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Fatty acid profiles of commercially important fish species from the Mediterranean, Aegean and Black Seas

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Abstract

The fat content and fatty acid compositions in the flesh of eight commercially important fish species from the seas of Turkey were evaluated. The fatty acid compositions of wild fish species ranged from 25.5% to 38.7% saturated (SFA), 13.2–27.0% monounsaturated (MUFAs) and 24.8–46.4% polyunsaturated acids (PUFAs). Among them, those occurring in the highest proportions were myristic acid (C14:0, 1.70–10.9%), palmitic acid (C16:0, 15.5–20.5%), palmitoleic acid (C16:1, 2.86–17.0%), stearic acid (C18:0, 3.32–8.18%), oleic acid (C18:1*n*9 *cis*, 6.11–20.8%), linoleic acid (C18:2*n*6, 0.93–4.03%), octadecatetraenoic acid (C18:4*n*3, 0.02–4.55%), *cis*-5, 8, 11, 14, 17-eicosapentaenoic acid (EPA, C20:5*n*3, 4.74–11.7%) and *cis*-4, 7, 10, 13, 16, 19-docosahexaenoic acid (DHA, C22:6*n*3, 7.69–36.2%). The proportions of PUFAs-*n*3 (ranging from 21.7 for mullet to 43.7 for scad) were higher than those of PUFAs-*n*6 (ranging from 1.24 for bogue to 4.34 for red scorpion fish). EPA and DHA were high in all fish species, increasing the value of these fish species.

Keywords: Fatty acids; GC; Seawater fish; EPA; DHA

1. Introduction

The significance of the long chain polyunsaturated fatty acids has gained attention because of the prevention of human coronary artery disease (Conner, 2000; JHCI, 2004; Kinsella, Broughton, & Whelan, 1990; Mozaffarian, Bryson, Lemaitre, Burke, & Siscovick, 2005; Simopoulos, 1991; Ward & Singh, 2005) and improvement of retina and brain development (Crawford, 1993), and also decreased incidence of breast cancer, rheumatoid arthritis, multiple scelerosis, psoriasis and inflammation (Goodnight, Harris, Connor, & Allingworth, 1982; JHCI, 2004; Kinsella, 1988). Marine lipids contain high level of polyunsaturated fatty acids, especially EPA (eicosapentaenoic acid, C20:5*n*3) and DHA (docosahexaenoic acid, C22:6*n*3) (Ackman, 1999). Mozaffarian et al. (2005) reported that consumption of broiled or baked fish, but not fried fish, is associated with lower incidence of congestive heart failure (CHF). General recommendations for daily dietary intakes of DHA/EPA are 0.5 g for infants, and an average of 1 g/day for adults and patients with coronary heart disease (Kris-Etherton, Harris, & Appel, 2001).

Fish are the main contributors of *n*3 PUFA for the human diet. However, there is a big variation in fatty acid compositions of different individual fish of the same species. Diet, location and season are the major factors affecting the fatty acid composition (Gruger, 1967, chap. 1). Researchers have found that freshwater fish contain lower proportions of *n*3 PUFA than do marine fish (Rahman, Huah, Hassan, & Daud, 1995). Therefore, the ratio of total *n*3–*n*6 fatty acids is much higher for marine fish than for freshwater fish, varying from 5 to 10 or more. Nutritionists believe that the desirable ratio *n*6/*n*3 should be 5 and the addition of *n*3 polyunsaturated fatty acids (*n*3 PUFA) could improve nutritional value and prevent diseases (Moreira, Visentainer, de Souza, & Matsushita, 2001).

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Knowledge of the fatty acid composition of commercially important fish species is needed owing to post-mortem deterioration and changes of the nutritional value of fish. The marine lipids also have applications in food, healthcare, pharmaceutical products and as an ingredients in feed, in agriculture and the aquaculture industry. In addition, although Turkey has four seas and a great variety of fish species, the consumption of fish is small and the population should thus be encouraged to change their habits. Therefore, the present paper reports the lipid contents and fatty acid compositions of a range of commercial fish species from Turkish Seas.

