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Fish oil for human health: omega-3 fatty acid profiles of marine seafood species

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Abstract

The purpose of this study was to investigate the fat contents and fatty acid profiles of the edible meat of 13 different seafood species caught in the Northeastern Mediterranean coast. The fatty acid compositions of seafood species ranged from 27.68% to 36.59% saturated fatty acids, 8.99% to 35.84% monounsaturated fatty acids and 10.69% to 39.57% polyunsaturated fatty acids. Myristic acid (C14:0, 0.93-5.59%), palmitic acid (C16:0, 13.68-23.89%), palmitoleic acid (C16:1n7, 0.85-6.00%), heptadecanoic acid (C17:0, 0.67-2.23%), stearic acid (C18:0, 6.82-10.89%), vaccenic acid (C18:1n-7, 1.05-4.01%), oleic acid (C18:1n-9, 4.87-28.73%), linoleic acid (C18:2n-6, 0.32-2.63%), arachidonic acid (C20:4n-6, 0.22-0,82%), eicosapentaenoic acid (C20:5n-3, 1.72-10.73%) and docosahexaenoic acid (C22:6n-3, 4.07-31.44%) were the most important fatty acids in most of species. All seafood species had high levels of EPA and DHA and much higher total n-3 PUFA than n-6 PUFA content. The ratio of w6/w3 PUFAs ranged from 0.02 in European squid to 0.48 in striped piggy. Atherogenicity (IA) and Thrombogenicity Index (IT) values ranged from 0.40 to 0.87 and from 0.17 to 0.79, respectively.

Keywords: seafoods; fatty acids; pufa; atherogenicity index; Thrombogenicity Index.

Practical Application: Demonstrate the importance of commercial seafood in terms of human health and nutrition.

1 Introduction

Marine bioactive components from marine resources such as oils from fish, algae and the blubber of of marine mammals (seals and whales) and shark liver contain high level of w3-polyunsaturated fatty acids (PUFA) such as eicosapentaenoic acid (EPA, C20:5w3), docosapentaenoic acid (DPA, C22:5w3) and docosahexaenoic acid (DHA, C22:6 w3), chitin, chitosan, enzymes, peptides, vitamins (A, D and E), seaweeds, protein hydrolysates (Suleria et al., 2016; Rasmussen & Morrissey, 2007; Lordan et al., 2011). Among marine bioactives, fish oils have received much attention in recent years. The importance of long chain n-3 fatty acids found in seafood is known worldwide and essential for the management of cardiovascular diseases. The consumption of polyunsaturated fatty acids, especially EPA and DHA from the omega-3 fatty acid series can prevent the formation of many diseases in humans, especially cardiovascular disorders by reducing risk factors such as heart arrhythmias, blood pressure, triglyceride concentrations and platelet aggregation (Raatz & Bibus, 2016; Fung et al., 2009; Mol, 2008). In addition, human diet enriched with fish oil was determined to have beneficial effects in the prevention of cognitive disorders (Graciano et al., 2016; Pinel et al., 2014) and brain development for children and aged people (He et al., 2017). High-dose fish oil (>6 g/day) and concentrated omega-3 fatty acids (4 g/day) are used as triglyceride lowering agents in patients with significant hypertriglyceridemia (Asztalos et al., 2016). While 1 g fish oil capsule containing up to 200 mg of DHA and 300 mg of EPA is recommended by the health service, two capsules are recommended daily for preventive therapy. DHA is a significant component of the brain, retina and sperm. Problems such as depression, memory loss, Alzheimer's, schizophrenia and visual disorders arise from the decrease of DHA level in brain

cells (Kaya et al., 2004). Children who consumed fish at least twice a week, including one of the fatty fish, were found to be less likely to show emotional and behavioral problems than those did not (Gispert-Llaurado et al., 2016). Rendeiro et al. (2016) suggested that a diet rich in omega-3 PUFAs might help cure neurogenic deficits induced by chemotherapy. Omega-3 fatty acids protect against the development of certain cancers such as breast (Rendeiro et al., 2016; Palmquist, 2009; Stoll, 2002) and prostate cancer (Itsiopoulos et al., 2009). Fish oils are also known to have beneficial effects in diabetic patients (Pinel et al., 2014). Moreover, fatty acids have been reported to have positive effects in the treatment of patients with AIDS (Vieira & Silveira, 2017; Tort et al., 2016). Given the high benefits of consuming seafood in human health, the American Heart Association Nutrition Committee suggests eating fish of 2 or 3 times a week (Kris-Etherton et al., 2003; Mnari et al., 2007).

Oils obtained from seafood are also used in food, pharmaceutical products, and as an ingredients in feeds, agricultural and aquaculture industries (Shepherd & Jackson, 2013). Therefore, the determination of the amount of fat and fatty acids in seafood is essential. Many researchers have investigated the nutritional characteristic of seafood species in the Northeastern Mediterranean (Ozogul et al., 2009; Pethybridge et al., 2014; Cardona et al., 2015). Since the lipit content and fatty acid profiles of seafood are affected by many factors such as diet, salinity, temperature, age, season and sex (Ackman, 1989; Saito et al., 1999; Ozyurt & Polat, 2006; Ozogul et al., 2009), updating of nutritional information of economically important seafood species is important for seafood industry and also consumer health. Therefore, in the current

study an attempt has been made to determine the fat contents and fatty acid profiles of thirteen different seafood species caught in the Northeastern Mediterranean coast.

