganese concentrations were higher in liver than in muscle tissue ($p < 0.05$).

Key words: Family Moronidae, *Dicentrarchus labrax*, essential minerals, fatty acids, EPA, DHA.

INTRODUCTION

Fish are known for their high nutritional value, mainly due to the high protein content, phospholipids and polyunsaturated fatty acids, as well as the covering percentage of the essential minerals - recommended daily allowance/intake (RDA/RDI) (Steffens, 1997; Simopoulos, 2002). Polyunsaturated fatty acids (PUFA) present in fish, specially n-3 and n-6, are particularly important, since their consumption contributes to the reduction of incidence of cardiovascular diseases (Kris-Etherton et al., 2003; Chen et al., 2007; Din et al., 2008). The n-3 PUFA have shown to be very beneficial in the prevention of inflammatory diseases (Tapiero et al., 2002; Harris, 2007), colon cancer (Larsson et al., 2004; Roynette et al., 2004) and disorders of the immune system (Belluzzi, 2001). Phospholipids are the main constituents of biological membranes and play an essential role in the regulation of biophysical properties, protein sorting and cell signalling pathways. Also, n-3 PUFA have beneficial health effects in conditions of hypertension, arrhythmias, psoriasis, aggression and depression (Pike, 1999; Turkmen et al., 2005). They are essential components of the human diet and their carence in the human organism can lead to a number of serious diseases (Turkmen et al., 2005).

Marine foods are also very rich sources of mineral components. Aquatic animals require minerals for their normal life processes. Fish absorb minerals not only from their diets but also from the surrounding water via their gills and skin (Craig and Helfrich, 2002; Lall, 2002).

Sodium (Na), potassium (K), magnesium (Mg) and calcium (Ca) are important for human nutrition

*Corresponding author. E-mail: amira_mnari@yahoo.fr.

Abreviations: Zn, Zinc; **Fe,** Iron; **Cu,** Copper; **Mg,** Magnesium **Ca,** Calcium; **K,** Potassium; **Na,** Sodium.

Table 1. Composition of the diet used for the farmed sea bass.

	Content (%)
Protein	50
Fat	21
Carbohydrates	12
Ashes	11.5
Raw fiber	1.5
Fatty acids (% on total fatty acids)	
C16:0	18.6
C18:1 n-9 (cis)	13.4
C18:2 n-6 (c9.c12)	6.9
C18:3 n-3 (cis)	1.3
C20:4 n-6	0.9
C20:5 n-3	10.7
C22:6 n-3	14.2
Σ SFA[a]	34.9
Σ MUFA[b]	29.9
Σ PUFA n-3[c]	26.8
Σ PUFA n-6[d]	8.3
Σ PUFA	35.1
PUFA/SFA	1.0
n-3/n-6	3.2
EPA/DHA	0.75

[a]Σ SFA also includes C12:0, C14:0, C16:0, C17:0, C18:0, C20:0, C22:0 and C24:0.
[b]Σ MUFA also includes C14:1, C16:1 n-7*c,* C17:1, C18:1 n-7c, C20:1 n-9, C22:1 n-9 and C24:1 n-9.
[c]Σ PUFA n-3 also includes C18:3 n-3c, C20:3 and C22:5
[d]Σ PUFA n-6 also includes C18:3, C20:2, C20:3, C22:2 and C22:4.

(Sikorski et al., 1990; Munoz-Olivas and Camara, 2001). Also, certain elements such as zinc (Zn), copper (Cu), iron (Fe) and manganese (Mn) are indispensable for the maintenance of normal growth and reproduction (Turkmen et al., 2005; Roy and Lall, 2006).

There is a remarkable difference in the chemical composition (including fatty acids and minerals) among and within fish species (Luzia et al., 2003; Grigorakis et al., 2002; Orban et al., 2002; Periago et al., 2005; Mnari et al., 2007). Sea bass (*Dicentrarchus labrax,* Linnaeus, 1758), which is very appreciated by Tunisian consumers, is an economically important cultured fish species in the Mediterranean coastal waters (Saglik et al., 2003). World production of fish has increased in recent years due to the overexploitation of the seas and increasing human population. The production of farmed sea bass in Tunisia has raised concerns over the quality of fish, in comparison with that of the wild caught fish. It is, therefore, of importance to compare the farmed and wild sea bass in terms of their fatty acid and mineral compositions. Recently, several studies have been undertaken to study the flesh fatty acid and mineral compositions of Sea bass (Saglik et al., 2003; Periago et al., 2005; Ozyurt and Polat, 2006; Yeldiz, 2008; Erdem et al., 2009). Yet, there is no information regarding the fatty acid and mineral composition of ventral muscle and liver in wild and farmed Sea bass. The aim of present study was to analyze the fatty acid profile and selected mineral content (Zn, Cu, Fe, Mg, Mn, Na, K and Ca), that have an important impact on human health, in dorsal and ventral muscles and liver in wild and farmed sea bass (*D. labrax*).

Table 2. Mineral concentrations (mg/kg dry weight) of the diet used for the farmed sea bass.

Element	Concentration
Ca	21600
K	7800
Na	6700
Mg	2360
Fe	194.1
Zn	186.8
Mn	87.1
Cu	6.7

MATERIALS AND METHODS

Samples

Farmed sea bass (92 ± 5 g and 19.5 ± 0.5 cm) were obtained in the summer 2006, from the Station of Tunisian Aquaculture located in Hergla (center east of Tunisia). Sea bass were raised in the usual farming conditions, with the same diet (50% crude protein, 21% crude fat, 12% carbohydrates, 11.5% ashes and 1.5% raw fiber), and by the same rearing techniques in the same conditions (temperature: 17°C; salinity: 40%; pH: 8.2). The fatty acid profile of the diet used in this study is shown in Table 1. The mineral concentrations of standard diet fed to farmed sea bass is shown in Table 2. Wild sea bass (85 ± 3 g and 21.5 ± 0.7 cm) were caught with fishing net in the same season from the coastal waters of Monastir (Center East Tunisia) (temperature: 25°C; salinity: 38%; pH: 7.8).

