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SEASONAL VARIABILITY IN THE CHEMICAL COMPOSITION OF TEN COMMONLY CONSUMED FISH SPECIES FROM OMAN

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ABSTRACT

Nutritional quality, fatty acids and mineral composition of 10 commonly consumed fish species from Oman were evaluated. Significant ($P < 0.05$) differences were observed in the condition factor, flesh percentage (edible yield), proximate chemical composition, fatty acids and mineral contents of different fish species. Seasonal variability only affected the moisture, ash, fat and fatty acids but did not affect the crude protein and minerals. The condition factor and flesh percentage (edible yield) of various fish species ranged from 0.5 to 1.4 and 31.7 to 71.5% respectively. The average moisture, ash, total fat, and crude protein contents in the fish muscles of various species ranged from 67.0-78.2%, 1.1-1.5%, 0.6-6.2%, 19.1-26.1%, respectively. The energy values in fish muscles ranged from 86 to 136 kcal/100g of fish flesh. Variable concentrations of twenty different fatty acids and 16 minerals were identified in these fishes. Commonly consumed fish species from Oman represent an excellent source of protein, essential fatty acids and minerals.

Keywords: Seasonal variability, chemical composition, fatty acids, minerals, fish, Oman

INTRODUCTION

The Sultanate of Oman has rich marine fish resources which contribute significantly to national economy. According to an estimate, the Omani waters habitat about 1142 fish species from 164 families (Al-Waili, 2006). Seafood is an important source of highly nutritious food. The per capita consumption of fish in Oman during the year 2000 was estimated to be approximately 21 kg/year (Al-Hosni, 2002). Fish contain the best quality protein and many other important nutrients including essential fatty acids and minerals (Mansfield, 2011). The consumption of fish and fish oil has been associated to lower or prevent the risk of many health related problems including immune dysfunction, coronary heart diseases, diabetes, and certain cancers (Whelton *et al*., 2004, Ruxton, 2011, Villegas *et al*., 2011, Djouse *et al*., 2012). Fish flesh (edible yield) varies from about 30 to 70% of the total fish weight and the differences are largely associated with body shape, nutritional condition, and skeletal characteristics of fish (William, 1996).

The chemical composition of fish can vary both between and within the same species. A number of studies have been conducted in various parts of the World to evaluate the nutritional quality and chemical composition of various fish species (William, 1996, Hege *et al*., 2005, Özogul *et al*., 2009, Fallah *et al*., 2010, Küçükgülmez *et al*., 2010, Younis *et al*., 2011). Seasonal variability has been reported to affect the chemical composition of fish in particular the total fat and fatty acids content of fish harvested during the different time periods of the year (Küçükgülmez *et al*., 2010, Fallah *et al*., 2010, Özogul *et al*., 2011). Regional differences have also been reported in the mineral concentration of various fish species (Zeynali *et al*., 2009, Burger *et al*., 2011, Younis *et al*., 2011). Higher concentrations of various metals were observed in fish muscles and liver caught from the areas with higher industrial activity on the Western coast of United Arab Emirates (Kosanovic *et al*., 2007). The consumer's preferences for selecting fish depends on variety, supply channel, price and production methods (Akpinar *et al.*, 2009, Tveteras *et al.*, 2012).

Very little information is available on the chemical composition of commonly consumed fish species in Oman. Keeping in view the significance of fish in Omani diet and its importance in maintaining human health, the present study was conducted to determine the nutritional quality, fatty acids and mineral composition of ten commonly consumed fish species from Oman.

MATERIALS AND METHODS

Ten most commonly consumed and commercially important fish species in the Sultanate of Oman were selected for this study (Table 1). Five representative samples of each fish species were procured from the local fish market in Muscat. The samples were collected during June (summer season) and September (autumn season). The length and weight of fishes were immediately recorded to calculate the condition factor (k). The condition factor (k) was calculated according to the equation, k = [W (g) / L (cm)^3] x 100, where W is weight of fish in grams and L is the length in centimeters (Al-Asgah and Ali, 1997). The fish flesh was separated manually from the fish and weighed to determine the flesh percentage. The flesh percentage was calculated as: (weight of flesh / weight of whole fish) x 100. The fish flesh was ground, homogenized and then divided into portions. One portion was immediately processed for determining the moisture and ash contents, whereas the other portion was preserved at -70 ºC for further chemical analysis at a later stage. The analysis of fish samples was carried out for the proximate chemical composition, fatty acid composition, mineral composition and energy value.