2 Materials and methods

2.1 Sampling

Thirteen fish species were caught in Northeastern Mediterranean between coordinates 36°43'31.8"N, 34°54'27.0"E and 36°08'53.6"N, 33°39'40.7"E (Figure 1) using a commercial trawler in December 2016. The captured seafoods were 1 or 2 hours post-capture on arrival at the laboratory in ice. The Latin and English names of the 13 different seafood species caught are given in Table 1. 10 individuals from each species were gutted, filleted and muscle tissue (edible muscle) was minced for analyses.

2.2 Lipid Analysis and Fatty Acid Methyl Ester analyses (FAME)

Lipid analysis was performed according to the method of Bligh & Dyer (1959). Extracted lipid, fatty acids methyl esters were performed according to the method of Ichıhara et al. (1996) with minor modifications. 4 mL of 2M KOH and 2 mL of n-heptane were added to 25 mg of extracted oil sample. It was then vortexed for 2 minutes at room temperature and centrifuged at 4000 rpm for 10 minutes at 4 °C and the heptane layers were taken up for gas chromatography (GC) analysis.

2.3 Index of Atherogenicity (IA) and Thrombogenicity (IT)

The index of atherogenicity and the index of thrombogenicity were calculated with the following equations, as proposed by Ulbricht & Southgate (1991), taking into account the different effects of different fatty acids on human's health:

The IA and IT linked to the FA composition were calculated according to Ulbricht & Southgate (1991) (Equations 1, 2). The formulas shown below were used to calculate the index of atherogenicity (IA) and thrombogenicity (IT)

$$IA = \left[(a \; x \; C12:0) + (b \; x C14:0) + (a \; x \; C16:0) \right] / \left[(d \; x \; (PUFAs \; w6 + w3)) + (e \; x \; C18:1n9) + (f \; x \; (MUFAs - C18:1n9)) \right] \quad (1)$$

$$IT = \left[(g \; x \; (C14:0 + C16:0 + C18:0)) \right] / \left[(h \; x \; C18:1n9) + (i \; x \; (MUFAs - C18:1n9)) + (m \; x \; w6) + (n \; x \; w3) + (w3 / w6) \right] \quad (2)$$

a, c, d, e, f = 1, b = 4, g = 1, h, i, m = 0.5 and n = 3

2.4 Statistical analysis

A one-way analysis of variance (ANOVA) was run using the SPSS version 22 software (SPSS, Chicago, Illinois, USA). Duncan's multiple range test at P value of <0.05 were used to evaluate the fat content of seafood species.

3 Results and discussion

3.1 Lipid content

The lipid contents of thirteen different seafood species caught from Mersin Bay in the Northeastern Mediterranean coast are demonstrated in Table 1. Among the seafood species, the highest lipid content was found in shi drum (5.94%) followed by largehead hairtail (3.12%) and striped piggy (3.00%) while the lowest amount of lipid was found in spiny gurnard (0.90%) followed by john dory (1.07%).
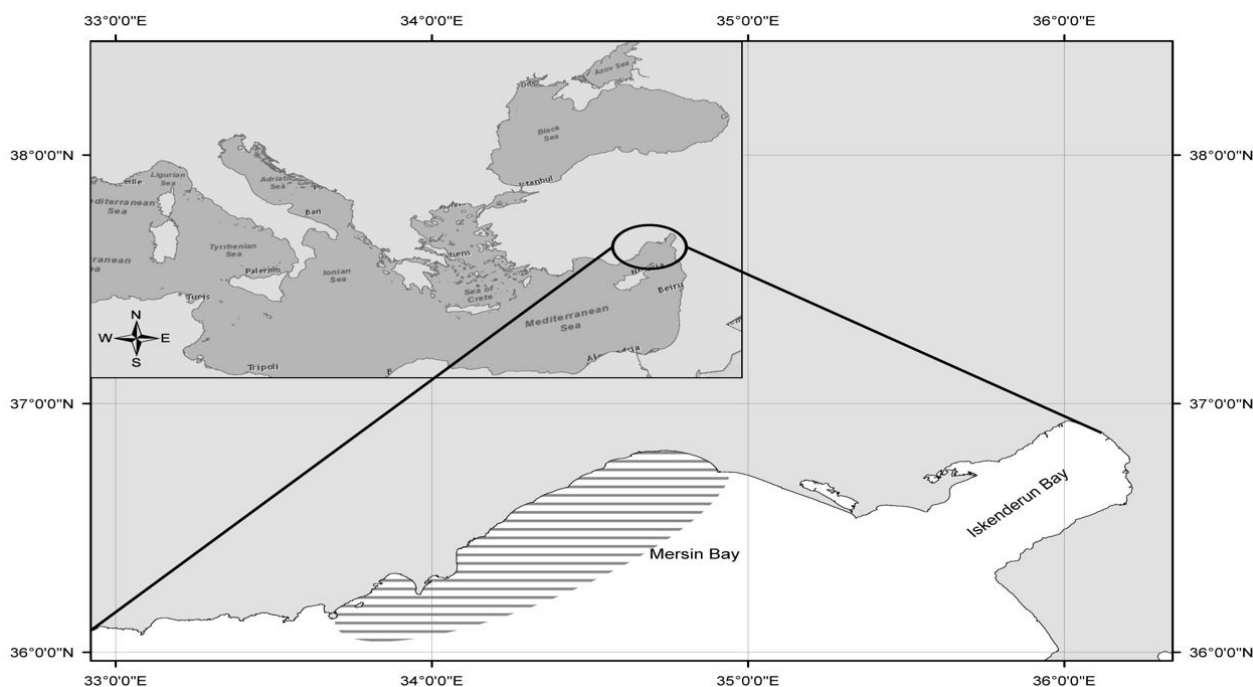

Figure 1. Map of the sampling area.

