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Research Article

Fatty Acid Composition of Some Commercial Marine Fish Feeds Available in Turkey

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Abstract: The fatty acid composition was determined for 14 feeds commonly available in Turkey for marine fish species, particularly sea bream and sea bass (juvenile, adult, and broodstock). Nine of the juvenile and adult fish feeds and 1 of the broodstock fish feeds were imported. The other feeds were produced in Turkey.

The n-3 highly unsaturated fatty acids (n-3 HUFA) levels in the feeds of juvenile, adult, and broodstock fish were 2.5%-3.9%, 1.5%-3.5%, and 2.1%-4.9% of the dry weight of diets, respectively. Similarly, the docosahexaenoic acid (DHA) levels of these feeds were 1.4%-2.3%, 0.5%-1.8%, and 1.2%-3.0% of the dry weight of diets, respectively, and the eicosapentaenoic acid (EPA) levels of the dry weight in the diets were 1.1%-1.5%, 1.0%-1.6%, and 0.8%-1.8%, respectively. In addition, the arachidonic acid (ArA) levels in the feeds of juvenile, adult, and broodstock fish were 0.5%-0.9%, 0.5%-0.8%, and 0.6%-0.9% of total fatty acids, respectively.

The results showed that the DHA, EPA, or ArA levels and DHA/EPA ratios in the feeds of juvenile or adult sea bass and sea bream were sufficient for good growth and development. The broodstock feeds also had adequate levels of EPA, DHA, or ArA and ratios of ArA/EPA or DHA/EPA for normal reproductive performance of sea bass or sea bream broodstock.

Key Words: Marine fish, commercial feed, fatty acids, n-3 EFA

Türkiye'de Kullanılan Bazı Ticari Deniz Balığı Yemlerinin Yağ Asidi Kompozisyonu

Özet: Türkiye'de deniz balığı türlerinden özellikle çipura ve levrek balıkları (genç, ergin ve anaç) için çoğunlukta kullanılan 14 adet yemdeki yağ asidi kompozisyonu saptanmıştır. Genç ve ergin balıkların yemlerinden dokuz tanesi, anaç balığı yemlerinden bir tanesi ithal yemlerdir. Diğer yemler ise Türkiye'de üretilmiştir.

Genç, ergin ve anaç balıkların kuru yemlerindeki n-3 HUFA düzeyleri sırasıyla % 2,5 - % 3,9; % 1,5 - % 3,5 ve % 2,1 - % 4,9 değerleri arasında belirlenmiştir. Benzer bir şekilde bu kuru yemlerdeki DHA düzeyleri sırasıyla % 1,4 - % 2,3; % 0,5 - % 1,8 ve % 1,2 - % 3,0 ve EPA düzeyleri de sırasıyla % 1,1 - % 1,5; % 1,0 - % 1,6 ve % 0,8 - % 1,8 değerleri arasında bulunmuştur. Genç, ergin ve anaç balıkların yemlerindeki ArA düzeyleri toplam yağ asitlerinin yüzdesi olarak sırasıyla % 0,5 - % 0,9; % 0,5 - % 0,8 ve % 0,6 - % 0,9 değerleri arasında saptanmıştır.

Sonuçlar levrek ya da çipura balıklarının genç ve ergin yemlerindeki DHA, EPA ve ArA miktarları ile DHA/EPA oranlarının iyi bir büyüme ve gelişme için yeterli olduğunu göstermiştir. Benzer olarak anaç yemleri de balıkların normal üreme performansları için yeterli miktarlarda EPA, DHA ve ArA ile yeterli oranlarda ArA/EPA ve DHA/EPA içerdikleri görülmüştür.

Anahtar Sözcükler: Deniz balıkları, ticari yem, yağ asitleri, n-3 EFA

Introduction

Sea bream (*Sparus aurata*) and sea bass (*Dicentrarchus labrax*) are the most important cultured marine fish species in Turkey. Total production of these species was 64.9 t in 2005 (1). White grouper (*Epinephelus aeneus*), striped seabream (*Lithognathus mormyrus*), common seabream (*Pagrus pagrus*), common dentex (*Dentex dentex*), and sharpsnout bream (*Puntazzo puntazzo*) are becoming candidate marine fish species for aquaculture in Turkey. These marine fish species are also fed with commercial feeds for sea bream or sea bass.

