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Fatty Acid Profile, Lipid and Cholesterol Content, and Nutritional Lipid Quality of Seven Fish Species from the Persian Gulf

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ABSTRACT

A total of seven fish species from the Persian Gulf, belonging to three pelagic, benthopelagic, and demersal habitat groups were evaluated for the fatty acid composition, lipid and cholesterol contents, and nutritional lipid quality characteristics of their edible muscles during winter and summer. The values of lipid (g/100 g) and cholesterol (mg/100 g) varied from 0.66 to 2.74 and 27.80 to 44.91, respectively. Lipid and cholesterol contents of most fish species were significantly higher in summer than in winter. The highest contents of lipid and cholesterol belonged to pelagic and benthopelagic fish species, respectively. All fish species had much higher $\sum$ *n*-3 PUFAs than $\sum$ *n*-6 PUFAs. A higher level of PUFAs and MUFAs was observed during the winter, while a higher content of SFAs was detected in the summer. Low values of index of atherogenicity (< 0.8) and index of thrombogenicity (< 0.5) indicated that all fish species, especially demersal and benthopelagic fish had favorable nutritional lipid quality properties. The results indicated that season and habitat can significantly influence the lipid and cholesterol content, and fatty acid profile of fish muscles.

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Introduction

Over the past few decades, the fish consumption has increased throughout the world because it provides a healthy nutritional source of protein, unsaturated fatty acids, vitamins, and low cholesterol diet (1–4). The essential fatty acids such as docosahexaenoic acid (DHA), eicosapentaenoic acid (EPA), linoleic acid, linolenic acid and, arachidonic acid are not sufficiently synthesized by humans to meet their necessary metabolic needs; therefore these fatty acids should be entered into the human body via consumption of seafood-based dishes (5). Also, recommendations for sufficient intakes of the omega-3 fatty acids have been highlighted by expert nutritionists in recent years (5, 6). In fact, the role of n-3 fatty acids or a balanced n-3/n-6 ratio in the diet are necessary for normal human growth and prevention of different diseases or disorders such as coronary heart disease, asthma, arthritis, diabetes, cancers, hypotension, and psoriasis (7). According to authentic literature, a well-balanced food of n-3/n-6 ratio being equal to 1/1 to 1/2 is highly recommended (8).

According to Annual Fishery Statistics of Iran (2017), the annual per capita fish consumption increased from 8.1 kg in 2012 to 10.6 in 2016. Also, the total amount of marine fish caught in Iran was estimated 600802 tons in 2016 which mainly belonged to the Persian Gulf (9). Countries surrounding the Persian Gulf are Iran (with the longest coastline), Iraq, Kuwait, Qatar, Saudi Arabia, and United Arab Emirates. (2, 10). The Persian Gulf is considered as the main source of seafood for these countries. In the Persian Gulf, the open period of routine fishing activities is approximately restricted to a period between November and May.

Several investigations have indicated that there are remarkable differences in the fatty acid profiles, lipid, and cholesterol levels among different fish species. In addition, these differences depend on factors such as season, age, depth of habitat, water temperature, size, and season (7, 11).

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It is estimated that the Persian Gulf is inhabited by more than seven hundred fish species (12). Many of these species are being considered as the most well-known saltwater fish species all over the world. To our best knowledge, no comprehensive study has been carried out on the fatty acid profile, cholesterol content, and indices of nutritional quality of the majority of fish species of the Persian Gulf under the influence of season and habitat. Therefore, knowing the different nutritional aspects or constituent properties of commercially important fish species from the Gulf along with being acquainted with the factors affecting these properties is useful and inevitable.

Thus, the objectives of this study are as below:

(i) To determine the fatty acid profile and cholesterol content of seven commercially fish species from the Persian Gulf.

(ii) To assess the three classified pelagic, benthopelagic, and demersal habitat groups according to their fatty acids profile, lipid, and cholesterol content.

(iii) To assess the influence of season on the fatty acids profile, lipid, and cholesterol content of the tested fish species.

(iv) To evaluate the nutritional indices and quality characteristics of lipids of the studied fish species.

Materials and Methods

Fish Sampling

Seven fish species, including fourteen individuals from each species, were collected from Bandar Abbas, which is one of the most important fishing ports of the Persian Gulf from July to September (summer) of 2016 and January to March (winter) of 2017. The fish species were collected according to their remarkable economic and dietary importance. In addition, only marketable-size fish samples were selected according to their average weights and lengths and immediately transported in clean plastic bags covered with ice, to the laboratory. Upon arrival at the laboratory, the fish species were confirmed and classified in three habitat groups including: pelagic (*Scomberomorus commerson*: narrow-barred Spanish mackerel and *Thunus tonggol*: long tail tuna), benthopelagic (*Otolithes ruber*: tiger tooth croaker, *Pampus argenteus*: silver pomfret, and *Parastromateus niger*: black pomfret), and demersal (*Acanthopagrus latus*: yellowfin seabream and *Psettodes erumei*: Indian spiny turbot) (12). Thereafter, length (cm) and weight (kg) measurements were taken on single specimens (Table 1). The fish were beheaded, eviscerated, washed with deionized water and the excess water was removed by a water drawer. The muscle tissues were filleted and kept frozen (– 18 °C) in polyethylene pouches until further analysis.

Lipid and Cholesterol Determination

According to Thammapat et al. (13), the lipid content was determined gravimetrically with slight modifications. Briefly, the lipids were extracted from 2 g of each sample using 20 mL of chloroform:methanol (2:1 v/v) containing BHT (10 ppm) as an antioxidative agent. The mixture then was homogenized for 2 min and the homogenate was filtered. In order to recover maximum lipid content, the residue was re-extracted by three successive washes with 10 mL of chloroform:methanol and re-filtered. The filtrate was then centrifuged (10000 × *g*, for 10 min), evaporated under vacuum, and total lipid quantification was performed gravimetrically. In addition, extracted lipids were stored at – 18 °C until further analysis.

The total cholesterol content in the fillet of the fish species was determined according to a study conducted by De Hoff et al. (14), which was based on an enzymatic assay. All measurements were carried out in triplicate.

