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Amino Acids Pattern and Fatty Acids Composition of the Most Important Fish Species of Saudi Arabia

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Research Article

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ABSTRACT

The aim of this work was to explore amino acids pattern and fatty acids composition of the most common consumed fish in Saudi Arabia. This study was just a trial to encourage Saudi residents to increase their consumption of fish and fish products. To achieve this goal, elven fresh fish species were randomly collected from the Central Fish Market, El-Kaakia, Makkah, Saudi Arabia, beheaded, eviscerated, filleted and minced. Amino acids and fatty acids composition were determined. In case of essential amino acids EAA, the major amino acids are lysine (4.47 - 6.28%), leucine (4.14 - 5.80%), valine (3.23 - 4.37%). P-PER ratio ranged from 1.18 in Indian oil sardine to 1.84 in grey mullet. The percentage of total saturated fatty acids ranged from 34.19 ± 1.70% in golden thread fin bream to 54.67 ± 3.61% in grey mullet. Oleic acid (C18:1) was identified as the primary monoenoic fatty acid in all studied fish flesh samples. Total polyunsaturated fatty acids of studied fish flesh samples ranged from 20.48 ± 1.53% to 43.19 ± 0.17% in sabaki tilapia and golden thread fin bream, respectively. Among ω-3 series, C22:6 docosahexaenoic acid (DHA) was the most common fatty acid in all studied fish samples. Golden thread fin bream had the highest value of biological value (1.7), followed by job fish which recorded 1.41. Finally, these studied fish species were considered vital sources of essential amino acids and polyunsaturated fatty acids especially DHA, ω-3 fatty acid. So it is necessary to change the nutritive pattern of Saudis and residents to encourage them to increase their fish consumption.

INTRODUCTION

Seafood is one of the most important food constituents in human nutrition and has an important economic value. Besides, seafood has received considerable attention due to reasons concerning health. In fact, fish are important source of protein rich in essential amino acids, micro and macro elements (calcium, phosphorus, fluorine, iodine), fats that are valuable sources of energy, fat-soluble vitamins, and polyunsaturated fatty acids that, among other benefits, have a hypocholesterolic effect (anti-arteriosclerosis)[1,2].

In addition, seafood is a precious source of high-quality proteins, vitamins, mineral elements. It is the only significant source in the human diet of ω-3 polyunsaturated fatty acids (PUFA) that play beneficial and protective function towards cardiovascular, chronic and inflammatory diseases[3,4].

Fish products are comparable to meat and dairy products in nutritional quality, depending on the methods used in preservation or preparation. The protein content of fish ranged from 15 to 20%. Fish also contains significant amounts of the essential amino acids, particularly lysine in which cereals are relatively poor. Fish protein can be used therefore to complement the amino acid pattern and improve the overall protein quality of a mixed diet. Moreover, the sensory properties of an otherwise bland diet can be enhanced through fish products, thus facilitating and contributing to greater consumption[5].

This is particularly true for the countries of the Arabian Gulf which are dominated by desert regions. Whereas these countries have poor agricultural potential and thus have to import most of their food, they are to a large extent self-sufficient in seafood[6]. Burger et al.[7] examined fish consumption behavior and rates in native and non-native people in Saudi Arabia. They found that for Saudis, 3.7% of males and 4.3% of females do not eat fish; for expatriates, the percent not eating fish is 6.6% and 6.1% respectively. Saudis ate 2.2 fish meals/week, while expats ate 3.1 meals/week. Grouper (*Epinephelus* and *Cephalopholis*) were eaten by 72% and 60%, respectively. This study confirmed that there was a real need to do effort for increasing the Saudis fish consumption, where 11.5 kg of fish per year was the consumed amount per capita in Saudi Arabia. This ratio was very low in comparable with the world ratio (18.9 kg)[8].

Tao et al.[9] stated that the biochemical composition of fish is influenced by many factors such as biological variations (species, sex, size, and age), diet, environmental conditions (temperature, pH, salinity, etc.), and seasonal changes.

In Saudi Arabia, Three highly consumed fish in Saudi market were evaluated for their fatty acids. The fish species were known as Kanad, Hammour and Hammam in Saudi market. The fatty acids composition in the muscle of fish species was evaluated. C16:0 and C18:0 were the main saturated fatty acids (SFA), C18:1 and C16:1 were the main monounsaturated fatty acids (MUFA), while C22:6 (DHA) and C20:5 (EPA) were the main polyunsaturated fatty acids (PUFA)[10].

While, in Italy, fatty acid profile was evaluated on red mullet (*Mullus barbatus*) caught in the Central Tyrrhenian and Central Adriatic seas. The obtained results showed that polyunsaturated fatty acids (PUFA) were significantly higher in spring (30-40% of total fatty acids), when fish was lean, than in autumn (20%), while monounsaturated fatty acids were significantly higher in autumn (35-38%) than in spring (18-29%). Saturated fatty acids were almost stable throughout the year (34-39% of total fatty acids). Red mullet from the two sites showed a good nutritional value; in particular they proved to be a good source of ω-3 PUFA, which accounted for 75-80% of total PUFA, regardless of the fishing season[11].

Another example, butter catfish (*Ompok bimaculatus*) is highly rich in polyunsaturated fatty acids. The percentage of total polyunsaturated fatty acids was found to be 40.92 followed by 26.54% of total monounsaturated fatty acids, indicating excellent nutritive value of this fish species. Amino acid analysis showed that fish flesh contains essential amino acids such as leucine, lysine, threonine, phenylalanine, valine and isoleucine in a significant amount. The ratio of essential to non-essential amino acid is 0.89 indicating its high protein quality[12].