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Dietary fats play an important role in fish nutrition as a source of body energy and essential fatty acids (EFA) (2). The nutritional aspects of EFA in marine finfish have been extensively studied. The previous feeding investigations on the essentiality of polyunsaturated fatty acids (PUFA) in fish diets (3-5) have demonstrated that marine fish species require n-3 highly unsaturated fatty acids (n-3 HUFA), particularly eicosapentaenoic (EPA, 20:5n-3) and docosahexaenoic (DHA, 22:6n-3) acids, for optimum growth and development. The essentiality of these fatty acids is based on the important structural role they play as membrane phospholipid components. However, marine fish cannot convert linolenic acid (18:3 n-3) to EPA or DHA. The same limitation exists in the conversion of linoleic acid (18:2 n-6) to n-6 HUFA. Among n-6 HUFA, several studies have reported that arachidonic acid (ArA, 20:4 n-6) was important for the nutrition of marine fish species (4,6-8). It is thought that the general function of ArA is as a main precursor fatty acid of eicosanoids (prostaglandins, thromboxanes, and leukotrienes) in fish (9), and it is also one of the main components of phosphatidylinositol (PI). Therefore, marine fish diets should include EPA, DHA, and ArA. The HUFA requirements of marine fish species have been studied in larvae (10-14), juveniles (5,7,15-19), and broodstock (20-26). A few studies have been performed on the fatty acid composition of commercial feeds used in marine fish farms in Turkey (27).

The aim of the present work was to study the fatty acid composition in some commercial feeds currently used by marine fish farms in Turkey and to evaluate their efficacy to cover EFA for these species.

Materials and Methods

Feed samples

Feed samples were obtained from different commercial marine fish farms in the Aegean region of Turkey during 2004 and 2005. They were classified into 14 groups depending on brand and pellet size of extruded or pelleted. Fourteen feeds were analysed, 5 for juveniles (Table 1), 5 for pre-adult fish (Table 2), and 4 for adults or broodstock (Table 3). Details concerning the type of diet (extruded or pelleted), origin (locally or imported), and pellet size are given in the respective tables.

Lipid extraction and fatty acid analysis

Total lipid content was gravimetrically measured after extraction with chloroform/methanol (2/1, v/v) containing 0.01% butylated hydroxytoluene (BHT) as antioxidant, according to the method described by Folch et al. (28). Fatty acid methyl esters were prepared from total lipid by acid-catalysed transesterification using 2 ml of 1% H_2SO_4 in methanol plus 1 ml of toluene as described by Christie (29), and the fatty acid analysis of the feed was performing using gas-liquid chromatography (Perkin Elmer Auto System XL) with a 30×0.25 mm capillary column, FID detector, CP-2330 Supelco). Helium was used as the carrier gas. Flame-ionisation detection temperature was 220 ºC, split rate 1/50, and oven temperature was programmed for a rise from 120 ºC/2 min to 220 ºC/15 min at a rate of 5 ºC/min. Injector temperature was 240 ºC. Individual methyl esters were identified by reference to known standards (Sigma, 189-19). All analyses were performed in triplicate.

Statistics

All data were presented as means ± standard deviation. The statistical significance of differences in the fatty acid composition among the feed samples was analysed with one-way analysis of variance (ANOVA) and Tukey's multiple range test using a statistical package (SPSS version 13.0); $P < 0.05$ was taken to indicate a significant difference (30).

Results

The total lipid and major fatty acid composition in the feeds of juvenile, preadult and adult, and broodstock fish are shown in Tables 1, 2, and 3. Total lipid is expressed as percent of dry weight of the feeds. Major fatty acid levels are expressed as percent of total lipids in the feeds. The fatty acids such as 16:0 and 18:1n-9 in all feeds were the most abundant within the saturates or monoenes, respectively. Among the polyenes, the n-6 fatty acids were always less abundant than the n-3 PUFA. In n-3 PUFA, the EPA and DHA were the most abundant fatty acids. The n-6 PUFA were almost entirely composed of 18:2n-6.

In Table 1, most values of total lipid contents in juvenile feeds were higher than 19% and only one feed contained less lipid (16.1%) ($P < 0.05$). Feed 1 had the highest percentages of n-3 HUFA (3.9%) and DHA (2.3%) of dry diet ($P < 0.05$). The EPA percentage (1.1%) of dry diet in feed 4 was significantly lower than that in the other feeds ($P < 0.05$). The ArA percentage of

Table 1. Lipid and main fatty acid composition in the experimental feeds for juvenile fish production[a].