Biochemical determinations

Lipid and fatty acid content

Fifteen immature of each wild and farmed sea bass were used for fatty acids and minerals analysis. Specimens were transported in ice to the laboratory where they weighed and immediately processed. Dorsal and ventral muscles as well as liver were taken out and frozen at -80°C, after being immersed in liquid nitrogen. Total lipids extraction was made with chloroform/methanol (2:1) and according to Folch et al. (1957) methodology modified by Bligh and Dyer (1959). Fatty acids were methylated with Boron Trifluoride (BF_3) in methanol. The fatty acid methyl esters were recovered with hexane according to Metcalfe et al. (1966) methodology. The chromatographic separation was carried out using a Hewlett-Packard (HP 5890) chromatograph, a split/splitless injector and a flame-ionization detector (FID) linked to an HP Chemstation integrator. A fused silica capillary column HP-Innoawax (30 m × 0.25 mm id × 0.25 µm as film thickness) was used with nitrogen as the carrier gas at a flow rate of 1 ml/min, flame ionization detection

Table 3. Summary of certified element concentrations and concentrations determined in this study.

Element	Reference material	Reference material observed value
	Certified value	
Zn (mg kg^{-1})	67.1 ± 3.8	67.3 ± 0.6
Cu (mg kg^{-1})	3.3 ± 0.4	3.4 ± 0.0
Fe (mg kg^{-1})	146 ± 14	132.9 ± 1.4
Mn (mg kg^{-1})	3.5 ± 0.3	3.8 ± 0.8
Mg (g kg^{-1})	2.7 ± 0.1	2.5 ± 1.9
Na (g kg^{-1})	13.1 ± 0.6	13.5 ± 0.0
K (g kg^{-1})	13.1 ± 1.2	10.7 ± 2.1
Ca (g kg^{-1})	27.0 ± 1.8	27.6 ± 0.0

temperature 280°C; injector temperature 250°C and an oven temperature programmed from 180 to 250°C. The total time of the chromatograph was 30 min for each analysis. The identification of fatty acid methyl esters (FAMEs) was performed by external standards submitted to the same processes of manipulation as the biological samples. FAMEs were identified by comparison of their retention times with those of standard mixtures and their areas were automatically integrated using nonadecanoic acid methyl ester (C19:0) as internal standard.

Mineral content

For mineral analysis, special care was taken to pull the skin. All samples were washed with deionised water and stored at -80°C prior to analysis. To prevent trace metal contamination of the samples by laboratory equipment, all laboratory ware was soaked in a 2 M HNO_3 solution for 48 h, and rinsed three times with distilled water, and then three times with deionised water prior to use. All frozen samples were lyophilized and then homogenized. Approximately, 0.2 g of each homogenized lyophilized samples were weighed into a 100 ml Teflon reactor. Thereafter, 5 ml of 65% HNO_3 was added to the sample. The samples were heated at 100°C for 4 h and allowed to cool in a fume hood. The digest was transferred to a 50 ml volumetric flask and diluted to volume with Milli-Q water. Reagent blanks and 0.2 g of Standard Reference Material (SRM) IAEA-407 (2003) (Analytical Quality Control Services, Austria), were also prepared in a similar manner to the sea bass samples for each eight elements to analyse.

Zn, Fe, Cu, Mg, Mn, Ca, K and Na determination in samples was made using a flame Atomic Absorption Spectrometer GTA-96 Varian AA 10 (UNEP/IAEA/FAO, 1990). Six aliquots were taken from each homogenised sample. Standard solutions were prepared from stock solutions (Sharlau, multi element standard). The wavelengths monitored were 213.9 nm for Zn, 248.3 nm for Fe, 324.8 nm for Cu, 285.2 nm for Mg, 279.5 nm for Mn, 422.7 nm for Ca, 766.5 nm for K and 589.0 nm for Na. Detection limits were set to the standard deviation of the concentrations recorded for the blank. A good agreement between the available certified value for each element and the experimental data obtained in this study demonstrates the accuracy of the results obtained through the analysis of the standard material reference IAEA-407 (Table 3).

Statistical analysis

Univariate analysis of variance (ANOVA) with significance levels of 5% was used to test the differences in fatty acids and mineral concentrations of the different tissue in wild and farmed fish. Post hoc test (SNK, LSD and Fisher's tests) was used to determine statistically significant differences following ANOVA. Results are presented as mean±standard errors (SE). All statistical analyses were conducted using a statistical analysis system (SPSS Version 12).

RESULTS AND DISCUSSION

Fatty acids composition

The total lipid content (TL mg/g wet weight) of wild and farmed sea bass is presented in Figure 1. The farmed sea bass possessed a considerably higher TL content than wild sea bass ($p < 0.05$). Among samples, liver showed the highest level of TL in wild and farmed Sea bass. Ventral muscle was richer than the dorsal one in both types of fish. Differences observed between samples of wild and farmed fish were statistically significant ($p < 0.05$) except for liver. A high TL content in farmed fish has also been reported by Alasalvar et al. (2002); Saglik et al. (2003) for Sea bass. The fatty acid profiles of dorsal and ventral muscles and of liver of wild and farmed sea bass are listed in Table 4. In both muscle and liver of wild and farmed fish, PUFA ranged from 38.77 - 47.24% of total fatty acids (TFA) and they were higher than the saturated (SFA) (26.75 - 33.3%) and monounsaturated (MUFA) (21.77 - 29.18%) fractions. The fatty acid profile of both fish types generally exhibited a dominance of the two classes, SFA and PUFA.

The results are in agreement with those reported by Alasalvar et al. (2002); Periago et al., (2005); Erdem et al. (2009) for farmed and wild sea bass (*D. labrax*). It has been reported that assimilation patterns of dietary fatty acids in fish muscle reflect the content of the dietary lipid sources (Pirini et al., 2000; Grigorakis et al., 2002; Mnari et al., 2007). Generally, the high content of SFA observed in farmed fish is due to the manufactured diet that usually contain high SFA and MUFA content, but are deficient in n-3 PUFA (Alasalvar et al., 2002; Orban et al., 2002; Periago et al., 2005; Mnari et al., 2007). The FA composition of diet used for the current study confirms that the level of SFA (34.9% TFA) was predominant over