Table 1. The lipid content of seafood species caught in the Northeastern Mediterranean coast.

Fish	N	English name	Lipit content
Penaeus semisulcatus (De Haan, 1844)	10	Green tiger prawn	1.34 ± 0.06[de]
Alosa fallax (Lacepède, 1803)	10	Twaite shad	1.37 ± 0.09[de]
Umbrina cirrosa (Linnaeus, 1758)	10	Shi drum	5.94 ± 0.34[a]
Zeus faber (Linnaeus, 1758)	10	John dory	1.07 ± 0.12[ef]
Sparus aurata (Linnaeus, 1758)	10	Gilthead seabream	1.27 ± 0.19[def]
Fistularia commersonii (Rüppell, 1838)	10	Bluespotted cornetfish	2.29 ± 0.23[c]
Trichiurus lepturus (Linnaeus, 1758)	10	Largehead hairtail	3.12 ± 0.19[b]
Lepidotrigla dieuzeidei (Blanc & Hureau, 1973)	10	Spiny gurnard	0.90 ± 0.08[f]
Loligo vulgaris (Lamarck, 1798)	10	European squid	1.60 ± 0.07[d]
Boops boops (Linnaeus, 1758)	10	Bogue	1.12 ± 0.14[ef]
Scorpaena notata (Rafinesque, 1810)	10	Small red scorpionfish	1.25 ± 0.16[def]
Serranus cabrilla (Linnaeus, 1758)	10	Comber	1.25 ± 0.06[def]
Pomadasys stridens (Forsskål, 1775)	10	Striped piggy	3.00 ± 0.15[b]

Values are expressed as g/100 g wet weight and are means ± SD. Different letters (a-f) in the same columns for each species significant differences ($p < 0.05$).

The rate of lipid, one of the basic items of fish meat, varies depending on factors such as nutrition, species, season, geographical region, biological condition, age, gender maturity, reproduction and temperature (Rahnan et al., 1995; Yılmaz et al., 1996; Rasoarahona et al., 2005; Lunn & Theobald 2006; Ozogul et al., 2007). Ozogul et al. (2009) investigated fat contents and fatty acid profiles of 34 fish species from the Mediterranean Sea. According to the results, the lowest fat concent was reported in leaping mullet (0.30%) while the highest fat content was determined in keeled mullet (10.67%) followed by European barracuda (8.23%). Li et al. (2011) investigated lipid content and fatty acid profile in edible meats of marine fish, freshwater fish and shrimp from China and reported similar lipid contents in marine fish compared with those in the present study. According to Li et al. (2011), the lipid content ranged from 0.58% in bluefin leather jacket to 7.83% in chub mackerel in marine fish, from 1.71% in swamp eel to 7.43% in black carp in freshwater fish and from 0.46% in ridgetail white prawn to 1.86% in giant freshwater prawn in shrimps. According to the amount of lipid, fish are classified as fatty fish (>10%), medium-fat fish (5-10%) and lean fish (lipid content <5%) (Bennion, 1980). Based on this classification, all seafood in this study except for shi drum were catagorized as lean fish.

3.2 Fatty acid profiles of seafood

The fatty acid profile of 13 seafood species are presented in Table 2. Total saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) percentages of the total lipid ranged from 27.68% to 36.59%, from 8.99% to 35.84% and from 10.69% to 39.57%, respectively. Twenty-three fatty acids in muscle lipids of seafood were classified and evaluated. Important fatty acids detected in most of species were myristic acid (C14:0, 0.93-5.59%), palmitic acid (C16:0, 13.68-23.89%), palmitoleic acid (C16:1n7, 0.85-6.00%), heptadecanoic acid (C17:0, 0.67-2.23%), stearic acid (C18:0, 6.82-10.89%), vaccenic acid (C18:1n-7, 1.05-4.01%), oleic acid (C18:1n-9, 4.87-28.73%), linoleic acid (C18:2n-6, 0.32-2.63%), arachidonic acid (C20:4n-6, 0.22-0,82%), cis-5,8,11,14,17-EPA (C20:5n-3, 1.72-10.73%) and cis-4,7,10,13,16,19-DHA (C22:6n-3, 4.07-31.44%). Similarly, many researchers reported that these fatty acids are major fatty acids in marine seafood species (Ozogul et al., 2007, 2009; Li et al., 2011).