Total lipid and fatty acids	Diet no.				
	1 (I)[b] Extruded 1.5 mm	2 (I)[b] Extruded 2 mm	3 (I)[b] Extruded 2.5 mm	4 (I)[b] Extruded 2.5 mm	5 (I)[b] Extruded 2.5 mm
Total lipid (%, DWB)	20.0 ± 0.6[bc]	20.9 ± 0.2[b]	19.3 ± 0.5[c]	16.1 ± 0.15[d]	23.7 ± 0.20[a]
n-3 HUFA in diet (%, DWB)	3.9 ± 0.12[a]	3.5 ± 0.06[b]	2.9 ± 0.07[c]	2.5 ± 0.01[d]	3.5 ± 0.04[b]
DHA in diet (%, DWB)	2.3 ± 0.07[a]	2.0 ± 0.04[b]	1.5 ± 0.04[c]	1.4 ± 0.01[c]	2.0 ± 0.02[b]
EPA in diet (%, DWB)	1.5 ± 0.04[a]	1.5 ± 0.01[a]	1.3 ± 0.03[b]	1.1 ± 0.02[c]	1.5 ± 0.01[a]
Fatty acids (% of total fatty acids)					
14:0	5.1 ± 0.02[a]	5.1 ± 0.11[a]	4.7 ± 0.03[b]	5.1 ± 0.06[a]	4.7 ± 0.05[b]
16:0	15.1 ± 0.03[bc]	15.2 ± 0.17[ab]	14.7 ± 0.08[c]	15.6 ± 0.20[a]	15.1 ± 0.06[bc]
18:0	3.0 ± 0.00[b]	2.1 ± 0.01[c]	3.2 ± 0.00[a]	3.2 ± 0.07[a]	3.2 ± 0.04[a]
Total saturates[c]	25.5 ± 0.09[a]	24.3 ± 0.29[b]	24.3 ± 0.13[b]	25.2 ± 0.12[a]	24.1 ± 0.14[b]
16:1n-7	5.4 ± 0.01[a]	5.1 ± 0.07[b]	4.8 ± 0.02[c]	5.4 ± 0.03[a]	5.1 ± 0.05[b]
18:1n-9	12.5 ± 0.02[e]	13.5 ± 0.02[c]	13.1 ± 0.01[d]	18.2 ± 0.04[a]	15.5 ± 0.05[b]
20:1n-9	5.5 ± 0.01[b]	6.2 ± 0.03[a]	4.5 ± 0.00[c]	2.6 ± 0.04[e]	2.8 ± 0.04[d]
22:1n-9	6.9 ± 0.03[b]	8.3 ± 0.11[a]	6.0 ± 0.01[c]	2.4 ± 0.00[e]	4.5 ± 0.05[d]
24:1n-9	0.8 ± 0.00[b]	0.9 ± 0.01[a]	0.03 ± 0.01[d]	0.3 ± 0.01[c]	0.3 ± 0.00[c]
Total monoenes[d]	31.5 ± 0.36[b]	34.7 ± 0.42[a]	28.9 ± 0.00[c]	25.2 ± 0.19[d]	28.4 ± 0.12[c]
18:2n-6	4.6 ± 0.00[e]	6.3 ± 0.02[d]	14.8 ± 0.03[c]	16.4 ± 0.11[b]	17.5 ± 0.06[a]
18:3n-6	0.1 ± 0.00[a]	0.1 ± 0.00[a]	0.1 ± 0.00[a]	0.06 ± 0.01[a]	0.1 ± 0.00[a]
20:4n-6	0.9 ± 0.00[a]	0.6 ± 0.00[b]	0.5 ± 0.01[b]	0.9 ± 0.01[a]	0.9 ± 0.03[a]
18:3n-3	1.3 ± 0.00[d]	2.0 ± 0.00[c]	2.4 ± 0.01[b]	2.3 ± 0.04[b]	2.5 ± 0.03[a]
20:3n-3	0.1 ± 0.01[a]	0.1 ± 0.01[a]	0.1 ± 0.03[a]	0.1 ± 0.00[a]	0.1 ± 0.02[a]
20:5n-3	7.7 ± 0.01[a]	7.1 ± 0.03[b]	7.0 ± 0.01[b]	6.8 ± 0.04[c]	6.4 ± 0.04[d]
22:6n-3	11.6 ± 0.03[a]	9.7 ± 0.11[b]	7.9 ± 0.01[e]	8.8 ± 0.13[c]	8.4 ± 0.03[d]
Total polyenes	25.6 ± 0.01[d]	25.9 ± 0.11[d]	32.8 ± 0.02[c]	35.4 ± 0.15[b]	36.0 ± 0.03[a]
Total n-6 PUFA	5.6 ± 0.03[e]	7.0 ± 0.02[d]	15.4 ± 0.03[c]	17.4 ± 0.11[b]	18.5 ± 0.03[a]
Total n-3 PUFA	20.0 ± 0.03[a]	18.9 ± 0.13[b]	17.4 ± 0.01[d]	18.1 ± 0.04[c]	17.5 ± 0.00[d]
Total n-3 HUFA	19.5 ± 0.04[a]	16.9 ± 0.13[b]	15.0 ± 0.02[d]	15.7 ± 0.04[c]	15.0 ± 0.03[d]
Total n-3/Total n-6	3.6 ± 0.00[a]	2.7 ± 0.03[b]	1.1 ± 0.00[c]	1.0 ± 0.00[c]	0.9 ± 0.00[d]
DHA/EPA	1.5 ± 0.00[a]	1.4 ± 0.01[b]	1.1 ± 0.00[d]	1.3 ± 0.03[c]	1.3 ± 0.01[c]

