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ARAŞTIRMA MAKALESİ **RESEARCH PAPER**

Determination of Proximate Composition and Fatty Acid Profiles of Commercial Fish Feeds

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Abstract: The proximate composition and fatty acid profiles of the selected fish feeds (S, A, G3, and G6) prepared with different rations were investigated. The results showed that the crude protein, moisture, crude lipid and crude ash level in feeds were in the range of 44.07% – 46.69%, 6.54% – 8.41%, 15.72% – 18.32%, and 7.44% – 11.37%, respectively. The percentages of total saturated fatty acids (SFA) and total polyunsaturated fatty acids (PUFA) were higher in group A than in all other group, whereas the corresponding total monounsaturated fatty acids (MUFA) content was lower. All of the feeds had higher levels of polyunsaturated fatty acid (PUFA). The n6/n3 ratio of feeds was in the range of 1.15 - 1.98. The data obtained indicate that the % composition of n3 PUFAs was lower for G3 feed. These feeds were good sources of EPA (in the range of 3.13%-4.57%) and DHA (in the range of 3.41%-8.50%). Therefore, it was concluded that these fish feeds are suitable as a balanced food choice for aquaculture.

Keywords: Fatty acid, fish feeds, proximate composition, MUFA, PUFA, SFA.

Ticari Balık Yemlerinin Besinsel Kompozisyonu ve Yağ Asidi Profillerinin Belirlenmesi

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Öz: Farklı rasyonlarla hazırlanan balık yemlerinin (S, A, G3 ve G6) besinsel kompozisyon ve yağ asidi profilleri incelenmiştir. Çalışmadan elde edilen sonuçlar yemlerdeki ham protein, nem, ham yağ ve ham kül düzeylerinin sırasıyla % 44,07 – % 46,69, % 6,54 – % 8,41, % 15,72 – % 18,32 ve % 7,44 – % 11,37 aralığında olduğunu göstermiştir. Toplam doymuş yağ asitleri (SFA) ve toplam çoklu doymamış yağ asitleri (PUFA) oranları A grubunda diğer tüm gruplara göre daha yüksek iken, buna karşılık toplam tekli doymamış yağ asitleri (MUFA) içeriği daha düşük olarak bulunmuştur. Yemlerin tamamında yüksek oranlarda çoklu doymamış yağ asitleri (PUFA) tespit edilmiştir. Analiz edilen yemlerin n6/n3 oranı 1,15–1,98 aralığında bulunmuştur. Elde edilen veriler, n3 PUFA'ların % kompozisyonlarının G3 yemi için daha düşük olduğunu göstermiştir. Bu yemlerin iyi birer EPA (% 3,13-% 4,57 aralığında) ve DHA (% 3,41-%8,50 aralığında) kaynakları olduğu tespit edilmiştir. Bu nedenle, bu balık yemlerinin su ürünleri yetiştiriciliği için dengeli bir besin seçimi olarak uygun olduğu sonucuna varılmıştır.

Anahtar kelimeler: Yağ asitleri, balık yemleri, besinsel kompozisyon, MUFA, PUFA, SFA.

INTRODUCTION

Today, the importance of seafood in human nutrition has increased considerably and the rise of aquaculture has become inevitable. In recent years, due to the rapid development of the aquaculture sector in Turkey, the demand for fish feed has increased significantly, as well (Ertör & Ortega-Cerdà, 2019; Bayraklı & Duyar, 2019). Aquaculture is becoming more and more attractive due to the increase in market prices as a result of increasing aquaculture demand and supply-demand imbalance, and the ability to meet the demand in the desired time, quality and amount through aquaculture. The aquaculture sector has a great socio-economic importance in terms of being an important source of animal and vegetable protein, creating a wide employment area and providing an important foreign currency inflow (Doğan, 2003; Gümüş & Yılmaz, 2011). The gradual increase in the number and production amount of aquaculture enterprises and the accompanying increase in the demand for fish feed encourage the development of the aquaculture feed industry (Deng et al., 2021). While production via aquaculture was approximately 60 thousand tons in 1999, fish feed production was 38 thousand tons; while aquaculture production was 240 thousand tons in 2015, fish feed production was recorded as 375 thousand tons. Aquaculture production increased by 13% compared to the previous year and amounted to 421,411 tons. According to the data of the Ministry of Agriculture and Forestry, General Directorate of Food Control, feed prices increased by 23% in 2020 compared to the previous year. More than 50% increase in feed prices in 2018 and 2019 is due to the exchange rate difference (TÜİK, 2021). However, reducing production costs is a serious issue and has increased its importance (Hoşsu et al., 2012; Korkut et al., 2004; Kutlu & Çelik, 2010).