Fatty Acid Analysis

To prepare fatty acid methyl esters (FAMEs), the IUPAC standard method No. 2.301 (15) was applied. Briefly, 100 mg of the extracted lipid was dissolved in 20 mL methanol. Potassium hydroxide (1 N solution) was added as the alkaline catalyst, which was then refluxed for 60 min. Subsequently, 10 mL of hexane was added to extract the esterified fatty acids. The FAMEs were analyzed with an Agilent 6890N gas chromatograph (Agilent Technologies, Santa Clara, CA, USA) fitted with an HP-88 capillary column (100 m × 0.25 mm i.d., × 0.2 µm film thickness; Agilent Technologies), and a flame ionization detector (FID). Detector and injector temperatures were adjusted at 250 ˚C and 240 ˚C, respectively. The oven temperature was initiated at 160 ˚C for 2 min. Then, the temperature of the column was raised to 180 ˚C at 4 ˚C/min, raised again to 200 ˚C at 1 ˚C/min, and finally held at 200 ˚C for 42 min. The total run time of each analysis was 69 min. Helium was used as carrier gas at a

linear velocity of 1.0 mL/min; and the split ratio was 1:10. The internal standard applied was nonadecanoic acid methyl ester (C19:0). The FAMEs were identified by comparing the retention time of the chromatographic peak of each sample with that of the commercial standard FAME mix 47885-U (Supelco, Germany). The limit of detection (LOD) of C16:0, C18:1, and C18:3 was 0.015, 0.011, and 0.009 mg/kg, respectively. Also, the limit of quantification (LOQ) of the C16:0, C18:1, and C18:3 was 0.028, 0.023, and 0.024 mg/kg, respectively. The calibration curves coefficients (R^2) for the C16:0, C18:1, and C18:3 were greater than 0.98. The LOD and LOQ values and the R^2 indicated the validity of the method.

Table 1 Lipid (g/100 g wet weight) and cholesterol (mg/100 g wet weight) contents, fatty acid composition (% of total fatty acids), and nutritional indices of muscle tissues of two pelagic fish species from the Persian Gulf (mean ± SD).

Analyte	**Pelagic fish species**					
	Scomberomorus commerson			***Thunnus tonggol***		
	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter
Lipid	3.21 ± 0.55[a]	2.26 ± 0.34[b]	2.74 ± 0.66	1.61 ± 0.12[a]	1.04 ± 0.15[b]	1.32 ± 0.32
Cholesterol	44.96 ± 3.10[a]	36.99 ± 3.0[b]	40.97 ± 5.11	33.09 ± 1.29[a]	26.83 ± 1.32[b]	29.96 ± 3.56
Fatty acids						
C14:0	7.19 ± 0.71[a]	5.95 ± 0.6[b]	6.47 ± 0.90	4.92 ± 0.59[a]	3.69 ± 0.38[b]	4.31 ± 0.80
C16:0	19.15 ± 0.9[a]	16.55± 0.54[b]	17.8 ± 1.49	19.6 ± 0.78[a]	17.65 ± 0.97[b]	18.63 ± 1.33
C17:0	0.51 ±0.18[a]	0.30 ± 0.09[a]	0.40 ± 0.17	0.31 ± 0.08[a]	0.33 ± 0.08[a]	0.32 ± 0.08
C18:0	8.5 ± 0.76[a]	6.92 ± 0.3[b]	7.60 ± 1.0	9.06 ± 0.65[a]	6.83 ± 0.76[b]	7.95 ± 1.36
C20:0	0.5 ± 0.15[a]	0.41 ± 0.11[a]	0.35 ± 0.13	0.10 ± 0.03	Nd	0.10 ± 0.03
C22:0	nd	0.10 ± 0.01	0.1 ± 0.01	0.11 ± 0.03[a]	0.09 ± 0.04[a]	0.10 ± 0.03
C24:0	0.16± 0.04[a]	0.17 ± 0.06[a]	0.16 ± 0.05	0.11 ± 0.02[a]	0.1 ± 0.02[a]	0.10 ± 0.02
∑ SFA	36.22 ± 1.72[a]	30.66 ± 1.01[b]	33.42 ± 3.24	34.20 ± 1.11[a]	28.71 ± 1.6[b]	31.45 ± 3.21
C16:1 *n*-7	6.0 ±0.35[a]	6.53 ± 0.94[a]	6.27 ± 0.72	3.89 ± 0.26[a]	3.86 ± 0.34[a]	3.88 ± 0.28
C17:1	0.65± 0.11[a]	0.57 ± 0.11[a]	0.61 ± 0.11	0.55 ± 0.18[a]	0.43 ± 0.11[a]	0.49 ± 0.15
C18:1 *n*-9	16.2 ± 1.06[a]	17.36 ±1.0[a]	16.8 ± 1.12	15.02 ± 0.84[a]	15.46 ± 0.56[a]	15.24 ± 0.7
C20:1 *n*-9	0.6 ± 0.14[a]	0.81 ± 0.09[b]	0.71 ± 0.15	0.69 ± 0.19[a]	0.87 ± 0.28[a]	0.78 ± 0.25
C22:1 *n*-9	0.37 ± 0.06[a]	0.51 ± 0.16[a]	0.44 ± 0.13	0.67 ± 0.09[a]	0.64 ± 0.20[a]	0.65 ± 0.15
C24:1 *n*-9	0.74 ± 0.055[a]	0.81 ± 0.06[a]	0.78 ± 0.06	0.33 ± 0.10[a]	0.24 ± 0.09[a]	0.28 ± 0.10
∑ MUFA	24.62 ± 1.32[a]	26.58 ± 1.48[a]	25.6 ± 1.67	21.15 ± 0.65[a]	21.53 ± 1.16[a]	21.34 ± 0.89
C18:2 *n*-6	1.97 ± 0.48[a]	2.04 ± 0.42[a]	2.00 ± 0.42	0.94 ± 0.16[a]	1.27 ± 0.13[b]	1.11 ± 0.22
C18:3 *n*-3	0.93 ± 0.17[a]	1.00 ± 0.14[a]	0.97 ± 0.15	1.21 ± 0.24[a]	1.37 ± 0.28[a]	1.29 ± 0.26
C20:2 *n*-6	0.27 ± 0.08[a]	0.22 ± 0.02[a]	0.25 ± 0.06	nd	0.13 ± 0.04	0.13 ± 0.04
C20:3 *n*-6	nd	0.17 ± 0.11	0.17 ± 0.11	nd	0.09 ± 0.07	0.09 ± 0.07
C20:3 *n*-3	0.48 ± 0.17[a]	0.59 ± 0.05[a]	0.54 ± 0.13	0.39 ± 0.10[a]	0.50 ± 0.16[a]	0.45 ± 0.13
C20:4 *n*-6	1.7 ± 0.40[a]	1.76 ± 0.28[a]	1.73 ± 0.32	2.02 ± 0.18[a]	2.55 ± 0.39[b]	2.28 ± 0.40
C20:5 *n*-3 (EPA)	7.56 ± 0.42[a]	8.54 ± 0.30[b]	8.05 ± 0.62	10.11 ± 1.31[a]	12.24 ± 0.39[b]	11.18 ± 1.44
C22:5 *n*-3	1.31 ± 0.38[a]	1.42 ± 0.39[a]	1.36 ± 0.37	1.29 ± 0.16[a]	1.24 ± 0.07[a]	1.27 ± 0.11
C22:6 *n*-3 (DHA)	20.67 ± 1.94	23.24 ± 0.72	21.79 ± 1.81	25.87 ± 1.5[a]	28.86 ± 1.68[b]	27.37 ± 2.17
∑ PUFA	34.91 ± 2.88[a]	38.05 ± 0.85[b]	36.96 ± 2.94	41.82 ± 2.36[a]	48.22 ± 1.78[b]	45.03 ± 3.93
∑ *n*-3	30.97 ± 2.86[a]	34.45 ± 0.85[b]	32.72 ± 2.7	38.86 ± 2.47[a]	44.21 ± 1.43[b]	41.54 ± 3.42
∑ *n*-6	3.95 ± 0.06[a]	3.23 ± 0.54[b]	3.59 ± 0.53	2.94 ± 0.19[a]	4.03 ± 0.57[b]	3.48 ± 0.7
***n*-3/*n*-6**	7.84 ± 0.69[a]	10.9 ± 1.8[b]	9.37 ± 2.08	12.23 ± 2.66[a]	11.12 ± 1.59[a]	11.67 ± 2.1
PUFA/SFA	0.96 ± 0.05[a]	1.27 ± 0.05[b]	1.11 ± 0.17	1.22 ± 0.04[a]	1.68 ± 0.15[b]	1.45 ± 0.27
AI	0.79 ± 0.04[a]	0.62 ± 0.05[a]	0.71 ± 0.1	0.62 ± 0.03[a]	0.47 ± 0.03[b]	0.54 ± 0.09
TI	0.3 ± 0.008[a]	0.23 ± 0.01[b]	0.26 ± 0.04	0.24 ± 0.01[a]	0.18 ± 0.01[b]	0.21 ± 0.03