DWB: Dry weight basis

[a]Values reported are means ± S.D. of 3 replicate measurements. Values in the same row with different letters are significantly different ($P < 0.05$). Means were tested by ANOVA and ranked by Tukey's multiple range test.

[b]Imported feed. [c]Includes 15:0, 17:0, 20:0, 21:0, 22:0, 23:0, and 24:0. [d]Includes 14:1, 15:1, and 17:1.

feed 3 was lower than that of the other feeds ($P < 0.05$). The total n-6 PUFA contents increased with the increase in pellet size of the juvenile feeds ($P < 0.05$). In contrast, the total n-3 PUFA, n-3 HUFA, DHA/EPA, and n-3/n-6 values decreased with the increase in pellet size of the juvenile feeds ($P < 0.05$).

In Table 2, the total lipid contents in preadult or adult feeds were higher than 18% for extruded and lower than 14% for pelleted ($P < 0.05$). Most values of the n-3 HUFA percentage of dry diet in preadult or adult feeds ranged from 2.7% to 3.1%. One diet was outside this range (1.5%) ($P < 0.05$). Diet 10 had the lowest values

Table 2. Lipid and main fatty acid composition in the experimental feeds for preadult and adult fish production[a].

Total lipid and fatty acids	Diet no. 6 (I)[b] Extruded 4 mm	7 (I)[b] Extruded 6 mm	8 (T)[c] Extruded 6 mm	9 (T)[c] Pelleted 6 mm	10 (T)[c] Pelleted 6 mm
Total lipid (%, DWB)	21.4 ± 0.2[a]	21.8 ± 0.52[a]	18.4 ± 0.44[b]	12.9 ± 0.28[c]	13.7 ± 0.37[c]
n-3 HUFA in diet (%, DWB)	3.1 ± 0.03[a]	2.9 ± 0.07[a]	2.7 ± 0.05[b]	2.9 ± 0.06[a]	1.5 ± 0.05[c]
DHA in diet (%, DWB)	1.7 ± 0.02[a]	1.5 ± 0.03[b]	1.4 ± 0.02[c]	1.7 ± 0.01[a]	0.5 ± 0.01[d]
EPA in diet (%, DWB)	1.3 ± 0.01[ab]	1.4 ± 0.03[a]	1.2 ± 0.02[b]	1.2 ± 0.02[b]	1.0 ± 0.04[c]
Fatty acids (% of total fatty acids)					
14:0	4.1 ± 0.03[c]	4.5 ± 0.01[b]	4.4 ± 0.03[b]	6.0 ± 0.05[a]	6.0 ± 0.01[a]
16:0	14.2 ± 0.01[d]	14.0 ± 0.01[d]	14.6 ± 0.07[c]	20.2 ± 0.08[a]	17.4 ± 0.03[b]
18:0	3.2 ± 0.00[c]	3.0 ± 0.01[e]	3.1 ± 0.00[d]	4.2 ± 0.01[b]	4.3 ± 0.02[a]