An investigation into the amino acids pattern in three species of Nigerian fish: *Clarias anguillaris*, *Oreochromis niloticus* and *Cynoglossus senegalensis* was carried out. The most abundant amino acid was Glutamic acid (10.8-11.8% of crude protein) and Leucine was the most abundant essential amino acid (5.80-6.47% of crude protein). While total amino acid content was 61.8–63.7% of crude protein, the total essential amino acid content was 48.6-50.0% with Histidine, but 45.8-47.0% without Histidine[13].

Finfish tend to have higher levels of polyunsaturated fatty acids and lower levels of saturated fatty acids than other mean sources of protein. The proportion of saturated, monounsaturated, and polyunsaturated fatty acids found in beef are approximately 40-45%, 50% and 4-10%[14]. The fatty acid profile of chicken (30-35% saturates, 35-40% monounsaturates, and 25-30% polyunsaturates) falls between that of fish and beef. Dairy products have a much higher saturated fat component (40-65%), similar monounsaturated levels (30-45%), and much lower polyunsaturated levels (5%) than fish. As for the protein efficiency ratio (PER) is a measure of protein quality, usually calculated by putting young animals on diets with various test proteins and monitoring their growth (PER = gain in body weight (in grams)/grams of protein consumed). The P-PER of fish (3.55) is higher than beef (2.30) and milk proteins (casein=2.50) and close to that of egg (3.92)[15].

Moving from these considerations, the aim of this work was undertaken to explore amino acids pattern and fatty acids profile of the most common consumed fish in Saudi Arabia. This study was just a trial to encourage Saudi residents to increase their consumption of fish and fish products.

MATERIALS AND METHODS

Materials

Three replicates of elven fresh fish species were randomly collected from the Central Fish Market, El-Kaakia, Makkah, Saudi Arabia during spring 2015. They were classified and named as follows: grey mullet *Liza ramada*, sabaki tilapia *Oreochromis spilurus*, indian oil sardine *Sardinella longiceps*, golden thread fin bream *Nemipterus japonicas*, gilt head bream *Sparus aurata*, asian seabass *Lates calcarifer*, job fish *Apharus rutilanus*, spangled emperor *Lethrinus nebuloses*, dusky grouper *Epinephelus marginatus*, rusty parrot fish *Scarus ferrugineus* and half spotted grouper *Cephalopholis hemistiktos*. These species are commonly consumed by the local population in Saudi Arabia. Fish samples were mixed with soft ice, put in ice box and transported to biology Lab, Faculty of Applied Science, Umm Al-Qura University.

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Methods

Samples preparation: All fish samples were manually beheaded, eviscerated and filleted. Muscle tissues, below the dorsal fin were taken as the samples. The fish flesh was minced. Moisture content was determined, then fish flesh was dried at 70˚C, grinded and stored at -18˚C until chemical analysis.

Chemical analysis

Amino acids pattern: Amino acids pattern of fish flesh samples was analyzed out in Food and Feed Quality Laboratory, Regional Center for Food and Feed (RCFF), Agricultural Research Center, Egypt using the method described by AOAC[16].

The predicted protein efficiency ratio (P-PER) was determined using one of the equations of Alsmeyer et al.[17] as adapted by Adeyeye[13].

P-PER = -0.468 + 0.454 (Leu) - 0.105 (Tyr)

Fish oil extract

Fish oil was extracted from dried minced fish samples using the method described by Bligh and Dyer[18] and extracted oil was kept into dark glass bottles at -18˚C until fatty acids analysis.

5Fatty acids composition

Fatty acids profile of fish oil samples was analyzed out in the Central Laboratory Unit, High Institute of Public Health, Alexandria University, Egypt.

Preparation of fatty acid methyl ester (FAME) was carried out according to Siew et al.[19] and Jumat et al.[20].

A standard mixture of fatty acid methyl esters were used to identify of the peaks by their retention time. The different fatty acid methyl esters (FAMEs) were determined and identified using a gas chromatography (Hewlett Packard 6890) equipped with a flame ionization detector (FID). A HP-5 column (30 m, 0.32 mm ID, 0.25 µm film thickness) [5% diphenyl, 95% dimethyl polysiloxane] was used.

The detector and injector temperatures were 280˚C and 220˚C, respectively. Sample size 3 µl, spilt ratio 50:1. Nitrogen was used as carrier gas at a flow rate of 1 ml/min. Oven temperature was programmed as:

- Set point (initial temperature) 150˚C for 2 Min.
- Rate 10°C/min to 200°C.
- Rate 5˚C/min to 250˚C and hold for 9 Min.

The concentrations of fatty acids were calculated as following equation:

Fatty acid% = peak area ÷ overall area of peaks × 100.

Statistical analysis

Statistical analysis such as mean, standard error and analysis of variance (one way ANOVA) test were done using SPSS[21] version 17 program for windows.

RESULTS AND DISCUSSION

Amino acids composition (g/100 g crude protein) of the most important studied fish flesh samples were presented in **Table 1.** The tabulated results reflected that glutamic acid (14.47 - 15.89%) is the abundant amino acid as a percentage of total amino acids followed by aspartic acid (8.98 - 10.78%) compared to other amino acids. All the data given in **Table 1** had been expressed in percentage of total area of amino acids.

Table 1. Amino acids content (g/100 g crude protein) of studied fish flesh samples.