The proximate chemical composition was determined according to the methods of the Association of Official Analytical Chemists, AOAC (2000). All the samples were run in duplicate for the analysis of various parameters. The total fat and fatty acids were determined using a gas chromatographic technique as described by Gertz and Fiebig (2000) and Feifel *et al*. (2000). In the first phase the fat from the sample matrix was extracted with n-butanol solvent and was simultaneously saponified in the presence of potassium hydroxide. After the extraction was completed, the alkali salts of fatty acids were then converted to fatty acids by the addition of an acidic aqueous salt solution that produced a two-phase system. An aliquot from the upper organic phase containing the fatty acids and an internal standard were then injected into the fatty acid determination system (B-820). The fatty acids were separated from the solvent by gas chromatography and were detected by a flame ionization detector. The total fat and fatty acid contents were then calculated from the internal standards and the individual fatty acid peak areas. The results are presented as g fatty acid/100g of flesh (fillet).

To determine the mineral composition, the fish samples were ashed at 550°C for 24 hours in a muffle furnace and the ash was digested and dissolved in 5 ml of 6N hydrochloric acid. The samples were then transferred and filtered into volumetric flasks, and the volume was made up to 100 ml with deionized water. The samples were analyzed for individual minerals by using Inductively Coupled-Plasma Atomic Emission Spectrophotometer (ICP-AES) type Perkins Elmer Optima 3300 DV (MOOPAM, 1999). The gross energy (GE) value of fish fillet was calculated by the formula; (GE kcal/100g = %protein (g)*4 + %fat (g)*9 + %carbohydrate (g)*4). The data collected was subjected to statistical analysis using the analysis of variance technique and the means were compared by Fisher's LSD test according to Snedecor and Cochran (1989). All the data was analyzed using statistical software package SPSS v.14.

RESULTS AND DISCUSSION

Condition Factor: The data on the condition factor of different fish species in seasons 1 and 2 as well as the overall average condition factor for both the seasons is presented in Table 2. Significant (P < 0.05) differences were observed in the condition factor of different fish species. Seasonal variation did not affect (P > 0. 05) the condition factor of fish. Season x specie interactions were however significant. The overall mean condition factor of individual fish specie was compared among each other. Kingfish and shark showed lower condition factor (0.5) whereas the yellowfin tuna, emperor and yellowfin goatfish showed higher condition factor (1.4). No significant differences were however observed in the condition factors of yellowfin tuna, emperor, yellowfin goatfish and seabream. The condition factor (k) is frequently used as an index to study the fish biology as it furnishes important information related to the physiological state of fish in relation to their environmental conditions.

The study of condition factor is important for understanding the lifecycle of fish species and can contribute to an adequate management of these species and maintenance of equilibrium in the ecosystem (Lizma and Ambrosio, 2002, Erguden *et al*., 2011). The results of the present study however did not show any difference in the condition factor of fish in both the seasons (June and September), which may be because of a lower turn over of food biomass in the marine ecosystem during these periods. The lower condition factor of kingfish and shark may be attributed to poor natural food supply chain. Our results suggest that by improving the trophic environment and natural food supply chain in marine ecosystem may improve the nutritional and physiological conditions of these species.

Flesh Percentage (edible yield): The data on flesh percentage (edible yield) of different fish species in seasons 1 and 2 as well as the overall average values in both the seasons are presented in Table 2. Significant (P < 0.05) differences were observed in the flesh percentage of different fish species. The seasonal variability affected (P < 0.05) the flesh percentage (edible yield) of fishes. Grouper showed the lowest flesh percentage (31.7%) whereas kingfish showed the highest flesh percentage (71.5%). No significant differences were however observed in the flesh percentages of emperor, grouper, yellowfin goatfish and seabream. Fish flesh (edible yield) is the part used for human consumption. In the present study it varied from one third (31%) to almost three quarters (73.5%) of the total fish body weight. Grouper had the lower flesh percentage because of its body shape, as it has large head and short trunk. It also showed the same values in both seasons, which may be because it is a demersal fish. On the other hand, the kingfish which is a pelagic fish, its flesh percentage depends on the harvest season. The higher percentage of flesh in kingfish is also because it has a small head and large trunk. Our results are in line with the findings of William (1996) who reported that fish flesh can vary from 30% to 70%. The differences in percentage of fish flesh are largely due to body shape and harvest season.