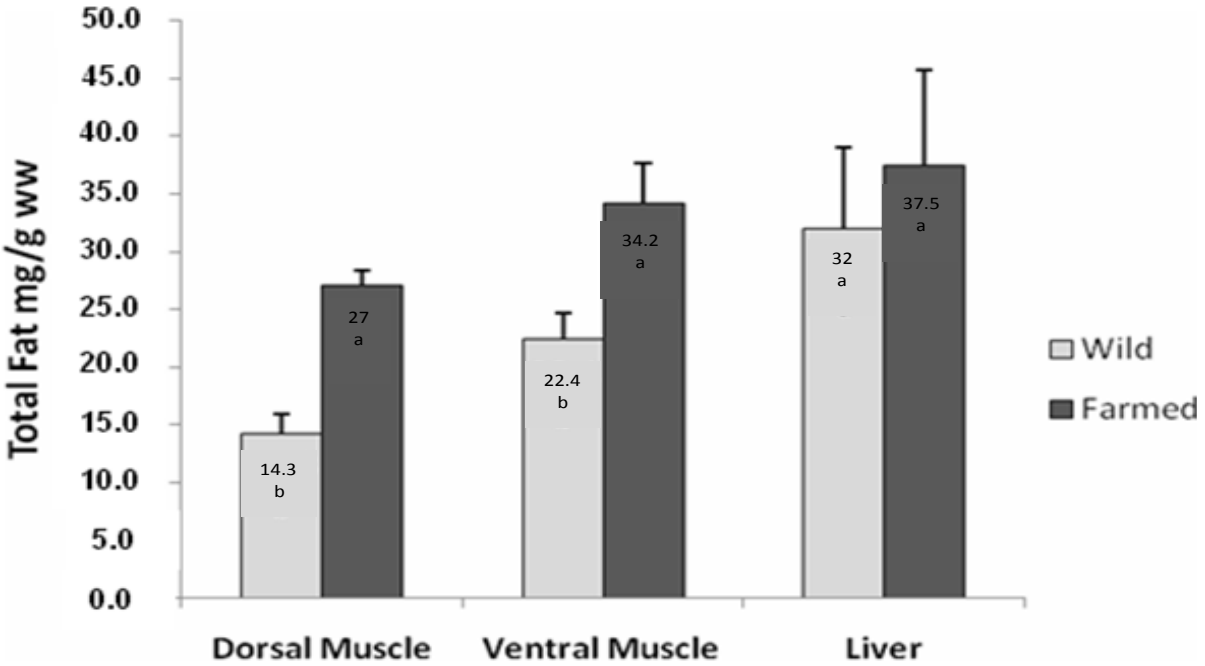

Figure 1. Total lipid content (expressed in mg/g wet weight) of dorsal and ventral muscles and liver in farmed and wild sea bass (*D. labrax*). Values are mean ± SE, n = 15. Bars represent standard errors. Means with different small letters within a specific tissue are significantly different ($p < 0.05$).

MUFA (29.9% TFA) and n-3 PUFA (26.8% TFA) (Table 1). Palmitic acid (C16:0) was the primary SFA contributing 63.4 - 65.8% of the total SFA content of lipids for all studied samples of wild and farmed sea bass (Table 4). Similar results for sea bass (Krajnovic-Ozretic et al., 1994; Alasalvar et al., 2002; Periago et al., (2005); Ozyurt and Polat, 2006; Erdem et al., 2009) and others fish species have also been reported in the literature (Grigorakis et al., 2002; Mnari et al., 2007; Ozugul and Ozugul, 2007). As far as for MUFA fraction, oleic acid (C18:1 n-9) was predominant (15.31 - 20.16% TFA) over C16:1 n-7 (2.52 - 5.99% TFA) and C18:1 n-7 (0.04 - 1.64% TFA). A high oleic acid value was found in liver of wild sea bass (20.16% TFA) ($p < 0.05$). The higher amount of oleic acid in farmed sea bass and sea bream ($p < 0.05$) has been reported to arise from its dominance in the commercial diet (Krajnovic-Ozretic et al., 1994; Grigorakis et al., 2002; Orban et al., 2002; Periago et al., 2005; Mnari et al., 2007; Erdem et al., 2009).

PUFA were the major component of muscles and liver fatty acid content of wild and farmed sea bass. No differences were observed between wild and farmed fish for the studied samples (Table 4). The result does not agree with a previous report on wild and farmed Sea bass (Periago et al., 2005; Erdem et al., 2009). They have observed that PUFA were significantly lower in farmed Sea bass than in wild Sea bass. The n-3 PUFA levels were similar in both fish types. The n-6 PUFA fraction revealed lowest values compared to those of n-3 PUFA. In dorsal and ventral muscles, the concentration of n-6 PUFA were similar in both fish types, whereas in liver, the n-6 PUFA levels were higher ($p < 0.05$) in farmed fish (17.2% TFA). Docosahexaenoic acid (DHA) (C22:6 n-3; 15.01 - 24.35% TFA) was the prominent PUFA in muscles and liver in wild and farmed sea bass. It was followed by arachidonic acid (C20:4 n-6) (1.73 - 8.60% TFA) and eicosapentaenoic acid (EPA) (C20:5 n-3; 5.52 - 8.99% TFA) in wild sea bass and by EPA and linoleic acid (C18:2 n-6) (1.62 - 13.09% TFA) in muscles in farmed one. While in liver of farmed sea bass, the level of linoleic acid (13.12% TFA) was higher than EPA (8.54% TFA). Among n-6 PUFA, farmed sea bass displayed higher levels ($p < 0.05$) of linoleic acid for all studied samples. However, wild fish accumulated arachidonic acid which is a precursor for prostaglandin and thromboxane biosynthesis (Pompeia et al., 2002). Similar n-6 PUFA content was reported by Alasalvar et al. (2002) for cultured and wild sea bass (*D. labrax).* The higher level of linoleic acid in farmed fish has been related to the diet ingredients of farmed fish (Krajnovic-Ozretic et al., 1994; Serot et al., 1998). This fatty acid is present in plant oils used in the manufacture of farmed fish feed and is largely accumulated in an unchanged form in the lipids of marine fish. This is due to fish reduced capacity for chain elongation and desaturation (Yamada et al., 1980). Among n-3 PUFA both type of fish displayed high content of EPA and DHA. Several studies have also mentioned that DHA was mainly accumulated

Table 4. Fatty acid compositions of dorsal and ventral muscles and liver in wild and farmed sea bass.