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid; AI: index of atherogenicity; TI: index of thrombogenicity. [a,b]Different superscript letters indicate significant differences ($P < 0.05$) between summer and winter.

Fatty Acid Quality Indices

The polyunsaturated fatty acids/saturated fatty acids (PUFAs/SFAs) ratio cannot be merely attributed to the incidence of coronary heart diseases (16). Therefore, the nutritional lipid quality of the studied fish species were assessed by calculating the indices of atherogenicity (AI) and thrombogenicity (TI) (Ulbricht & Southgate, 1991), using the following equations:

$$\mathbf{AI} = \frac{[\mathrm{C12{:}\,0} + (4 \times \mathrm{C14{:}\,0}) + \mathrm{C16{:}\,0}]}{[\sum MUFA + PUFA(n-6) + (n-3)]}$$

$$\mathbf{TI} = \frac{(C14{:}\,0 + C16{:}\,0 + C18{:}\,0)}{[(0.5 \times MUFA) + (0.5 \times \sum PUFA(n-6) + (3 \times \sum PUFA(n-3) + (n-3)/(n-6)]}$$

Statistical Analysis

All results of the analyses are reported as the mean ± standard deviation (SD). Statistical analyses were performed using the GraphPad InStat software version 3 package (GraphPad Software Inc., San Diego, Calif., U.S.A.). Comparisons between the parameters were done by one-way analysis of variance (ANOVA). Differences were considered statistically significant at a probability of $P < 0.05$.

Table 2 Lipid (g/100 g wet weight) and cholesterol (mg/100 g wet weight) contents, fatty acid composition (% of total fatty acids), and nutritional indices of muscle tissues of three benthopelagic fish species from the Persian Gulf (mean ± SD).

