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Determination of Proximate and Amino Acid Composition of Five Different *Tilapia* Species from the Cukurova Region (Turkey)

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Abstract

Proximate and amino acid composition of the whole body tissue of juvenile *Oreochromis aureus, Tilapia rendalli, Tilapia zillii, Tilapia* spp. and *Oreochromis niloticus* were determined. Accordingly, protein and lipid levels in whole body were found higher in *Tilapia rendalli* than the other species. The amino acid composition was significantly different among species when expressed as g/100g amino acids. Although aspartic acid levels were different in all species, other amino acid levels were not highly different among the species. Similar findings were available for the A/E ratios ((each essential amino acid content/total essanstiel amino acid content) × 1000). However leucine, lysine and aspartic acid were higher, methionine, histidine and tyrosine were lower for all species.

Key words: **Amino acid composition, *Orecohromis aureus, Tilapia rendalli, Tilapia zillii, Tilapia* spp., *Oreochromis niloticus*.**

INTRODUCTION

Fish and other sea products are the primary and oldest food sources of human. It is known that fish and other sea products were most commonly consumed as they were easy to catch before the domestication of animals and cultivation of plants. In parallel with the developments in science and technology, some species consumed in the early periods of history have been abandoned over time; however, fish and other sea products have remained to be human diet since early periods of history. There are more than 20.000 fish, shellfish and crustacean species in world waters. Among them, around 250 species appear in human diet in different forms [1].

Tilapias within Cichlidae family are the second most farmed species throughout world after carp (Cyprinidae) [2, 3]. Tilapias known to have around 100 species are of East Africa origin and spread in many parts of world [2]. Tilapia species are preferred for farming due to several reasons including the fact that they can benefit from various nutrient matters that cannot be used by other fish species, and also due to their short food chain, their adaptation ability to crowded and dense pool conditions, their fertility, their resistant to parasites and diseases in general, and their delicious fish meat and their endurance against environmental effects with the exception of low temperatures [4].

Protein is one of the most important components of muscle tissue that is the edible part of animals in terms of nutrition. Muscle tissue of fishes contains 11-24% of crude protein in general [5].Total amount and quality of protein are very similar in fishes farmed or caught from nature [6]. Furthermore, protein content is reported to change seasonally in some species [7]. As known, amino acids are the building structure of proteins. Foods and tissue proteins contain 20 different amino acids which have dietary importance. Among them, threonine, valine, methionine, isoleucine, leucine, phenylalanine, lysine and histidine cannot be synthesized by humans. These amino acids have to be taken with foods. However, these amino acids are as important as essential amino acids for normal cells and organs to function properly [8]. Other amino acids including aspartic acid, arginine, serine, glutamic acid, glutamine, glycine, alanine, tyrosine, proline, taurine etc. are taken with daily diet and can be synthesized by body. Amino acid composition of muscle proteins shows very important differences among fish species. Proteins accounting for 65-70% of total dry body weight in fishes have high nutritional value due to their essential amino acid contents [9]. Many amino acids in body are in the form of protein component [10].

It is very useful to know amino acid compositions for many reasons. In addition to determination of nutritional value, aromatic properties of fish meat are partly depended on the amino acid distribution [11]. Information of free amino acid compositions in tissue of animal species subjected to farming is quite important to detect quality and quantity of amino acids in diets [12]. Protein amount and quality in fish feeds are the most important factors directly affecting the productivity of the farmed species. It is reported that there is a similarity between amino acid profiles in whole body tissues of species, amino acid quantity and composition required in feeds [13, 14].

For these reasons, this study aims to determine amino acid levels of some Tilapia species that could be used in monoculture and polyculture production in both fresh and sea waters in Mediterranean Region of Turkey.

MATERIALS AND METHODS

Sample Preparation

The experiment was conducted on *O. niloticus* farmed in Freshwater Research Station of Cukurova University, the species of *O. aureus*, *T. rendalli* and *T. zillii* farmed in net cage system in Seyhan Dam Lake in Adana and *Tilapia* spp. caught from Karagöçer village located in the area where Seyhan River (Adana) flows into Mediterranean Sea. The samples consisted of individuals with a mean weight of 60±10 g.

Carp pellet feed of 3mm diameter produced by Pınar Feed Factory was used in the study, and the feeding was made considering 4% of live fish weights. The producer firm presents the feed content as 28% crude protein, 12% water, 5% cellulose, 15% ash and 1% NaCl.