Nowadays, most of aquaculture manufacturer use mixing feed. These mixing feeds contain components of both plant and animal sources. The most commonly used grains are wheat and corn. In addition, beer pulp, corn gluten meal, cottonseed meal, hazelnut meal, soybean meal, rice bran and various wheat industry by-products are the most widely used another plant-based industrial by-products. Among the raw materials of animal origin, blood meal, hydrolyzed feather meal, fish meal, poultry meal, shrimp meal are the most common fish feed ingredients. Mixed feeds for fish can be prepared as complete or complementary mixed feed (Admasu & Wakjira, 2021; Aydın & Gümüş, 2016).

As in the whole animal husbandry sector, one of the most important issues in aquaculture is feeding. Nutrients are the most important factor that determines the vital activities of living things (Dawood, 2021). Nutritional demands vary according to the breed, age and environment of the breed. Both the gradual increase in the amount of aquaculture and the addition of new species to the aquaculture system encourages the enrichment of the demanded feed in terms of quantity and quality (Shah et al., 2022). The fact that feed is the most important input item in aquaculture and feed costs constitute 40-60% of the production cost, carries the feed industry to a very important position in terms of aquaculture (Orinda et al., 2021). As the formulas made from feed rations cannot be developed further, the development of fish slows down in formulas made from herbal products such as soy, causing them to reach market size in a much longer time and increase the rate of feed utilization. Feed quality directly affects egg quality, hatching rate, survival rate, growth performance, meat quality, rearing time and price of the final product (Majdoubi et al., 2021). For this reason, quality control analyzes should be done very carefully and precisely for the development of aquaculture, to increase the competitiveness (Altıniğne, 1992), to increase the quality of the feed and final product (Gündüz, 2002), to ensure development in a short time (Mueller, 2004), to increase the welfare of the animal, low cost, high profit and global traceability and validity (Skoog et al., 2007).

In fish feeding, it is difficult to predetermine the time required to reach the desired fatty acid composition by applying a special diet. While it is possible to see the effect of dietary fatty acids on the fatty acid composition of the fish in a very short time in fast growing young fish. But, the initial fatty acid composition continues its effect strongly until the final compound is formed in large fish with low weight gain. Concentration of fatty acids in tissues is modulated by many different metabolic factors. The final composition of fatty acids varies depending on the initial fatty acid content, the amount of dietary fatty acids, growth rate and duration (Robin et al., 2003).

The nutritional and commercial value of fish depends on the structure of different fish and seafood meats and edible parts. The main chemical components of fish meat are water, protein and fat. These components constitute 98% of the fish meat and affect the nutritional value, sensory quality and storage stability of the fish. The other 2% consists of carbohydrates, vitamins and mineral substances. The chemical structure of fish varies depending on species, age, sex, living environment and season. The protein amount of fish meat is quite constant and does not show any deviation between different species, but the effect of the nutrition and maturity level of the fish is observed (Varlık et al., 2004). The distribution of fatty acids in fish (especially polyunsaturated fatty acids; n-3 fatty acids) is of great importance for human health. Feed making and the use of related raw materials, which have an important share in the rapidly developing aquaculture production in recent years, are in an important position especially for the businesses related to the subject. Many studies have been conducted on feeds containing 40-65% of the cost in aquaculture. The purpose of these is generally to reduce feed costs and to evaluate them. In this study, it was aimed to reveal the nutrient composition and fatty acid profiles of different commercial feeds used in aquaculture.