Total saturates[d]	23.3 ± 0.13[d]	23.0 ± 0.30[d]	24.1 ± 0.13[c]	33.9 ± 0.11[a]	29.9 ± 0.06[b]
16:1n-7	4.5 ± 0.01[d]	4.9 ± 0.01[b]	4.6 ± 0.01[c]	5.0 ± 0.01[b]	6.7 ± 0.01[a]
18:1n-9	14.7 ± 0.01[a]	13.8 ± 0.01[b]	13.7 ± 0.03[b]	12.7 ± 0.01[c]	11.8 ± 0.23[d]
20:1n-9	2.3 ± 0.00[d]	5.7 ± 0.00[a]	4.4 ± 0.03[b]	1.2 ± 0.00[e]	2.7 ± 0.01[c]
22:1n-9	5.2 ± 0.02[c]	7.1 ± 0.02[a]	5.8 ± 0.04[b]	0.2 ± 0.01[e]	2.7 ± 0.05[d]
24:1n-9	0.1 ± 0.00[b]	0.1 ± 0.02[b]	0.1 ± 0.01[b]	0.1 ± 0.00[b]	1.4 ± 0.00[a]
Total monoenes[e]	29.8 ± 0.10[ab]	30.6 ± 2.03[a]	29.5 ± 0.48[ab]	19.9 ± 0.74[e]	25.9 ± 0.23[d]
18:2n-6	15.2 ± 0.05[b]	14.7 ± 0.01[c]	15.8 ± 0.18[a]	6.5 ± 0.01[e]	12.2 ± 0.00[d]
18:3n-6	0.1 ± 0.01[b]	0.1 ± 0.01[b]	0.1 ± 0.01[b]	0.1 ± 0.00[b]	0.2 ± 0.00[a]
20:4n-6	0.6 ± 0.00[b]	0.5 ± 0.01[c]	0.5 ± 0.00[c]	0.8 ± 0.00[a]	0.6 ± 0.01[b]
18:3n-3	2.3 ± 0.00[a]	2.2 ± 0.00[b]	2.4 ± 0.01[a]	1.2 ± 0.00[d]	1.7 ± 0.01[c]
20:3n-3	0.1 ± 0.00[b]	0.1 ± 0.01[b]	0.1 ± 0.01[b]	0.1 ± 0.00[b]	0.2 ± 0.00[a]
20:5n-3	5.9 ± 0.01[e]	6.3 ± 0.00[d]	6.8 ± 0.03[c]	9.3 ± 0.01[a]	7.2 ± 0.07[b]
22:6n-3	8.2 ± 0.02[b]	7.0 ± 0.01[d]	7.6 ± 0.05[c]	13.5 ± 0.20[a]	3.6 ± 0.01[e]
Total polyenes	32.6 ± 0.08[b]	30.9 ± 0.13[d]	33.3 ± 0.26[a]	31.5 ± 0.02[c]	25.7 ± 0.08[e]
Total n-6 PUFA	16.0 ± 0.06[a]	15.2 ± 0.12[c]	16.4 ± 0.18[b]	7.4 ± 0.01[e]	13.1 ± 0.01[d]
Total n-3 PUFA	16.6 ± 0.01[c]	15.6 ± 0.01[d]	16.8 ± 0.08[b]	24.0 ± 0.03[a]	12.7 ± 0.10[e]
Total n-3 HUFA	14.2 ± 0.01[b]	13.4 ± 0.01[c]	14.4 ± 0.08[b]	22.8 ± 0.02[a]	10.9 ± 0.08[d]
Total n-3/Total n-6	1.0 ± 0.00[b]	1.0 ± 0.01[b]	1.0 ± 0.02[b]	3.2 ± 0.00[a]	1.0 ± 0.01[b]
DHA/EPA	1.4 ± 0.01[a]	1.1 ± 0.00[b]	1.1 ± 0.00[b]	1.4 ± 0.00[a]	0.5 ± 0.01[c]

DWB: Dry weight basis

[a]Values reported are means ± S.D. of 3 replicate measurements. Values in the same row with different letters are significantly different ($P < 0.05$). Means were tested by ANOVA and ranked by Tukey's multiple range test.

[b]Imported feed. [c]Feed produced in Turkey.