Proximate Analysis

The farmed *Tilapia* species were analyzed after harvest, and natural *Tilapia* species were analyzed just after catching. All samples were homogenized by taking only meat portion (fillet) used in human consumption excluding head and innards to determine crude protein, total lipid, dry matter and ash content. Crude protein was detected by Kjeldahl method [15], while total lipid was determined according to the method described in AOAC [16]. Dry matter content was determined by keeping homogenate in drying oven at 105 ^{0}C for 3.5 hours, and the ash content was determined considering gray ash color formed after burning at 550 ^{0}C for 4 hours [16].

Amino Acid Analysis

The analyzes were made with Eppendorf LC 3000 amino acid analysis device and hydrolysis method. Samples were hydrolyzed under nitrogen with 6N hydrochloric acid at 112^{0}C for 23 hours [17]. In addition, proportional amino acid values ((each amino acid content/total amino acid content) x 1000) were determined [18].

Statistical Analysis

Statistical analyzes were made with Sigma plot 11 (Systat Software Inc.) statistical software and the presence of statistical difference among groups was determined with One-way variance analysis (one-way ANOVA). All data were subjected to one-way variance analysis at 0.05 significance level with three repetition, and Duncan test was used to analyze the differences [19].

RESULTS AND DISCUSSION

Studies are implemented to determine both proximate content and nutritional needs of these species and some other species farmed in sea and freshwater condition. Studies focus on the determination of nutritional value, the optimum feed mixture to improve nutritional quality and to what extent these species can benefit from these feed considering the growth and food content.

Proximate composition was prepared for all species subject to the study (Table 1). The results indicate that *T. rendalli* and *T. zillii* have higher dry matter, protein and lipid contents compared to other species. The highest dry matter contents were determined in *T. rendalli* and *T. zillii* as 26.06% and 26.03% respectively. This was also determined 24.50% in *O. aureus*, 23.54% in *O. niloticus*, 22.47% in *T.* spp. The results of crude protein contents were found similar; however, it was a little bit higher in *T. rendalli*, and relatively lower in *T. zillii*. The lowest protein value was detected in *Tilapia* spp. Lipid contents were found similar in three species (*T. rendalli*, *T. zillii* and *O. aureus*) and higher than 3%.

Rasoarahona et al., [20] determined lipid levels of three *Tilapia* species (*O. niloticus, O. macrochir* and *T. rendalli*). The lipid levels in this study were found lower than the findings of the present study. The reason could be age, sexual maturity, geographic origin and feed. A similar situation was observed in ash contents, and ash content was found over 1.1% level in all species. Gökçe et al., [21] carried out a study to determine nutritional compositions of three tilapia species (*Tilapia rendalli, Tilapia zillii, Oreochromis aureus*) farmed in cages in Seyhan Dam Lake and reported similar values to the results of the present study. *Tilapia* spp. had a lowest protein value according to the other species. Differences in the nutritional composition may be the reasons mentioned above. But the most important factor here, is the difficulty in finding feed under natural conditions. Because other species that are subject to investigation, was fed on a daily basis. Although the results of the previous studies were lower than the findings of the present study, they were found satisfactory by the researchers.

Many previous studies performed in the last 20 years indicated that amino acids are effective on functions and systems of many organs and the inexistence of one of these amino acids would prevent the functions of systems and recovery process [22, 23]. Considering the amino acid profiles of cancer patients, it was reported that the circulating amino acid profiles of these patients change [24, 25]. Fish meat proteins contain all the essential amino acids. Although essential amino acids (leucine, isoleucine, lysine, valine, methionine, phenylalanine, threonine and tryptophane) have many important functions in human body, food sources with these amino acids increase the essential protein quality of diet because these molecules cannot be synthesized in body [1]. One of the most important reasons why aqua-products are biologically important food sources is the essential amino acids they contain. Vegetable proteins contain very limited amount of essential amino acids like lysine and methionine; therefore, animal proteins are essential for a healthy nutrition [26].