Analyte	Benthopelagic fish species								
	Otolithes ruber			*Pampus argenteus*			*Parastromateus niger*		
	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter
Lipid	1.18 ± 0.11[a]	0.98 ± 0.12[b]	1.08 ± 0.15	2.24 ± 0.24[a]	1.92 ± 0.21[a]	2.08 ± 0.27	2.46 ± 0.23[a]	2.22 ± 0.18[a]	2.34 ± 0.23
Cholesterol	42.99 ± 0.84[a]	39.78 ± 2.8[a]	41.39 ± 2.57	47.76 ± 0.59[a]	42.06 ± 1.54[b]	44.91 ± 3.23	57.19 ± 3.32[a]	50.01 ± 1.58[b]	53.60 ± 4.53
Fatty acids									
C14:0	3.03± 0.39[a]	3.13 ± 0.61[a]	3.06 ± 0.48	5.62± 0.89a	5.74 ± 0.91a	5.68 ± 0.84	2.87 ± 0.32[a]	2.55 ± 0.28[a]	2.71 ± 0.33
C16:0	20.91 ± 1.16[a]	21.14 ± 0.64[a]	21.02 ± 0.87	28.03 ± 1.54[a]	28.4 ± 1.55[a]	28.21 ± 1.45	27.63 ± 1.93[a]	25.55 ± 1.3[a]	26.59 ± 1.89
C17:0	0.29 ± 0.09[a]	0.4 ± 0.11[a]	0.35 ± 0.11	1.93 ± 0.21[a]	1.62 ± 0.35[a]	1.78 ± 0.31	2.09 ± 0.33[a]	1.55 ± 0.18[b]	1.82 ± 0.38
C18:0	5.9 ± 0.73[a]	5.71 ± 0.39[a]	5.8 ± 0.56	7.84 ± 0.7[a]	7.53 ± 0.47[a]	7.69 ± 0.58	8.36 ± 0.9[a]	7.73 ± 0.65[a]	8.05 ± 0.81
C20:0	0.26 ± 0.04[a]	0.27 ± 0.05[a]	0.26 ± 0.05	0.9 ± 0.15[a]	0.95 ± 0.12[a]	0.93 ± 0.13	0.24 ± 0.16[a]	0.25 ± 0.08[a]	0.25 ± 0.12
C22:0	0.09 ± 0.06[a]	0.13 ± 0.04[a]	0.11 ± 0.05	0.13 ± 0.05[a]	0.18 ± 0.07[a]	0.15 ± 0.06	nd	0.13 ± 0.06	0.13 ± 0.06
C24:0	0.19± 0.05[a]	0.32 ± 0.17[a]	0.32 ± 0.17	nd	0.08 ± 0.01	0.08 ± 0.01	0.35 ± 0.16[a]	0.43 ± 0.14[a]	0.39 ± 0.14
∑ SFA	30.66± 1.57[a]	31.08 ± 1.03[a]	30.88 ± 1.26	44.45 ± 2.0[a]	44.51± 1.97[a]	44.48 ± 1.84	41.55 ± 1.34[a]	38.2 ± 0.84[b]	39.88 ± 2.07
C16:1 *n*-7	6.84 ± 0.75[a]	7.96 ± 0.72[b]	7.4 ± 0.91	4.55 ± 0.51[a]	3.88 ± 0.21[b]	4.21 ± 0.51	4.14 ± 0.34[a]	5.66 ± 0.84[b]	4.9 ± 1.01
C17:1	nd	nd	nd	0.55 ± 0.07[a]	0.39 ± 0.11[a]	0.47 ± 0.12	nd	nd	nd
C18:1 *n*-9	15.32 ± 0.53[a]	16.38 ± 1.14[a]	15.85 ± 0.99	20.16 ± 1.54[a]	20.31 ± 0.65[a]	20.24 ± 1.10	18.06 ± 0.79[a]	20.07 ± 1.03[b]	19.07 ± 1.37
C20:1 *n*-9	0.23 ± 0.06[a]	0.31 ± 0.05[a]	0.27 ± 0.07	1.36 ± 0.37[a]	1.48 ± 0.25[a]	1.42 ± 0.30	1.32 ± 0.32[a]	1.86 ± 0.28[b]	1.59 ± 0.40
C22:1 *n*-9	0.12 ± 0.03[a]	0.16 ± 0.02[a]	0.14 ± 0.03	0.84 ± 0.25[a]	0.81 ± 0.13[a]	0.83 ± 0.19	0.73 ± 0.26[a]	0.86 ± 0.13[a]	0.8 ± 0.21
C24:1 *n*-9	0.68 ± 0.17[a]	0.79 ± 0.13[a]	0.74 ± 0.15	0.69 ± 0.29[a]	0.71 ± 0.16[a]	0.70 ± 0.21	0.16 ± 0.04[a]	0.36 ± 0.09[b]	0.26 ± 0.13
∑ MUFA	23.21 ± 0.49[a]	25.6 ± 0.73[b]	24.39 ± 1.4	28.15 ± 1.25[a]	27.60 ± 0.64[a]	27.87 ± 0.96	24.41 ± 0.94[a]	28.91 ± 1.41[b]	26.57 ± 2.49
C18:2 *n*-6	1.1 ± 0.16[a]	1.16 ± 0.13[a]	1.13 ± 0.14	1.5 ± 0.24[a]	1.88 ± 0.22[b]	1.69 ± 0.29	0.85 ± 0.24[a]	0.93 ± 0.17[a]	0.89 ± 0.2
C18:3 *n*-3	1.0 ± 0.18[a]	1.06 ± 0.17[a]	1.04 ± 0.17	0.5 ± 0.11[a]	0.9 ± 0.09[b]	0.7 ± 0.23	1.07 ± 0.28[a]	1.49 ± 0.24[b]	1.28 ± 0.33
C20:2 *n*-6	0.1 ± 0.07[a]	0.12 ± 0.03[a]	0.11 ± 0.06	0.28 ± 0.05[a]	0.3 ± 0.03[a]	0.29 ± 0.04	1.46 ± 0.52[a]	1.86 ± 0.41[a]	1.66 ± 0.48
C20:3 *n*-6	0.56 ± 0.09[a]	0.49 ± 0.10[a]	0.53 ± 0.10	1.28 ± 0.27[a]	1.1 ± 0.10[a]	1.19 ± 0.21	0.24 ± 0.08[a]	0.26 ± 0.09[a]	0.25 ± 0.08
C20:3 *n*-3	1.05 ± 0.15[a]	1.24 ± 0.27[a]	1.15 ± 0.23	nd	0.38 ± 0.14	0.38 ± 0.14	nd	0.18 ± 0.04	0.18 ± 0.04
C20:4 *n*-6	3.22 ± 0.38[a]	3.56 ± 0.43[a]	3.39 ± 0.42	2.13 ± 0.39[a]	2.13 ± 0.25[a]	2.13 ± 0.3	3.55 ± 0.52[a]	4.13 ± 0.11[a]	3.84 ± 0.46
C20:5 *n*-3 (EPA)	9.47 ± 0.57[a]	10.62 ± 0.56[b]	10.05 ± 0.81	3.14 ± 0.5[a]	4.27 ± 0.47[b]	3.7 ± 0.75	3.17 ± 0.47[a]	4.48 ± 0.58[b]	3.83 ± 0.56
C22:5 *n*-3	2.92 ± 0.33[a]	2.71 ± 0.31[a]	2.81 ± 0.32	2.63 ± 0.31[a]	3.49 ± 0.34[b]	3.06 ± 0.55	1.69 ± 0.35[a]	2.41 ± 0.49[b]	2.05 ± 0.55
C22:6 *n*-3 (DHA)	16.49 ± 0.61[a]	17.51 ± 1.07[b]	17.0 ± 0.97	12.33 ± 0.6[a]	14.52 ± 0.31[b]	13.29 ± 1.12	10.1 ± 0.88[a]	13.42 ± 0.7[b]	11.76 ± 1.92
∑ PUFA	36.15 ±1.34[a]	38.48 ± 1.43[b]	37.21 ± 1.86	23.81 ± 1.27[a]	28.18 ± 1.09[b]	26.15 ± 2.82	22.28 ± 1.17[a]	28.33 ± 1.37[b]	25.31 ± 3.44

Analyte	Benthopelagic fish species								
	Otolithes ruber			*Pampus argenteus*			*Parastromateus niger*		
	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter
∑ *n*-3	30.96 ± 1.09[a]	33.13 ± 1.24[b]	32.04 ± 1.59	18.6 ± 1.41[a]	23.28 ± 0.73[b]	20.94 ± 2.71	16.03 ± 0.69[a]	21.98 ± 0.68[b]	19.0 ± 3.25
∑ *n*-6	4.99 ± 0.41[a]	5.34 ± 0.45[a]	5.17 ± 0.44	5.20 ± 0.59[a]	5.31 ± 0.67[a]	5.26 ± 0.59	6.1 ± 0.74[a]	7.2 ± 0.58[b]	6.64 ± 0.91
***n*-3/*n*-6**	6.21 ± 0.43[a]	6.43 ± 0.51[a]	6.32 ± 0.46	3.62 ± 0.54[a]	4.44 ± 0.55[b]	4.02 ± 0.68	2.65 ± 0.29[a]	3.08 ± 0.18[b]	2.86 ± 0.34
PUFA/SFA	1.17 ± 0.03[a]	1.25 ± 0.04[b]	1.21 ± 0.05	0.53 ± 0.04[a]	0.64 ± 0.03[b]	0.59 ± 0.07	0.54 ± 0.04[a]	0.74 ± 0.04[b]	0.64 ± 0.12
AI	0.56 ± 0.02[a]	0.52 ± 0.03[a]	0.54 ± 0.03	0.97 ± 0.07[a]	0.91 ± 0.08[a]	0.94 ± 0.07	0.84 ± 0.05[a]	0.62 ± 0.02[b]	0.73 ± 0.13
TI	0.26 ± 0.008[a]	0.24 ± 0.01[b]	0.24 ± 0.01	0.55 ± 0.05[a]	0.46 ± 0.03[b]	0.5 ± 0.06	0.58 ± 0.03[a]	0.41 ± 0.006[b]	0.5 ± 0.09

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid; AI: index of atherogenicity; TI: index of thrombogenicity. [a,b]Different superscript letters indicate significant differences ($P < 0.05$) between summer and winter.