Amino acids / Fish species	ASP	THR	SER	GLU	PRO	GLY	ALA
Grey mullet *Liza ramada*	6.79 ± 0.46^{ab}	3.33 ± 0.06^{ab}	2.98 ± 0.01^{a}	10.10 ± 0.14^{a}	2.59 ± 0.02^{abc}	3.75 ± 0.03^{abc}	5.36 ± 0.13^{a}
Sabaki tilapia *Oreochromis spilurus*	6.56 ± 0.80^{abcd}	3.17 ± 0.39^{abc}	2.65 ± 0.29^{abc}	9.27 ± 1.23^{abc}	2.44 ± 0.33^{abc}	3.40 ± 0.40^{bcd}	4.94 ± 0.56^{abc}
Indian oil sardine *Sardinella longiceps*	5.44 ± 0.11^{d}	2.66 ± 0.08^{c}	2.36 ± 0.06^{c}	7.88 ± 0.11^{c}	2.79 ± 0.16^{abc}	3.92 ± 0.13^{ab}	4.38 ± 0.07^{abc}
Golden thread fin bream *Nemipterus japonicas*	7.06 ± 0.11^{ab}	3.49 ± 0.02^{ab}	2.93 ± 0.03^{ab}	10.54 ± 0.12^{a}	2.63 ± 0.19^{abc}	3.42 ± 0.01^{bcd}	4.94 ± 0.14^{abc}

Gilt head bream ***Sparus aurata***	6.74 ± 0.10^{abc}	3.49 ± 0.03^{ab}	2.96 ± 0.03^{a}	9.90 ± 0.37^{ab}	2.61 ± 0.06^{abc}	3.53 ± 0.02^{abc}	4.58 ± 0.18^{abc}
Asian seabass ***Lates calcarifer***	6.97 ± 0.02^{ab}	3.39 ± 0.02^{ab}	2.89 ± 0.03^{ab}	10.29 ± 0.03^{a}	2.94 ± 0.04^{ab}	4.01 ± 0.07^{a}	5.28 ± 0.11^{a}
Job fish ***Apharus rutilanus***	6.63 ± 0.21^{abc}	3.48 ± 0.05^{ab}	2.90 ± 0.10^{ab}	9.74 ± 0.39^{ab}	2.79 ± 0.31^{abc}	3.36 ± 0.08^{bcd}	5.14 ± 0.18^{ab}
Spangled emperor ***Lethrinus nebuloses***	5.60 ± 0.31^{cd}	2.71 ± 0.17^{c}	2.29 ± 0.13^{c}	8.32 ± 0.33^{bc}	2.15 ± 0.32^{c}	2.69 ± 0.15^{e}	4.02 ± 0.33^{c}
Dusky grouper ***Epinephelus marginatus***	6.06 ± 0.20^{bcd}	2.93 ± 0.13^{bc}	2.50 ± 0.10b^{c}	8.86 ± 0.36^{abc}	2.30 ± 0.09^{bc}	2.88 ± 0.11^{de}	4.17 ± 0.27^{bc}
Rusty parrot fish ***Scarus ferrugineus***	6.91 ± 0.40^{ab}	3.32 ± 0.27^{ab}	2.84 ± 0.23^{ab}	10.37 ± 0.80^{a}	2.62 ± 0.25^{abc}	3.26 ± 0.28^{cd}	4.77 ± 0.52^{abc}
Half spotted grouper ***Cephalopholis hemistiktos***	7.26 ± 0.20^{a}	3.52 ± 0.08^{a}	2.87 ± 0.02^{ab}	10.54 ± 0.18^{a}	3.01 ± 0.13^{a}	3.75 ± 0.12^{abc}	5.33 ± 0.13^{a}
F value	**3.09**	**3.84**	**3.88**	**3.39**	**1.61**	**6.07**	**2.72**

Mean values ± standard error (n = 3). Means of samples having the same letter(s) within a column are not significantly different (P > 0.05).

Amino acids / Fish species	**VAL**	**ILE**	**LEU**	**TYR**	**PHE**	**HIS**	**LYS**	**ARG**
Grey mullet ***Liza ramada***	4.37 ± 0.13^{a}	3.74 ± 0.04^{ab}	5.80 ± 0.20^{a}	3.08 ± 0.07^{a}	3.29 ± 0.04^{a}	2.32 ± 0.10^{a}	6.22 ± 0.23^{a}	4.80 ± 0.07^{ab}
Sabaki tilapia ***Oreochromis spilurus***	3.78 ± 0.41^{abc}	3.28 ± 0.40^{ab}	5.34 ± 0.66^{ab}	2.68 ± 0.31^{ab}	3.17 ± 0.28^{ab}	2.06 ± 0.25^{abc}	5.86 ± 0.65^{ab}	4.29 ± 0.52^{abc}
Indian oil sardine ***Sardinella longiceps***	3.39 ± 0.06^{bc}	2.64 ± 0.04^{ab}	4.14 ± 0.05^{c}	2.16 ± 0.03^{c}	2.52 ± 0.09^{c}	2.02 ± 0.11^{abcd}	4.47 ± 0.02^{c}	3.67 ± 0.04^{c}
Golden thread fin bream ***Nemipterus japonicas***	4.13 ± 0.03^{a}	3.55 ± 0.02^{ab}	5.63 ± 0.00^{a}	3.02 ± 0.03^{a}	3.36 ± 0.05^{a}	1.83 ± 0.00^{cde}	6.26 ± 0.04^{a}	4.72 ± 0.01^{ab}
Gilt head bream ***Sparus aurata***	4.10 ± 0.27^{a}	3.65 ± 0.13^{ab}	5.63 ± 0.29^{a}	2.97 ± 0.03^{a}	3.23 ± 0.10^{a}	2.21 ± 0.02^{ab}	6.08 ± 0.34^{ab}	4.68 ± 0.12^{ab}
Asian seabass ***Lates calcarifer***	3.82 ± 0.03^{abc}	3.57 ± 0.05^{ab}	5.48 ± 0.07^{a}	2.92 ± 0.06^{a}	3.22 ± 0.03^{a}	1.93 ± 0.01^{bcde}	6.02 ± 0.07^{ab}	4.65 ± 0.02^{ab}
Job fish ***Apharus rutilanus***	3.98 ± 0.13^{ab}	3.84 ± 0.01^{a}	5.53 ± 0.20^{a}	3.04 ± 0.12^{a}	3.15 ± 0.05^{ab}	2.02 ± 0.02^{abcd}	5.85 ± 0.17^{ab}	4.72 ± 0.11^{ab}
Spangled emperor ***Lethrinus nebuloses***	3.23 ± 0.23^{c}	2.87 ± 0.20^{ab}	4.50 ± 0.21^{bc}	2.41 ± 0.21^{bc}	2.50 ± 0.11^{c}	1.58 ± 0.12^{e}	5.10 ± 0.19^{bc}	3.71 ± 0.13^{c}
Dusky grouper ***Epinephelus marginatus***	3.37 ± 0.13^{bc}	3.08 ± 0.16^{ab}	4.83 ± 0.18^{abc}	2.60 ± 0.12^{abc}	2.71 ± 0.13^{bc}	1.66 ± 0.07^{de}	5.36 ± 0.18^{abc}	4.06 ± 0.19^{bc}
Rusty parrot fish ***Scarus ferrugineus***	3.82 ± 0.31^{abc}	3.43 ± 0.29^{ab}	5.49 ± 0.48^{a}	2.89 ± 0.24^{ab}	3.08 ± 0.29^{ab}	1.79 ± 0.16^{cde}	6.10 ± 0.48^{ab}	4.56 ± 0.44^{ab}
Half spotted grouper ***Cephalopholis hemistiktos***	3.85 ± 0.09^{abc}	2.04 ± 1.58^{b}	5.69 ± 0.13^{a}	2.95 ± 0.07^{a}	3.40 ± 0.10^{a}	1.90 ± 0.04^{bcde}	6.28 ± 0.17^{a}	4.95 ± 0.09^{a}
F value	**3.09**	**1.17**	**3.54**	**4.14**	**5.34**	**4.26**	**3.84**	**3.87**