[d]Includes 15:0, 17:0, 20:0, 21:0, 22:0, 23:0, and 24:0. [e]Includes 14:1, 15:1, and 17:1.

of DHA (0.5%) or EPA (1%) of dry diet for preadult or adult feeds ($P < 0.05$). Generally, there were not significant differences among fatty acid percentages for preadult or adult feeds. The total n-6 PUFA levels of the extruded feeds were significantly higher than those of the pelleted feeds ($P < 0.05$). Diet 9 had the highest (22.8%) and diet 10 had the lowest (10.9 %) percentages of total n-3 HUFA ($P < 0.05$). Diet 9 had the highest value (3.2) of the total n-3/n-6 ratio ($P < 0.05$). The DHA/EPA ratio (0.5) in feed 10 was significantly lower ($P < 0.05$) than that of the other experimental feeds for preadult or adult feeds ($P < 0.05$).

Table 3. Lipid and main fatty acid composition in the experimental feeds for adult and broodstock fish production[a].

Total lipid and fatty acids	Diet no.			
	11 (I)[b] Extruded 4 mm	12 (T)[c] Extruded 6 mm	13 (T)[c] Pelleted 6 mm	14 (I)[b] Extruded 8 mm
Total lipid (%, DWB)	22.0 ± 0.23[a]	14.3 ± 0.42[b]	12.2 ± 0.14[c]	21.0 ± 0.15[a]
n-3 HUFA in diet (%, DWB)	3.5 ± 0.05[b]	2.5 ± 0.08[c]	2.1 ± 0.02[d]	4.9 ± 0.00[a]
DHA in diet (%, DWB)	1.8 ± 0.02[b]	1.0 ± 0.03[d]	1.2 ± 0.00[c]	3.0 ± 0.01[a]
EPA in diet (%, DWB)	1.6 ± 0.01[b]	1.4 ± 0.05[c]	0.8 ± 0.01[d]	1.8 ± 0.01[a]
Fatty acids (% of total fatty acids)				
14:0	5.2 ± 0.03[c]	5.6 ± 0.03[b]	4.6 ± 0.06[d]	6.3 ± 0.01[a]
16:0	15.5 ± 0.05[d]	17.8 ± 0.04[c]	18.5 ± 0.17[b]	19.8 ± 0.08[a]
18:0	3.2 ± 0.02[d]	3.7 ± 0.04[c]	4.9 ± 0.02[a]	4.0 ± 0.01[b]
Total saturates[d]	25.0 ± 0.08[d]	28.2 ± 0.06[c]	30.4 ± 0.03[b]	33.7 ± 0.06[a]
16:1n-7	5.3 ± 0.03[b]	5.3 ± 0.03[b]	4.5 ± 0.03[c]	5.9 ± 0.02[a]
18:1n-9	14.2 ± 0.04[b]	14.3 ± 0.01[b]	18.6 ± 0.06[a]	13.8 ± 0.06[c]
20:1n-9	2.2 ± 0.01[a]	0.8 ± 0.03[d]	1.1 ± 0.01[c]	1.3 ± 0.01[b]
22:1n-9	1.9 ± 0.01[a]	0.6 ± 0.00[b]	0.08 ± 0.01[d]	0.2 ± 0.01[c]
24:1n-9	0.3 ± 0.00[c]	0.3 ± 0.01[c]	0.5 ± 0.01[b]	0.6 ± 0.02[a]
Total monoenes[e]	24.3 ± 0.06[b]	21.8 ± 0.06[d]	25.3 ± 0.23[a]	22.6 ± 0.06[c]
18:2n-6	17.9 ± 0.03[a]	17.2 ± 0.03[b]	14.1 ± 0.02[c]	3.6 ± 0.01[d]
18:3n-6	0.1 ± 0.00[a]	0.1 ± 0.03[a]	0.1 ± 0.01[a]	0.1 ± 0.01[a]
20:4n-6	0.9 ± 0.01[a]	0.9 ± 0.01[a]	0.6 ± 0.01[b]	0.9 ± 0.01[a]
18:3n-3	2.6 ± 0.02[b]	3.5 ± 0.05[a]	2.2 ± 0.01[c]	1.3 ± 0.01[d]
20:3n-3	0.1 ± 0.01[a]	0.1 ± 0.01[a]	0.06 ± 0.01[b]	0.1 ± 0.01[a]
20:5n-3	7.4 ± 0.02[c]	10.0 ± 0.06[a]	6.9 ± 0.01[d]	8.8 ± 0.03[b]
22:6n-3	8.2 ± 0.03[c]	7.1 ± 0.03[d]	10.3 ± 0.00[b]	14.4 ± 0.17[a]
Total polyenes	37.3 ± 0.00[b]	38.9 ± 0.15[a]	25.7 ± 0.08e	29.3 ± 0.17[c]
Total n-6 PUFA	18.9 ± 0.04[a]	18.2 ± 0.02[b]	14.8 ± 0.00[c]	4.6 ± 0.01[d]
Total n-3 PUFA	18.4 ± 0.04[d]	20.7 ± 0.13[b]	19.5 ± 0.03[c]	24.6 ± 0.18[a]
Total n-3 HUFA	15.8 ± 0.02[c]	17.2 ± 0.08[b]	17.3 ± 0.02[b]	23.4 ± 0.18[a]
Total n-3/Total n-6	1.0 ± 0.00[d]	1.2 ± 0.01[c]	1.3 ± 0.01[b]	5.3 ± 0.05[a]
ArA/EPA	0.12±0.01[a]	0.09±0.03[a]	0.09±0.02[a]	0.10±0.01[a]
DHA/EPA	1.1 ± 0.01[c]	0.7 ± 0.00[d]	1.5 ± 0.01[b]	1.6 ± 0.01[a]