Results and Discussion

Lipid and cholesterol contents

The lipid and cholesterol contents in the edible fillet of seven fish species from the Persian Gulf are presented in Tables 1–3. Both these compounds were influenced by the interactions of species, habitat, and season effects. The fish can be classified into four groups according to their lipid content as lean fish (< 2%), low-fat (2-4 %), medium fat (4-8 %), and high-fat fish (> 8%) (17). Accordingly, the analyzed fish can be classified as lean to low fat fish. The samples collected in winter had lower lipid content in all fish species. However, the lipid contents in the flesh of silver pomfret and black pomfret in winter and summer seasons were not significantly different. The highest content of the lipid (2.74 ± 0.66 g/100 g wet weight) was found in the narrow-barred Spanish mackerel, while the lowest lipid content (0.66 ± 0.14 g/100g wet weight) was measured in the yellowfin seabream. In general, lipid content of fish changes over wider ranges than other components of the proximate composition. This mainly reflects the seasonal and nutritional variations at the time of sampling (18). As it was mentioned above, the routine fishing activity period in the Persian Gulf is approximately restricted to a period between November and May. This indicates that the pre-spawning and spawning periods for most of the species of the Persian Gulf are confined to late spring and summer season. On the one hand, the possible diet shortage in winter can decrease the lipid content (19), and on the other hand, the need for energy reservation and translocation of the lipid as the main energy source to gonads and reproductive organs in spawning period could result in a variable diminishment in fat contents of muscles (20). However, the results of our investigation have indicated the supposition that reproductive changes may have a more prominent influence than the nutritional conditions have on the lipid content. The values of lipid content in *S. commerson* and *T. tonggol* are somewhat comparable to that of investigations conducted by Puwastien et al. (21) and Sahari et al. (22), respectively. However, the lipid content of ordinary muscles of *T. tonggol* caught in the Japan Sea and analyzed by Saito et al. (23) was lower than the one measured in our study. The average lipid contents of *S. commersoni* sampled in February 2010 from three different harbors (Qeshm, Bostanu, and Salkh) on the Persian Gulf (22), and from the Qeshm Island in the Persian Gulf in November 2005 (24) were higher than the lipid contents of the identical species in the present study. According to authentic literature, the lipid content could even fluctuate within the individuals of the same species. Such fluctuations in the lipid content were reported by other investigators in case of tiger tooth croaker, silver pomfret, black pomfret, yellowfin seabream, and Indian spiny turbot from different geographical locations of the world (25–29).

Table 3 Lipid (g/100 g wet weight) and cholesterol (mg/100 g wet weight) contents, fatty acid composition (% of total fatty acids), and nutritional indices of muscle tissues of two demersal fish species from the Persian Gulf (mean ± SD).

