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A Comparative Study of Amino Acids and B-Group Vitamins of Commercial Fish Species

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Abstract

Marine-derived organisms are good sources of nutrients, making them crucial as we face food security. The amino acids and free amino acids profile as well as B-group vitamins of commonly consumed fish species (anchovy, mackerel, sea bream, sea bass, salmon, trout) in the northeastern Mediterranean were revealed. The most abundant amino acids and EAA were glutamic acid (616-757 mg/100g) and phenylalanine (282-368 mg/100g), respectively. The highest total EAA was found in seabream, where the lowest score was in mackerel. Valine was the limiting EAA in all fish samples. Salmon had required EAA/nEAA and EAA/TAA ratios, while seabream had higher BCAAs and SAAs. Anchovy had the best cholesterolemic index values. B3-niacin (155.08 µg/100g) and B3-nicotinamide (149.02 µg/100g) were found to be at the highest levels in salmon. Salmon meat was also rich in B5-pantothenic acid and B6-pyridoxal. The fish provide an adequate and balanced diet in terms of amino acids and B-group vitamins, considering the recommended daily intake values.

Introduction

The decrease in food resources due to population growth causes alarm in food security. Terrestrial land for agriculture is so limited or not as fertile as before. Fish, either caught from marine or freshwater or produced through aquaculture is a good source of essential amino acids (EAA), polyunsaturated fatty acids, vitamins, and minerals. Fish is also a good source of micronutrients that are more abundant than mammalian meat and herbs (Mohanty *et al.,* 2019).

Protein is vital for growth, maintenance, and repair of body tissues; muscle and bone, mediate the metabolism of both toxic and essential trace elements in organisms and provides energy (Man *et al.,* 2019; Weichselbaum *et al.,* 2021). EAA, which are not compensated by any another, should be obtained from both animal and plant origins. The protein content of fish is usually between 15 and 22% (Ganjeh *et al.,* 2023). The EAA profile makes fish a complete source of protein and readily digestible. In addition to their nutritional and functional properties, amino acids, especially free amino acids, are also responsible for the formation of flavor and aroma. Glutamic acid is responsible for the umami taste, while alanine is the main sweet amino acid. Arginine, methionine, lysine, valine, and histidine are the main flavor amino acids with bitter taste (Wang *et al.,* 2022). Free amino acids are the main precursors of biogenic amines. The consumption of excessive amounts of biogenic amines may cause health risks especially for allergic individuals. The free amino acid profile of fish species may change either due to the nature of fish or anthropogenic factors such as harvesting, processing and storage conditions.

Micronutrients are also vital compounds for the physical and mental development of human metabolism and should be supplied from foods. B-group vitamins are responsible for the treatment of liver damage, regulation of neurotransmitters, growth of cells, energy production, breakdown of nutrients, cofactors of some critical enzymes (B1-thiamin and B2riboflavin), enzyme functions, healthy skin and nerves (B3-niacin), energy production, hormone formation (B5- pantothenic acid), metabolism of carbohydrates, lipids, amino acids, and nucleic acids, production of insulin and hemoglobin (B6-pyridoxine), energy production (B7-biotin), red blood cell formation, liver damage repair, protein metabolism, tissue buildup, muscle protection, and growth (B9-folate), contribution to the formation of genetic material, production of normal red blood cells, and maintenance of the nervous system (B12-cobalamin) (Demir *et al.,* 2023; Olanbiwoninu *et al.,* 2023). Due to not being stored in the human body, water-soluble B-group vitamins should be daily taken, and fish species are good sources of these micronutrients (Yaman *et al.,* 2022).

A healthy food should contain all nutrient constituents for an adequate and balanced diet. This data is important not only for the consumer but also for seafood processors. The lipid content, fatty acid profile, lipid-soluble vitamins and their interactions with the health of commonly consumed fish species were discussed in an earlier research (Yerlikaya *et al.,* 2022). The identification amino acids and B- group vitamins, the two most important nutrients in fish, fulfils the need for a nutritional comparison. The present study aimed to reveal the amino acids, free amino acids and B- group vitamins composition of commonly consumed fish species and contribute to the global food composition database.