Palmitic acid was the major SFA in the current study as many researchers reported that palmitic acid is a dominant saturated fatty acid (Visentainer et al., 2007; Guler et al., 2008; Li et al., 2011). The lowest palmitic acid level was observed in green tiger prawn while the highest palmitic acid was determined in striped piggy. Stearic acid is the second most important saturated fatty acid. Stearic acid among the total saturated fatty acids varies from 20.66% in largehead hairtail to 35.55% in small red scorpionfish. Tanakol et al. (1999) investigated the fatty acid compositions of 18 fish species caught in the Black Sea and Marmara Sea. These researchers reported that 18 different species of dominant unsaturated fatty acids are palmitic and stearic acid.

Palmitoleic (C16:1n-7) and oleic acid (C18:1n-9) were found to be dominated in monounsaturated fatty acids. It was determined that 17.16% in comber and 79.90% in largehead hairtail of the total mono-saturated fatty acids were these two fatty acids, respectively. Similar to the results of this study, many researchers reported that marine fish contained especially oleic acid (C18: 1n-9) which is dominant fatty acids among MUFAs (Koizumi & Hiratsuka, 2009; Tanakol et al., 1999; Aydın et al., 2013). Guner et al. (1998) identified fatty acid profile in some species of fish commonly consumed in the Black Sea. These researchers found that palmitoleic (C16:1n-7) and oleic acid (C18:1n-9) ranged from 3.76% in whiting to 11.89% in red mullet and from 11.60% in spat to 33.40% in scad, respectively.

Omega-3 and omega-6 fatty acids are called essential fatty acids since they are not synthesized in the human body (Leaf & Weber, 1988). Thus, these fatty acids must be obtained in adequate amounts from diet. Taking these fatty acids from food are of great importance for metabolic health (Brown, 2000). Omega-3 fatty acids are also abundant in the oil of plants and their products such as hazelnut, walnut, sesame, flaxseed, soybean, canola and olive in addition to seafood products while omega-6 fatty acids are high in soya, cotton, corn and sunflower oil (Gogus & Smith, 2010).

Table 2. The fatty acid profile of seafood species caught in the Northeastern Mediterranean coast.