Analyte	**Demersal species**					
	Acanthopagrus latus			***Psettodeserumei***		
	Summer	Winter	Means of summer and winter	Summer	Winter	Means of summer and winter
Lipid	0.76 ± 0.10[a]	0.56 ± 0.10[b]	0.66 ± 0.14	0.96 ± 0.08[a]	0.72 ± 0.08[b]	0.84 ± 0.15
Cholesterol	30.53 ± 2.51[a]	25.08 ± 1.76[b]	27.80 ± 3.54	39.27 ± 0.95[a]	35.03 ± 1.08[b]	37.15 ± 2.45
Fatty acids						
C14:0	1.97 ± 0.19[a]	1.76 ± 0.34[a]	1.86 ± 0.28	4.69 ± 0.47[a]	4.36 ± 0.45[a]	4.53 ± 0.46
C16:0	14.22 ± 0.80[a]	13.46 ± 0.56[a]	13.84 ± 0.76	18.14 ± 1.28[a]	17.37 ± 0.97[a]	17.76 ± 1.13
C17:0	0.49 ± 0.11[a]	0.52 ± 0.11[a]	0.51 ± 0.10	1.6 ± 0.42[a]	1.00 ± 0.36[b]	1.30 ± 0.48
C18:0	8.62 ± 0.92[a]	7.96 ± 0.28[a]	8.29 ± 0.72	10.65 ± 0.63[a]	9.78 ± 0.50[b]	10.22 ± 0.71
C20:0	nd	0.12 ± 0.03	0.12 ± 0.03	0.26 ± 0.20[a]	0.30 ± 0.08[a]	0.28 ± 0.14
C22:0	0.97 ± 0.16[a]	0.75 ± 0.18[a]	0.86 ± 0.20	0.52 ± 0.12[a]	0.53 ± 0.07[a]	0.52 ± 0.09
C24:0	0.26 ± 0.07[a]	0.24 ± 0.07a	0.25 ± 0.07	nd	Nd	nd
∑ SFA	26.54 ± 1.25[a]	24.78 ± 0.36[b]	25.66 ± 1.27	35.88 ± 1.79[a]	33.32 ± 1.63[a]	34.61 ± 2.09
C16: 1 *n*-7	4.52± 0.47[a]	5.36 ± 0.49[b]	4.94 ± 0.63	6.57 ± 0.92[a]	7.50 ± 0.54[a]	7.03 ± 0.86
C17:1	nd	nd	nd	nd	0.2 ± 0.05	0.2 ± 0.05
C18:1 *n*-9	11.6 ± 0.82[a]	12.54 ± 0.65[a]	12.07 ± 0.85	9.18 ± 0.58[a]	10.41 ± 0.77[b]	9.79 ± 0.91
C20:1 *n*-9	0.71 ± 0.21[a]	0.78 ± 0.08[a]	0.74 ± 0.15	1.06 ± 0.22[a]	0.71 ± 0.13[b]	0.88 ± 0.25
C22:1 *n*-9	0.88 ± 0.09[a]	1.02 ± 0.18[a]	0.95 ± 0.15	0.23 ± 0.06[a]	0.25 ± 0.03[a]	0.24 ± 0.05
C24:1	0.22 ± 0.07[a]	0.23 ± 0.08[a]	0.22 ± 0.07	nd	Nd	nd
∑ MUFA	17.93 ± 1.27[a]	19.92 ± 0.90[b]	18.92 ± 1.47	17.04 ± 1.15[a]	19.07 ± 1.10[b]	18.06 ± 1.50
C18:2 *n*-6	9.03 ± 1.0[a]	9.6 ± 0.28[a]	9.31 ± 0.75	4.57 ± 0.71[a]	4.86 ± 0.45[a]	4.71 ± 0.57
C18:3 *n*-3	3.22 ± 0.63[a]	4.04 ± 0.26[b]	3.63 ± 0.62	1.98 ± 0.50[a]	2.99 ± 0.60[b]	2.48 ± 0.74
C20:2 *n*-6	1.09 ± 0.12[a]	1.23 ± 0.18[a]	1.16 ± 0.16	nd	0.35 ± 0.09	0.35 ± 0.09
C20:3 *n*-6	0.61 ± 0.13[a]	0.53 ± 0.27[a]	0.57 ± 0.20	0.24 ± 0.06[a]	0.24 ± 0.03[a]	0.24 ± 0.04
C20:3 *n*-3	nd	0.18 ± 0.05	0.18 ± 0.05	0.31 ± 0.14[a]	0.73 ± 0.17[b]	0.52 ± 0.27
C20:4 *n*-6	5.4 ± 0.74[a]	6.05 ± 0.63[a]	5.72 ± 0.73	7.57 ± 0.83[a]	7.59 ± 1.20[a]	7.58 ± 0.96
C20:5 *n*-3 (EPA)	7.55 ± 0.67[a]	7.78 ± 1.06[a]	7.67 ± 0.83	5.33 ± 0.74[a]	8.35 ± 0.44[b]	6.84 ± 1.71
C22:5 *n*-3	2.79 ± 0.62[a]	4.17 ± 0.82[b]	3.48 ± 1.0	0.31 ± 0.10[a]	0.52 ± 0.13[b]	0.41 ± 0.16
C22:6 *n*-3 (DHA)	16.82 ± 1.39[a]	17.56 ± 0.49[a]	17.19 ± 1.04	18.48 ± 0.80[a]	21.56 ± 0.49[b]	20.02 ± 1.76
∑ PUFA	46.52 ± 0.78[a]	50.88 ± 1.43[b]	48.70 ± 2.56	38.81 ± 0.80[a]	47.03 ± 1.75[b]	42.92 ± 4.57
∑ *n*-3	30.4 ± 1.43[a]	33.73 ± 1.0[b]	32.07 ± 2.12	26.41 ± 0.85[a]	34.15 ± 0.77[b]	30.28 ± 4.21
∑ *n*-6	16.13 ± 1.51[a]	17.39 ± 1.24[a]	16.76 ± 1.45	12.42 ± 0.72[a]	13.02 ± 1.11[a]	12.72 ± 0.92
***n*-3/*n*-6**	1.90 ± 0.24[a]	1.95 ± 0.14[a]	1.92 ± 0.18	2.16 ± 0.17[a]	2.63 ± .0.20[b]	2.39 ± 0.31
PUFA/SFA	1.75 ± 0.09[a]	2.04 ± 0.11[b]	1.90 ± 0.18	1.08 ± 0.05[a]	1.41 ± 0.04[b]	1.25 ± 0.18
AI	0.34 ± 0.004[a]	0.29 ± 0.02[b]	0.32 ± 0.03	0.66 ± 0.05[a]	0.52 ± 0.03[b]	0.59 ± 0.08
TI	0.23 ± 0.02[a]	0.19 ± 0.01[b]	0.21 ± 0.02	0.35 ± 0.02[a]	0.26 ± 0.01[b]	0.3 ± 0.05

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; EPA: eicosapentaenoic acid; DHA: docosahexaenoic acid; AI: index of atherogenicity; TI: index of thrombogenicity. [a,b]Different superscript letters indicate significant differences ($P < 0.05$) between summer and winter.

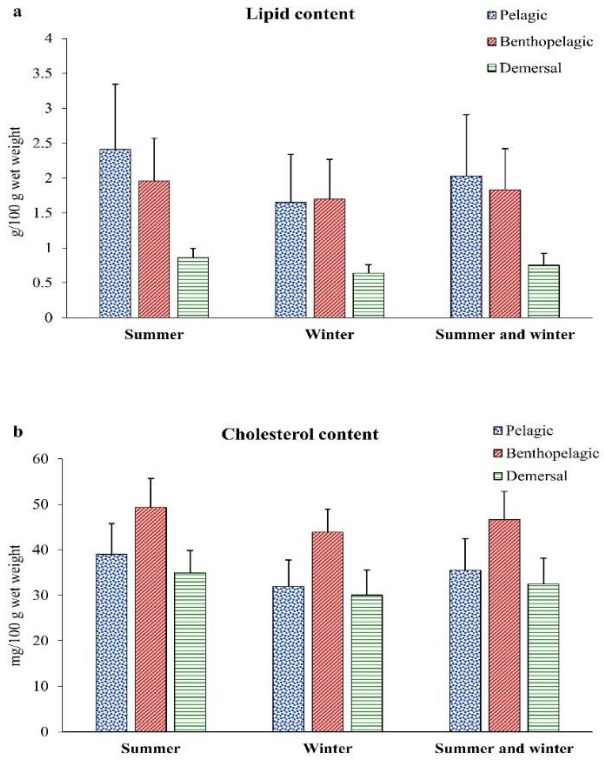

Figure 1. Contents of lipid (g/100 g; a) and cholesterol (mg/100 g; b) in muscle tissues of pelagic, benthopelagic, and demersal fish species from the Persian Gulf.

Lipid content of pelagic, benthopelagic, and demersal fish species in summer, winter, and summer and winter are shown in Figure 1a. The results showed statistically significant differences ($P < 0.05$) between sums of lipid concentrations (summer + winter) in pelagic, benthopelagic, and demersal fish species. Fish of the pelagic and demersal habitat presented the highest and the lowest percentages of lipid content, respectively. In general, this is consistent with the finding that pelagic fish, as oily fish, could effectively accumulate fat in their muscles. In contrast, as a general rule, demersal fish with meat which is whiter in colour mainly accumulate the fat in liver tissue (28, 29).