Materials and Methods

Materials

This study was based on the most consumed fish species purchased in Antalya, Türkiye. Salmon (*Salmo salar*), mackerel *(Scomber scombrus),* anchovy (*Engraulis encrasicolus*), seabass (*Sparus aurata*), seabream (*Dicentrarchus labrax*) and trout (*Oncorhynchus mykiss*) obtained from the fish market during the fishing season depending on their availability. Fish were transferred to the laboratory considering a cold chain, washed and beheaded immediately. All assays were conducted on duplicate samples of the homogenates for each of the three replications.

Methods

Amino Acid Analyses

Total amino acid composition of the samples was determined according to Chan and Matanjun (2017) with slight modifications. 0.2 g of sample was mixed with 6N HCl and vortexed for 5 min. Then sealed samples were kept in an oven (110ºC) for 24 h to hydrolysis. Samples were cooled to room temperature and centrifuged at 4000 rpm for 15 minutes at 4 °C. The upper phase was filtered through a 0.45 µm PTFE membrane filter and then injected into the UHPLC-MS/MS device Accela UHPLC, TSQ Quantum Access Max (Thermo Fisher Scientific Inc. Waltham, Massachussetts, USA).

Free Amino Acid Analyses

Free amino acid profile was determined according to Kivrak *et al.* (2014). 1.0 g sample was mixed with 10 ml of water:methanol (80:20) (v/v) containing %0.1 (v/v) formic acid. The mixture was shaken with vortex for 5 min, then centrifuged at 4ºC at 4000 rpm for 15 min.

The supernatant was filtered using 0.2 µm nylon membrane filter and injected to UHPLCMS/MS. Hypersil Gold RP C18 (1.9µm), 50x2.1 mm, (Thermo Fisher Scientific Inc. Waltham, Massachussetts, USA) column was used chromatographic separation.

B-group Vitamins

The amounts of water-soluble B vitamins in different fish samples were analyzed (Vit B1, Vit B2, Vit B3, Vit B5, Vit B6, Vit B7, Vit B9) according to Huang *et al.* (2009). 50 ml of 20% methanol (contained 5mM HCl) was added to a 1 g sample and homogenized with the ultraturrax (pH 2.6). The homogenized samples were extracted in an ultrasonic bath for 30 minutes. Then, the pH values of the extracts were adjusted to 4.5 to 5.5. The extract solutions were filtered through a 0.45µm µm PTFE membrane filter and injected into the UHPLC-MS/MS. Hypersil Gold RP C18 (1.9µm), 100x2.1 mm, (Thermo Fisher Scientific Inc. Waltham, Massachussetts, USA) was used for chromatographic separation.

Statistical Analysis

Statistical analyses were done using the SAS software (Statistical Analysis System, Cary, NC, USA). Duncan's multiple range test was performed in case of significance among main effects or interactions.

Results and Discussion

Amino Acids

The major EAA of commonly consumed fish species were phenylalanine, isoleucine+leucine and threonine, while the non-EAA were glutamic acid, aspartic acid and tyrosine (Figure 1). The highest total EAA, was found in seabream, where the lowest score was recorded in mackerel. Valine was the limiting EAA in all fish samples.

Lysine is the first-limiting EAA to be deformed during processing or prolonged storage (Olu and Adediran, 2015). Lysine deficiencies can lead to weakening of the immune system, decrease blood proteins and retard the development of children (Galili and Amir, 2013). Lysine content of commonly consumed fish species ranged between 234.68±11.14 mg/100g (trout) and 197.12±13.33 mg/100g (seabass) which exceeds the recommended level of lysine 30 mg/kg body weight per day (WHO/FAO/UNU 2007). Lysine content of organic and conventional salmon (*Salmo salar*) was 17.5 and 16.7 g/kg, respectively (Esaiassen *et al.,* 2022).

Phenylalanine, the most abundant EAA, content in fish samples reached to 368.28±14.48 mg/100g in seabream ($p<0.01$). Phenylalanine content of salmon, trout and anchovy (337.97±2.97, 308.21±6.24 and 331.02±9.18 mg/100g, respectively) were not statistically different ($p>0.05$). Phenylalanine was reported to constitute the highest essential amino acid (EAA) concentration in *O.niloticus* and *C.senegalensis* (Adeyeye, 2009). Ogretmen (2022) reported that the most abundant amino acids of anchovy caught from different locations were glutamic acid, aspartic acid, leucine, and lysine. However, in the present study, the most abundant EAA phenylalanine in anchovy samples.