Proximate Composition: The data on the proximate chemical composition of fish species in seasons 1 and 2 as well as the overall average mean values for both the seasons are presented in Tables 3. Significant ($P < 0.05$) differences were observed in the moisture content of different fish species. The differences due to season and for season x specie interactions were also significant. The mean moisture content of individual fish specie was compared among each other (Table 3). Sardine showed the lowest moisture content (67%) whereas emperor, grouper and seabream showed the highest moisture content (78%). Kingfish and Indian mackerel did not show any significant difference in their moisture contents. No significant differences were also observed in the moisture content of yellowfin tuna and longtail tuna. The moisture content of fish can vary greatly (Küçükgülmez *et al*., 2010, Younis *et al*., 2011). A number of factors, including specie, season, age, feeding regime and environment of the ecosystem, affect the moisture content as well as the other nutrient composition of fishes (Shearer, 1994). Our results are in line with these finding and showed that the moisture content ranged from 67.0% to 78.8%.

Significant ($P < 0.05$) differences were also observed in the ash content of different fish species. The seasonal variability also significantly affected the ash content of fish. Shark showed the lowest ash content (1.1%) while sardine and Indian mackerel showed the highest ash contents (1.5%). No significant differences were observed in the ash contents of kingfish, yellowfin tuna and grouper. The protein content of different species also differed significantly. The results indicated that the seasonal variability did not affect the protein content of fish. The mean crude protein content of individual fish species were compared among each other (Table 3). Grouper and yellowfin goatfish showed the lowest protein content (19%), while shark showed the highest protein content (26%). Emperor, sardine and seabream did not show any significant difference in their crude protein content. The protein content in marine fish varies greatly and can range from 11 to 24% (Younis *et al*., 2011). Our results are in line with these findings.

Significant ($P < 0.05$) differences were observed in the fat content of different fish species. The effects of season as well as the specie x season interaction on the fat content of species were also significant (Table 3). Shark and seabream showed the lowest fat content (0.6%), whereas sardine showed the highest fat content (6.2%). Yellowfin tuna, shark, emperor, yellowfin goatfish and seabream did not show any significant ($P > 0.05$) difference in their total fat contents. The fat content of the fish can vary widely depending on the fish species and season of the year (Özogul *et al*., 2011, Younis *et al*., 2011). The fish coming from the open sea (pelagic) have been shown to have much higher lipid contents as compared to other fish (Özogul *et al*., 2009). Our results are in conformity with these reported results. Significant ($P < 0.05$) differences were also observed in the energy values of different fish species (Table 3). Seasonal variability also significant affected the energy value of fish. Emperor, yellowfin goatfish and seabream showed the lowest energy value (86 kcal/100g) whereas sardine showed the highest energy value (136 kcal/100g). Emperor, yellowfin goatfish and seabream did not show any significant difference in their energy values.

Fatty Acids Composition: The data on the overall average fatty acids composition of different fish species in both the seasons is presented in table 4. Significant ($P < 0.05$) differences were observed in the saturated fatty acids (SFA), monounsaturated fatty acids (MUFA), ployunsaturated fatty acids (PUFA) and unidentified fatty acids (UIFA) contents of different fish species. The seasonal variability also sıgnificantly affected the fatty acid content of fısh specıes. Saturated fatty acids were found in higher amounts followed by monounsaturated and polyunsaturated fatty acids. Eicosapentaenoic acid (EPA) and docosahexaenoic acid (DHA) however either could not be detected due to analytical procedure limitations or were found only in very small quantities. Overall the seabream showed the lowest SFA content (0.3 g per 100g of fish flesh), whereas the sardine showed the higest SFA content (2.6 g per 100g of fish flesh). No significant differences were however observed between the SFA content of yellowfin tuna, emperor, yellowfin goatfish and seabream. Shark, emperor and yellowfin goatfish showed the lowest MUFA content (0.1 g per 100g of fish flesh) while the sardine showed the highest MUFA content (1.6 g per 100g of fish flesh). Yellowfin tuna, shark, emperor, yellowfin goatfish and seabream did not show any significant ($P < 0.05$) difference in their MUFA contents among each other. Higher PUFA contents were observed for sardine and Indian mackrel. Shark, seabream and emperor showed the lowest PUFA contents. The proportionate percentage of PUFA on the basis of total fatty acids in various fish species ranged from 4.8% to 11.1%. Shark, emperor and seabream showed the lowest UIFA content while sardine showed the highest UIFA content.