Similar to the seasonal variations in the lipid content, the cholesterol content of the analyzed fish species was higher in the summer when compared to the winter. The cholesterol content of the analyzed fish species ranged between 27.80 ± 3.54 to 53.60 ± 4.53 mg/100g (Tables 1–3). According to the habitat, the cholesterol content in the fish species can be categorized as follows: benthopelagic (46.63 ± 6.24 mg/100g) >pelagic (35.47 ± 7.11 mg/100g) >demersal (32.48 ± 5.65 mg/100g) (Figure 1b). Mathew et al. (1999) reported the content of cholesterol in several fish species of Indian waters (26). According to their study, the mean level of cholesterol in *P. niger*, *P. argenteus*, *O. ruber*, and *P. erumei* were reported to be equal to 60.2, 44, 41.6 and 41.7 mg/100g. Results of a Malaysian investigation showed that the mean content of cholesterol in *S. commerson*, *P. niger*, and *P. argenteus* were 41.8, 46.8 and 40.3 mg/100g, respectively. Sahari et al. reported that the sampled *T. tonggol* and *S. commersoni* from the harbors of Bostanu, Qeshm and Salkh of the

Persian Gulf were composed of 26.99 ± 14.23 and 45.65 ± 10.21 mg/100g of cholesterol (22). Our values on cholesterol contents are close and comparable to those values found by the abovementioned studies. Based on the data of the present study, there was no regular relation pattern between cholesterol and lipid contents. This means that an increase in the total fat couldn't essentially cause an increase in cholesterol and vice versa.

Table 4 Fatty acid composition and nutritional indices of muscle tissues of pelagic, benthopelagic, and demersal fish species from the Persian Gulf (mean ± SD).

Fish habitat	Season	Fatty acid (%)					*n*-3/*n*-6	PUFA/SFA	AI	TI
		SFA	MUFA	PUFA	∑ *n*-3	∑ *n*-6				
Pelagic	Summer	35.17 ± 1.69^{a}	22.89 ± 2.09^{a}	38.36 ± 4.42^{a}	34.92 ± 4.89^{a}	3.44 ± 0.56^{a}	10.03 ± 2.94^{a}	1.09 ± 0.15^{a}	0.71 ± 0.1^{a}	0.27 ± 0.03^{a}
	Winter	29.63 ± 1.59^{b}	24.05 ± 2.97^{a}	43.63 ± 5.11^{b}	39.35 ± 5.33^{a}	3.63 ± 0.68^{a}	11.01 ± 1.60^{a}	1.48 ± 0.24^{b}	0.54 ± 0.09^{b}	0.2 ± 0.03^{b}
	Summer and winter	32.40 ± 3.27^{A}	23.47 ± 2.55^{A}	40.99 ± 5.36^{A}	37.13 ± 5.45^{A}	3.53 ± 0.61^{A}	10.52 ± 2.34^{A}	1.28 ± 0.28^{A}	0.63 ± 0.12^{A}	0.24 ± 0.05^{A}
Benthopelagic	Summer	38.89 ± 6.38^{a}	25.25 ± 2.63^{a}	27.29 ± 6.54^{a}	21.86 ± 6.88^{a}	5.43 ± 0.74^{a}	4.16 ± 1.62^{a}	0.75 ± 0.31^{a}	0.79 ± 0.19^{a}	0.46 ± 0.15^{a}
	Winter	37.93 ± 5.87^{a}	27.37 ± 1.68^{b}	31.84 ± 5.05^{b}	26.13 ± 5.26^{a}	5.94 ± 1.05^{a}	4.58 ± 1.41^{a}	0.88 ± 0.27^{a}	0.68 ± 0.18^{a}	0.37 ± 0.09^{b}
	Summer and winter	38.41 ± 6.01^{B}	26.31 ± 2.28^{B}	29.56 ± 6.16^{B}	23.99 ± 6.37^{B}	5.69 ± 0.92^{B}	4.37 ± 1.50^{B}	0.81 ± 0.30^{B}	0.74 ± 0.19^{B}	0.42 ± 0.13^{B}
Demersal	Summer	31.21 ± 5.19^{a}	17.48 ± 1.22^{a}	42.66 ± 4.18^{a}	28.41 ± 2.40^{a}	14.28 ± 2.27^{a}	2.03 ± 0.24^{a}	1.41 ± 0.36^{a}	0.51 ± 0.17^{a}	0.29 ± 0.07^{a}
	Winter	29.06 ± 4.69^{a}	19.49 ± 1.03^{b}	48.96 ± 2.53^{b}	33.94 ± 0.86^{b}	15.21 ± 2.58^{a}	2.29 ± 0.40^{a}	1.75 ± 0.32^{b}	0.41 ± 0.13^{a}	0.22 ± 0.04^{b}
	Summer and winter	30.13± 4.91^{A}	18.49 ± 1.50^{C}	45.81 ± 4.66^{C}	31.17 ± 3.35^{C}	14.74 ± 2.39^{C}	2.16 ± 0.34^{C}	1.58 ± 0.37^{C}	0.45 ± 0.16^{C}	0.26 ± 0.06^{A}

SFA: saturated fatty acids; MUFA: monounsaturated fatty acids; PUFA: polyunsaturated fatty acids; AI: index of atherogenicity; TI: index of thrombogenicity. ^{a,b}Different superscript letters indicate significant differences (P < 0.05) between summer and winter. ^{A,B}Different superscript letters indicate significant differences (p < 0.05) between sum of summer and winter of pelagic , benthopelagic, and demersal fish species.

Fatty acid profile

Fatty acid profiles in fillet of the selected fish species are presented in Tables 1–3. Regardless of fish species variations, the major fatty acids in SFAs, MUFAs, and PUFAs classes were palmitic (C16:0), oleic (C18:1n-9), and DHA (C22:6 *n*-3), respectively. Silver pomfret and black pomfret had the greatest SFAs percentages. In addition, the highest PUFAs percentages were measured in the flesh of yellowfin seabream, long tail tuna and, Indian spiny turbot and the highest MUFAs percentages were measured in the flesh of silver pomfret, black pomfret, and narrow-barred Spanish mackerel. As shown in Tables 1–3, the total PUFAs content in the analyzed fish species were higher than the SFAs content, except for silver pomfret and black pomfret. Previous studies have shown marked variations in fatty acid composition of muscle tissues of similar fish species.

Although the total SFAs content in all fish species was quantitatively higher in summer than in winter; the significant differences (P < 0.05) were observed for narrow-barred Spanish mackerel, long tail tuna, black pomfret, and yellowfin seabream. In contrast, the total MUFAs content of fish samples was higher in winter than in summer, except for silver pomfret. In addition, the content of total PUFAs in seven analyzed fish species were significantly (P < 0.05) higher in winter than in summer.