Fatty acid (%)	Green Tiger Prawn	European squid	Gilthead seabream	Shi drum	John dory
C12:0	0.05 ± 0.01[b]	0.02 ± 0.01[c]	0.08 ± 0.00[a]	0.04 ± 0.01[b]	0.00 ± 0.00[d]
C14:0	0.93 ± 0.06[c]	2.36 ± 0.08[a]	1.88 ± 0.08[b]	2.21 ± 0.04[a]	1.00 ± 0.01[c]
C15:0	0.88 ± 0.05[b]	0.70 ± 0.03[c]	0.57 ± 0.03[d]	1.00 ± 0.02[a]	0.57 ± 0.01[d]
C16:0	13.6 ± 0.74[e]	23.0 ± 0.90[a]	17.0 ± 0.01[d]	21.0 ± 0.37[b]	18.8 ± 0.23[c]
C17:0	2.23 ± 0.13[a]	1.32 ± 0.06[b]	0.70 ± 0.01[d]	1.04 ± 0.02[c]	0.96 ± 0.01[c]
C18:0	9.91 ± 0.52[b]	6.88 ± 0.27[d]	8.99 ± 0.05[c]	7.45 ± 0.13[d]	10.6 ± 0.12[a]
C20:0	0.26 ± 0.01[b]	0.11 ± 0.00[c]	0.42 ± 0.03[a]	0.45 ± 0.01[a]	0.24 ± 0.01[b]
C22:0	0.16 ± 0.01[a]	0.03 ± 0.01[c]	0.07 ± 0.01[b]	0.04 ± 0.01[c]	0.09 ± 0.01[b]
C24:0	0.07 ± 0.01[b]	0.08 ± 0.01[b]	0.01 ± 0.00[c]	0.01 ± 0.00[c]	0.15 ± 0.01[a]
Σ SFA	28.14 ± 1.53[b]	34.53 ± 1.32[a]	29.75 ± 0.04[b]	33.29 ± 0.61[a]	32.44 ± 0.40[a]
C14:1	0.18 ± 0.03[b]	0.13 ± 0.01[c]	0.21 ± 0.02[b]	0.33 ± 0.01[a]	0.13 ± 0.01[c]
C15:1	0.33 ± 0.04[a]	0.07 ± 0.00[d]	0.01 ± 0.00[e]	0.25 ± 0.01[b]	0.16 ± 0.01[c]
C16:1	5.31 ± 0.29[a]	0.85 ± 0.04[d]	4.81 ± 0.06[b]	5.13 ± 0.08[ab]	2.20 ± 0.02[c]
C17:1	0.51 ± 0.02[a]	0.14 ± 0.01[d]	0.18 ± 0.01[c]	0.20 ± 0.01[c]	0.24 ± 0.00[b]
C18:1n9	8.53 ± 0.45[d]	5.43 ± 0.21[e]	17.9 ± 0.01[b]	23.26 ± 0.41[a]	11.9 ± 0.13[c]
C18:1n7	3.13 ± 0.16[b]	1.05 ± 0.04[d]	3.03 ± 0.04[bc]	3.75 ± 0.06[a]	2.87 ± 0.04[c]
C20:1n9	0.42 ± 0.02[d]	1.34 ± 0.06[a]	0.73 ± 0.01[b]	1.37 ± 0.03[a]	0.59 ± 0.01[c]
C24:1n9	0.07 ± 0.01[a]	0.12 ± 0.10[a]	0.08 ± 0.00[a]	0.15 ± 0.03[a]	0.06 ± 0.04[a]
Σ MUFA	18.45 ± 0.95[c]	9.11 ± 0.45[d]	27.03 ± 0.01[b]	34.42 ± 0.64[a]	18.19 ± 0.23[c]
C18:2n6	1.26 ± 0.06[a]	0.32 ± 0.01[d]	0.92 ± 0.01[b]	0.77 ± 0.01[c]	0.94 ± 0.01[b]
C18:3n3	0.23 ± 0.01[a]	0.04 ± 0.02[d]	0.06 ± 0.05[cd]	0.15 ± 0.01[b]	0.11 ± 0.01[bc]
C20:2 cis	0.10 ± 0.01[d]	0.13 ± 0.01[c]	0.58 ± 0.01[a]	0.01 ± 0.00[e]	0.24 ± 0.03[b]
C20:3 n6	0.24 ± 0.01[a]	0.07 ± 0.01[c]	0.22 ± 0.04[a]	0.24 ± 0.02[a]	0.12 ± 0.02[b]
C20:4 n6	0.82 ± 0.02[a]	0.22 ± 0.03[e]	0.41 ± 0.02[c]	0.48 ± 0.03[b]	0.30 ± 0.02[d]
C20:5n3	10.7 ± 0.57[a]	7.31 ± 0.31[b]	3.71 ± 0.04[c]	2.83 ± 0.05[d]	3.53 ± 0.05[cd]