Mean values ± standard error (n = 3). Means of samples having the same letter(s) within a column are not significantly different (P > 0.05).

In case of essential amino acids (EAA), the major amino acids are lysine (4.47 - 6.28%), leucine (4.14 - 5.80%), valine (3.23 - 4.37%) followed by threonine (2.66 - 3.52%) and phenylalanine (2.5 - 3.36%) which have a close link with previous results found in butter catfish[12]. The other amino acids (non-essential amino acids NEAA) such as arginine, histidine, alanine and glycine were found to range from 3.67% in Indian oil sardine to 4.95% in half spotted grouper, 1.58% in spangled emperor to 2.32%

in grey mullet, 4.02% in spangled emperor to 5.36% in grey mullet and 2.69% in spangled emperor to 4.01% in Asian seabass, respectively. Moreover, spangled emperor sample had the least value of serine (2.29%), while grey mullet sample had the highest value recorded 2.98%. Proline ranged from 2.15% in spangled emperor to 3.01% in half spotted grouper.

EAA to NEAA ratio is an index to define the quality of the protein[22]. Optimal EAA to NEAA ratio has been reported in gilt head sea bream (*Sparus aurata*) which is 0.71 and signify a high quality protein on the other hand a very high ratio was recorded in squid roe (0.93) and a low value was reported in sea urchin roe (0.65)[23]. The total essential amino acids content without methionine and tryptophan (which were not determined) ranged from 24.00 g/100 g crude protein in Indian oil sardine to 32.15 g/100 g crude protein in grey mullet, while total non-essential amino acids content ranged from 28.78 to 37.71 g/100 g crude protein in spangled emperor and half spotted grouper, respectively. These previous results were close to the value for egg reference protein (56.6 g/100 g crude protein)[24]. The current contents of TEAA are comparable to some literature values; i.e. 35.1 (*Zonocerus variegatus*) and 35.0 (*Macrotermes bellicosus*)[25,26]. The EAA to NEAA ratio of studied fish flesh samples were calculated to range from 0.79 in half spotted grouper and Indian oil sardine to 0.90 in gilt head bream **(Figure 1).** These ratios were in accordance with those obtained by Pinto et al.[22]. The higher value represents excellent protein quality.

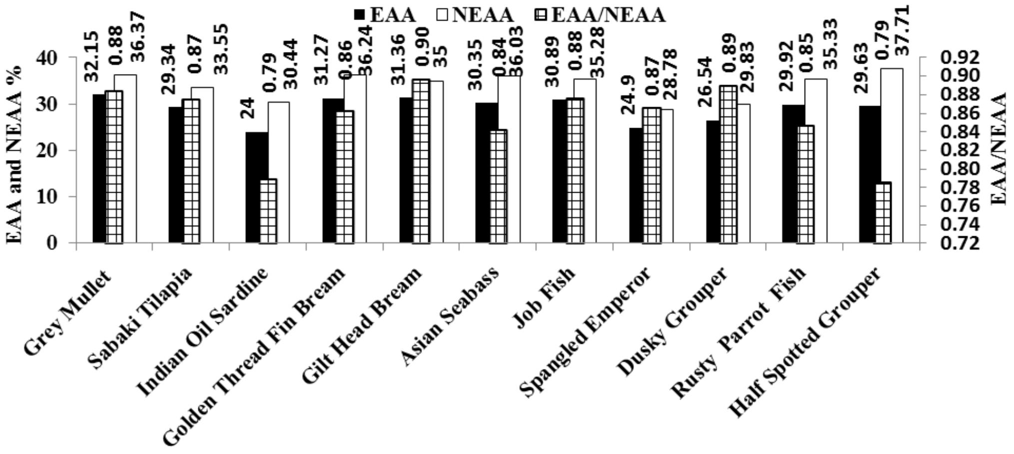

Figure 1. Essential amino acids (EAA), non-essential amino acids (NEAA) and EAA/NEAA ratio of studied fish flesh samples.