MATERIAL AND METHOD

Sampling: The feed samples used in this study were obtained from a commercial company located in Ordu, Turkey. The name of feeds were S, A, G3 and G6.

***Proximate Composition Analysis*:** The Kjeldahl method was used to determine the protein content (AOAC, 1984). To evaluate the crude lipid content, Bligh and Dyer, (1959) method was used. Moisture and ash analysis were carried out according to the methods of AOAC 920.153, (2002) and 950.46, (2002) respectively. As mentioned in the methods, samples were used for each group of feed as 1 g in protein analysis, 5 g in lipid analysis and 3 g in moisture-ash analysis. Each analysis was performed in triplicates.

Fatty Acid Methyl Ester Analyses (FAME): To determine fatty acid profiles, fatty acid methyl esters from the extracted lipid were made according to the method of Ichihara et al., (1996). 25 mg of the extracted oil sample was added with 4 ml of 2M KOH and 2 ml of n-heptane. Then, it was stirred in a vortex for 2 minutes at room temperature and centrifuged at 4000 rpm for 10 minutes and the n-heptane layer was taken for analysis on a gas chromatography (GC) instrument.

***Gas Chromatographic Condition*:** atty acid composition was analyzed using a Gas Chromatography (GC) Clarus 500 device (Perkin–Elmer, USA), one flame ionization detector (FID) and SGE (60 m X 0.32 mm ID BPX70 X 0.25 μm, USA) column. Injector and detector temperatures were set as 260 and 230 ºC, respectively. During this time, the furnace temperature was kept at 140 ºC for 8min. After that, it was increased by 4 ºC per minute until 220 ºC, and from 220 to 230 ºC by increasing the temperature 1 ºC per minute. It was kept at 230 ºC for 15 min to complete analysis. Sample scale was 1 μL and carrier gas was controlled at 16 psi. For split flow 40 mL min^{-1} (1:40) level was used. Fatty acids were identified by comparing the retention times of FAME (Supelco, Catalogue No: 18919) with the standard 37-component FAME mixture. Three replicates of GC analyses were carried out and the results were expressed in GC area % as mean value ± standard deviation (SD).

***Statistical Analysis*:** Statistical analyses were performed using SPSS 22.0 (SPSS Inc., Chicago, IL, USA). ANOVA (Duncan's New Multiple Range Test) was used to determine the significant differences in fatty acid profiles between the groups (p <0.05). For each group, triplicates were compared.

RESULTS and DISCUSSION

***Proximate Composition of Fish Feeds*:** Nutritional composition of four different fish feeds prepared with different formulations are given in Table 1.

Table 1. Proximate composition of fish feeds.

	Groups			
	S	**A**	**G3**	**G6**
Protein	45.21±0.60^{ab}	45.43±0.23^{b}	46.69±0.18^{c}	44.07±0.02^{a}
Lipid	15.72±0.39^{a}	16.31±0.57^{a}	16.63±0.58^{a}	18.32±0.35^{b}
Moisture	7.92±0.04^{c}	6.54±0.09^{a}	8.41±0.02^{d}	6.67±0.09^{b}
Ash	7.44±0.08^{a}	11.37±0.05^{d}	10.27±0.15^{c}	9.30±0.20^{b}

Different letters (a–d) in the same columns for each groups significant differences (p<0.05). Were the protein, lipid and ash values calculated on dry weight of samples.