The methionine content of mackerel and trout were around 79 mg/100g. Threonine, which was detected at high levels in seabass (184.52±0.45 mg/100g) and salmon (181.02±1.29 mg/100g), varies slightly in concentrations in anchovy, mackerel, sea bream and trout. WHO/FAO/UNU (2007) recommended methionine and threonine intake 10 and 15 mg/kg/day, respectively.

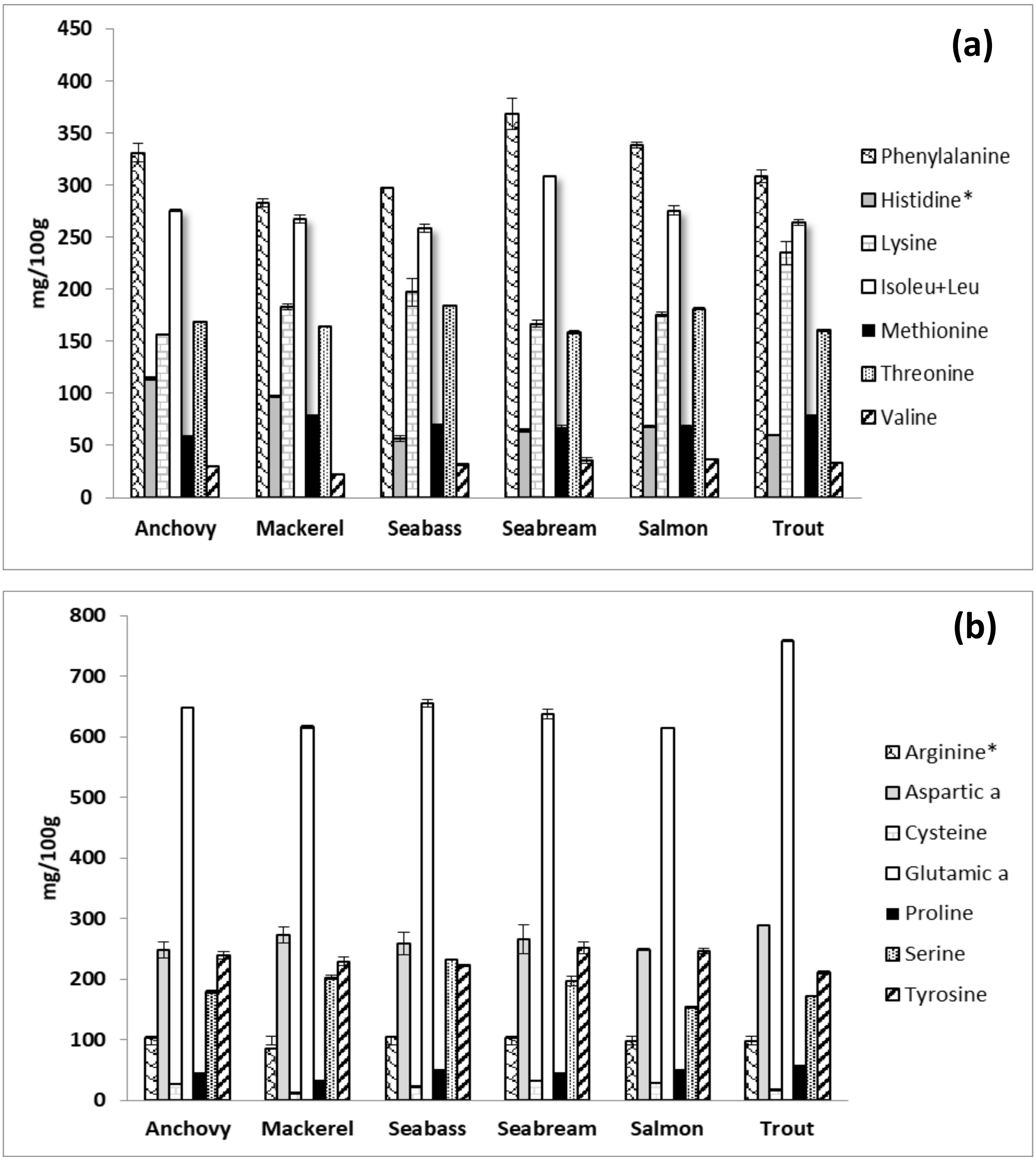

Figure 1. Essential amino acids (a) and non-essential amino acids of commonly consumed fish species *Essential amino acid for infants