The predicted protein efficiency ratio (P-PER) of studied fish flesh samples were calculated and illustrated in **Figure 2.** From illustrated data, it could be seen that P-PER ratio ranged from 1.18 in Indian oil sardine to 1.84 in grey mullet. Generally, all of P-PER ratios were comparable to 2.22 (*C. anguillaris*), 1.92 (*O. niloticus*) and 1.89 (*C. senegalensis*)[13].

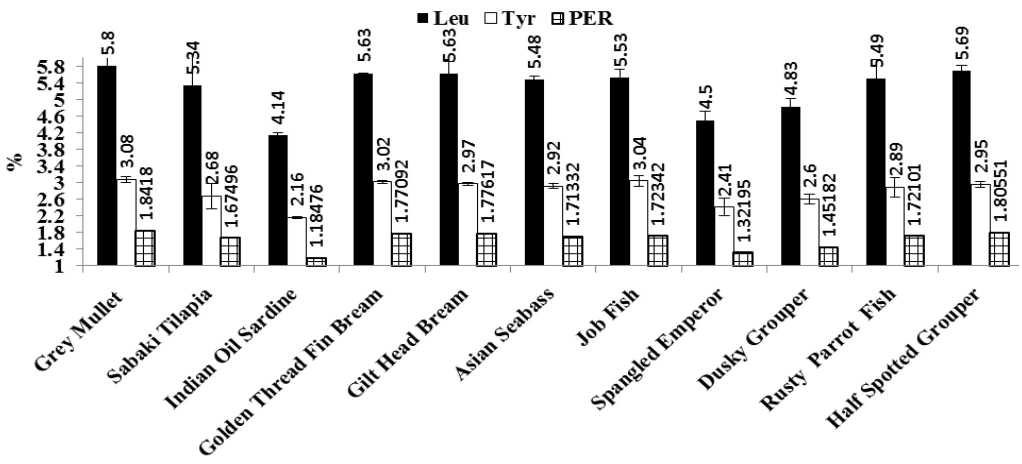

Figure 2. Leucine and tyramine content (g/100 g crude protein) and predicted protein efficiency ratio (P-PER) of studied fish flesh samples.

Statistical analysis showed that there were significant differences at P > 0.05 between all studied fish species in all amino acids content. For example, F value was 1.17 in isoleucine and 6.07 in glycine.

Dietary protein plays an important role providing amino acids for the biosynthesis of the body proteins. It is very important to provide all essential amino acids to the tissues in an appropriate amount for optimal protein synthesis. Fish proteins comprise all the essential amino acids vital for human nutrition which expand the overall protein quality of a diet[27].

Gas chromatography was used to establish identities of fatty acids extracted from studied fresh fish flesh samples. Results reported in **Table 2** showed mean of saturated fatty acids profile (%) of the eleven studied fish flesh as percentage of total fatty acid methyl esters, standard error and significance between all studied species. **Figure 3** showed standards and examples of fatty acids gas chromatography chromatogram. The percentage of total saturated fatty acids of studied fish were higher than 50% for most fish species which ranged from 34.19 ± 1.70% in golden thread fin bream to 54.67 ± 3.61% in grey mullet. Meanwhile, palmitic acid (C16:0) was the primary saturated fatty acid, contributing 46.27% and 61.83% of total saturated fatty acids of the lipids for gilt head bream and grey mullet, respectively. Stearic acid (C18:0) came in the second order in saturated fatty acids, which ranged from 11.05 ± 0.89% in golden thread fin bream to 24.78 ± 0.50% in sabaki tilapia. Meristic acid (C14:0) came in the third order of saturated fatty acids (0.92 ± 0.23 - 9.04 ± 1.54).

Table 2. Saturated fatty acids profile (%) of studied fish flesh samples as percentage of total fatty acid methyl esters.

Fatty acids / Fish species	C14:0	C15:0	C16:0	C17:0	C18:0	Total Saturated
Grey mullet *Liza ramada*	3.18 ± 0.52	0.92 ± 0.08	33.80 ± 1.86[a]	2.47 ± 0.00	15.82 ± 1.18[bc]	54.67 ± 3.61[a]
Sabaki tilapia *Oreochromis spilurus*	1.76 ± 0.17	0.00 ± 0.00	24.88 ± 1.92[cde]	0.00 ± 0.00	24.78 ± 0.50[a]	51.41 ± 2.01[a]
Indian oil sardine *Sardinella longiceps*	9.04 ± 1.54	0.75 ± 0.00	31.73 ± 1.02[ab]	0.00 ± 0.00	11.73 ± 0.40[c]	52.94 ± 2.51[a]
Golden thread fin bream *Nemipterus japonicas*	2.01 ± 0.18	0.52 ± 0.13	23.78 ± 1.18[de]	0.00 ± 0.00	11.05 ± 0.89[c]	37.19 ± 1.70[b]
Gilt head bream *Sparus aurata*	2.70 ± 0.18	0.31 ± 0.01	22.54 ± 1.19[e]	0.79 ± 0.02	22.02 ± 0.87[a]	48.71 ± 1.78[a]
Asian seabass *Lates calcarifer*	4.53 ± 0.64	0.43 ± 0.10	24.19 ± 1.77[de]	1.08 ± 0.05	22.06 ± 2.87[a]	52.31 ± 4.49[a]
Job fish *Apharus rutilanus*	0.41 ± 0.00	1.00 ± 0.11	23.23 ± 0.60[e]	1.84 ± 0.18	13.64 ± 1.23[cd]	40.17 ± 0.86[b]
Spangled emperor *Lethrinus nebuloses*	3.25 ± 1.34	0.94 ± 0.01	26.76 ± 0.66[bcde]	2.07 ± 0.05	17.55 ± 0.80[b]	51.27 ± 0.65[a]
Dusky grouper *Epinephelus marginatus*	1.48 ± 0.91	0.69 ± 0.05	30.80 ± 3.38[abc]	1.91 ± 0.14	16.61 ± 0.64[bc]	51.86 ± 1.98[a]
Rusty parrot fish *Scarus ferrugineus*	0.92 ± 0.23	0.28 ± 0.00	27.83 ± 3.86[abcde]	1.20 ± 0.53	23.75 ± 0.51[a]	54.14 ± 4.25[a]
Half spotted grouper *Cephalopholis hemistiktos*	4.47 ± 0.37	0.71 ± 0.02	29.86 ± 0.67[abcd]	1.92 ± 0.13	16.73 ± 0.72[bc]	54.03 ± 0.24[a]
F value	**8.72**	**11.14**	**3.91**	**5.19**	**16.68**	**5.09**