The results showed that the crude protein, crude lipid, moisture and crude ash level in feeds were in the range of 44.07% – 46.69%, 15.72% – 18.32%, 6.54% – 8.41% and 7.44% – 11.37%, respectively. Among the 4 different commercial fish feed diets, the highest crude protein ratio was found in G3 (46.69%) and the crude protein content of all diets was within the recommended recommendable range (40-45%) for commercial fish (NRC, 1983). The protein requirement of commercial fish is influenced by a variety of factors, including fish size, water temperature, feeding rate, availability and quality of natural foods, and overall digestible energy content of the diet (Satoh, 2000; Wilson, 2000). Watanabe et al., (1990) observed that fish production could be increased and more profitable by using a high protein (>35%) ration in their diet. Protein ratio of 34-55% and lipid ratio of 14-38% were determined in salmon rearing and rearing feeds in European countries (FAO, 2007). Increasing protein retention from the diet, quality and mix of different proteins and the inclusion of partially pre-digested proteins have shown good results (Calheires, 2003; FAO, 2004, Lunger et al., 2007).

Protein deficiency will mean slower growth, while overfeeding will incur the cost. For this reason, feeds are formulated to contain the right amount of protein (Wilson, 1994). In the studies carried out, the researchers determined the protein ratio in the rations to be between 40-60% (Aniebo et al., 2008; Atteh & Ologbenla, 1993; Fasakin et al., 2003; Ugwumba et al., 2001). The highest lipid ratio among the groups was found to be 18.32% in the G6 feed. 40% of the total energy in the ration can be met with fats. Fat level in the ration can be in the range of 15-25%. Trout starter feeds should contain 12-16% oil, grower feeds should contain 8-10% and breeder feeds should contain 6-8% oil. Harel, (1992) revealed that the lipid composition in the tissues of sea bream rootstocks is equal to the lipid composition in the feed, even in a 15-day feeding. Lipids are an important source for fish. It helps transport energy and fat-soluble vitamins and steroids. Essential fatty acids support normal larval development and play an important role in fish growth and reproduction (Mishra & Mukhopadhaya, 1996). According to the results of the analysis for 4 feed rations, the highest moisture content was found to be 8.41% in G3 feed. Compared to low humidity, high humidity fish food molds easily. It is vulnerable to bacteria and parasites and therefore should be stored well (Awoniyi et al., 2004). The highest ash rate was found to be 11.37% in the group of A feed. The minerals in a food provide a measure of the total amount. Fish need the same minerals for tissue formation and other metabolic functions.

In determining the nutritional value of the feed, giving the energy needed by the fish in the fish feed ration; macronutrients consisting of protein, fat and carbohydrates, and micronutrients and additives consisting of various vitamins and minerals (Erteken & Haşimoğlu, 2007). The required protein quality is an important factor regarding feed raw materials, and the differences in protein content of plant-based and animal-origin raw materials should be well examined and should be kept complementary in feed rations when necessary (Korkut & Yıldırım, 2003).

Fatty Acids Profiles of Fish Feeds: Fish farming has rapidly developed in recent years with the increasing world population. However, the production of fish feed makes it very expensive and difficult to obtain fish farming in some countries. In 2018, global fish production reached approximately about 179 million tonnes (FAO, 2018). 55% of this production is obtained by fishing and 45% by aquaculture. The general opinion is that fishing will not increase in 15-20 years but it will be increase further. This situation shows that fishing production will not meet the nutrient needs of the people after a while and that the deficit will be covered by aquaculture production. Accordingly, fish feed production and raw material supply gain importance (FAO, 2015). Again, the selection of these raw materials according to the nutritional needs of the fish species and their return to the feed cost gained importance. Fish oil is one of the raw materials used in fish feeds and contains the most omega 3 fatty acids such as EPA and DHA. Fatty acid profiles of four different fish feeds prepared with different formulations are given in Tables 2-5.