DWB: Dry weight basis

[a]Values reported are means ± S.D. of 2 replicate measurements. Values in the same row with different letters are significantly different ($P < 0.05$). Means were tested by ANOVA and ranked by Tukey's multiple range test, [b]Imported feed. [c]Feed produced in Turkey. [d]Includes 15:0, 17:0, 20:0, 21:0, 22:0, 23:0, and 24:0. [e]Includes 14:1, 15:1, and 17:1.

As shown in Table 3, the total lipid contents in adult or broodstock diets were higher than 20% for the imported extruded feeds and lower than 14.5% for feeds produced in Turkey ($P < 0.05$). Diet 14 had the highest percentages of n-3 HUFA (4.9%) or EPA (1.8%) and diet 13 had the lowest percentages of n-3 HUFA (2.1%) or EPA (0.8%) in adult and broodstock feeds ($P < 0.05$) as percent of dry diet. Most values of the DHA percentages in adult or broodstock diets ranged from 1% to 1.8% ($P < 0.05$). One diet was outside this range (3.0%). The total n-6 PUFA levels in the adult feeds were significantly higher than those in broodstock feeds. However,

broodstock diets had the highest values of total n-3 HUFA levels, n-3/n-6, or DHA/EPA ratios ($P < 0.05$). Values of ArA/EPA ratios in broodstock feeds ranged from 0.09 to 0.12.

Discussion

Recent evaluations of the EFA requirements of marine fish species indicated that the n-3 EFA requirements can be met only by EPA together with DHA (2). According to these authors, the n-3 HUFA requirements in the dry diet of some older juvenile and preadult marine fish species such as turbot (*Scophthalmus maximus*), red sea bream (*Pagrus major*), gilthead sea bream (*Sparus aurata*), and European sea bass (*Dicentrarchus labrax*) were 0.8%, 0.5%, 0.9% (DHA/EPA = 1), or 1.9% (DHA/EPA = 0.5) and 1%, respectively. Skalli and Robin (31) indicated that the requirement for growth of n-3 HUFA of juvenile sea bass was at least 0.7% of the dry diet. Furthermore, Parpoura and Alexis (32) reported that European sea bass of medium size had a minimum requirement of 1.35% EPA+DHA for optimum performance. However, reductions in growth of gilthead sea bream juveniles fed a diet containing 5% n-3 HUFA in the form of triglycerides were found by Ibeas et al. (5). In the present study, the levels of dietary n-3 HUFA, mostly including DHA and EPA, were from 2.5% to 3.9% in the juvenile fish feeds as percent of dry diet and from 1.5% to 3.1% in the preadult or adult fish feeds as percent of dry diet (Tables 1 and 2). Furthermore, the ratios of DHA/EPA in the juvenile and preadult or adult fish feeds were from 1.1 to 1.5 or from 0.5 to 1.4, respectively (Tables 1 and 2). The results of the present study were significantly higher than those reported by the researchers cited above for juvenile or adult gilthead sea bream or sea bass. Only one diet (feed 10) had a lower ratio (0.5) of DHA/EPA.