Leucine, isoleucine, and valine are reported to promote muscle protein synthesis and reduce protein catabolism (De Bandt and Cynober, 2006). Both isoleucine+leucine and valine contents of seabream and salmon were higher than those of other samples. Leucine, along with lysine, was the most abundant EAA in marine fishes commonly consumed in Nigeria: *Clupea harengus, Scomber scombrus, Trachurus trachurus* and *Urophycis tenuis* (Oluwaniyi *et al.* 2010). Leucine was reported to be the highest EAA in swordfish (Cobas et al, 2022). The limiting amino acid was valine in all fish samples of the present study, as in *O.niloticus* (Adeyeye, 2009).

Initially, the requirements for histidine and arginine are considered as essential especially for infants. This can be attributed to the presence of histidine in haemoglobin and histidine-containing dipeptide carnosine. However, hemoglobin concentration should not be compromised to maintain histidine concentrations during histidine deficiency (ThalackerMercer and Gheller, 2020). Histidine, as expected, recorded at high concentrations in Clupeidae family member anchovy (114.47±1.74 mg/100g) and Scombridae family member mackerel (97.11±1.42 mg/100g). Although arginine is not considered essential due to de novo synthesis between species, this amino acid is dispensable for neonates and children based on nitrogen retention and growth data (Ball *et al.,* 2007). Arginine content of all fish species varies between 96.69 and 103.85 mg/100g, except for mackerel (84.30±1.38 mg/100g) ($p<0.01$). As reported earlier, the increase in lysine, histidine and arginine content allows the protein to be more functional due to the ability of ionic interaction. Among the fish studied, trout had the highest total content of such amino acids followed by anchovy.

The content of total non-EAA was high in trout (1602.94 mg/100g), while low in salmon (1439.22 mg/100g). In the present study, the most abundant amino acid was glutamic acid ranging from 615.14 (salmon) to 757.98 (trout) mg/100g ($p<0.01$), followed by another two carboxylic acids grouped aspartic acid with a similar trend. The aspartic acid contents of fish samples were not statistically different from each other ($p>0.05$). Glutamic acid and aspartic acid were quantitatively the most abundant amino acids in many fish species such as three local Malaysian Channa spp. fish (Zuraini *et al.,* 2006), three species of Nigerian fish (Adeyeye 2009), herring (*Clupea harengus*) and Atlantic mackerel (*Scomber scombrus*) (Oluwaniyi *et al.,* 2010), Atlantic bonito (*Sarda sarda*) (Ormanci and Colakoglu, 2015), cod (*Gadus morhua*) (Teixeira and Mendes, 2020), European eel (*Anguilla anguilla*) (Gomez-Limia *et al.,* 2021), swordfish (*Xiphias gladius*) (Cobas *et al.,* 2022).

Aromatic amino acids such as phenylalanine, tryptophan, and tyrosine can donate protons to electron-deficient radicals. Thus, these amino acids are significant radical scavengers in peptides (Ao and Li, 2013). Tyrosine is the third most abundant non-EEA of the fish samples and its amount reached to 252.06±9.76 mg/100g in seabream.

Serine content was between 153.63 mg/100g (salmon) and 231.84 mg/100g (seabass). The limiting non-EAA was cysteine (12.74-32.53 mg/100g) and proline (33.40-57.98 mg/100g).

Mohanty *et al.* (2014) reported that cold water species were rich in lysine and aspartic acid, meanwhile marine fishes in leucine, small indigenous fishes in histidine. The same researcher added that marine fishes were also rich in glycine and glutamic acid besides leucine (Mohanty *et al.,* 2019).

Mass Fraction Ratios, SAAs, BCAAs and Cholesterol Index (CI) Values

The ratios of mass fraction EAA/nEAA and EAA/TAA (total amino acids) in the protein recommended by the World Health Organization are about 40%, and EAA/nEAA is about 60%, respectively (Usydus *et al.,* 2009). The ratio between EAA/nEAA is an indicator of protein quality. This value ranges from 70.92% (seabass) to 79.44% (salmon) (Table 1). Qi *et al.* (2022) found 80.17% in salmon. Similar results were found 0.75 in cod (Teixeira and Mendes, 2020), 0.74 in swordfish (Cobas *et al.,* 2022). EAA/nEAA was recorded between 0.81 and 0.86 in European eels and reported to be increased with the size (Gomez-Limia *et al.,* 2021). Significant differences in EAA/nEAA of anchovy ranging from 0.76 to 1.20 was determined depending on locations (Ogretmen, 2022) and European plaice depending on seasons (Kendler *et al.* 2023). EAA/TAA of all fish samples were higher than recommendations and ranged between 41.49 to 44.27%. The highest EAA/TAA