26 different fatty acids were identified in the feed samples. The major fatty acids in all feeds are C14: 0, C16: 0, C18: 0, C16: 1, C18: 1n-9, C20: 1n-9, C18: 2n-6, C18: 3n-3, EPA and DHA. The percentages of saturated fatty acids (SFA), monounsaturated fatty acids (MUFA) and polyunsaturated fatty acids (PUFA) of feed samples were determined between 19.45-23.42%, 31.74-44.29% and 29.28-38.12% respectively.

SFA values of feed samples are shown in Table 2. Total SFA level of feed S was the lower than those of the other 3 feeds. Among the SFAs, myristic acid (C14: 0), palmitic acid (C16: 0) and stearic acid (C18: 0) were found to be the highest fatty acids in all groups. While the highest levels of palmitic acid (13.84%) and stearic acid (4.05%) were detected in group A, the lowest level (11.08% and 3.10%, respectively) was observed in group S. The level of myristic acid, which is another important SFA, was determined to vary between 2.89-2.11%. The highest level of myristic acid was determined in group A (2.89%) and the lowest in G3 group (2.11%). Statistically significant differences were observed among myristic, palmitic and stearic acid value of groups ($p < 0.05$).

Table 2. SFA contents of fish feeds.

Fatty Acids	Groups			
	S	**A**	**G3**	**G6**
C14:0	2.61 ± 0.08^{c}	2.89 ± 0.01^{d}	2.11 ± 0.01^{a}	2.46 ± 0.04^{b}
C15:0	0.28 ± 0.01^{bc}	0.38 ± 0.01^{c}	0.02 ± 0.00^{a}	0.11 ± 0.14^{ab}
C16:0	11.08 ± 0.45^{a}	13.84 ± 0.04^{c}	12.05 ± 0.04^{b}	11.91 ± 0.05^{b}
C17:0	0.27 ± 0.01^{c}	0.21 ± 0.01^{a}	0.24 ± 0.00^{b}	0.27 ± 0.00^{c}
C18:0	3.10 ± 0.11^{a}	4.05 ± 0.02^{c}	3.66 ± 0.04^{b}	3.61 ± 0.23^{b}
C20:0	0.38 ± 0.03^{b}	0.78 ± 0.01^{c}	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}
C22:0	0.64 ± 0.03^{c}	0.43 ± 0.01^{a}	0.57 ± 0.01^{b}	0.67 ± 0.00^{c}
C24:0	1.10 ± 0.11^{b}	0.87 ± 0.01^{a}	0.93 ± 0.01^{a}	1.11 ± 0.00^{b}
∑SFA	**19.45**$\pm0.54^{a}$	**23.42**$\pm0.04^{b}$	**19.58**$\pm0.06^{a}$	**20.14**$\pm0.47^{a}$

Different letters (a–d) in the same row represent significant differences ($p < 0.05$) for each group

In contrast of SFA, total monounsaturated fatty acids (MUFA) level of feed G6 was significantly ($p<0.05$) higher than those of the other feeds (Table 3). The major FA in MUFA for all groups was oleic acid (C18:1n-9) followed by eicosenoic acid (C20:1n9) and palmitoleik asit (C16:1). There were statistically significant differences in these fatty acids for all groups ($p < 0.05$). Oleic, eicosenoic and palmitoleic acid levels were in the range of 25.00-35.81% (G6>S>G3>A), 1.85-3.85% (S>G6>G3>A) and 2.74-3.16% (G6>A>S>G3), respectively.

Table 3. MUFA contents of fish feeds.