Table 1. Proximate composition of species (%)

Species	Dry matter	Protein	Lipid	Ash
Oreochromis aurea	24.50±0.60^{b}	20.20±0.01^{a}	3.01±0.10^{ab}	1.22±0.05^{a}
Tilapia rendalli	26.06±0.22^{a}	20.52±0.47^{a}	3.52±0.22^{a}	1.24±0.01^{a}
Tilapia zillii	26.03±0.61^{a}	19.76±0.13^{b}	3.34±0.40^{a}	1.21±0.07^{a}
Tilapia spp.	22.47±1.01^{bc}	18.75±0.01^{c}	2.64±0.07^{b}	1.10±0.01^{ab}
Oreochromis niloticus	23.54±0.32^{b}	19.05±0.14^{c}	2.72±0.16^{b}	1.16±0.02^{ab}

Values were measured as g/100g for easy comparison of amino acid levels (Table 2). As indicated in Table 2, aspartic acid levels were significantly different among species, and the highest was found in *T. zillii* (9.18±0.28), while the lowest was in *T.* spp (6.22±0.23). Threonin was found at similar levels in *O. aureus* (3.49±0.20) , *T. rendalli* (3.49±0.40) and *O. niloticus* (3.26±0.26), while it was lowest in *T.spp* (2.95±0.20) and highest in *T. zillii* (4.38±0.37). *T. zillii* was determined to have highest amounts of serine (5.37±0.26), glutamic acid (9.23±0.30) phenylalanine (4.09±0.15), and these amounts were similar in the other four species. Glutamic acid is a free amino acid, and it is found in skeletal muscles at around 60% rate in human body [22].

Proline (2.42±0.17) and glycine (3.34±0.19) were found lowest in *O. niloticus*. On the other hand, the highest amount of proline (3.65±0.33 and 3.62±0.33) was detected in *O. aureus* and *T.* spp., while the highest glycine (4.09±0.26) was determined in *T.* spp, as well. The other amino acids were found at similar amounts in these species. Glycine is an important amino acid as it is one of the main components of human connective tissue [23]. Essential amino acids in glycine and polypeptide forms including alanine, proline, arginine, serine, isoleucine and phenylalanine help ameliorate and renew tissues [27, 28].

Alanine (5.78±0.36) and lysine (8.52±0.38) levels showed similarity in the study. These amino acids were found highest in *T. zillii*. All the other species had similar levels for all the three amino acids. Both *O.aureus* and *T. zillii* had similarly high levels of valine (4.23±0.53;14±0.33) and histidine (2.20±0.15; 2.32±0.19). However, their levels did not significantly differ in other three species. Lysine is considered as a limiting amino acid for most foods. Requirement levels of other amino acids are expressed depending on lysine requirement with reference to ideal protein requirement [29]. For instance, calculated amino acid requirements of canal catfish based on the determined lysine and essential amino acid rates, and found the determined and calculated amino acid requirements at close rates [30]. In addition, similar results were reported for saltwater fish like painted eel by Brown et al., [31] and Japanese flounder by Forster and Ogata [32]. In the present study, lysine and aspartic acid were determined to be the highest among amino acids. Leucine (6.86±0.19) and histidine (2.32±0.19) were found highest in *T. zillii*. This species was followed by *O.aureus*, *T. rendalli*, *T.* spp. and *O. niloticus*. Methionine was found at similar levels in *O.aureus* (2.40±0.12) and *T.* spp. (2.31±0.25, but it was highest in *T. zillii*. Methionine was determined in different amounts in the other three species, and it was lowest in *T. rendalli* (1.64±0.15) (P<0.05).

The obtained results indicated that the statistically highest amount of TEAA (Total Essential Amino Acid) was determined in *Tilapia zillii* (42.17±1.27), and the lowest amount was detected in *Tilapia* spp (34.82±1.47). The lowest amount of NEAA (Total Non-Essential Amino Acids) was determined in *O. niloticus* (29.94±0.55), while the highest amount was recorded in *T. zillii* (38.76±1.10) (Figure 1).

Table 2. Amino acid composition of species (g/100 g).