	Dorsal muscle		Ventral muscle		Liver	
Fatty acid	**Wild**	**Farmed**	**Wild**	**Farmed**	**Wild**	**Farmed**
C14:0	1.03 ± 0.07^{b}	1.75 ± 0.12^{a}	2.32 ± 0.35^{b}	3.80 ± 0.34^{a}	1.35 ± 0.06^{b}	3.1 ± 0.24^{a}
C16:0	21.91± 0.64^{a}	20.13 ± 0.16^{a}	18.99 ± 0.17^{a}	19.46 ± .01^{a}	19.51 ± 0.65^{a}	16.3 ± 0.26^{b}
C17:0	0.58 ± 0.08^{a}	0.95 ± 0.21^{a}	0.48 ± 0.02^{a}	0.69 ± 0.06^{a}	1.04 ± 0.37^{a}	0.75 ± 0.04^{a}
C18:0	6.85 ± 0.32^{a}	4.27 ± 1.47^{a}	6.84 ± 0.11^{a}	5.19 ± 0.37^{b}	7.64 ± 0.47^{a}	3.96 ± 0.33^{b}
C20:0	0.41± 0.07^{b}	0.62 ± 0.06^{a}	0.55 ± 0.09^{a}	0.53 ± 0.29^{a}	0.43 ± 0.11^{b}	1.06 ± 0.07^{a}
C22:0	1.20 ± 0.17^{a}	1.99 ± 0.54^{a}	1.37 ± 0.17^{a}	1.46 ± 0.47^{a}	0.5 ± 0.13^{a}	0.34 ± 0.06^{a}
C24:0	1.31 ± 0.09^{a}	0.88 ± 0.06^{b}	1.35 ± 0.12^{a}	0.87 ± 0.02^{b}	1.56 ± 0.26^{a}	1.23 ± 0.08^{a}
SFA	33.3 ± 0.58^{a}	30.6 ± 1.8^{a}	32.14 ± 0.27^{a}	31.38 ± 1.22^{a}	32.03 ± 0.65^{b}	26.75 ± 0.6^{a}
C14:1n-5	0.43 ± 0.11^{a}	0.12 ± 0.02^{a}	1.37± 0.14^{b}	3.24 ± 0.42^{a}	0.86 ± 0.12^{a}	0.21 ± 0.03^{b}
C16:1n-7	3.47 ± 0.25^{a}	3.49 ± 0.34^{a}	2.52 ± 0.62^{a}	3.81 ± 0.33^{a}	5.99 ± 0.68^{a}	5.68 ± 0.19^{a}
C18:1n-7	0.23 ± 0.08^{a}	1.64 ± 1.64^{a}	0.04 ± 0.02^{a}	0.06 ± 0.04^{a}	0.50 ± 0.07^{a}	0.08 ± 0.07^{a}
C18:1n-9	15.31 ± 1.33^{a}	17.50 ± 0.84^{a}	17.81 ± 2.23^{a}	16.42 ± 0.93^{a}	20.16 ± 2.32^{a}	19.47± 0.72^{a}
C20:1n-9	1.53 ± 0.20^{a}	2.31 ± 0.55^{a}	1.54 ± 0.06^{a}	1.12 ± 0.46^{a}	0.60 ± 0.24^{a}	0.3 ± 0.02^{a}
C22:1n-9	0.25 ± 0.06^{a}	0.33 ± 0.15^{a}	0.16 ± 0.02^{a}	0.30 ± 0.09^{a}	0.21 ± 0.06^{a}	0.19 ± 0.05^{a}
C24:1n-9	0.55 ± 0.08^{a}	0.62 ± 0.21^{a}	0.60 ± 0.43^{a}	0.36 ± 0.18^{a}	0.95 ± 0.48^{a}	0.08 ± 0.02^{a}
MUFA	21.77 ± 1.64^{b}	26.01 ± 1.1^{a}	24.01± 2.4^{a}	25.3 ± 1.4^{a}	29.18 ± 3.22^{a}	26.00 ± 0.8^{a}
C18:2n-6	1.64 ± 0.57^{b}	6.86 ± 0.19^{a}	2.01 ± 0.26^{b}	6.54 ± 0.75^{a}	1.62 ± 0.16^{b}	13.12 ± 1.42^{a}
C20:2n-6	0.09 ± 0.01^{a}	0.20 ± 0.08^{a}	0.15 ± 0.03^{a}	0.71± 0.55^{a}	0.56 ± 0.25^{b}	1.88 ± 0.13^{a}
C20:3n-6	0.76 ± 0.14^{a}	0.60 ± 0.14^{a}	0.74 ± 0.09^{a}	0.29 ± 0.11^{b}	0.42 ± 0.16^{a}	0.21± 0.03^{a}
C20:4n-6	7.82 ± 1.0^{a}	2.13 ± 0.23^{b}	8.60 ± 1.05^{a}	2.01± 0.28^{b}	7.20 ± 0.69^{a}	1.71 ± 0.07^{b}
C22:4n-6	0.17 ± 0.04^{a}	0.25 ± 0.01^{a}	1.07 ± 0.29^{a}	0.24± 0.06^{a}	1.38 ± 0.55^{a}	0.28 ± 0.16^{a}
n-6 PUFA	10.5 ± 1.31^{a}	10.0 ± 0.4^{a}	12.6± 1.15^{a}	9.8 ± 0.81^{a}	11.17 ± 0.91^{b}	17.2 ± 1.5^{a}
C18:3n-3	1.15 ± 0.11^{a}	1.24 ± 0.02^{a}	1.05 ± 0.14^{a}	1.78 ± 0.84^{a}	1.15 ± 0.15^{a}	1.94 ± 0.33^{a}
C20:5n-3	7.79 ± 0.26^{a}	8.68 ± 0.47^{a}	6.75 ± 0.78^{b}	8.99 ± 0.33^{a}	5.52 ± 0.75^{b}	8.54 ± 0.48^{a}
C22:5n-3	1.15 ± 0.09^{a}	0.44 ± 0.08^{b}	1.23 ± 0.23^{a}	0.44 ± 0.12^{b}	1.20 ± 0.58^{a}	0.64 ± 0.19^{a}
C22:6n-3	24.35 ±2.18^{a}	22.98 ±1.69^{a}	22.48 ± 0.62^{a}	22.03 ± 1.76^{a}	19.72 ± 3.07^{a}	18.91± 1.14^{a}
n-3 PUFA	34.44 ± 2.11^{a}	33.34 ± 2.08^{a}	31.51 ± 1.2^{a}	33.24 ± 1.3^{a}	27.6 ± 3.4^{a}	30.04 ± 2^{a}
PUFA	44.92 ± 2.08^{a}	43.32 ± 1.76^{a}	44.08 ± 2.4^{a}	43.03 ± 1.06^{a}	38.77 ± 3.53^{a}	47.24 ± 1.2^{a}
PUFA/SFA	1.35 ± 0.08^{a}	1.44 ± 0.14^{a}	1.37 ± 0.08^{a}	1.38 ± 0.06^{a}	1.21 ± 0.12^{b}	1.77 ± 0.08^{a}
n-6/n-3	0.31 ± 0.02^{a}	0.29 ± 0.03^{a}	0.4 ± 0.16^{a}	0.31 ± 0.03^{a}	0.43 ± 0.05^{a}	0.58 ± 0.08^{a}
EPA/DHA	0.33 ± 0.04^{a}	0.38 ± 0.01^{a}	0.30 ± 0.03^{b}	0.41 ± 0.02^{a}	0.30 ± 0.04^{b}	0.89 ± 0.44^{a}

Values in the same row with different letters are significantly different (p≤0.05). Mean values from 15 samples ± SE). Fatty acids are expressed in % of total fatty acids.

in wild fish compared with farmed in sea bass (Krajnovic-Ozretic et al., 1994; Alsavar et al., 2002; Periago et al., 2005; Erdem et al., 2009).