Among the saturated fatty acids, myristic acid (C14) and palmitic acid (C16) were the most important one, while palmitoleic acid (16:1), oleic acid (C18:1), and nervonic acid (C24:1) were the main monounsaturated fatty acids. Sardine and Indian mackerel were found to be the most suitable pelagic species in terms of fatty acid contribution. Interspecies differences and seasonal variability in fatty acids composition of fish have been reported in the literature (Özogul *et al*., 2009, Küçükgülmez *et al*., 2010, Özogul *et al*., 2011). The results of our study indicated that the fatty acid contents varied greatly between different fish species. The results of the present study showed similar trends to those reported in above studies. The differences in the results however may be attributed to specie, season and regional variability. It is difficult to compare the reported results on the fatty acid composition of fish as some of the studies have reported them based on actual amounts of fatty acids whereas the others on the basis of relative percentages of the total fatty acids (Krakatsouli, 2012). Therefore, the analytical methodology for the determination of fatty acids as well as the presentation of results should be standardized to have more unified comparisons of fatty acid contents and nutritional quality of fish.

Mineral Composition: The data on the overall average mineral composition of different fish species is presented in table 5. Significant ($P < 0.05$) differences were observed in the mean values of individual mineral contents of different fish species. Seasonal variability however did not affect the mineral composition of fish. Sodium content of various fish species ranged from 457 to 2145 mg/kg. Yellowfin tuna showed the lowest sodium (Na) content (457 mg/kg), while sardine showed the highest (2145 mg/kg). No significant ($P < 0.05$) differences were observed in the Na content of Kingfish, Longtail tuna and Grouper. Longtail tuna showed the highest potassium content (4853 mg/kg), while sardine showed the lowest potassium content (3343 mg/kg). Indian mackerel showed the lowest calcium (Ca) content (98 mg/kg), while emperor showed the highest calcium content (198 mg/kg). The magnesium (Mg) content in various fish species ranged from 78 and 315 mg/kg. Large variability (3.0 to 513 mg/kg) was observed in the Aluminum (Al) content of various fish species. Similarly the iron (Fe) content ranged from 2.1 to 23 mg/kg.

The concentrations of copper (Cu), zinc (Zn) chromium (Cr), manganese (Mn) and barium (Ba) differed significantly in various fish species. Nickel (Ni) was only detected in emperor (0.1 mg/kg), whereas cadmium (Cd) was detected in emperor, seabream, and Indian mackerel. No lead (Pb) was found in yellowfin tuna, longtail tuna and seabream. Yellowfin goatfish and Indian mackerel showed the lowest lead content (0.1 mg/kg) while emperor showed the higher lead content (7.0 mg/kg). The concentration of minerals in fish species can vary depending on age, feeding behavior, environment, ecosystem, as well as many other factors such as time and region of sampling (Zeynali *et al*., 2009, Fallah *et al*., 2010, Burger *et al*., 2011). Our results are in line with the data reported in various previous studies (Kosanovic, *et al*., 2007, Younis *et al*., 2011). The concentration of these minerals and trace elements in fish observed in our study were within the permissible limits and do not constitute a risk factor for human health.

Table 1. Scientific, common and local names of fishes used for the study

No.	Family	English Name	Species Name	Local Name
1	*Scombridae*	Kingfish	*Scomberomorus commerson*	Kanaad
2	*Scombridae*	Yellowfin tuna	*Thunnus albacores*	Jeidhar
3	*Scombridae*	Longtail tuna	*Thunnus tonggol*	Sahwa
4	*Carcharhinidae*	Milk Shark	*Rhizoprionodon acutus*	Jarjur
5	*Lethrinidae*	Emperor	*Lethrinus elongates*	Shaari
6	*Serranidae*	Grouper	*Cephalopholis aurantia*	Hamour
7	*Mullidae*	Yellowfin goatfish	*Mulloidichthys flavolineatus*	Sultan Ibrahim
8	*Clupedae*	Sardine	*Sardinella longiceps*	Ouma
9	*Scombridae*	Indian mackerel	*Rastrelliger kanagurta*	Dhalaa
10	*Sparidae*	Seabream	*Argyrops spinifer*	Kowfar