Amino acid	***O. aureus***	***T. rendalli***	***T. zillii***	***Tilapia* spp.**	***O. niloticus***
Threonine	3.49±0.20^{b}	3.49±0.40^{b}	4.38±0.37^{a}	2.95±0.20^{b}	3.26±0.26^{b}
Valine	4.23±0.53^{a}	3.69±0.28^{a}	4.14±0.33^{a}	3.56±0.26^{a}	3.69±0.23^{a}
Methionine	2.40±0.12^{a}	1.64±0.15^{b}	2.61±0.18^{a}	2.31±0.25^{a}	2.00±0.12^{ab}
Isoleucine	3.90±0.16^{a}	4.08±0.24^{a}	3.96±0.17^{a}	3.56±0.34^{a}	3.69±0.35^{a}
Leucine	6.16±0.23^{b}	6.10±0.23^{b}	6.86±0.19^{a}	5.78±0.19^{b}	5.90±0.26^{b}
Phenylalanine	3.45±0.12^{b}	3.24±3.12^{b}	4.09±0.15^{a}	3.25±0.20^{b}	3.22±0.37^{b}
Histidin	2.20±0.15^{a}	1.86±0.19^{ab}	2.32±0.19^{a}	1.95±0.23^{ab}	1.87±0.12^{ab}
Lysine	7.80±0.21^{b}	7.10±0.23^{c}	8.52±0.38^{a}	7.05±0.42^{c}	7.17±0.20^{c}
Arginine	4.71±0.15^{ab}	4.91±0.23^{a}	5.29±0.28^{a}	4.42±0.35^{ab}	4.29±0.23^{ab}
Total EAA	**38.36±1.21^{b}**	**36.11±1.08^{c}**	**42.17±1.27^{a}**	**34.82±1.47^{c}**	**35.09±0.51^{c}**
Serine	4.31±0.14^{b}	4.34±0.18^{b}	5.37±0.26^{a}	3.99±0.40^{b}	4.22±0.11^{b}
Glutamic acid	6.86±0.21^{b}	6.88±0.26^{b}	9.23±0.30^{a}	6.67±0.30^{b}	7.04±0.21^{b}
Proline	3.63±0.33^{a}	2.79±0.11^{b}	3.01±0.21^{b}	3.65±0.33^{a}	2.42±0.17^{bc}
Glycine	3.62±0.38^{a}	3.76±0.19^{a}	3.98±0.24^{a}	4.09±0.26^{a}	3.34±0.19^{ab}
Alanine	5.27±0.40^{a}	4.57±0.33^{b}	5.78±0.36^{a}	4.60±0.31^{b}	4.37±0.33^{b}
Aspartic acid	7.39±0.64^{c}	8.27±0.29^{b}	9.18±0.28^{a}	6.22±0.23^{d}	6.66±0.36^{d}
Tyrosine	1.90±0.12^{b}	1.73±0.12^{b}	2.21±0.17^{a}	1.76±0.14^{b}	1.89±0.18^{b}
Total NEAA	**32.97±1.05^{b}**	**32.34±0.62^{b}**	**38.76±1.10^{a}**	**30.97±0.98^{bc}**	**29.94±0.55^{bc}**