2. Materials and methods

2.1. Sample preparation

Eight commercially important fish species were chosen and purchased from the local fish market. These were bogue (*Boops boops*), mullet (*Mugil cephalus*), scad (*Trachurus mediterraneous*), sardine (*Sardinella aurita*), pandora (*Pagellus erythrinus*), red scorpion fish (*Scorpaena scrofa*), turbot (*Scopthalmus maeticus*) and common sole (*Solea solea*). Fish were 2 or 3 days post-captured on arrival at the laboratory in ice. All these species exist in the Mediterranean and Aegean Seas except turbot (Black Sea). At least six individuals from each species were gutted, filletted and minced for analyses.

2.2. FAME analyses

Lipid extraction was done according to the Bligh and Dyermethod (1959). Methyl esters were prepared by transmethylation using 2 M KOH in methanol and *n*-hexane according to the method described by Ichihara, Shibahara, Yamamoto, and Nakayama (1996) with minor modification; 10 mg of extracted oil were dissolved in 2 ml hexane, followed by 4 ml of 2 M methanolic KOH. The tube was then vortexed for 2 min at room temperature. After centrifugation at 4000 rpm for 10 min, the hexane layer was taken for GC analyses.

2.3. Gas chromatographic conditions

The fatty acid composition was analysed by a GC Clarous 500 with autosampler (Perkin–Elmer, USA) equipped with a flame ionization detector and a fused silica capillary SGE column (30 m × 0.32 mm ID × 0.25 μm BP20 0.25 UM, USA). The oven temperature was 140 °C, held 5 min, raised to 200 °C at the rate 4 °C/min and held at 220 °C at 1 °C/min, while the injector and the detector temperatures were set at 220 and 280 °C, respectively. The sample size was 1 μl and the carrier gas was controlled at 16 ps. The split used was 1:100. Fatty acids were identified by comparing the retention times of FAME with the standard 37 component FAME mixture. Two replicate GC analyses were performed and the results were expressed in GC area % as mean values ± standard deviation.

3. Results and discussion

Tables 1 and 2 show the fat content and the fatty acid composition of a range of Turkish seawater species, respectively. The lipid content of fish change due to species, diet, geographical origin and season (Rasoarahona, Barnathan, Bianchini, & Gaydou, 2005). In this study, lipid content ranged from 0.74% for common sole to 3.64% for bogue, which could be classified as lean or semi-fatty fish. Fatty fish usually contain a minimum of 5–8% fat in edible tissue.

Table 2 gives the % as a mean value of 30 FA for each species. The fatty acid compositions of wild fish species ranged from 25.5% to 38.7% saturated (SFA), 13.2–27.0% monounsaturated (MUFAs) and 24.8–46.4% polyunsaturated acids (PUFAs). Among them, those occurring in the highest proportions were myristic acid (C14:0, 1.70–10.9%), palmitic acid (C16:0, 15.5–20.5%), palmitoleic acid (C16:1, 2.86–17.0%), stearic acid (C18:0, 3.32–8.18%), oleic acid (C18:1*n*9 *cis*, 6.11–20.8%), linoleic acid (C18:2*n*6, 0.93–4.03%), octadecatetraenoic acid (C18:4*n*3, 0.02–4.55%), *cis*-5, 8, 11, 14, 17-eicosapentaenoic acid (EPA, C20:5*n*3, 4.74–11.7%) and *cis*-4, 7, 10, 13, 16, 19-docosahexaenoic acid (DHA, C22:6*n*3, 7.69–36.7%). These results are in agreement with previous studies on FA of other species (Chen, Chapman, Wei, Porteir, & O''Keefe, 1995; Luzia, Sampaipo, Castellucci, & Torres, 2003). It was also observed that the proportion of these fatty acids changed significantly between species. All fish species had low levels of 20:4*n*6 (arachidonic acid, 0.08–0.61%), which may be advantageous to consumers for cardiovascular health due to the antagonistic effects to the health benefits of the *n*3 fatty acids (Kinsella, 1986).