In this study, DHA and EPA displayed high content in all studied samples thus increasing the value of wild and farmed sea bass. The n-6/n-3 ratios of dorsal and ventral muscles were similar in both fish types. However, in liver, the highest n-6/n-3 ratio was observed in farmed fish. The UK Department of health recommends an ideal ratio of n-6/n-3 of 4.0 at maximum (HMSO, 1994). Values higher than the maximum value are harmful to health and may promote cardiovascular diseases. In this study, the n-6/n-3 ratio was found to range from 0.29 for dorsal muscle to 0.58 for liver of farmed sea bass. All three studied samples in wild and farmed sea bass had the n-6/n-3 ratio within the maximum value of the recommended ratio. A minimum value of PUFA/SFA ratio recommended is 0.45 (HMSO, 1994) which is lower than those obtained from all studied samples in wild and farmed sea bass. The highest PUFA/SFA ratio was obtained from liver of farmed fish (1.77), the lowest was observed in liver of wild one (1.21). Several studies had reported that fatty acid amount of wild and farmed fish vary mainly with fish natural diet (Sargent et al., 1999). The fatty acid composition of fish may also be influenced by intrinsic (fish species, size and sexual maturity) and extrinsic factors (season, water salinity, temperature, etc.) (Borrensen, 1992; Saito et al., 1999).

Table 5. Mineral concentrations (mg/kg dry weight) of different tissues in wild and farmed sea bass (*D. labrax*).

	Dorsal muscle		Ventral muscle		Liver	
	Wild	**Farmed**	**Wild**	**Farmed**	**Wild**	**Farmed**
K	17071 ± 128^{b}	19180 ± 149^{a}	18056 ± 138^{a}	13030 ± 219^{b}	9580 ± 93^{a}	4425 ± 72^{b}
Na	3000 ± 37^{a}	2987 ± 50^{a}	4054 ± 65^{a}	2123 ± 42^{b}	6350 ± 82^{a}	2647 ± 60^{b}
Ca	1340 ± 73^{b}	2650 ± 58^{a}	2310 ± 52^{a}	1600 ± 46^{b}	800 ± 38^{b}	1030 ± 52^{a}
Mg	1620 ± 51^{a}	1740 ± 68^{a}	1600 ± 65^{a}	1150 ± 58^{b}	880 ± 39^{a}	500 ± 46^{b}
Fe	18.42 ± 2.22^{a}	6.24 ± 1.12^{b}	16.97 ± 1.13^{a}	IND	581.4 ± 42^{a}	134.1 ± 27^{b}
Zn	46.3 ± 1.45^{b}	53.4 ± 1.4^{a}	26.5 ± 1.5^{b}	38 ± 2^{a}	131.8 ± 13.5^{a}	97.2 ± 4.6^{b}
Cu	7 ± 1^{a}	3.7 ± 1.15^{b}	8.3 ± 0.9^{a}	9.7 ± 1^{a}	33.9 ± 6.3^{b}	76.2 ± 7.4^{a}
Mn	9. 8 ± 1.2^{b}	13.6 ± 0.6^{a}	9.02 ± 0.4^{b}	11.45 ± 0.8^{a}	16.6 ± 1^{a}	18.4 ± 0.7^{a}

Values in the same row with different letters are significantly different ($p \leq 0.05$). Values represent the mean of six replicate determinations ± SE.

Mineral content

The concentrations (mg kg^{-1} dry weight) of the studied minerals (Zn, Cu, Fe, Mn, Mg, Na, K and Ca) in dorsal and ventral muscles and liver of wild and farmed sea bass are shown in Table 5. A different concentration of minerals was detected in dorsal and ventral muscles and liver samples. In dorsal and ventral muscle and in liver of wild sea bass the concentrations decreased as follows: K > Na > Mg > Ca > Zn > Fe > Mn > Cu; K > Na > Ca > Mg > Zn > Fe > Mn > Cu; K > Na > Mg > Ca > Fe > Zn > Cu > Mn, respectively. However, in dorsal and ventral muscle and in liver of farmed sea bass, the order was: K > Na > Ca > Mg > Zn > Mn > Fe > Cu; K > Na > Ca > Mg > Zn > Mn > Cu > Fe; K > Na > Ca > Mg > Fe > Zn > Cu > Mn, respectively (Table 5). The comparison between cultured and wild fish by the post hoc analysis (SNK and LSD) revealed that there were statistically significant higher ($p < 0.05$) concentrations of Na (in ventral muscle and liver), K, Mg (in ventral muscle and liver), Ca (in ventral muscle), Zn (in liver), Cu (in dorsal muscle), Fe (in dorsal and ventral muscles and in liver,) and statistically significant lower ($p < 0.05$) concentrations of Mg (in dorsal muscle), K (in dorsal muscle) Ca (in dorsal muscle and in liver), Zn (in dorsal and ventral muscles), Cu (in ventral muscle and in liver), Mn (in dorsal and ventral muscles and in liver,) in wild sea bass ($p < 0.05$). There were no statistically significant differences in the concentrations of Na in dorsal muscle in wild and farmed sea bass ($p > 0.05$) (Table 5).

K was more concentrated in muscles compared to liver in both fish groups. The K contents ranged from 9580 mg/kg for liver to 18056 mg/kg for ventral muscle in wild sea bass and from 4425 mg/kg for liver to 19180 mg/kg for dorsal muscle in farmed fish. These results were higher to those (4597 mg/kg) reported for sea bass by Erkan and Ozden (2007). Na was concentrated in liver of the wild fish while in the farmed ones the highest Na level was observed in dorsal muscle. Differences observed between different tissues in both fish types were statistically significant ($p < 0.05$) except for dorsal muscle. The Na contents ranged from 3000 mg/kg for dorsal muscle to 6350 mg/kg for liver in wild sea bass and it ranged from 2123 mg/kg for ventral muscle to 2987 mg/kg for dorsal muscle in the farmed ones. The contents of Na were higher to those reported by Erkan and Ozden (2007) for sea bass (773 mg/kg) and sea bream (289 mg/kg).