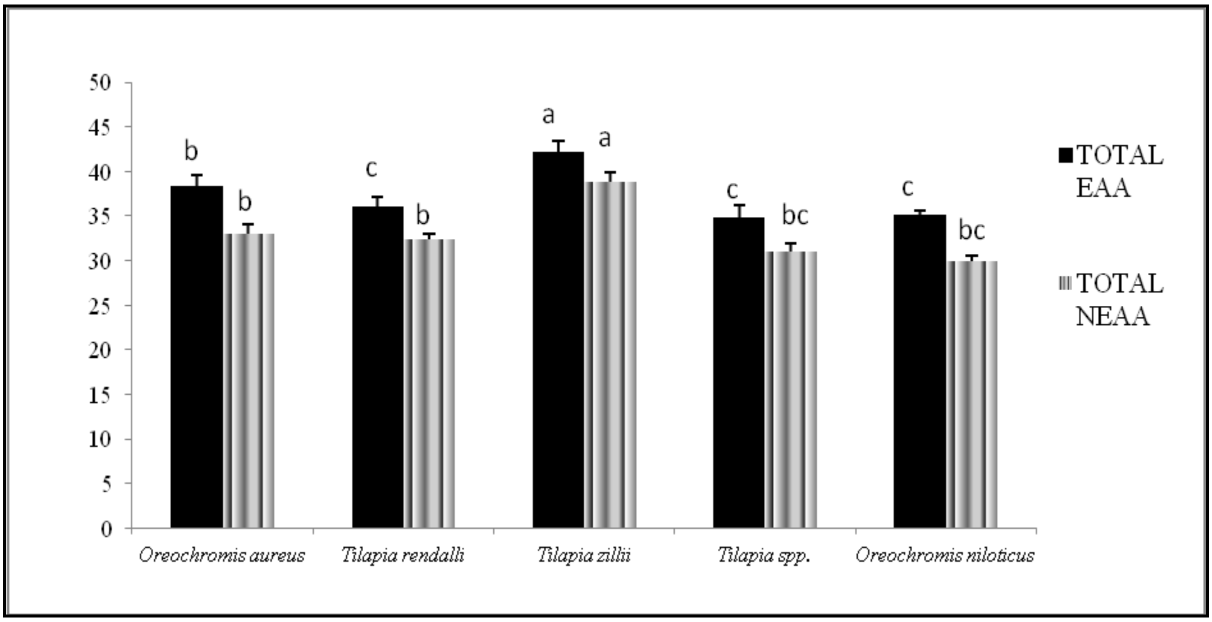

Figure 1. Total EAA and Total NEAA values of species included in the study

Table 3. Proportional rate of essential amino acids in edible parts of species

Amino acid	***O. aureus***	***T. rendalli***	***T. zillii***	***T.* spp.**	***O. niloticus***
Threonine	91.02±2.69[ab]	96.62±10.48[ab]	103.94±7.82[a]	84.95±8.79[b]	92.86±6.59[ab]
Valine	110.16±11.12[ab]	102.03±5.58[a]	98.02±5.16[b]	102.08±3.79[ab]	105.01±5.08[ab]
Methionine	62.63±1.62[ab]	45.47±3.00[c]	61.78±2.95[ab]	66.14±4.46[a]	57.11±3.87[b]
Isoleucine	101.88±6.89[ab]	112.97±7.84[a]	94.01±3.59[b]	102.12±5.76[ab]	105.15±11.40[ab]
Leucine	160.64±1.89[b]	169.00±2.75[a]	162.62±0.36[ab]	165.97±2.55[ab]	168.11±6.47a
Phenylalanine	89.92±0.53[b]	89.78±4.09[b]	97.09±3.04[a]	93.30±1.94[ab]	91.76±3.75[ab]
Histidin	57.52±5.23[a]	51.46±5.59[a]	55.01±5.28[a]	56.13±8.45[a]	53.30±3.65[a]
Lysine	203.43±2.39[a]	196.61±0.59[b]	202.00±2.51[a]	202.30±3.66[a]	204.38±2.82[a]
Arginine	122.79±2.81[b]	136.07±5.29[a]	125.54±5.61[ab]	127.01±7.72[ab]	122.32±8.09[b]

There was statistically difference among the species in terms of proportional rate of amino acids (Table 3). The highest rates were observed in lysine and leucine, while the lowest rates were determined in methionine and histidine.

Akiyama et al., [33] investigated essential amino acid requirements of species in a different way, and reported that it could be caused by the differences between families or species. Another noteworthy discussion is the presence of a strong correlation between amino acid models in feeds and tissues of fishes consuming these feeds [34].

Some studies are implemented to determine the nutrient content and nutrition requirements of the certain species farmed both in sea and freshwater environments. Studies generally focus on such matters as what kind of a nutrition mixture should be prepared to increase nutritional quality and determine the nutrition value and nutrition content and how much growth and nutrition content the species can receive from the prepared diet.

Amino acid content in muscle tissues of aquatic organisms is reported to change between 0.5–2.5% of total muscle weight [35]. Amino acid levels were found higher in cultivated fishes compared to wild fishes in some studies. For instance, the this result was reported in a study performed on Coho Salmon by Hata et al., [29] and sea bream by Morishita et al., [36]. Therefore, the lowest levels of amino acids were found in *Tilapia spp*. caught from the river, while the highest levels found in *Tilapia zillii* kept in the cage conditions. This finding is compatible with the results on *Salvelinus alpinus* [35].

The results of the present study indicated that amino acids showed some differences among species in terms of quantity, but the values were quite close to each other (Table 2). A similar tendency was detected in the proportional rate of essential amino acids, as well (Table 3). Similar findings were reported by Kim and Lall [18] for three flat fish species.