Fatty Acids	Groups			
	S	**A**	**G3**	**G6**
C14:1	0.11 ± 0.00^{c}	0.06 ± 0.01^{b}	0.03 ± 0.01^{a}	0.03 ± 0.00^{a}
C15:1	0.03 ± 0.01^{a}	0.01 ± 0.01^{ab}	0.01 ± 0.00^{ab}	0.00 ± 0.00^{a}
C16:1	2.90 ± 0.11^{b}	2.96 ± 0.01^{b}	2.74 ± 0.01^{a}	3.16 ± 0.04^{c}
C17:1	0.17 ± 0.01^{a}	0.25 ± 0.00^{d}	0.19 ± 0.00^{b}	0.20 ± 0.0^{c}
C18:1n9	33.68 ± 1.53^{bc}	25.00 ± 0.03^{a}	32.39 ± 0.06^{b}	35.81 ± 1.12^{c}
C18:1n7	1.99 ± 0.01^{a}	1.41 ± 0.02^{a}	1.51 ± 0.02^{a}	1.42 ± 0.47^{a}
C20:1n9	3.85 ± 0.19^{d}	1.85 ± 0.01^{a}	2.91 ± 0.02^{b}	3.30 ± 0.01^{c}
C22:1n9	0.48 ± 0.04^{c}	0.21 ± 0.01^{a}	0.33 ± 0.01^{b}	0.37 ± 0.00^{b}
C24:1n9	0.13 ± 0.01^{b}	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}	0.01 ± 0.00^{a}
∑MUFA	**43.31**$\pm1.26^{c}$	**31.74**$\pm0.06^{a}$	**40.09**$\pm0.10^{b}$	**44.29**$\pm0.62^{c}$

Different letters (a–d) in the same row represent significant differences ($p < 0.05$) for each group.

Total polyunsaturated fatty acid (PUFA) levels of feed A (38.12%) were higher compared with the other feed groups ($p<0.05$), followed by groups G3 (33.98%), S

(31.70%) and G6 (29.28%), respectively (Table 4). The main FA in PUFAs was linoleic acids (C18:2n-6) which is the highest to lowest was observed in groups G3>A>G6>S. The highest PUFAs after linoleic acid were linolenic acid (C18:3n-3), EPA (C20:5n-3), and DHA (C22:5n-3). EPA and DHA are crutial fatty acids essential for human. Main resource of these essential FAs is seafood. In this respect, the amount of these fatty acids is very important in feed rations used in fish feeding. The highest level of EPA and DHA were observed in the group A followed by S> G6> G3 groups, respectively. While the highest EPA was determined in group A with 4.57%, the lowest EPA was determined in G3 group with 3.13% ($p<0.05$). DHA which is an important fatty acid was detected in the range of 3.41-8.50% in fish feeds.

Table 4. PUFA contents of fish feeds.

Fatty Acids	Groups			
	S	A	G3	G6
C18:2n6	14.55±0.93[a]	19.56±0.06[b]	20.55±0.12[b]	15.03±0.05[a]
C18:3n6	0.13±0.04[b]	0.05±0.01[a]	0.08±0.00[ab]	0.11±0.00[b]
C18:3n3	5.43±0.36[c]	3.63±0.01[a]	4.61±0.06[b]	4.45±0.06[b]
C20:2 cis	0.92±0.06[c]	0.46±0.00[a]	0.67±0.01[b]	0.85±0.01[c]
C20:3 n6	1.72±0.34[b]	1.23±0.01[a]	1.47±0.01[ab]	1.64±0.02[ab]
C20:4 n6	0.04±0.00[a]	0.04±0.00[a]	0.02±0.00[a]	0.03±0.01[a]
C20:5n3	3.44±0.25[a]	4.57±0.01[b]	3.13±0.02[a]	3.23±0.01[a]
C22:2 cis	0.02±0.01[a]	0.09±0.00[c]	0.06±0.00[b]	0.11±0.00[d]
C22:6 n3	5.46±0.58[b]	8.50±0.00[c]	3.41±0.01[a]	3.84±0.01[a]
∑PUFA	**31.70**±1.79[ab]	**38.12**±0.04[c]	**33.98**±0.16[b]	**29.28**±0.13[a]

Different letters (a–d) in the same row represent significant differences ($p < 0.05$) for each group