Ca is necessary to maintain an optimal bone development (Erkan and Ozden, 2007). The highest content of Ca was observed in ventral muscle (2310 mg/kg) of the wild sea bass and in dorsal muscle (2650 mg/kg) of the farmed sea bass. In both fish groups, the lowest Na level was found in liver (800 and 1030 mg/kg, respectively). The highest Mg level was observed in dorsal muscle of the wild and the farmed sea bass (1620 and 1740 mg/kg, respectively), while the lowest one was observed in liver (880 and 500 mg/kg, respectively). All the observed differences for Ca and Mg between different tissues in both fish types were statistically significant ($p < 0.05$) except for dorsal muscle. The major elements K, Ca, Na and Mg, essential to cellular metabolism, are very common and generally found in high concentrations in biological tissues (Wagner and Boman, 2003). Fe, Zn, Cu and Mn concentrations were higher ($p < 0.05$) in liver than in the muscles tissues, both in wild and in farmed sea bass. Dorsal muscle accumulated Fe, Zn and Mn, while Cu was concentrated in ventral muscle in both fish groups (Table 5).

Zn is known to be involved in most metabolic pathways in plants, animals and humans (Hambidge, 2000). Cu takes part in enzyme formation and participates in respiratory process, with accumulation levels varying widely among aquatic organisms. Average Zn content of different tissues varied from 26.55 - 131.83 mg/kg in the wild sea bass and 37.96 - 97.22 mg/kg in the farmed ones. The obtained values for Zn contents were higher than those reported by Alsalvar et al. (2002) for farmed and wild sea bass (45.1 and 43.6 mg/kg) and by Erkan and Ozden (2007) for farmed sea bass (2.83 mg/kg). Mean Cu concentrations of different tissues ranged from 7.02 - 33.87 mg/kg in the wild fish and from

3.73 - 76.22 mg/kg in the farmed ones. These results were higher to those reported by Alasalvar et al. (2002) for farmed (3.87 mg/kg) and wild sea bass (2.96 mg/kg). It is known that a variation in the mineral concentrations of marine foods is closely related to seasonal and biological differences (species, size, dark/white muscle, age, sex and sexual maturity), area of catch, processing method, food source and environmental conditions (water chemistry, salinity, temperature and contaminants) (Alasalvar et al., 2002; Turhan et al., 2004; Yeldiz, 2008). Within an individual organism, the concentrations may vary from tissue to tissue and with age (Erkan and Ozden, 2007).

Cu and Zn are essential elements and are carefully regulated by physiological mechanisms in most organisms; they accumulate in porphyrins and enzymes (Bowen, 1979). Also, feeding studies on copper and zinc have indicated the influence of the uptake pathway on their concentrations in fish tissues. While uptake from diet tends to be regulated, uptake from water tends to be proportional to aqueous concentrations (Reinfelder et al., 1998). Despite their toxicity when ingested at excessive concentrations, in human nutrition Cu and Zn are essential nutrients which must be present in the diet at some minimum levels for the maintenance of human health. Comparing the average values with the Canadian food standards (Cu: 100 µg g^{-1}; Zn: 100 µg g^{-1}) and with the range of international standards (Cu: 10 - 100 µg g^{-1}; Zn: 40 - 100 µg g^{-1}), the Cu and Zn concentrations observed in wild and farmed sea bass were lowest and did not exceed the established quality standards for fish.

Several studies have considered fish as a major source of Fe for children and adults (Fraga, 2005). Highest iron amount was observed in the liver of wild fish (581.4 mg kg^{-1}), while in the muscle the Fe concentration ranged from 0 - 18.42 mg/kg in wild and farmed sea bass, respectively. The observed values were lower than those reported by Alasalvar et al. (2002); Erkan and Ozden (2007) and higher than those mentioned by Yeldiz (2008) for wild and farmed Sea bass. The considerably higher Fe concentration in liver is expected due to the physiological role of this organ in blood synthesis (Wagner and Boman, 2003). Fe serves as a carrier of oxygen to the tissues from the lungs by red blood cell haemoglobin, as a transport medium for electrons within cells and as an integrated part of important enzyme systems in different tissues (Wagner and Boman, 2003; Camara et al., 2005).

Daily intake of small amounts of Mn is needed for growth and good health in humans, otherwise deficiency can cause nervous system problems (Agency for Toxic Substances and Disease Registry, 2004). The Mn content of different tissues ranged from 9.01 - 16.58 mg/kg in the wild sea bass and from 11.45 - 18.41 mg/kg in the farmed ones. The results revealed also that Mn contents were significantly higher ($p < 0.05$) in liver of wild and farmed sea bass (16.58 and 18.41 mg/kg, respectively) than in dorsal and ventral muscles (9.78 and 9.02; 13.64 and 11.45 mg/kg, respectively). These values were higher than those reported by Alasalvar et al. (2002); Erkan and Ozden (2007); Yeldiz (2008) for wild and farmed sea bass. Mn belongs to the essential elements which display higher concentrations in liver than in muscle tissues, due to its function as cofactor for the activation of a number of enzymes (Sures et al., 1999).

In the study, the authors determined that there were statistically significant differences in concentrations of Zn (dorsal and ventral muscles), Cu (ventral muscle, liver) and Mn (liver, dorsal and ventral muscles) between wild and farmed fish with higher concentrations in farmed sea bass (Table 5). These higher concentrations may be due to release of minerals from fish diet (minerals concentrations provided in Table 2) and fish excreta. Quality of fish flesh is the result of a complex set of characteristics involving factors such as chemical composition and texture among others. These quality parameters are influenced by fish species, size, sexual maturity, source of nutrients, season, etc) (Borrensen, 1992, Roy and Lall, 2006; Yamashita et al., 2006; Ye et al., 2006). The nutritional value and organoleptic characteristics of fish are especially affected by rearing conditions, so that composition and sensory parameters are expected to be different between wild and farmed fish (Borrensen, 1992). In farmed fish, artificial diets provide a wide range of nutrients, which not only determine fish growth rate but also flesh composition, in particular lipid and mineral contents, which may be quantitatively and qualitatively modified (Izquierdo et al., 2003).