The fatty acid profile generally exhibits a dominance of the two classes, SFAs and PUFAs (Table 2). The proportions of PUFAs-*n*3 (ranging from 21.7 for mullet to 43.7 for scad) were higher than those of PUFAs-*n*6 (ranging from 1.24 for bogue to 4.34 for red scorpion 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 (Moreira et al., 2001). In this study, the ratio of *n*6/*n*3 was found to range from

Table 1
The fat contents of fish species *n*:4

Fish species	Fat content (%)
Boops boops (Bogue)	3.64 ± 0.22
Mugil cephalus (Mullet)	2.09 ± 0.07
Trachurus mediterraneous (Scad)	1.37 ± 0.25
Sardinella aurita (Sardine)	3.47 ± 0.25
Pagellus erythrinus (Pandora)	1.67 ± 0.02
Scorpaena scrofa (Red scorpion fish)	0.87 ± 0.04
Scopthalmus maeticus (Turbot)	1.30 ± 0.12
Solea solea (Common sole)	0.74 ± 0.05

Table 2
Fatty acids profiles of fish species *n*:3

Fatty acids (%)	*Boops boops* (Bogue)	*Mugil cephalus* (Mullet)	*Trachurus mediterraneous* (Scad)	*Sardinella aurita* (Sardine)
C12:0	0.04 ± 0.0	0.03 ± 0.0	0.08 ± 0.06	0.16 ± 0.0
C13:0	0.03 ± 0.0	0.02 ± 0.0	0.04 ± 0.05	0.04 ± 0.0
C14:0	2.66 ± 0.02	4.37 ± 0.57	1.99 ± 0.19	10.9 ± 0.08
C15:0	0.60 ± 0.01	0.54 ± 0.02	0.53 ± 0.03	0.61 ± 0.0
C16:0	20.5 ± 0.06	21.5 ± 0.33	17.4 ± 0.45	20.5 ± 0.02
C17:0	0.78 ± 0.0	1.63 ± 0.02	1.03 ± 0.02	0.74 ± 0.0
C18:0	6.83 ± 0.01	3.97 ± 0.04	8.18 ± 0.01	5.14 ± 0.02
C20:0	0.36 ± 0.0	0.11 ± 0.0	0.28 ± 0.10	0.26 ± 0.0
C22:0	0.39 ± 0.01	0.04 ± 0.01	0.19 ± 0.11	0.16 ± 0.0
C23:0	0.04 ± 0.0	0.60 ± 0.01	0.06 ± 0.07	0.21 ± 0.24
C24:0	0.07 ± 0.0	0.08 ± 0.01	0.26 ± 0.10	0.0 ± 0.0
ΣSFA	32.3	32.8	30.1	38.7
C14:1	0.07 ± 0.0	0.06 ± 0.01	0.03 ± 0.04	0.03 ± 0.0
C15:1	0.10 ± 0.0	0.05 ± 0.01	0.03 ± 0.04	0.01 ± 0.0
C16:1	4.48 ± 0.05	17.0 ± 0.32	2.86 ± 0.37	11.7 ± 0.11
C17:1	0.45 ± 0.06	1.94 ± 0.03	0.30 ± 0.11	0.05 ± 0.02
C18:1*n*9	20.80 ± 0.20	6.11 ± 0.07	9.73 ± 0.49	5.57 ± 0.13
C20:1	0.36 ± 0.05	0.57 ± 0.02	0.15 ± 0.01	0.20 ± 0.01
C22:1*n*9	0.61 ± 0.0	0.08 ± 0.0	0.11 ± 0.05	0.04 ± 0.0
C24:1	0.11 ± 0.0	0.03 ± 0.04	0.0 ± 0.0	0.0 ± 0.0
ΣMUFA	27.0	25.8	13.2	17.6
C18:2 *n*6	0.93 ± 0.03	1.79 ± 0.02	1.40 ± 0.20	2.05 ± 0.02
C18:3 *n*6	0.15 ± 0.0	0.36 ± 0.01	0.27 ± 0.02	0.37 ± 0.0
C18:3 *n*3	0.39 ± 0.0	1.38 ± 0.01	0.34 ± 0.02	0.35 ± 0.0
C18:4 *n*3	1.79 ± 0.01	2.10 ± 0.03	1.80 ± 0.04	2.29 ± 0.0
C20:2 *cis*	0.24 ± 0.01	0.45 ± 0.06	0.75 ± 0.49	0.15 ± 0.0
C20:3 *n*6	0.06 ± 0.0	0.35 ± 0.01	0.08 ± 0.04	0.05 ± 0.0
C20:3 *n*3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
C20:4 *n*6	0.10 ± 0.01	0.14 ± 0.0	0.12 ± 0.06	0.61 ± 0.01
C20:5 *n*3	5.09 ± 0.08	10.5 ± 0.14	5.39 ± 0.33	11.7 ± 0.07
C22:2 *cis*	0.04 ± 0.01	0.02 ± 0.02	0.16 ± 0.04	0.20 ± 0.19
C22:6 *n*3	18.7 ± 0.40	7.69 ± 0.25	36.2 ± 0.16	13.3 ± 0.18
ΣPUFA	27.5	24.8	46.4	31.02
PUFA/SFA	0.85	0.75	1.54	0.80
Σ*n*6	1.24	2.64	1.87	3.08
Σ*n*3	26.0	21.7	43.7	27.6
*n*6/*n*3	0.05	0.12	0.04	0.11
DHA/EPA	3.68	0.73	6.70	1.13
Unidentified	13.3	16.6	10.3	12.7