Table 1. Mass fraction ratios, SAAs, BCAAs and cholesterol index values

	EAA/nEAA (%)	EAA/TAA (%)	BCAAs (mg/100g)	SAAs (mg/100g)	CI
Anchovy	76.27	43.26	305.80	86.61	0.65
Mackerel	75.52	43.02	289.35	92.11	0.45
Seabass	70.92	41.49	291.01	92.62	0.52
Seabream	76.34	43.29	343.93	100.66	0.61
Salmon	79.44	44.27	312.08	97.22	0.55
Trout	71.10	41.55	297.52	96.13	0.41

EAA/nEAA: Total essential amino acids / total non-essential amino acids, EAA/TAA: Total essential amino acids / total amino acids, BCAAs: Total branched-chain amino acids (leucine, isoleucine and valine), SAAs: Total sulphur amino acids (methionine and cysteine), CI: cholesterolemic index (arginine/lysine) value belongs to salmon with 44.27, as well as Qi *et al.* (2022) similarly determined 44.49%.

Total sulphur amino acids (SAAa) content is derived mainly from methionine, which can be converted to cysteine. Methionine is a methyl group donor for DNA and RNA synthesis and a component of many proteins. Seabream (100.66 mg/100g) had the highest SAAs content followed by salmon (97.22 mg/100g) and trout (96.13 mg/100g) (Table 1). The SAA content of *Clarias anguillaris, Oreochromis niloticus* and *Cynoglossus senegalensis* were found 0.307, 0.335 and 0.292 mg/ 100g crude protein, respectively. SAAs of sardine 1030 mg amino acid/100 g protein (Garcia-Arias *et al.,* 2003), herring 3440, Atlantic mackerel 3500 and horse mackerel 3250 mg/100g protein were recorded by researchers (Oluwaniyi *et al.,* 2010).

Branched-chain amino acids (BCAAs), composed of leucine, isoleucine, and valine, encourage the formation of human myofibrillar protein synthesis, reduce muscle breakdown and maintain immune function. The BCAAs values are presented in Table 1. The highest BCAAs were found in seabream 343.73 mg/100g, while mackerel had the lowest score of 289.35 mg/100g. European plaice had 19.5-19.7 mg/100g BCAAs (Kendler *et al.* 2023), while European eel had 294-307 mg/100g (Gomez-Limia *et al.,* 2021). The total of leucine, isoleucine, and valine in three Channa spp. fish were 15.5-15.9% (Zuraini *et al.,* 2006).

The arginine to lysine ratio, which is involved in the inhibition of intestinal lipid absorption, is used as a measure of the cholesterolemic effect of a protein. A high arginine to low lysine ratio is desired in heart-healthy foods and infant formulas (Kaushik *et al.,* 2016). The highest cholesterolemic index (CI) was found in anchovy (0.65), followed by seabream (0.61) (Table 1). Ogretmen (2022) reported CI values of anchovy ranging from 0.31 to 0.68 depending on locations. A CI value of salmon was 0.55 in the present study, while Qi *et al.* (2022) found 0.65 in salmon (*Salmo salar*) from China, organic and wild salmon CI scores were 0.72 and 0.62, respectively (Esaiassen *et al.*, 2022). In addition to the locational effect, the feeding method, whether it is fed naturally or manually, is also important for the composition of amino acids.

Free Amino Acids

Free amino acids are classified according to their contribution to flavor; umami (glutamic acid and aspartic acid), sweetness (alanine, glycine, serine, threonine), pleasant sweetness/bitterness (proline), unpleasant sweetness/bitterness (arginine, lysine, valine), unpleasant sweetness/bitterness/sulphur (methionine), bitterness (histidine, isoleucine, leucine, phenylalanine) (Wang *et al.,* 2022). Interestingly, anchovy and mackerel had high contents of all categories, whereas seabass and trout had the least unpleasant flavor.