Conclusion

The results enable a positive evaluation of the nutritional quality of wild and farmed sea bass. Both fish types have a comparable nutritional quality characterized by good fat and mineral contents. Significant differences observed in the concentrations of minerals between the two fish groups were mainly related to the fish diet but also to the environmental conditions, fish mobility and ability to concentrate minerals. The lipid fraction in wild and farmed sea bass was characterized by a high proportion of n-3 PUFA, particularly DHA and EPA, and a good n-6/n-3 ratio value which is considered to be an important dietetic parameter because it is the key factor for the balanced eicosanoids synthesis in the human organism (Steffens, 1997).

ACKNOWLEDGEMENTS

This research was in part supported by a grant from Ministère de l'Enseignement Supérieur et de la Recherche Scientifique et de la Technologie 05/UR-09/05 "Physiologie et Ecophysiologie des Organismes Aquatiques" at the Faculty of Sciences of Tunis (Tunisia).

The authors are grateful to all persons who contributed to making this possible research, mainly to the technical staff of the laboratory of Physiology at the Faculty of Medicine of Monastir (Tunisia) and of the laboratory “Milieu Marin”, Institut National des Sciences et Techniques de la Mer, La Goulette Tunis (Tunisia). The authors thank Station of Tunisian Aquaculture (Hergla Tunisia) for supplying the samples.

REFERENCES

Agency for Toxic Substances and Disease Registry (2004). Agency for toxic Substances and Disease Registry, Division of Toxicology, Clifton Road, NE, Atlanta, GA. Available from: http://www.atsdr.cdc.gov/toxprofiles/.

Alasalvar C, Taylor KDA, Zubcov E, Shahidi F, Alexis M (2002). Differentiation of cultured and wild sea bass (*Dicentrarchus labrax*): total lipid content, fatty acid and trace mineral composition. Food. Chem. 79: 145-150.

Belluzzi A (2001). N-3 and n-6 fatty acids for the treatment of autoimmune diseases. Eur. J. Lipid. Sci. Technol. 103: 399-407.

Bligh E G, Dyer WJ (1959). A rapid method of total lipid extraction and purification. Can. J. Biochem. Physiol. 37: 911-917.

Borrensen T (1992). Quality aspects of wild and reared fish. In HH Huss, M Jacobsen, J Liston (Eds.), Quality assurance in the food industry Amsterdam: Elsevier, pp. 1–17.

Bowen HJM (1979). Environmental chemistry of the elements. London: Academic Press, p. 269.

Camara F, Amaro MA, Barbera R, Clemente G (2005). Bioaccessibility of minerals in school meals: comparison between dialysis and solubility methods. Food. Chem. 92: 481-489.

Chen YQ, Edwards JJ, Kridel SJ, Thornburg T, Berquin IM (2007). Dietary fat gene interactions in cancer. Cancer. Metastasis. Rev. 26: 535-551.

Din JN, Harding SA, Valerio CJ, Sarma J, Lyall K, Riermersma RA, Newby DE, Flapan AD (2008). Dietary intervention with oil rich fish
reduces platelet monocyte aggregation in man. Artherosclerosis. 197: 290-296.

Erdem ME, Baki B, Samsun S (2009). Fatty Acid and Amino Acid Compositions of Cultured and Wild Sea Bass (*Dicentrarchus labrax* L., 1758) from Different Regions in Turkey. J. Anim. Vet. Adv. 8(10): 1959-1963.

Erkan N, Ozden O (2007). Proximate composition and mineral contents in aquacultured sea bass (*Dicentrarchus labrax*), sea bream (*Sparus aurata*) analyzed by ICP-MS. Food. Chem. 102: 721-725.

Fraga CG (2005). Relevance, essentiality and toxicity of trace elements in human health. Mol. Aspects. Med. 26: 235-244.

Folch J, Lees M, Sloane-Stanley G H (1957). A simple method for the isolation and purification of total lipids from animal’s tissues. J. Biol. Chem. 226: 497-509.

Craig S, Helfrich L A (2002). Understanding fish nutrition, feeds, and feeding. Virginia Cooperative Extension, Virginia Polytechnic Institute and State University, Publication number pp. 420-256.

Grigorakis K, Alexis MN, Taylor A, Hole M (2002). Comparison of wild and cultured gilthead sea bream (*Sparus aurata*): composition, appearance and seasonal variations. Int. J. Food. Sci. Technol. 37: 1-8.

Hambidge M (2000). Human zinc deficiency. J. Nutr. 130: 1344S-1349S.

Harris WS (2007). Omega-3 fatty acids and cardiovascular disease: A case for omega-3 index as a new risk factor. Pharmacol. Res. 55: 217-223.

HMSO (1994). Nutritional aspects of cardiovascular disease (report on health and social subjects No. 46). London. HMSO.

Izquierdo MS, Obach A, Arantzamendi L, Montero D, Robaina L, Rosenlund G (2003). Dietary lipid sources for sea bream and sea bass: Growth performance, tissue composition and flesh quality. Aquacult. Nutr. 9: 397-407.

Krajnovic-Ozretic M, Najdek M, Ozretic B (1994). Fatty acid in liver and muscle of farmed and wild sea bass (*Dicentrarchus labrax* L.). Comp. Biochem. Physiol. 109: 611-617.

Kris-Etherton P, Harris WS, Appel LJ (2003). Fish consumption, fish oil, omega-3 fatty acids, and cardiovascular disease. Arterioscler. Thromb. Vasc. Biol. 23: 20-31.

Lall SP (2002). The minerals. In: Fish nutrition, 3rd edn. J. E. Halverand R. W. Hardy (Eds). Academic Press, San Diego, CA, pp. 259-308.

Larsson SC, Kumlin M, Ingelman-Sundberg M (2004). A. Wolk., Dietary long chain n-3 fatty acids for the prevention of cancer: a review of potential mechanisms. Am. J. Clin. Nutr. 79: 935-945.

Luzia LA, Sampaio GR, Castellucci CMN, Torres EAFS (2003). The influence of season on the lipid profiles of five commercially important species of Brazilian fish. Food. Chem. 83: 93-97.

Metcalfe LD, Schmitz AA, Pelka JR (1966). Rapid preparation of fatty acids esters from lipids for gas chromatographic analysis. Ann. Chem. 38: 524-535.

Mnari A, Bouhlel I, Chraief I, Hammami M, Romdhane MS, El Cafsi M, Chaouch A (2007). Fatty acids in muscles and liver of Tunisian wild and farmed gilthead sea bream, *Sparus aurata.* Food. Chem. 100: 1393-1397.