	Pagellus erythrinus (Pandora)	*Scorpaena scrofa* (Red scorpion fish)	*Scopthalmus maeticus* (Turbot)	*Solea solea* (Common sole)
C12:0	0.07 ± 0.0	0.04 ± 0.02	0.02 ± 0.0	0.10 ± 0.01
C13:0	0.02 ± 0.0	0.03 ± 0.01	0.02 ± 0.01	0.04 ± 0.01
C14:0	1.70 ± 0.04	1.97 ± 0.03	2.69 ± 0.36	1.89 ± 0.09
C15:0	0.52 ± 0.0	0.55 ± 0.01	0.57 ± 0.04	1.28 ± 0.06
C16:0	20.2 ± 0.03	18.2 ± 0.10	15.5 ± 0.55	16.8 ± 0.25
C17:0	0.86 ± 0.01	0.81 ± 0.01	0.38 ± 0.04	1.12 ± 0.01
C18:0	7.06 ± 0.13	7.27 ± 0.11	3.32 ± 0.16	6.63 ± 0.01
C20:0	0.31 ± 0.01	0.52 ± 0.04	0.24 ± 0.11	0.44 ± 0.01
C22:0	0.07 ± 0.06	0.22 ± 0.0	0.07 ± 0.04	0.03 ± 0.0
C23:0	0.45 ± 0.30	0.02 ± 0.01	0.15 ± 0.03	1.16 ± 0.01
C24:0	0.10 ± 0.01	0.19 ± 0.04	2.54 ± 0.20	0.11 ± 0.0
ΣSFA	31.33	29.79	25.51	29.60
C14:1	0.04 ± 0.0	0.01 ± 0.01	0.05 ± 0.0	0.01 ± 0.01
C15:1	0.06 ± 0.03	0.04 ± 0.06	0.01 ± 0.01	0.03 ± 0.01
C16:1	4.79 ± 0.24	2.92 ± 0.02	4.28 ± 0.25	5.05 ± 0.16
C17:1	0.44 ± 0.01	0.45 ± 0.06	0.40 ± 0.05	1.45 ± 0.04
C18:1 *n*9	18.3 ± 0.34	13.7 ± 1.12	13.3 ± 0.34	9.11 ± 0.23
C20:1	0.24 ± 0.01	0.13 ± 0.01	3.71 ± 0.33	1.33 ± 0.09
C22:1*n*9	0.10 ± 0.01	0.03 ± 0.0	1.64 ± 0.13	0.25 ± 0.0
C24:1	0.05 ± 0.02	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
ΣMUFA	24.0	17.3	23.4	17.2

Table 2 (*continued*)