Free amino acids allow the formation of relevant biogenic amines, and the resulting amines reduce food quality and cause health concerns due to their toxic effects. Species in the families of Scombridae (e.g., mackerel, tuna, and bonito) and Clupeidae families (e.g., sardine, anchovy and herring) are the most common vehicles for free histidine in their muscular tissues (Rossano *et al.,* 2006). Confirming this data, the highest histidine was recorded in mackerel (13.86±0.03 mg/100g) and anchovy (10.45±0.10 mg/100g) (Figure 2). The same fish species also had higher isoleucine+leucine and valine content compared to the other fish samples ($p<0.01$). Methionine was the limiting free EAA in all fish species. The total free EAA was found in anchovy and mackerel (66 mg/100g), while seabass and trout had lower contents of free EAA (14-15 mg/100g).

Serine is the most abundant free non-EAA and ranges between 1.99 mg/100g (mackerel) and 3.57 mg/100g (salmon). However, as reported for total free EAA, the highest total free non-EAA was recorded in anchovy and mackerel (25 mg/100g). Free glutamic acid, aspartic acid, tyrosine, and phenylalanine contribute to impressing savory or umami taste and found high in anchovy and mackerel, while seabass had the least.

Cysteine, a highly reactive sulfhydryl (SH) group, was not detected in anchovy, mackerel, seabass, and seabream. As mentioned above, cysteine was the limiting non-EAA in all fish samples. Man *et al.* (2019) reported that when cysteine forms a conjugated bond with methylmercury (MeHg-Cys) MeHg can easily be transported to the mammalian cells and allows a better absorption and uptake of Hg by body tissues.

Fuentes *et al.* (2010) compared wild and cultured seabass and found that cultured sea bass showed higher levels of free glutamic acid, glycine, histidine, and alanine, and lower levels of serine, arginine, taurine, and methionine than wild samples. Total free amino acid content of seabass, which was mainly composed of taurine, ranged from 355.38 mg/kg (cultured) to 379.29 mg/kg (wild). In the present study, the main free amino acids of seabass were serine, threonine, lysine, and histidine, while total free amino acid score was 25.10 mg/100g.

B-group Vitamins

Briefly, the deficiency in B-group vitamins reduces mitochondrial function, disrupts energy metabolism, and endangers growth, function, and survival (Demir *et al.,* 2023). Consuming seafood can be a solution to filling the nutritional gaps of such vitamins. The highest levels of B-group vitamins in all fish species examined were B3-niacin and B3-nicotinamide. B6-Pyridoxamine and B9-folic acid cannot be detected in any of the fish samples, while B1-thiamine was only can be detected in seabass, seabream, and salmon. The results of B-group vitamin contents of the fish species were summarized in Table 2.

Bioavailability and bioaccessibility of vitamins B1, B2, and B3 in plant-sourced foods are generally less than