Munoz-Olivas R, Camara C (2001). Speciation related to human health. In L. Ebdon, L. Pitts, R. Cornelis, H. Crews, O.F.X. Donard and P. Quevauviller (Eds), Trace element speciation for environment, food and health, pp. 331-353.

Orban E, Di Lena G, Nevigato T, Casini I, Santaroni G, Marzetti A, et al (2002). Quality characteristics of sea bass intensively reared and from lagoon as affected by growth conditions and the aquatic environment. J. Food. Sci. 67: 542-546.

Ozugul Y, Ozugul F (2007). Fatty acids profile of commercially important fish species from the Mediterranean, Aegean and Black Seas. Food. Chem. 100: 1634-1638.

Özyurt G, Polat A (2006). Amino acid and fatty acid composition of wild sea bass (*Dicentrarchus labrax*): A seasonal differentiation. Eur. J. Food. Res. Technol. 222: 316-320.

Periago MJ, Ayala MD, Lopez-Albors O, Abdel I, Martinez C, Garcia-Alcazar A, et al (2005). Muscle cellularity and flesh quality of wild and farmed sea bass, Dicentrarchus labrax L. Aquaculture. 249: 175-188.

Pike HI (1999). Health benefits from feeding fish oil and fish meal. UK: International Fishmeal and Oil Manufactures Association.

Pirini M, Gatta PP, Testi S, Trigari G, Monetti PG (2000). Effect of refrigerated storage on muscle lipid quality of sea bass (*Dicentrarchus labrax*) fed on diets containing different levels of vitamin E. Food. Chem. 68: 289-293.

Pompeia C, Freitas JS, Kim JS, Zyngier SB, Curi R (2002). Arachidonic acid cytotoxicity in leucocytes: implication of oxidative stress and eicosanoids synthesis. Biol. Cell. 94(4-5): 251-265.

Reinfelder JR, Fisher NS, Luoma SN, Nichols JW, Wang WX (1998). Trace elements trophic transfer in aquatic organism: a critique of the kinetic model approach. Sci. Total. Environ. 219: 117-135.

Roy PK, Lall SP (2006). Mineral nutrition of haddock *Melanogrammus aeglefinus* (L.): a comparison of wild and cultured stock. J. Fish. Biol. 68: 1460-1472.

Roynette CE, Calder PC, Dupertuis YM (2004). N-3 Polyunsaturates fatty acids and colon cancer prevention. Clin. Nutr. 23: 139-151.

Saglik S, Alpasian M, Gezgin T, Cetinturk K, Tekinay A, Guven KC (2003). Fatty acids composition of wild and cultivated gilthead seabream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*). Eur. J. Lipid. Sci. Technol. 105: 104-107.

Saito H, Yamashiro R, Alsalvar C, Konno T (1999). Influence of diet on fatty acids of three subtropical fish, subfamily Caesioninae (*Caesio diagramma* and *C. title*) and family Siganidae (*Siganus canaliculatus*). Lipids. 34: 1073-1082.

Sargent J, Bell G, McEvoy L, Tocher D, Estevez A (1999). Recent developments in the essential fatty acid nutrition of fish. Aquaculture. 177: 191-199.

Serot T, Gandemer G, Demaimay M (1998). Lipid and fatty acids compositions of muscle from farmed and wild adult Turbot. Aquacult. Int. 6: 331-343.

Sikorski ZE, Lolakowska A, Pan BS (1990). The nutritive composition of major groups of marine food organisms. In Sikorski ZE (Ed.), Resources Nutritional Composition and Preservation) Boca

Raton, Florida: CRC Press-Inc. pp. 30-52.
Simopoulos P (2002). The importance of the ratio of omega-6/omega-3 essential fatty acids. Biomed. Pharmacother. 56: 365-379.
Steffens W (1997). Effects of variation in essential fatty acids in fish feeds on nutritive value of freshwater fish for humans. Aquaculture. 151: 97-119.
Sures B, Steiner W, Rydlo M, Taraschewski H (1999). Concentrations of 17 elements in the Zebra Mussel (*Dreissena polymorpha*), in different tissues of perch (*Perce fluviatilis*), and in perch intestinal parasites (*Acanthocephalus lucii*) from the subalpine lake Mondsee, Austria. Environ. Toxicol. Chem. 18: 2574-2579.
Tapiero H, Nguyen Ba G, Couvreur P, Tew KD (2002). Polyunsaturated fatty acids (PUFA) and eicosanoids in human health and pathologies. Biomed. Pharmacother. 56: 215-222.
Turkmen A, Turkmen M, Tepe Y, Akyrt I (2005). Heavy metals in three commercially valuable fish species from Iskenderun Bay, Northen East Mediterranean Sea, Turkey. Food. Chem. 91: 167-172.
Turhan S, Ustun SN, Altunkaynak B (2004). Effect of cooking methods on total and heme iron contents of anchovy (*Engraulis encrasicholus*). Food. Chem. 88: 169-172.
UNEP/IAEA/FAO (1990). Determination of total cadmium, zinc, lead and copper in selected marine organisms by atomic absorption spectrophotometer. Reference Methods for Marine Pollution Studies N° 11 Rev. 1149.
Wagner A, Boman J (2003). Biomonitoring of trace elements in muscle and liver tissue of freshwater fish. Spectrochimica. Acta. Part B. 58: 2215-2226.
Yamada K, Kobayashi K, Yone Y (1980). Conversion of linoleic acid to ω_3 highly unsaturated fatty acids in marine fishes and rainbow trout. Bull. Jpn. Soc. Sci. Fish. 46: 1231-1233.
Yamashita Y, Omura Y, Okazaki E (2006). Distinct regional profiles of trace element content in muscle of Japanese eel *Anguilla japonica* from Japan, Taiwan, and China. Fish. Sci. 72: 1109-1113.
Ye CX, Liu YJ, Tian LX, Mai KS, Zhen-Yu Du ZY, Hui-Jun Yang HJ, Niu J (2006). Effect of dietary calcium and phosphorus on growth, feed efficiency, mineral content and body composition of juvenile grouper, *Epinephelus coioides*. Aquaculture. 255: 263-271.
Yildiz M (2008). Mineral composition in fillets of sea bass (*Dicentrarchus labrax*) and sea bream (*Sparus aurata*): a comparison of cultured and wild fish. J. Appl. Ichthyol. 24(5): 589-594.