Table 2. Condition factor (k) and Flesh percentage of fish species in seasons 1, 2 and the overall values for both seasons

	Condition Factor (k)			Flesh percentage (%)		
Fish Species	**Season 1**	**Season 2**	**Overall**	**Season 1**	**Season 2**	**Overall**
Kingfish	0.6±0.1	0.4±0.1	0.5±0.9[e]	73.5±2.4	69.5±4.0	71.5±3.8[a]
Yellowfin tuna	1.1±0.1	1.7±0.3	1.4±0.3[a]	55.3±2.4	56.1±3.3	55.7±2.7[c]
Longtail tuna	1.0±0.1	0.8±0.7	0.7±0.3[d]	53.0±1.1	44.9±0.7	48.9±4.3[d]
Shark	0.4±0.1	0.7±1.0	0.5±0.2[4]	46.9±0.1	73.9±14.5	60.4±7.2[b]
Emperor	1.5±0.1	1.3±0.6	1.4±0.1[a]	35.7±2.8	34.3±2.7	35.0±2.7[f]
Grouper	1.1±0.6	1.3±0.1	1.2±0.4[bc]	31.1±1.0	32.3±3.6	31.7±2.6[g]
Sardine	1.1±0.1	1.2±0.1	1.2±0.1[bc]	38.4±2.8	41.2±4.3	39.8±3.7[e]
Yellowfin goatfish	1.5±0.1	1.3±0.8	1.4±0.2[a]	34.6±1.2	35.3±3.0	35.0±2.2[f]
Indian Mackerel	1.1±0.1	1.0±0.4	1.1±0.1[c]	44.9±1.8	41.7±2.4	43.3±2.6[e]
Seabream	1.2±0.1	1.3±0.6	1.3±0.1[ab]	38.1±1.1	32.4±1.8	35.2±3.3[f]

Overall = average values for both the seasons *different alphabets in the same column means statistically significant at 5% level ($P < 0.05$)

Table 3. Proximate chemical composition of fish species in seasons 1, 2 and overall (Mean ± SD, as g/100g of fish flesh)

Composition /Fish name	Moisture			Ash			Crude Protein			Total Fat			Energy Value (kcal/100g)		
	S-1	S-2	Overall	S-1	S-2	Overall	S-1	S-2	Overall	S-1	S-2	Overall	S-1	S-2	Overall
Kingfish	73.2±1.0	77.1±0.2	75.1±2.2^{c}	1.3±0.1	1.3±0.0	1.3±0.1^{b}	22.0±0.4	21.7±0.7	21.9±0.6^{c}	2.41±0.4	0.72±0.1	1.6±0.9^{c}	109.7±3.5	93.0±2.8	101.4±9.4^{d}
Yellowfin tuna	74.3±0.5	71.9±1.3	73.1±1.6^{ed}	1.4±0.1	1.3±0.2	1.3±0.1^{bc}	24.0±0.8	25.3±0.1	24.7±0.8^{b}	0.90±0.1	0.56±0.3	0.7±0.3^{d}	103.2±3.1	106.0±2.4	104.6±3.0^{d}
Longtail tuna	71.8±2.1	73.9±0.5	72.8±1.8^{d}	1.1±0.1	1.2±0.1	1.2±0.0^{bc}	24.7±0.7	24.8±0.8	24.8±0.7^{b}	3.08±0.3	0.60±0.8	1.8±1.3^{c}	126.8±4.3	104.0±2.8	115.4±12.6^{b}
Shark	76.3±1.0	76.3±0.4	76.3±0.3^{b}	1.2±0.1	1.0±0.1	1.1±0.1^{e}	26.1±0.6	26.1±0.4	26.1±0.5^{a}	0.56±0.2	0.54±0.1	0.6±1.2^{d}	109.7±3.6	109.1±0.8	109.4±2.5^{c}
Emperor	79.1±o.5	78.5±0.7	78.8±0.7^{a}	1.4±0.2	0.9±0.1	1.2±0.3^{bc}	19.8±0.8	20.4±0.5	20.1±0.7^{d}	0.71±0.1	0.74±0.3	0.7±0.2^{d}	84.9±4.1	88.6±2.1	86.8±3.6^{ef}
Grouper	76.8±0.8	80.3±0.7	78.6±2.0^{a}	1.4±0.2	1.2±0.1	1.3±0.2^{b}	19.9±0.5	18.4±1.4	19.1±1.3^{d}	2.27±0.5	1.01±0.3	1.6±0.8^{c}	99.6±5.9	83.4±5.9	91.6±10.2^{e}
Sardine	69.7±1.1	64.3±2.6	67.0±3.4^{e}	1.5±0.1	1.6±0.1	1.5±0.1^{a}	20.2±0.3	20.1±0.7	20.1±0.5^{d}	4.39±1.0	8.08±1.1	6.2±2.2^{a}	120.2±7.2	153.1±7.1	136.6±18.8^{a}
Yellowfin goatfish	76.3±0.5	78.8±0.5	77.5±1.4^{a}	1.4±0.1	1.4±0.1	1.4±0.1^{a}	19.9±0.2	19.4±0.6	19.6±0.5^{d}	0.95±0.1	0.83±0.2	0.9±0.1^{d}	88.2±0.1	84.8±3.5	86.5±3.0^{f}
Indian Mackerel	72.8±2.1	76.6±0.5	74.7±2.5^{c}	1.5±0.1	1.5±0.1	1.5±0.1^{a}	22.9±0.7	21.9±1.3	22.4±1.2^{c}	4.19±1.2	0.66±0.1	2.4±2.1^{b}	128.2±11	94.5±5.4	111.3±19.7^{bc}
Seabream	77.8±0.7	78.6±0.3	78.2±0.7^{a}	1.6±0.1	1.2±0.1	1.4±0.3^{a}	20.7±1.1	19.9±0.6	20.3±1.0^{d}	0.61±0.1	0.48±0.1	0.6±0.1^{d}	89.1±4.7	84.2±2.5	86.6±4.4^{f}