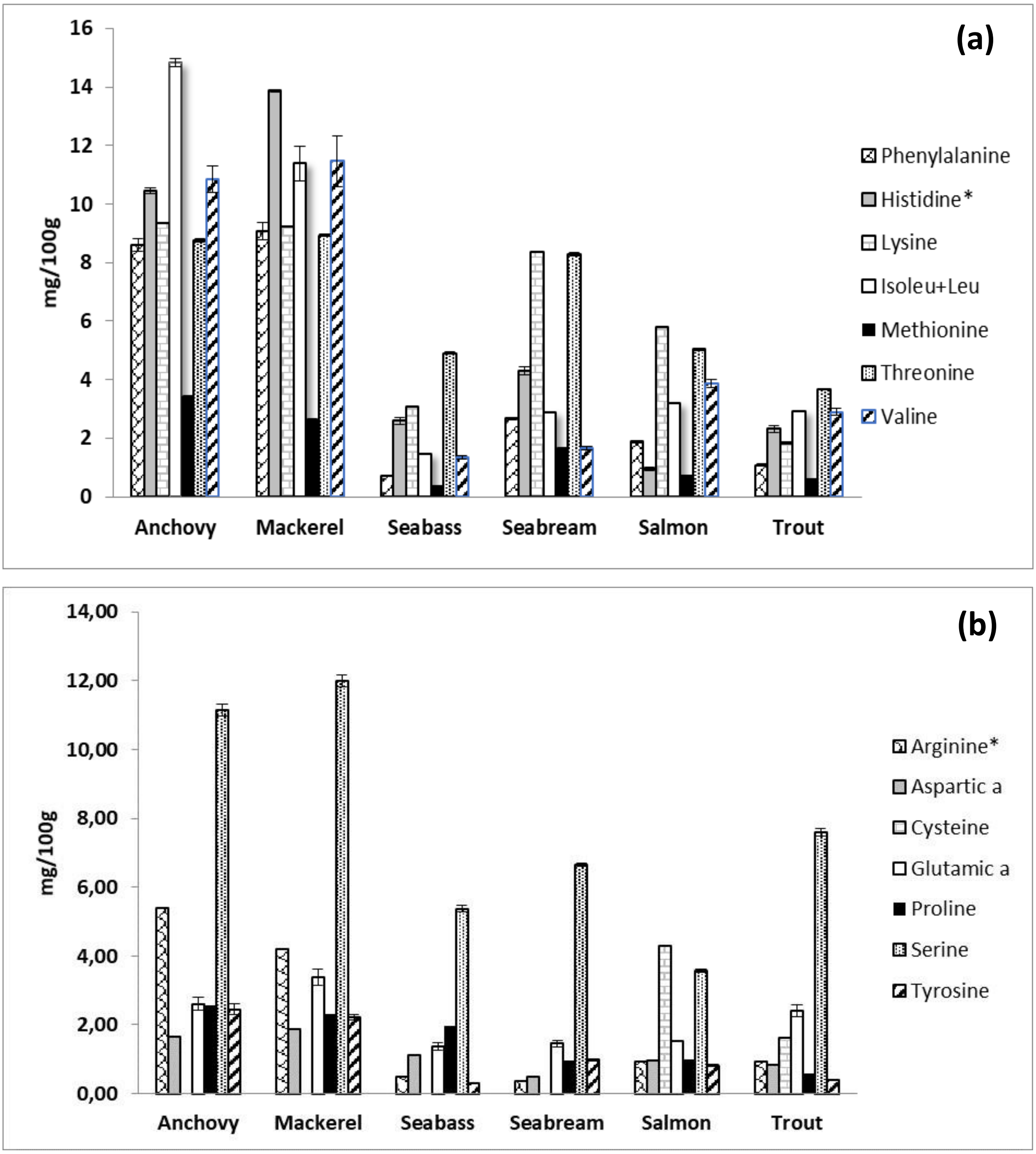

Figure 2. Free EAA (a) and free non-EAA of commonly consumed fish species. *Essential amino acid for infants.

Table 2. B-group vitamin contents of commonly consumed fish species.

Fish (µg/100g)	B1 Thiamine	B2 Riboflavin	B3 Niacin	B3 Nicotinamide	B5 Pantothenic acid	B6 Pyridoxal	B6 Pyridoxine	B6 Pyridox amine	B7 Biotin	B9 Folic acid
Trout	N.D.	5.19±0.00[c]	79.09±1.59[d]	75.93±1.71[c]	8.86±0.09[b]	9.28±0.01[d]	1.30±0.04[a]	N.D.	0.14±0.02[d]	N.D.
Mackerel	N.D.	6.00±0.00[b]	113.98±2.31[b]	93.32±2.07[b]	6.21±0.06[c]	6.31±0.06[e]	0.74±0.02[e]	N.D.	0.05±0.00[f]	N.D.
Seabass	1.19±0.02[a]	7.05±0.01[a]	37.19±0.74[f]	40.69±0.94[e]	4.14±0.04[e]	10.10±0.11[c]	1.12±0.03[b]	N.D.	0.06±0.00[e]	N.D.
Seabream	0.87±0.02[c]	0.87±0.00[f]	99.33±2.01[c]	92.85±2.06[b]	6.39±0.06[c]	6.50±0.07[e]	0.94±0.03[d]	N.D.	0.25±0.03[a]	N.D.
Salmon	0.95±0.02[b]	4.31±0.00[d]	155.08±3.15[a]	149.02±3.10[a]	21.32±0.22[a]	11.81±0.12[b]	1.00±0.03[c]	N.D.	0.16±0.01[c]	N.D.
Anchovy	N.D.	3.03±0.00[e]	62.30±1.25[e]	60.92±1.39[d]	5.20±0.05[d]	20.69±0.23[a]	0.56±0.02[f]	N.D.	0.20±0.01[b]	N.D.