The ArA requirement of juvenile or adult marine fish has not been determined quantitatively. However, recent studies showed that ArA was required for survival, optimal growth, and development of turbot juveniles (33). The same studies stated that the ArA was essential for 0.3% of dry weight of turbot diet. However, Fountoulaki et al. (7) found that fingerlings of gilthead sea bream fed with increasing dietary ArA levels from 0.2% to 11.2% of total fatty acids did not differ in growth during a 54-day feeding trial. In the present study, the ArA contents in the feeds of juvenile, preadult, or adult marine fish species ranged from 0.5% to 0.8% of total fatty acids (Tables 1 and 2). These ArA levels appeared to cover the requirements of juvenile or adult marine fish species according to the results reported by the researchers cited above.

Broodstock nutrition affects the reproduction and egg quality of fish. EFA are one of the nutritional factors that greatly affect egg and larval quality (20,34,35). Throughout the developing egg and larval stages, fish have greater n-3 HUFA requirements, because of the preponderance of n-3 HUFA in their neural and visual tissue, which predominates in the early stages of development (2). Several studies showed that egg fatty acid compositions of marine fish could be affected by broodstock diets in various species such as gilthead sea bream (20,22), European sea bass (23,24), and white sea bream (*Diplodus sargus*) (26). Fecundity in gilthead sea bream was found to increase significantly with an increase in dietary n-3 HUFA levels up to 1.6% of the diet, while higher levels reduced larval survival (20). Similar results have been reported in other sparids (34). An increase in dietary α-tocopherol content from 125 to 190 mg/g was necessary for reducing mortality in a diet containing 2.5% n-3 HUFA (36). Navas et al. (35) reported that n-3 HUFA level of diet fed during vitellogenesis had a remarkable influence on the quality of the eggs spawned by the broodstock of European sea bass. According to the same studies, the ratio of DHA and EPA present in the eggs correlates directly with the normal development of eggs up to hatching and may be equally important in early larval development.

Traditionally, wet diets based on trash fish have been used to feed sea bass broodstock with better results than when using commercial diets (23,37). Analysis of wet and commercial diet (37) indicated the following dietary contents and ratios in EFA: ArA 0.48% and 0.13%, DHA 2.3% (similar in commercial and wet diets), ArA/EPA 0.7 and 0.1, and DHA/EPA 3.3 and 1.3, respectively. Bruce et al. (23) enriched a commercial diet with a special oil type to approach the composition of wet diet in levels and ratios of EFA and succeeded in increasing early survival and hatching success significantly. Although the artificial diet containing about 1.6% DHA appeared to supply sufficient amounts of this FA to the eggs, the main differences were in the DHA/EPA and ArA/EPA ratios, which were higher for the supplemented and control diets compared to the commercial diet. The ArA/EPA and

DHA/EPA (0.06 and 1.3, respectively) of the commercial diet were not adequate for optimal broodstock performance.

The sperm of sea bass fed trash fish (21) was quite similar in levels and ratios of FAs to that of wild fish, while the sperm of sea bass fed a commercial diet had elevated EPA and decreased ArA levels, which resulted in a much decreased ArA/EPA ratio in sperm phospholipids. Reproductive performance of male sea bass fed a wet diet base on bogue and squid (3/1 ratio) was compared by Asturiano et al. (25) to that of fish fed 2 commercial diets enriched with a Northern hemisphere oil or tuna orbital oil. Contrary to what was found for female sea bass, a better reproductive performance was found for fish fed the commercial diets. The authors suggested that a reduction in n-3 PUFAs and an increase in ArA and therefore a different n-3/n-6 PUFA ratio (3.6 for the commercial diets and 4.8 for wet diet) could be better for male sea bass.

In conclusion, the results of the present study indicated that the n-3 and n-6 HUFA percentages especially DHA, EPA, or ArA levels and DHA/EPA ratios in the feeds of juvenile or adult sea bass and sea bream were sufficient for better growth and development. However, feed 10 had a slightly lower DHA level required for adult sea bass or sea bream. The broodstock feeds also had adequate levels of EPA, DHA, or ArA and adequate ratios of ArA/EPA or DHA/EPA for normal reproductive performance of sea bass or sea bream broodstock. However, more research is required concerning the optimum levels and especially the ratios of n-3 and n-6 HUFA for optimal reproductive performance of sea bass and sea bream.

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