C22:2 cis	0.15 ± 0.01[a]	0.06 ± 0.01[c]	0.11 ± 0.02[ab]	0.08 ± 0.01[bc]	0.11 ± 0.02[ab]
C22:6 n3	10.8 ± 0.54[d]	31.4 ± 1.28[a]	13.1 ± 0.15[c]	7.43 ± 0.13[e]	25.1 ± 0.25[b]
Σ PUFA	24.34 ± 1.19[c]	39.57 ± 1.64[a]	19.08 ± 0.01[d]	11.97 ± 0.20[e]	30.48 ± 0.37[b]
PUFA/SFA	0.87 ± 0.01[c]	1.15 ± 0.00[a]	0.64 ± 0.00[d]	0.36 ± 0.00[e]	0.94 ± 0.00[b]
Σn-6	2.31 ± 0.06[a]	0.61 ± 0.02[d]	1.54 ± 0.01[b]	1.49 ± 0.04[b]	1.35 ± 0.02[c]
Σn-3	21.7 ± 1.12[c]	38.7 ± 1.60[a]	16.8 ± 0.01[d]	10.40 ± 0.17[e]	28.80 ± 0.32[b]
Σn-6/Σn-3	0.11 ± 0.00[b]	0.02 ± 0.00[e]	0.09 ± 0.00[c]	0.14 ± 0.00[a]	0.05 ± 0.00[d]
DHA/EPA	1.01 ± 0.00[e]	4.30 ± 0.01[b]	3.54 ± 0.03[c]	2.83 ± 0.05[d]	7.14 ± 0.03[a]
IA	0.41 ± 0.00[e]	0.67 ± 0.0[a]	0.54 ± 0.01[c]	0.65 ± 0.00[b]	0.47 ± 0.00[d]
IT	0.29 ± 0.00[c]	0.17 ± 0.00[e]	0.37 ± 0.00[b]	0.55 ± 0.00[a]	0.26 ± 0.00[d]

Fatty acid (%)	Spiny gurnard	Small red scorpionfish	Twaite shad	Bogue
C12:0	0.09 ± 0.01[a]	0.00 ± 0.00[c]	0.05 ± 0.01[b]	0.02 ± 0.01[c]
C14:0	1.61 ± 0.02[b]	0.96 ± 0.06[d]	3.04 ± 0.01[a]	1.47 ± 0.06[c]
C15:0	0.51 ± 0.01[b]	0.48 ± 0.03[b]	1.42 ± 0.09[a]	0.55 ± 0.02[b]
C16:0	17.0 ± 0.07[b]	16.6 ± 0.67[b]	20.72 ± 0.02[a]	14.2 ± 0.60[c]
C17:0	0.87 ± 0.01[c]	0.96 ± 0.04[b]	1.78 ± 0.04[a]	0.82 ± 0.03[c]
C18:0	9.04 ± 0.04[b]	10.8 ± 0.45[a]	8.99 ± 0.01[b]	9.74 ± 0.43[b]
C20:0	0.38 ± 0.01[b]	0.37 ± 0.01[b]	0.56 ± 0.01[a]	0.38 ± 0.02[b]
C22:0	0.11 ± 0.00[a]	0.09 ± 0.01[b]	0.03 ± 0.00[d]	0.06 ± 0.00[c]
C24:0	0.20 ± 0.01[c]	0.27 ± 0.04[b]	0.02 ± 0.00[d]	0.38 ± 0.02[a]
Σ SFA	29.83 ± 0.15[bc]	30.64 ± 1.28[b]	36.59 ± 0.16[a]	27.68 ± 1.20[c]
C14:1	0.22 ± 0.04[a]	0.09 ± 0.02[c]	0.17 ± 0.02[ab]	0.09 ± 0.03[bc]
C15:1	0.11 ± 0.02[a]	0.14 ± 0.03[a]	0.14 ± 0.01[a]	0.12 ± 0.04[a]
C16:1	3.91 ± 0.01[a]	2.07 ± 0.08[b]	1.53 ± 0.01[c]	1.61 ± 0.07[c]
C17:1	0.26 ± 0.01[c]	0.45 ± 0.02[a]	0.29 ± 0.00[b]	0.17 ± 0.01[d]
C18:1n9	13.6 ± 0.06[a]	8.65 ± 0.33[b]	4.87 ± 0.01[d]	7.43 ± 0.33[c]
C18:1n7	2.96 ± 0.01[a]	2.31 ± 0.08[b]	1.82 ± 0.09[c]	2.23 ± 0.10[b]
C20:1n9	0.63 ± 0.04[a]	0.45 ± 0.01[b]	0.42 ± 0.04[b]	0.56 ± 0.03[a]
C24:1n9	0.02 ± 0.00[d]	0.34 ± 0.04[b]	0.17 ± 0.00[c]	0.40 ± 0.02[a]

SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; EPA, eicosapentaenoic acid; DHA - docosahexaenoic acid; IA, index of atherogenicity; IT index thrombogenicity. Results are the means ± S.D. Different letters (a-d) in the same lines for each species significant differences ($p < 0.05$).

Table 2. Continued...

Fatty acid (%)	Spiny gurnard	Small red scorpionfish	Twaite shad	Bogue
Σ MUFA	21.74 ± 0.04[a]	14.48 ± 0.56[b]	9.39 ± 0.09[d]	12.60 ± 0.56[c]
C18:2n6	1.15 ± 0.06[d]	1.47 ± 0.06[c]	1.83 ± 0.04[b]	2.12 ± 0.09[a]
C18:3n3	0.13 ± 0.03[c]	0.00 ± 0.00[d]	0.39 ± 0.01[a]	0.22 ± 0.00[b]
C20:2 cis	0.14 ± 0.04[a]	0.09 ± 0.04[ab]	0.05 ± 0.01[b]	0.14 ± 0.01[a]
C20:3 n6	0.09 ± 0.03[b]	0.22 ± 0.03[a]	0.19 ± 0.03[a]	0.19 ± 0.01[a]
C20:4 n6	0.37 ± 0.05[b]	0.38 ± 0.04[b]	0.58 ± 0.04[a]	0.56 ± 0.06[a]
C20:5n3	5.73 ± 0.02[a]	3.94 ± 0.31[c]	4.69 ± 0.01[b]	2.65 ± 0.12[d]
C22:2 cis	0.06 ± 0.00[a]	0.14 ± 0.06[a]	0.13 ± 0.01[a]	0.12 ± 0.01[a]
C22:6 n3	23.2 ± 0.11[c]	24.0 ± 1.10[c]	29.4 ± 0.67[b]	32.1 ± 1.48[a]
Σ PUFA	30.86 ± 0.16[b]	30.31 ± 1.55[b]	37.30 ± 0.66[a]	38.09 ± 1.77[a]
PUFA/SFA	1.03 ± 0.00[b]	0.99 ± 0.01[a]	1.02 ± 0.01[b]	1.38 ± 0.00[a]
Σn-6	1.60 ± 0.04[c]	2.07 ± 0.12[b]	2.59 ± 0.04[a]	2.86 ± 0.16[a]
Σn-3	29.06 ± 0.16[b]	28.02 ± 1.41[b]	34.5 ± 0.69[a]	34.98 ± 1.60[a]
Σn-6/Σn-3	0.06 ± 0.00[b]	0.07 ± 0.00[a]	0.08 ± 0.00[a]	0.08 ± 0.00[a]
DHA/EPA	4.05 ± 0.00[c]	6.12 ± 0.20[b]	6.29 ± 0.13[b]	12.14 ± 0.01[a]
IA	0.45 ± 0.00[c]	0.46 ± 0.00[b]	0.71 ± 0.01[a]	0.40 ± 0.00[d]
IT	0.24 ± 0.00[b]	0.27 ± 0.00[a]	0.27 ± 0.01[a]	0.20 ± 0.00[c]
Fatty acid (%)	**Bluespotted cornetfish**	**Largehead hairtail**	**Comber**	**Striped piggy**
C12:0	0.05 ± 0.00[ab]	0.04 ± 0.00[b]	0.08 ± 0.01[a]	0.08 ± 0.02[a]
C14:0	2.12 ± 0.02[c]	3.19 ± 0.01[b]	5.59 ± 0.11[a]	2.24 ± 0.05[c]
C15:0	0.76 ± 0.01[a]	0.43 ± 0.04[c]	0.55 ± 0.01[ab]	0.61 ± 0.17[ab]
C16:0	19.1 ± 0.16[c]	21.5 ± 0.09[b]	17.4 ± 0.25[d]	23.89 ± 0.90[a]
C17:0	1.26 ± 0.01[a]	0.67 ± 0.06[b]	0.81 ± 0.01[b]	0.84 ± 0.15[b]
C18:0	9.58 ± 0.08[a]	6.82 ± 0.02[c]	7.50 ± 0.06[b]	7.14 ± 0.21[c]
C20:0	0.37 ± 0.00[b]	0.31 ± 0.04[c]	0.48 ± 0.00[a]	0.49 ± 0.03[a]
C22:0	0.12 ± 0.01[ab]	0.03 ± 0.00[b]	0.05 ± 0.00[b]	0.22 ± 0.09[a]
C24:0	0.04 ± 0.02[b]	0.02 ± 0.00[b]	0.09 ± 0.01[a]	0.04 ± 0.01[b]
Σ SFA	33.40 ± 0.31[ab]	33.00 ± 0.18[b]	32.59 ± 0.44[b]	35.53 ± 1.61[a]
C14:1	0.15 ± 0.01[bc]	0.18 ± 0.01[b]	0.11 ± 0.03[c]	0.30 ± 0.02[a]
C15:1	0.16 ± 0.02[b]	0.06 ± 0.01[c]	0.22 ± 0.01[a]	0.23 ± 0.04[a]
C16:1	2.97 ± 0.03[d]	4.07 ± 0.10[c]	6.00 ± 0.08[a]	4.86 ± 0.50[b]
C17:1	0.24 ± 0.00[a]	0.20 ± 0.07[a]	0.26 ± 0.02[a]	0.16 ± 0.06[a]
C18:1n9	8.83 ± 0.07[d]	28.7 ± 0.09[a]	12.4 ± 0.11[c]	23.4 ± 1.03[b]
C18:1n7	2.66 ± 0.02[bc]	2.26 ± 0.01[c]	4.01 ± 0.04[a]	3.00 ± 0.42[b]
C20:1n9	0.43 ± 0.01[b]	0.36 ± 0.06[b]	0.35 ± 0.01[b]	2.48 ± 0.11[a]
C24:1n9	0.07 ± 0.04[a]	0.08 ± 0.03[a]	0.04 ± 0.01[a]	0.13 ± 0.05[a]
Σ MUFA	15.49 ± 0.17[d]	35.92 ± 0.12[a]	23.37 ± 0.21[c]	34.53 ± 0.16[b]
C18:2n6	1.82 ± 0.01[b]	0.84 ± 0.06[d]	1.36 ± 0.01[c]	2.63 ± 0.18[a]
C18:3n3	0.37 ± 0.00[a]	0.23 ± 0.05[b]	0.16 ± 0.03[bc]	0.09 ± 0.00[c]
C20:2 cis	0.13 ± 0.01[a]	0.09 ± 0.01[a]	0.02 ± 0.01[b]	0.12 ± 0.03[a]
C20:3 n6	0.06 ± 0.01[b]	0.05 ± 0.00[b]	0.08 ± 0.01[b]	0.37 ± 0.08[a]
C20:4 n6	0.42 ± 0.01[a]	0.23 ± 0.02[b]	0.45 ± 0.05[a]	0.42 ± 0.05[a]
C20:5n3	3.69 ± 0.01[b]	1.72 ± 0.04[d]	5.08 ± 0.03[a]	2.96 ± 0.06[c]
C22:2 cis	0.15 ± 0.02[a]	0.11 ± 0.00[ab]	0.07 ± 0.03[b]	0.06 ± 0.02[b]
C22:6 n3	24.93 ± 0.22[a]	16.6 ± 0.05[b]	15.5 ± 0.08[c]	4.07 ± 0.12[d]
Σ PUFA	31.54 ± 0.27[a]	19.90 ± 0.01[c]	22.75 ± 0.07[b]	10.69 ± 0.00[d]
PUFA/SFA	0.94 ± 0.00[a]	0.60 ± 0.00[c]	0.70 ± 0.01[b]	0.30 ± 0.01[d]
Σn-6	2.29 ± 0.03[b]	1.12 ± 0.04[d]	1.88 ± 0.03[c]	3.41 ± 0.05[a]
Σn-3	28.98 ± 0.21[a]	18.5 ± 0.06[c]	20.78 ± 0.14[b]	7.11 ± 0.06[d]
Σn-6/Σn-3	0.08 ± 0.00[b]	0.06 ± 0.00[c]	0.09 ± 0.00[b]	0.48 ± 0.01[a]
DHA/EPA	6.76 ± 0.07[b]	9.67 ± 0.27[a]	3.06 ± 0.00[c]	1.38 ± 0.07[d]
IA	0.59 ± 0.00[c]	0.62 ± 0.00[c]	0.87 ± 0.01[a]	0.73 ± 0.03[b]
IT	0.28 ± 0.00[c]	0.35 ± 0.00[b]	0.36 ± 0.00[b]	0.78 ± 0.03[a]

SFAs, saturated fatty acids; MUFAs, monounsaturated fatty acids; PUFAs, polyunsaturated fatty acids; EPA, eicosapentaenoic acid; DHA - docosahexaenoic acid; IA, index of atherogenicity; IT index thrombogenicity. Results are the means ± S.D. Different letters (a-d) in the same lines for each species significant differences ($p < 0.05$).