Values are means ± standart deviation.

The different letters (a-e) in the same columns indicate that there are statistical differences between fish species (p<0.01) N.D. not determined.

the other foods due to low protein digestibility and high fiber content (Demir *et al.,* 2023). The B1-thiamine content of seabass, seabream and salmon were in the range of 0.87 and 1.9 µg/100g. Thiamine content of gilthead seabream and salmon were both 180 µg/100g, seabass was 260 µg/100g, mackerel was 110 µg/100g, rainbow trout was 91 µg/100g (Dias *et al.,* 2003), African catfish was 70 µg/100g (Ersoy and Ozeren, 2009), gilthead seabream was 134 µg/100g (Catak *et al.* 2022) and salmon was 68 µg/100g (Yaman *et al.,* 2022). Different findings can be attributed to mainly the fish species, the composition of the fish diet or available food resources, fishing season, reproduction status, age, temperature, salinity etc.

Vitamins B2, together with B3, is a part of energy metabolism in relation with FAD/FMN and NAD. FAD/FMN and NAD are electron carriers in chemical reactions such as oxidative phosphorylation, beta-oxidation, and catabolism of branched-chain amino acids (Demir *et al.,* 2023). The highest B2-riboflavin content was found in seabass, followed by mackerel and trout. Vitamin B3, which was the most abundant B-group vitamin in fish samples, was detected in the forms of niacin (37.19-155.08 µg/100g) and nicotinamide (40.69 -149.02 µg/100g). The highest total B3 content was recorded in salmon, while the lowest belonged to seabass. Çatak *et al.* (2022) compared such chicken parts with anchovy, seabream, and bonito, and reported that meat and meat products contain higher amounts of vitamin B3 than other foods and can be considered a good source of B-group vitamins.

B5-Pantothenic acid content of salmon (21.32±0.22 µg/100g) was found to be significantly ($p<0.01$) high, while it varied between 4.14 and 8.86 µg/100g in other fish samples. Islam *et al.* (2022) found 1.162, 1. 605 and 0.274 mg/100g of vit B5 in Pacific herring, Korean pomfret and Black throat seaperch, respectively and reported that shellfish as well as fish were good sources of B5.

Vit B6 can be found in different forms in nature. In the present study pyridoxine, pyridoxal, and pyridoxamine compositions of fish samples were studied. Pyridoxal was the most abundant vit B6 ranging between 6.31 (mackerel) to 20.69 (anchovy) µg/100g, followed by Pyridoxine ranging between 0.56 (anchovy) to 1.30 (trout) µg/100g. Pyridoxamine could not be detected in any of the fish samples. It was reported that animal-based foods are rich in pyridoxal and/or pyridoxamine, whereas plant-based food contains mostly pyridoxine (Islam *et al.,* 2022). B6 contents of such fish species were studied by many researchers (Ceylan *et al.,* 2018; Yaman 2019; Dias *et al.,* 2003) and it was revealed that B6 content of animal-based foods are high as well as high levels of pyridoxal form.

Many of the studies related to B7-Biotin is based on fish feeding requirements and its effect on fish growth performance. Biotin is responsible for the biosynthesis of fatty acids, and metabolism of amino acids. The highest B7 content (0.25±0.03 µg/100g) was found in seabream, while the lowest (0.05-0.006 µg/100g) was recorded in mackerel and seabass. B-group vitamins serve as coenzymes in biological processes of macronutrient metabolism and energy production. The deficiency of micronutrients may cause serious health problems. Fish consumption can be a solution.

Conclusion

The obtained data indicates that fish consumption is a solution to maintaining food and nutritional security and eradicating malnutrition. Due to the wide variety of fish species, the food source of any income group can be satisfied. It is important to increase the knowledge of nutrition to cope with health problems and perform a qualified life. The information about nutritional composition is useful not only for consumers but also for processors and food-policy authorities.

Ethical Statement

Ethics approval and consent to participate not applicable for this study.

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Author Contribution

First author: Supervision, Conceptualization, Methodology, Investigation, Data curation, Visualization, Writing–original draft, Writing–review & editing; Second author: Methodology, Investigation, Formal analysis, Data curation, Visualization, Writing–original draft, Writing–review & editing.

Conflict of Interest

The authors declare that they have no known competing financial or non-financial, professional, or personal conflicts that could have appeared to influence the work reported in this paper.

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