S-1 = Season 1, and S-2 = Season 2, Overall = average values for both the seasons *different alphabets in the same column means statistically significant at 5% level ($P < 0.05$)

Table 4. Overall average fatty acids composition of fish species in both the seasons (g/100g of fish flesh)

Fish/FAs	Kingfish	Yellowfin tuna	Longtail tuna	Shark	Emperor	Grouper	Sardine	Yellowfin goatfish	Indian Mackerel	Seabream
SFA	0.8±0.4^{b}	0.5±0.1^{c}	1.0±0.5^{b}	0.4±0.1^{cd}	0.5±0.1^{c}	0.9±0.3^{b}	2.6±1.2^{a}	0.5±0.1^{c}	1.0±0.8^{b}	0.3±0.1^{d}
MUFA	0.6±0.4^{bc}	0.4±0.1^{c}	0.5±0.6^{bc}	0.2±0.1^{d}	0.1±0.1^{d}	0.6±0.4^{bc}	1.6±0.6^{a}	0.2±0.1^{d}	0.7±0.8^{b}	0.1±0.1^{d}
PUFA	0.13±0.1^{b}	0.11±0.1^{b}	0.17±0.1^{b}	0.07±0.03^{c}	0.04±0.02^{c}	0. 19±0.1^{b}	0.40±0.2^{a}	0.08±0.1^{c}	0.31±0.2^{a}	0.07±0.1^{c}
UIFA	0.3±0.1^{c}	0.3±0.1^{c}	0.3±0.1^{c}	0.2±0.1^{c}	0.2±0.1^{c}	0.3±0.1^{c}	1.7±0.6^{a}	0.3±0.1^{c}	0.7±0.5^{b}	0.2±0.1^{c}
C4	0.05^{ab}	0.05^{ab}	0.06^{a}	0.05^{ab}	0.06^{a}	0.05^{ab}	0.06^{a}	0.05^{ab}	0.04^{b}	0.05^{ab}
C6	0.04^{a}	0.04^{a}	0.04^{a}	0.03^{b}	0.04^{a}	0.04^{a}	0.03^{b}	0.04^{a}	0.03^{b}	0.04^{a}
C8	0.05^{a}	0.05^{a}	0.06^{a}	0.05^{a}	0.05^{a}	0.06^{a}	0.05^{a}	0.05^{a}	0.04^{ab}	0.05^{a}
C10	0.01^{c}	0.01^{c}	0.03^{a}	0.01^{c}	0.01^{c}	0.01^{c}	0.01^{c}	0.01^{c}	0.02^{b}	0.01^{c}
C12	0.02^{b}	0.01^{b}	0.07^{a}	0.01^{b}	0.02^{b}	0.02^{b}	0.03^{b}	0.06^{ab}	0.02^{b}	0.01^{b}
C14	0.13^{c}	0.07^{c}	0.27^{b}	0.12^{c}	0.11^{c}	0.19^{bc}	0.74^{a}	0.09^{c}	0.19^{bc}	0.09^{c}
C16	0.41^{b}	0.15^{e}	0.28^{d}	0.07^{f}	0.14^{e}	0.37^{c}	1.33^{a}	0.17^{e}	0.46^{b}	0.10^{ef}
C16:1	0.18^{b}	0.07^{cd}	0.12^{bc}	0.05^{d}	0.08^{c}	0.16^{b}	0.73^{a}	0.06^{cd}	0.17^{b}	0.05^{d}
C18	0.10^{bc}	0.08^{c}	0.20^{b}	0.05^{cd}	0.06^{c}	0.09^{c}	0.27^{a}	0.03^{d}	0.17^{b}	0.01^{e}
C18:1	0.19^{b}	0.10^{c}	0.15^{c}	0.10^{cd}	0.05^{d}	0.22^{b}	0.56^{a}	0.07^{d}	0.21^{b}	0.03^{e}
C18:2	0.02^{c}	ND	ND	ND	0.02^{c}	0.02^{c}	0.15^{a}	ND	0.04^{b}	ND
C18:3	ND	ND	ND	ND	ND	ND	0.02^{b}	ND	0.03^{a}	ND
C20	ND	ND	ND	ND	ND	ND	0.03^{b}	ND	0.05^{a}	ND
C20:1	ND	ND	ND	ND	ND	ND	0.03^{a}	ND	0.02^{b}	ND
C20:4	ND	ND	ND	ND	ND	ND	0.04^{a}	ND	ND	ND
C20:5	ND	ND	ND	ND	ND	0.01^{a}	ND	ND	ND	ND
C22:5	ND	ND	ND	ND	ND	ND	0.04^{a}	ND	ND	ND
C22:6	ND	ND	ND	ND	ND	ND	ND	0.09^{a}	ND	ND
C24	ND	ND	ND	ND	ND	0.07^{b}	ND	ND	0.11^{a}	ND
C24:1	0.19^{b}	0.19^{b}	0.20^{b}	ND	ND	0.20^{b}	0.29^{a}	0.09^{c}	0.33^{a}	0.11^{c}
% PUFA**	7.1	8.4	8.6	8.0	4.8	9.5	6.3	7.4	11.1	10.4