Mean values ± standard error (n = 3). Means of samples having the same letter(s) within a column are not significantly different (P > 0.05).

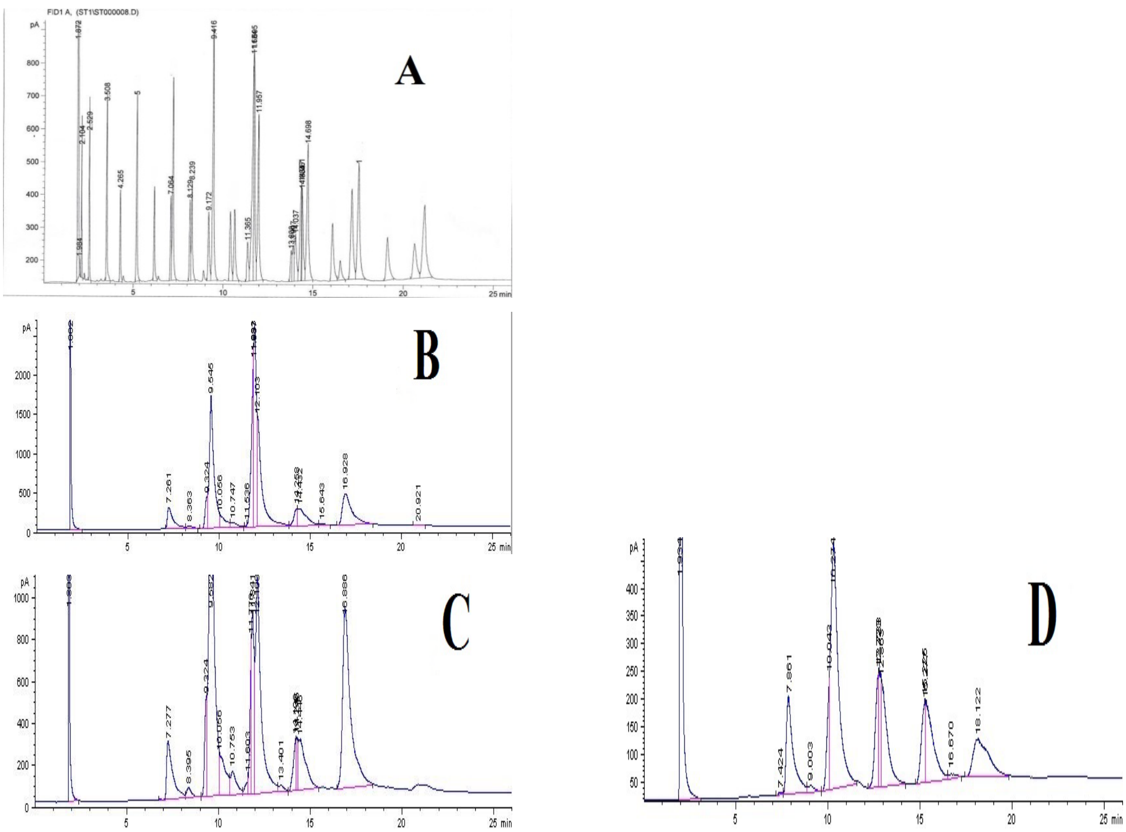

Figure 3. Fatty acids GC chromatograms, A: Standard chromatogram, B: asian seabass, C: half spotted grouper and D: indian oil sardine.

Eboh et al.[28] reported that palmitic acid was the most prevalent in all species with mean values of 8.50% (catfish), 31.90% (tilapia), 36.20% (ilisha), 37.50% (bonga fish) and 9.94% (mudskipper). In general, fish are relatively low in saturated fatty acids (< 30%), except for certain species. This higher SFA content in this study was probably due to the high temperature in Saudi Arabia[29]. These previous findings were in close link with those obtained by Zuraini et al.[30] and Tawfik[10]. Statistical analysis showed there were significant differences at $P > 0.05$ between all studied fish species in C16:0, C18:0 and TSF with F value of 3.91, 16.68 and 5.09, respectively.

Table 3 showed monounsaturated fatty acids profile (%) of the studied fish flesh sample as percentage of total fatty acid methyl esters. Oleic acid (C18:1) was identified as the primary monoenoic fatty acid in all studied fish flesh samples. The highest value of oleic acid was found in sabaki tilapia sample representing 22.20 ± 0.87%, while the least value was noticed in dusky grouper sample recorded 5.65 ± 0.54%. The second monounsaturated fatty acid was C16:1 which ranged from 0.63% in rusty parrot fish to 5.49% in grey mullet. However, total monounsaturated fatty acids showed wide range in the elven studied fish samples where it ranged from 7.31% to 28.10% in rusty parrot fish and sabaki tilapia, respectively. Statistical analysis showed there were significant differences at $P > 0.05$ between all studied fish species in C18:1, C16:1 and total monounsaturated fatty acids with F value of 39.83, 12.55 and 26.49, respectively. These results were similar to those reported by Tawfik[10].