All of the analyzed fish species demonstrated high levels of n-3 PUFAs (ranging from 16.03 ± 0.69% to 38.86 ± 2.47% in summer; and from 21.98 ± 0.68% to 44.21 ± 1.43% in winter), but low levels of n-6 PUFAs (ranging from 2.94 ± 0.19% to 16.13 ± 1.51% in summer; and from 3.23 ± 0.54% to 17.39 ± 1.24% in winter) (Tables 1–3). Accordingly, most of the examined fish exhibited a favourable n-3/n-6 ratio, especially in the winter season. The highest value of n-3/n-6 ratio belonged to long tail tuna (11.67 ± 2.1), followed by narrow-barred Spanish mackerel (9.37 ± 2.08), whereas, the lowest values of n-3/n-6 ratios belonged to yellowfin seabream

(1.92 ± 0.18), Indian spiny turbot (2.39 ± 0.31), and black pomfret (2.86 ± 0.34). The n-3/n-6 ratio of tiger tooth croaker and silver pomfret was equal to 6.32 ± 0.46 and 4.02 ± 0.68, respectively (Table 2). It has been suggested that a dietary intake of seafood with high n-3/n-6 ratio could be beneficial for citizens of developed societies who tend to intake more n-6 PUFAs via normal diet (30). It should be noted that the carnivore fish are able to accumulate markedly n-3 PUFAs in their muscles. In fact, the fatty acid chain elongation and complete desaturation are carried out in muscles of prey fish before being consumed by carnivore fish (31). As a result, narrow-barred Spanish mackerel and long tail tuna as pelagic carnivore fish are rich in longer-chain n-3 PUFAs. Feeding habit is reported to have a significant effect on total MUFAs content of marine fish (32). As omnivorous/planktivorous fish, the silver and black pomfret had higher amount of MUFAs than the carnivorous fish of the present study (Tables 1–4). This could be due to the consumption of MUFA-rich marine invertebrate and copepods by omnivorous/planktivorous fish (32). Among the investigated fish, the carnivore fish including Spanish mackerel, long tail tuna, tiger tooth croaker, and yellowfin seabream can be classified according to their trophic levels. According to Li, Sinclair, and Li (33), carnivore fish with high trophic levels had higher levels of total PUFAs and EPA + DHA content. In contrast, our results have indicated that PUFAs content of Spanish mackerel and long tail tuna with high trophic level (≥ 4.0) was lower than the PUFAs content of yellowfin seabream with a low trophic level (3.20). However, similar to the results of Li et al. (33), the content of EPA + DHA was higher in high trophic carnivores than in low trophic carnivores. Based on the results, EPA + DHA content in meat of long tail tuna (trophic level: 4.1), Spanish mackerel (trophic level: 4.5), tiger tooth croaker (trophic level: 3.6), and yellowfin seabream (trophic level: 3.2) were 38.85, 29.94, 27.05, and 24.86%, respectively.

Table 4 shows the fatty acid composition of the fish species based on their habitat. The SFAs percentages order can be ranged as follows: benthopelagic > pelagic > demersal. A similar pattern was observed for MUFAs. In addition, PUFAs showed the demersal > pelagic > benthopelagic pattern. Despite the higher percentage of total PUFAs in fillet of demersal fish species, a significantly ($P < 0.05$) higher level of n-3 PUFAs was detected in pelagic fish species in comparison to demersal and benthopelagic ones. It has been reported that the pelagic fish are characterized by significant higher levels of n-3 PUFAs, particularly EPA and DHA, compared to demersal and benthic fish (29). In contrast, the level of n-6 PUFAs was significantly ($P < 0.05$) higher in demersal fish species when compared to pelagic and benthopelagic ones.

3.3. Health and nutritional indices and characteristics with regard to lipids

The AI is a quantitative criterion to assess the effect of different fatty acids on the plasma cholesterol of human. The saturated fatty acids, especially the myrisitic acid (C14:0) are atherogenic, whereas the unsaturated fatty acids can decrease the atherogenicity effect (34). The TI refers quantitatively to the degree of the effect of various fatty acids on platelet aggregation in the cardiovascular system. The SFAs are thrombogenic, whereas the MUFAs and the PUFAs from n-3 and n-6 classes are anti-thrombogenic (35). The higher the AI and TI values, the higher the risk of cardiovascular diseases (36). The indices of atherogenicity (AI) and thrombogenicity (TI) are displayed in Tables 1–3. The lowest AI values in summer (0.34 ± 0.004) and winter (0.29 ± 0.02) were obtained for yellowfin seabream; whereas the highest AI values in summer (0.97 ± 0.07) and winter (0.91 ± 0.08) were achieved for silver pomfret. Yellowfin seabream (0.23 ± 0.02) and long tail tuna (0.18 ± 0.01) presented the lowest TI values in summer and winter, respectively. In addition, the highest TI values in summer (0.58 ± 0.03) and winter (0.46 ± 0.03) belonged to black pomfret and silver pomfret, respectively. Among fish species analyzed, benthopelagic fish presented the greatest ($P < 0.05$) AI and TI values conducted by comparing the pelagic and demersal ones. Heretofore, to our knowledge, there are no data, however, indicating the value of nutritional indices of the lipid of fish species from the Persian Gulf. But our results are close to those values found for other marine fish species (37). It has been reported that the higher values of AI and TI (> 1.0) are harmful to human health (38). According to the British Department of Health (39), a favorable PUFAs/SFAs ratio for healthy foods should be above 0.45. As Tables 1–3 show, PUFAs/SFAs ratios in summer and winter are ranged from 0.59 ± 0.07 to 1.90 ± 0.18 in the

studied species. Like PUFAs/SFAs and *n*-3/*n*-6 ratios, marked variations also observed in AI and TI of evaluated species according to the species, season, and habitat (Tables 1–4).

Conclusion

This study has shown that there are differences between lipid and cholesterol contents and fatty acids profile of the muscle tissues of the analyzed fish species from the Persian Gulf. All fish species were shown to have higher lipid and cholesterol contents in summer. Compared to the benthopelagic and demersal fish species, the pelagic fish species have a higher content of the total lipid in their fillets. However, the highest cholesterol content was found in fish species from the benthopelagic habitat.

The composition of fatty acid profiles of the analyzed fish was influenced by the habitat and season. The PUFA and MUFA contents were higher in fish species sampled in winter. With regards to PUFAs/SFAs and *n*-3/*n*-6 ratios, the fish collected during winter showed a higher value compared to those collected during the summer. Based on the habitat, demersal fish species composed a higher level of PUFAs content, either those of pelagic or benthopelagic fish species. However, the highest level of *n*-3 fatty acids and *n*-3/*n*-6 fatty acid ratio was obtained from pelagic fish species. The nutritional fatty acid indexes indicated the lipid quality of fish sampled during the winter was more desirable. All in all, further studies are needed to compare the impact of theoretical data with the impact of real clinical trials concerning the seasonal changes and associated human health consequences.

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Conflict of Interest

All authors declare that they have no conflict of interest.

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