CONCLUSIONS

Considering the nutritional value of Tilapias caught from wild and farmed, lipid and other nutrient components, which are quite important for human health, have similar levels. However, it is not possible to produce fish that could better satisfy consumers in length and weight in Cukurova Region because the fishes here can be cultivated only in 6 months. The previous studies reported that the fish size and fat rate are in linear relation; from this regard, it can be suggested that fishes with higher length are more preferred by consumers as they are fattier and more delicious. Furthermore, white meat fishes are preferred by consumers than other freshwater fishes as they have a more evident bone structure that can be easily extracted. However, it is concluded that it is possible to introduce Tilapias to Turkish market as an alternative fish product by providing producers with diet that can improve growth performance and nutrient components in this limited production period.

In the light of these findings, it is considered that Tilapia production can be made both in freshwater and sea water conditions in the regions of Turkey with subtropical climate and more attention should be given to this species regarded as an important nutritional source for human health.

REFERENCES

[1] Brown A. 2000. Understanding Food. Fish and Shellfish. Wadsworth/Thomson Learning, USA., 299-318.

[2] Çelikkale MS. 1994. İçsu Balıkları ve Yetiştiriciliği Cilt2 2. Baskı. Karadeniz Teknik Üniversitesi Sürmene Deniz Bilimleri Fakültesi Genel Yayın No:128 Fakülte Yayın., No:3 460s. Trabzon.

[3] Alpbaz A. 2005. Su Ürünleri Yetiştiriciliği. Alp Yayınları., 567s. Izmir.

[4] Bekcan S. 1999. Tilapya Yetiştiriciliği.Türk-Koop Ekin Dergisi, 3 (10): 90-96.

[5] Skorski ZE. A. Kolakowska and J.R. Burst, 1990. Post Harvest Biochemical and Microbial Changes. In Seafood, Reources. Nutritional Composition and preservation. Boca Raton FL: CRC Press, 29-54.

[6] Nettleton JA. 1990. Comparing Nutrients in Wild and Farmed Fish, Aquaculture Magazine. January/February, 34-41.

[7] Hirano T, Nakamura H, Suyama M. 1980. Quality of Wild ned Cultured Ayu-II. SeasonalVariation of proximate Composition. Nippon Suisan Gakk., 46: 75-78.

[8] Kucukgulmez A, Celik M. 2008. Aminoacid composition of blue crab (*Callinectes sapidus*) from the North Eastern mediterranean. Journal of Applied Biological Sciences, 2: 39-42.

[9] Wilson RP. 1989. Amino Acid and Proteins. Fish Nutrition. San Diago. Academic Press, inc. 112-153.

[10] Cowey JE, Walton MJ. 1989. Intermediary Metabolism. Fish Nutrition. San Diego, Academic Press, inc. 260-331.

[11] Hall GM, Ahmad NH. 1992. Functional Properties of Fish Protein Hydrolysates. Fish Processing Technology. New York, Ny: VCH Publishers., inc. 249-274.

[12] Pion R. 1976. Dietary Effects and Amino Acids in Tissues. Protein Metabolism and Nutrition., London, Butterworths. 259-278.

[13] Wilson RP, Poe WE. 1985. Relationship of Whole Body and Egg Essential Amino Acid Patterns to Amino Acid Requirement Patterns in Channel Catfish, *Ictalurus punctatus*. Comparative Biochemistry and Physiology (80B): 385-388.

[14] Mambrini M, Kaushik SJ. 1995. Indispensable Amino Acid Requirements of Fish: Correspondance Between Quantitative Data and Amino Acid Profiles of Tissue Proteins. Journal of Applied Ichthyology, 11: 240-247.

[15] Matissek R, Schnepel FM, Steiner G. 1989. Lebensmittelanaliytik Springer Verlag, Berlin, Heidelberg, p 440.

[16] AOAC. 1990. Official methods of analysis, sixteenth ed., 4th rev. Washington, DC: Association of Analytical Chemists.

[17] Cohen SA, Mewyes M, Travin TL. 1989. The Pico-Tag Method: A Manual of Advanced Techniques for Amino Acid Analysis. Millipore Corporation, Milford, USA., pp: 124.

[18] Kim JD, Lall SP. 2000. Amino Acid Composition of Whole Body Tissue of Atlantic Halibut (*Hippoglossus hippoglossus*), Yellowtail Flounder (*Pleuronectes ferruginea*) and Japanese Flounder (*Paralichthys olivaceus*). Aquaculture 187: 367-373.

[19] Duncan DB. 1955. Multiple range and multiple F tests. Biometrics., 11: 1–42.