Table 3. Monounsaturated fatty acids profile (%) of studied fish flesh samples as percentage of total fatty acid methyl esters.

Fatty acids / Fish species	C14:1	C16:1	C18:1	C20:1	Total monounsaturated
Grey mullet *Liza ramada*	0.00 ± 0.00	5.49 ± 0.64^{a}	10.21 ± 0.74^{c}	0.00 ± 0.00	16.28 ± 0.73^{de}
Sabaki tilapia *Oreochromis spilurus*	0.00 ± 0.00	1.39 ± 0.20^{de}	22.20 ± 0.87^{a}	4.50 ± 0.14	28.10 ± 0.77^{a}
Indian oil sardine *Sardinella longiceps*	0.20 ± 0.04	4.29 ± 0.30^{b}	6.09 ± 1.23^{d}	11.34 ± 0.39	21.92 ± 1.45^{bc}
Golden thread fin bream *Nemipterus japonicas*	0.00 ± 0.00	1.35 ± 0.17^{de}	11.84 ± 1.90^{c}	6.43 ± 0.79	19.62 ± 1.53^{cd}
Gilt head bream *Sparus aurata*	0.00 ± 0.00	1.81 ± 0.08^{cde}	21.61 ± 1.01^{a}	3.70 ± 0.11	27.59 ± 1.14^{a}
Asian seabass *Lates calcarifer*	0.00 ± 0.00	2.62 ± 0.24^{cd}	17.06 ± 1.38^{b}	4.14 ± 0.49	24.59 ± 2.75^{ab}
Job fish *Apharus rutilanus*	4.19 ± 0.16	2.31 ± 0.13^{cd}	7.29 ± 0.28^{d}	0.00 ± 0.00	14.19 ± 0.49^{ef}
Spangled emperor *Lethrinus nebuloses*	1.81 ± 1.77	2.86 ± 0.64^{c}	7.02 ± 0.61^{d}	0.00 ± 0.00	11.25 ± 0.98^{fg}
Dusky grouper *Epinephelus marginatus*	4.07 ± 0.41	3.05 ± 0.51^{c}	5.65 ± 0.54^{d}	0.00 ± 0.00	11.42 ± 2.30^{fg}
Rusty parrot fish *Scarus ferrugineus*	0.00 ± 0.00	0.63 ± 0.13^{e}	6.69 ± 0.50^{d}	0.00 ± 0.00	7.31 ± 0.53^{g}
Half spotted grouper *Cephalopholis hemistiktos*	0.00 ± 0.00	2.37 ± 0.60^{cd}	6.89 ± 0.72^{d}	0.00 ± 0.00	9.26 ± 1.25^{g}
F value	**9.03**	**12.55**	**39.83**	**46.80**	**26.49**

Mean values ± standard error (n = 3). Means of samples having the same letter(s) within a column are not significantly different ($P > 0.05$).

Mean of polyunsaturated fatty acids profile (%) of studied fish flesh samples were presented in **Table 4.** Tabulated data showed that total polyunsaturated fatty acids of studied fish flesh samples ranged from 20.48 ± 1.53% to 43.19 ± 0.17% in sabaki tilapia and golden thread fin bream, respectively. Moreover, there were significant differences at $P > 0.05$ between all fish species in total polyunsaturated fatty acids with F value of 11.56. Among ω-6 series of the fatty acids, gilt head bream sample had the highest level of C18:2 ω-6 (15.86% represented 66.92% of total polyunsaturated fatty acids), in despite of the low value of TPUFA recorded 23.70%. On the other hand, dusky grouper had the least value of C18:2 ω-6 (3.33 ± 0.74%). C20:3 ω-6 fatty acid was also present in six samples of the studied fish with highest value of 10.89% in rusty parrot fish. Among ω-3 series, C22:6 docosahexaenoic acid (DHA) was the most common fatty acid in all studied fish samples. It recorded the highest value in golden thread fin bream (27.82 ± 1.24%), followed by job fish (26.43%) without any significant differences. While, it was 5.61 ± 0.77% in sabaki tilapia (the least value), followed by gilt head bream (6.41%). In addition, C20:5 eicosapentaenoic acid (EPA) ω-3 ranged from 0.44% to 8.52% in rusty parrot fish and grey mullet, respectively.

Table 4. Polyunsaturated fatty acids profile (%) of studied fish flesh samples as percentage of total fatty acid methyl esters.

Fatty acids / Fish species	C18:2 w6	C18:3	C20:3w3	C20:3w6	C20:5w3	C22:6w3	Total polyunsaturated
Grey mullet *Liza ramada*	7.79 ± 0.90^{d}	1.03 ± 0.37	0.00 ± 0.00	0.00 ± 0.00	8.52 ± 2.76	10.42 ± 1.69^{fg}	29.11 ± 4.36^{cd}
Sabaki tilapia *Oreochromis spilurus*	13.38 ± 0.63^{ab}	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	1.49 ± 0.26	5.61 ± 0.77^{g}	20.48 ± 1.53^{de}
Indian oil sardine *Sardinella longiceps*	6.48 ± 1.03^{de}	0.00 ± 0.00	7.48 ± 0.82	0.00 ± 0.00	0.00 ± 0.00	11.17 ± 0.52^{efg}	25.14 ± 1.99^{de}