Omega-3 fatty acids such as eicosapentaenoic acid (EPA) and decosahexaenoic acid (DHA) are first synthesized by algae such as *Chlorella pyrenoidosa, Dunaliella salina, Arthrospira platensis* in water (Öztürk, 2014). These fatty acids then accumulate in the fish via the food chain. For this reason, EPA and DHA, which are ω-3 family fatty acids, are essential fatty acids abundantly found in fish (Gordon & Ratliff 1992). Fish, therefore, are an important dietary source for EPA and DHA, which are essential for human metabolic activities (Leaf & Weber, 1988).

The highest amount of total PUFA was observed in the European squid (39.57%), followed by bogue (38.09), twaite shad (37.30%), bluespotted cornetfish (31.54%) and spiny gurnard (30.86%) while the lowest amount of PUFA was determined in the striped piggy (10.69%). Similar results were reported in previous studies (Zlatanos & Laskaridis 2007). The level of EPA in total PUFA, which ranged from 8.64% of total fatty acids in largehead hairtail to 44.08% in green tiger prawn, were always lower than those of DHA in total PUFA, which ranged from 38.07% of total fatty acids in striped piggy to 84.33% in bogue. It was determined that the seafood species investigated had a high nutritional quality in terms of EPA and DHA values. It is well known that EPA plays an important role in the prevention of cardiovascular diseases, brain disorders and cancer treatment while DHA is necessary for the visual function, growth and brain development (Ward & Singh, 2005). Gómez Candela et al. (2011) demonstrated that w-3 (DHA and EPA) plays a role in suppressing the development of many cancers including breast, colon, prostate, liver and pancreatic cancers. Whfoods (The World's Healthiest Foods, 2012) reported that two portions per week of non-fried fish may be sufficient to significantly increase the level of omega-3 fatty acids in the blood.

HMSO UK (Her Majesty's Stationery Office, 1994) suggested that the PUFA / SFA ratio was at least as 0.45. In the present study, the highest PUFA/SFA ratio was observed in bogue (1,38) followed by European squid (1.15), spiny gurnard (1.04) and twaite shad (1.02) while the lowest value was determined in shi drum (0.36). It was determined that all seafood in this study were above the recommended value except for shi drum. Similar to our study, Ozogul et al. (2009) also reported that the ratio of PUFA/SFA was above the recommended value for 34 fish species from the Mediterranean Sea.

Based on the total amount of w6 and w3 PUFA, it was determined that the total w3 amount was more than the total w6 amount in all species in this study. It has been suggested that the ratio of w6/w3 was useful indicators to compare the relative nutritional values of fish oils (Pigott & Tucker, 1990). It was reported that the ratio of omega-6/omega-3 should be kept as low as 1:1 or 2:1 (Gómez Candela et al., 2011; Granados et al., 2006). The UK Department of Health has proposed a rate of w6/w3 of maximum 4 (Her Majesty's Stationery Office, 1994). A low omega-6/omega-3 ratio was associated with a reduced risk of breast cancer in women and also positive affect on asthmatic patients (Simopoulos, 2004). Reduction in the ratio of w6/w3 fatty acids in the human diet was essential to help prevent coronary heart disease and to reduce the risk of cancer (Kinsella et al., 1990). The ratio of w6 PUFAs/w3 PUFAs in total lipids of 13 different seafood species caught in the Northeastern

Mediterranean coast ranged from 0.02 in European squid to 0.48 in striped piggy. Ozogul et al. (2009) found similar results in 34 fish species from the Mediterranean Sea. Similarly, Ayas et al. (2013) reported that the w6/w3 ratio of shrimp varied between 0.2 and 0.7. In this study, w6/w3 ratios were in the range of recommended levels by researcher (Gómez Candela et al., 2011; Granados et al., 2006). In France and Norway daily EPA and DHA intake levels were recommended to be 500 mg/day and 1-2 g/day, respectively (Gómez Candela et al., 2011). The World Health Organization (WHO) recommends this consumption as 0.3-0.5 g/day. Moreover, American Heart Association (AHA) advises adults to consume fish at least twice a week.

Lipid quality indicators that depend on the relative contents of particular groups of FAs are the IA and IT, which indicate the global dietetic quality of lipids and their potential effect on the development of coronary disease (Ulbricht & Southgate 1991). In current study, IA and IT values ranged from 0.40 to 0.87 and from 0.17 to 0.79, respectively (Table 2). The highest IA and IT values were obtained from comber and striped piggy whereas the lowest values were determined in bogue and European squid. Similar to this study, Valfré et al. (2003) reported that the IA and IT values of the different seafoods varied from species to species. Turan et al. (2011) reported that the IT and IA values for brown shrimp were 0.31 and 1.34, respectively. Ayas et al. (2013) found that IA values varied between 0.27 for kuruma prawnin spring and 0.48 for caramote prawn and speckled shrimpin while TI values varied from 0.21 for kuruma prawn and to 0.30 for green tiger prawn, speckled shrimp and deepwater pink shrimp.

4 Conclusion

The w3 fatty acids can be used as pharmaceuticals since the consumption of marine oils provides numerous health benefits. It is well documented that the lipid content and FA profiles of fish vary between/within species even in dark and white muscle, which are affected by many factors i.e. diet, temperature, salinity, season, size, age, spawning period. The current study showed that when the levels of EPA, DHA and w6/w3 are considered, all species were rich in PUFA (especially EPA and DHA) and can be used as good marine oil sources.

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