[20] Rasoarahona JRE, Barnathan G, Bianchini J, Gaydou EM. 2005. Influence of season on the lipid content and fatty acid profiles of three tilapia species (*Oreochromis niloticus*, *O. macrochir* and *Tilapia rendalli*) from Madagascar. Food Chemistry, 91: 683–690.

[21] Gökçe MA, Dikel S, Çelik M, Taşbozan O. 2003. Seyhan Baraj Gölü'nde Kafes Koşullarında Yetiştirilen Üç Tilapia [*Tilapia rendalli* (Boulenger, 1896), *Tilapia zillii* (Gervais, 1848), *Oreochromis aureus* (Steindachner, 1864)] Türünün Besinsel Kompozisyonlarının Belirlenmesi, Ege Journal of Fisheries and Aquatic Sciences, 20, (1-2): 9 – 14.

[22] Christina J, Palmer A, Griffiths RD. 1999. Randomized clinical outcome study of critically ill patients given glutamine-supplemented enteral nutrition. Nutrition. 15:108–115.

[23] Mat Jais AM, McCulloh R, Croft K. 1994. Fatty acid and amino acid composition in haruan as a potential role in wound healing. General Pharmacology, 25: 947–950.

[24] Kubota Y, Petras RE, Easley KA, Bauer TW, Tubbs RR, Fazio VW. 1992. Ki67-determined growth fraction versus standard staging and grading parameters in colorectal carcinoma. A multivariate analysis. Cancer, 70: 2602-2609.

[25] Zhang W, Zalcberg JR, Cosolo W. 1992. Interaction of epirubicin with other cytotoxic and anti-emetic drugs. Anti-Cancer Drugs, 3(6): 593-597.

[26] Turan C, Oral M, Ozturk B, Duzgunes E. 2006. Morphometric and meristic variation between stocks of Bluefish (*Pomatomus saltatrix*) in the Black, Marmara, Aegean and Northeastern Mediterranean Seas. Fisheries Research, 79: 139–147.

[27] Heimann W. 1982. Fundamentals of food chemistry. West Port, Connecticut, USA: Avi Pub. Co.

[28] Witte MB, Thornton FJ, Tantry U, Barbul A. 2002. L-Arginine supplementation enhances diabetic wound healing: involvement of the nitric oxide synthase and arginase pathways. Metabolism, 51(10): 1269–1273.

[29] Hata M, Sato Y, Yamaguchi T, Ito M, Kuno Y. 1988. The Chemical Composition and Amino Acid Composition of Tissues of Cultured and Wild Coho Salmon, *Oncorhyncus kisuch* Nippon Suison Gakk., 54: 1365-1370.

[30] Wilson RP. 1991. Amino Acid Nutrition of Fish: a New method Astimating Requirement Values. Proc. 12th U.S.- Japan Symp. On aquaculture Nutrition. Newport, Oregon., pp; 49-54.

[31] Brown J, Helm M, Moir J. 1995. New Candidate Species for Aquaculture. Cold water Aquaculture in Atlantic Canada. 2nd edn. New Brunswick. Tribune Press., 341-362.

[32] Forster I, Ogata HY. 1998. Lysine Requirement of Juvenile Japanese Flounder, *Paralychthys olivaceus* and Juvenile Red Sea Bream, *Pagrus major.* Aquaculture., 161 (1-4): 131-142

[33] Akiyama T, Oohara I, Yamamoto T. 1997. Comparison of Essential Amino acid Requirements With A / E ratio Among Fish Species. Fish.Sci., 63: 963-970.

[34] Yamamoto T, Unuma T, Akiyama T. 2000. The Influence of Diatery protein and fat levels on Tissue Free Amino Acid levels on Fingerling Rainbow Trout (*Oncorhynchus mykiss*). Aquaculture 182: 353-372.

[35] Metusalach. Brown, J.A., and F. Shahidi, 2000. Variations in the Contents of Crude Ptotein, Total and Free Amino acids of Arctic Charr (*Salvelinus alpinus*) Rared at Different Stocking Densities. J. Aquat. Food Prod. Technol. 9 (3): 39-56.

[36] Morishita T, Uno K, Araki T, Takahashi T. 1989. Comparison of the Fatty Acid Composition in Cultured Red Sea Bream Differing in the Localities and Culture Methods, and Those in Whild Fish. Nippon Suisan Gakk. 55: 847-852.