Golden thread fin bream ***Nemipterus japonicas***	8.34 ± 0.76[cd]	1.54 ± 0.34	5.49 ± 0.62	0.00 ± 0.00	0.00 ± 0.00	27.82 ± 1.24[a]	43.19 ± 0.17[a]
Gilt head bream ***Sparus aurata***	15.86 ± 0.83[a]	0.15 ± 0.02	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	6.41 ± 0.64[g]	23.70 ± 0.98[de]
Asian seabass ***Lates calcarifer***	11.17 ± 1.35[bc]	0.11 ± 0.00	1.74 ± 0.51	1.42 ± 0.00	0.00 ± 0.00	9.59 ± 0.50[fg]	23.13 ± 1.87[de]
Job fish ***Apharus rutilanus***	4.01 ± 0.31[e]	0.18 ± 0.03	4.65 ± 0.20	7.09 ± 0.71	0.16 ± 0.02	26.43 ± 0.52[ab]	42.51 ± 0.48[a]
Spangled emperor ***Lethrinus nebuloses***	6.35 ± 1.86[de]	0.30 ± 0.08	5.29 ± 0.42	8.17 ± 0.17	0.46 ± 0.19	13.54 ± 1.90[ef]	34.09 ± 0.88[bc]
Dusky grouper ***Epinephelus marginatus***	3.33 ± 0.74[e]	0.23 ± 0.07	3.16 ± 0.35	5.12 ± 0.18	0.44 ± 0.00	22.28 ± 4.22[bc]	34.26 ± 3.85[bc]
Rusty parrot fish ***Scarus ferrugineus***	3.35 ± 0.80[e]	0.19 ± 0.00	6.59 ± 0.54	10.89 ± 0.58	0.00 ± 0.00	16.27 ± 2.26[de]	37.69 ± 3.44[ab]
Half spotted grouper ***Cephalopholis hemistiktos***	3.48 ± 0.50[e]	0.41 ± 0.07	2.61 ± 0.44	3.58 ± 1.24	0.00 ± 0.00	20.87 ± 0.53[cd]	32.67 ± 0.76[bc]
F value	**18.82**	**6.40**	**13.54**	**16.90**	**6.23**	**20.35**	**11.56**

Mean values ± standard error (n = 3). Means of samples having the same letter(s) within a column are not significantly different (P > 0.05).

Among the total percentage of ω-3 polyunsaturated fatty acids, it is higher than ω-6 in all studied fish species except in sabaki tilapia, gilt head bream and Asian seabass. As referred in earlier research reports, fish contain high amounts of ω-3 and low amounts of ω-6 PUFA. The lipids of marine fish are characterized by their high proportion of polyunsaturated fatty acids, such as the nutritionally important EPA and DHA, which are highly susceptible to autoxidation because of their high degree of unsaturation[31].

Biological value is an index of nutritional evaluation of oil or fat calculating as a ratio between total unsaturated fatty acids and total saturated fatty acids. The increase of biological value, the high nutritional value of fat or oil occurred. Total unsaturated fatty acids, total saturated fatty acids and biological value of studied fish flesh samples were illustrated in **Figure 4.**

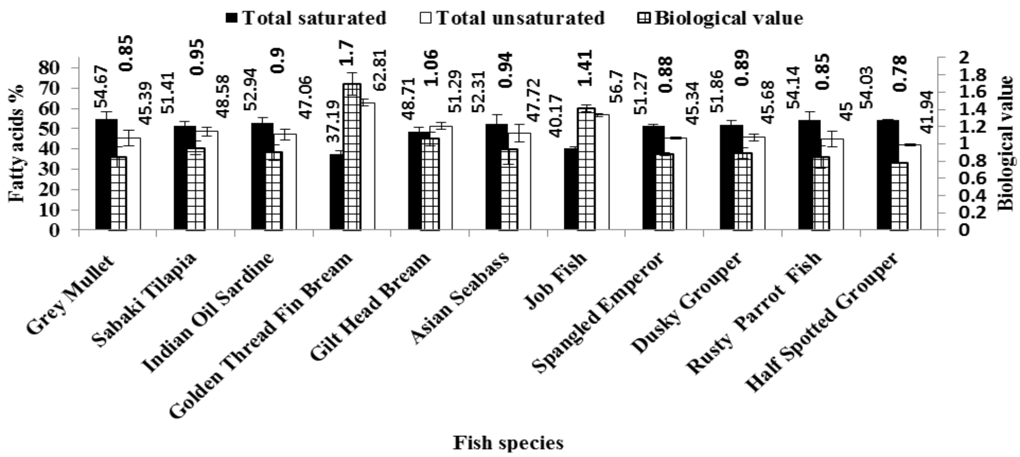

Figure 4. Total saturated, total unsaturated fatty acids and biological value of studied fish flesh samples as percentage of total fatty acid methyl esters.

From obtained results it could be noticed that total saturated fatty acids ranged from 37.19% in golden thread fin bream to 54.67% in grey mullet. Meanwhile, the highest value of total unsaturated fatty acids was found in golden thread fin bream (62.81%), the least value was recorded in half spotted grouper (41.94%). Consequently, golden thread fin bream had the highest value of biological value (1.7), followed by job fish which recorded 1.41. It has been reported that the type and amount of fatty acids in fish tissues mainly vary with what the fish eat, but other factor may also influence their fatty acid composition. Size or age, reproductive status, geographic location and season all influence fat content and composition of fish muscle[28,32].

CONCLUSION

Taking into account all previous findings, it could be concluded that all studied fish species highly found in Saudi Arabia and Arabian Gulf countries had higher nutritive value as compared with other animals such as camels, cows, lambs and chickens. These fish species were considered vital sources of essential amino acids and polyunsaturated fatty acids especially DHA, ω-3 fatty acid. So it is necessary to change the nutritive pattern of Saudis and residents to encourage them to increase their fish consumption benefitting the high content of essential amino acids and polyunsaturated fatty acids, the acceptable prices of fish and the higher digestibility of fish.

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