*different alphabets in the same row means statistically significant at 5% level ($p < 0.05$), ** Proportionate %age of PUFA of the total fatty acids ND = not detected

Table 5. The overall average mineral composition of fish species in both the seasons (mg/kg of fish flesh)

Fish / Mineral	Kingfish	Yellowfin tuna	Longtail tuna	Shark	Emperor	Grouper	Sardine	Yellowfin goatfish	Indian Mackerel	Seabream
Na	678 ± 101^{d}	457 ± 60.8^{e}	632 ± 209^{d}	1561 ± 464^{b}	760.4 ± 117^{cd}	653.3 ± 65.4^{d}	2144 ± 484^{a}	842 ± 230^{c}	707 ± 99.5^{cd}	793 ± 162^{cd}
K	4467 ± 825^{ab}	4446 ± 571^{ab}	4853 ± 522^{a}	3682 ± 361^{bc}	3755 ± 648^{bc}	3604 ± 875^{bc}	3343 ± 316^{c}	4257 ± 835^{ab}	4288 ± 394^{ab}	4074 ± 816^{b}
P	2182 ± 384^{b}	2124 ± 360^{b}	2602 ± 334^{a}	1599 ± 138de	1767 ± 48.4^{d}	1426 ± 289^{e}	1599 ± 139de	1883 ± 83^{cd}	2033 ± 166^{bc}	1909 ± 270^{c}
Ca	123 ± 58^{bc}	148 ± 47^{bc}	178 ± 31^{ab}	103 ± 50^{c}	198 ± 91^{a}	83 ± 74^{c}	89.± 31^{c}	124 ± 32^{bc}	98 ± 18^{c}	143 ± 63^{bc}
Mg	241 ± 96^{b}	243 ± 95^{b}	315 ± 84^{a}	125 ± 36^{d}	212 ± 77^{b}	78 ± 50^{e}	125 ± 42^{d}	198 ± 82^{bc}	157 ± 79^{c}	146 ± 63^{cd}
Al	23.0 ± 10.4^{b}	16.2 ± 14.4^{b}	11.6 ± 12.3^{b}	5.8 ± 1.2^{bc}	51.8 ± 12.3^{a}	5.2 ± 4.8^{bc}	3.7 ± 1.2^{c}	5.3 ± 5.4^{bc}	15.6 ± 10.2^{b}	8.0 ± 2.3^{b}
S	74.3 ± 23.5^{c}	61.3 ± 5.3^{c}	73.3 ± 12.4^{c}	104 ± 30.0^{bc}	107.2 ± 33.1^{bc}	191.7 ± 55.7^{a}	63.6 ± 4.5^{c}	142.0 ± 108^{b}	77.1 ± 9.9^{c}	131.7 ± 29.8^{b}
Fe	4.3 ± 1.6^{e}	17.1 ± 3.4^{b}	23.6 ± 7.5^{a}	2.5 ± 1.0^{e}	7.8 ± 3.7^{d}	2.6 ± 3.1^{e}	12.3 ± 1.6^{c}	3.2 ± 2.4^{e}	11.3 ± 2.6^{c}	2.1 ± 0.4^{e}
Cu	2.3 ± 1.3^{b}	1.4 ± 1.5^{b}	1.9 ± 1.0^{b}	2.2 ± 1.3^{b}	4.1 ± 1.2^{a}	0.7 ± 0.5^{c}	1.8 ± 0.4^{b}	2.5 ± 1.5^{b}	1.2 ± 0.8^{bc}	4.1 ± 4.0^{a}