Fatty acids (%)	*Pagellus erythrinus* (Pandora)	*Scorpaena scrofa* (Red scorpion fish)	*Scopthalmus maeticus* (Turbot)	*Solea solea* (Common sole)
C18:2 *n*6	0.99 ± 0.01	4.03 ± 0.77	1.87 ± 0.35	1.37 ± 0.09
C18:3 *n*6	0.18 ± 0.0	0.18 ± 0.0	0.17 ± 0.01	0.39 ± 0.01
C18:3 *n*3	0.31 ± 0.0	0.28 ± 0.08	0.46 ± 0.06	0.14 ± 0.01
C18:4 *n*3	2.79 ± 0.0	3.99 ± 0.15	0.02 ± 0.02	4.55 ± 0.06
C20:2 *cis*	0.33 ± 0.02	0.24 ± 0.01	0.42 ± 0.02	0.28 ± 0.01
C20:3 *n*6	0.05 ± 0.01	0.05 ± 0.01	0.09 ± 0.01	0.04 ± 0.0
C20:3 *n*3	0.0 ± 0.0	0.0 ± 0.0	1.85 ± 0.08	0.02 ± 0.02
C20:4 *n*6	0.11 ± 0.0	0.08 ± 0.01	0.18 ± 0.01	0.10 ± 0.03
C20:5 *n*3	5.27 ± 0.15	4.74 ± 0.57	5.25 ± 0.42	7.69 ± 0.02
C22:2 *cis*	0.03 ± 0.01	0.04 ± 0.04	0.08 ± 0.03	0.32 ± 0.01
C22:6 *n*3	21.9 ± 0.18	28.0 ± 1.41	30.3 ± 1.54	18.7 ± 0.37
ΣPUFA	32.0	41.6	41.1	33.6
PUFA/SFA	1.02	1.39	1.61	1.13
Σ*n*6	1.33	4.34	2.31	1.9
Σ*n*3	30.3	37.0	38.4	31.1
*n*6/*n*3	0.04	0.11	0.06	0.06
DHA/EPA	4.15	5.89	5.86	2.42
Unidentified	12.7	11.4	9.97	19.6

0.04 for scad and pandora to 0.12 for mullet. The addition of *n*3 PUFA could improve the nutritional value and protect against diseases (Moreira et al., 2001). A minimum value of PUFA/SFA ratio recommended is 0.45 (HMSO, 1994), which is lower than those obtained from all fish species studied. The highest PUFA/SFA ratio was obtained from turbot (1.61), followed by scad (1.54) and red scorpion fish (1.39), whereas the lowest values were found for mullet (0.75), sardine (0.80) and bogue (0.85).

Palmitic acid (C16:0) was the primary saturated fatty acid, contributing 53–65% of the total saturated fatty acid (SFA) content of lipids for all species. Oleic acid (C18:1 *n*-9) was the most represented of the MUFAs, accounting for 52–79% of total MUFAs for most fish species, whereas palmitoleic acid (C16:1) was the primary MUFA for mullet and sardine, contributing 66% of total MUFAs. The major fatty acids identified as polyunsaturated fatty acids were eicosapentaenoic acid (EPA, C20:5*n*3) and docosahexaenoic acid (DHA, C22:6*n*3). The highest EPA values were obtained from mullet and sardine, accounting for 42% and 38% of total PUFAs, respectively. The high proportion of DHA was found with scad (78%), turbot (75%), pandora (69%), and red scorpion fish (68% of total PUFAs), whereas sardine (43%) and mullet (31%) showed lower DHA contents among fish species. EPA is the most important essential fatty acid of the *n*3 series in the human diet because it is the precursor to the 3-series eicosanoids (Chen et al., 1995). DHA and EPA were reported to be interchangeable by retrogradation (von Schacky and Weber, 1985). It was reported that DHA decreases the concentration of low density lipoprotein cholesterol in plasma (Childs, King, & Knopp, 1990). In this study, EPA and DHA were high in all fish species, increasing the value of these wild fish species compared to cultured fish species (Ackman & Takeuchi, 1986; Chen et al., 1995; Rahman et al., 1995).

It was confirmed that the fatty acid profile of fish muscle reflects the content of the dietary lipid sources (Arzel et al., 1994; Cowey, 1993; Pirini, Gatta, Testi, Trigari, & Monetti, 2000). Compared with freshwater fish, marine fish have higher levels of PUFAs, especially DHA and EPA. In this study, it was observed that seawater species had high levels of the *n*3 series, ranging from 21.7 for mullet and 43.7 for scad. However, the level of the *n*6 series was found to be low, ranging from 1.24 for bogue and 4.34 for red scorpion fish (Table 2). Differences in fatty acids of marine and freshwater fishes should not only be considered with respect to species habitat but also based on their natural diet, especially whether a species is herbivorous, omnivorous or carnivorous (Sargent, Bell, Bell, Henderson, & Tocher, 1995). Apart from that, size, age, reproductive status of fish, environmental conditions, and especially water temperature, influence lipid content and fatty acid composition of fish muscle to a certain extent (Ackman, 1989; Gruger, 1967; Saito, Yamashiro, Alasalvar, & Konno, 1999).

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