Yıldız (2008) reported that the 15 different fatty acids were determined for 14 fish feeds commonly available in Turkey for marine fish species, particularly sea bream and sea bass (juvenile, adult, and broodstock). The researcher found that n-3 HUFA levels in juvenile, adult, and broodstock fish feeds were in the range of 2.5-3.9%, 1.5-3.5%, and 2.1-4.9%, respectively. Similarly, DHA levels in these dry feeds were in the range of 1.4-2.3%, 0.5-1.8%, and 1.2-3.0%, and EPA levels were in the range of 1.1-1.5%, 1.0-1.6%, and 0.8-1.8%, respectively. Arachidonic acid (C20:4n-6) levels as percentage of total fatty acids in juvenile, adult, and broodstock fish feeds were 0.5-0.9%, 0.5-0.8%, and 0.6-0.9%, respectively. Similar results were found in our current study.

Table 5. ∑PUFA/SFA, ∑n6, ∑n3, ∑n6/∑n3 and DHA/EPA contents of fish feeds.

Fatty Acids	Groups			
	S	A	G3	G6
∑PUFA/SFA	1.63±0.05[b]	1.63±0.00[b]	1.74±0.01[c]	1.45±0.01[a]
∑n6	16.44±0.54[a]	20.87±0.06[b]	22.11±0.13[c]	16.80±0.04[a]
∑n3	14.33±1.20[b]	16.70±0.02[c]	11.15±0.02[a]	11.52±0.08[a]
∑n6/n3	1.15±0.06[a]	1.25±0.00[b]	1.98±0.01[d]	1.46±0.01[c]
DHA/EPA	1.59±0.05[c]	1.86±0.00[d]	1.09±0.00[a]	1.19±0.00[b]

Different letters (a–d) in the same row represent significant differences ($p < 0.05$) for each group.

ΣPUFA/ΣSFA, Σn-3, Σn-6, n-6/n-3 and DHA/EPA comparatively contents of fish feeds are given in Table 5. Statistical differences were observed between groups in terms of ΣPUFA/ΣSFA ($p<0.05$). The highest ΣPUFA/ΣSFA ratio (1.74) was determined in the G3 group, while the lowest value (1.45) was determined in the G6 group. HMSO, (1994) reported that the PUFA/SFA ratio should be at least 0.45.

The results obtained from our study were above this threshold. Therefore, it is predicted that fish fed with a balanced PUFA/SFA ratio will have a similar accumulation in muscle tissue. While Σn-6 amount was highest in G3 group with 22.11%, the lowest value was observed in S group with 16.44%. When investigate the amount of Σn-3, which constitutes an important part of the lipids found in fish muscle, it was determined that it was in the range of 11.15-16.70% in all groups. Σn-6/Σn-3 ratios were found to be highest in G3 group (1.98) and lowest in S group (1.15). The UK Department of Health recommended a maximum n6/n3 ratio as 4 (HMSO, 1994). None of the results we obtained were observed to exceed this threshold value. The DHA/EPA ratio was a good indicator of the lipid quality of the product, which was in the range of 1.09-1.86, and statistical differences were found between the groups ($p <0.05$). Yildiz, (2008) reported that the DHA/EPA rates for juvenile, adult, and broodstock fish feed were in the range of 1.1-1.5%, 0.5-1.4%, and 0.7-1.6%, respectively. These results were consistent with our study. Parpoura and Alexis (2001) reported that European sea bass has a minimum requirement of 1.35% EPA + DHA (EFA) for optimum performance. In our study, the lowest amount of EFA was found in the G3 group (6.54%) and the highest in the A group (13.07%).

CONCLUSION

Feed making which have an important share in the rapidly developing aquaculture production in recent years, are in an important position especially for businesses that are related to the subject. Many studies have been conducted on feeds containing 40-65% of the cost in aquaculture. The purpose of these is generally to reduce feed costs and to evaluate them. Various companies are researching to produce feeds with less cost and higher feed conversion ratio by using alternative protein sources for fish feed production. In conclusion, it may be concluded that these feeds are suitable items in the aquaculture diet. These feeds were good sources of EPA and DHA.

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