Zn	3.3 ± 0.5^{b}	3.7 ± 1.0^{ab}	5.2 ± 1.4^{a}	3.2 ± 0.6^{b}	3.4 ± 0.9^{b}	1.0 ± 1.0^{c}	4.1 ± 1.6^{ab}	1.9 ± 1.6^{d}	4.5 ± 1.6^{ab}	3.0 ± 0.8^{b}
Cr	0.3 ± 0.05^{ab}	0.3 ± 0.03^{ab}	0.3 ± 0.06^{ab}	0.3 ± 0.07^{ab}	0.4 ± 0.15^{a}	0.2 ± 0.05^{b}	0.3 ± 0.10^{ab}	0.2 ± 0.03^{b}	0.3 ± 0.04^{ab}	0.3 ± 0.08^{ab}
Mn	0.2 ± 0.1^{b}	0.3 ± 0.1^{ab}	0.4 ± 0.1^{ab}	0.3 ± 0.4^{ab}	0.2 ± 0.1^{b}	0.1 ± 0.1^{b}	0.5 ± 0.7^{a}	0.1 ± 0.1^{b}	0.2 ± 0.1^{b}	0.3 ± 0.1^{ab}
Ba	0.3 ± 0.1^{b}	0.3 ± 0.1^{b}	0.3 ± 0.1^{b}	0.3 ± 0.1^{b}	0.3 ± 0.1^{b}	0.2 ± 0.1^{b}	0.3 ± 0.1^{b}	0.8 ± 1.2^{a}	0.3 ± 0.1^{b}	0.3 ± 0.1^{b}
Ni	ND	ND	ND	ND	0.1 ± 0.1^{a}	ND	ND	ND	ND	ND
Cd	ND	ND	ND	ND	0.1 ± 0.04^{b}	ND	ND	ND	1.1 ± 0.5^{a}	0.1 ± 0.05^{b}
Pb	0.6 ± 0.7^{b}	ND	ND	0.3 ± 0.6^{b}	7.0 ± 15^{a}	0.3 ± 0.7^{b}	0.7 ± 1.0^{b}	0.1 ± 0.1^{b}	0.1 ± 0.1^{b}	ND

*Different alphabets in the same row means statistically significant at 5% level ($P < 0.05$). ND = not detected

Conclusion: The results of the present study indicated that significant variability exists in the proximate composition of various fish species. The condition factor, flesh percentage (edible yield), proximate composition as well as fatty acids and mineral content of different fish species differed significantly. Seasonal variability affected the moisture, ash, fat and fatty acids content but did not affect the protein and mineral contents. Demersal fish contained lower fat content as compared to pelagic fish. It may be concluded that the commonly consumed fish species in Oman represent an excellent source of protein, essential fatty acids, minerals and many other important nutrients and should therefore remain a regular part of Omani diet.

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