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Research Article

The Effect of Dietary Oils of Vegetable Origin on the Performance, Body Composition and Fatty Acid Profiles of Sea Bass (*Dicentrarchus labrax* L., 1758) Juveniles*

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Abstract: Body fat composition and growth performance of sea bass juveniles fed with different kinds of vegetable oils instead of fish oil were studied. Feeding trials were carried out with 600 sea bass (*Dicentrarchus labrax* L.) juveniles with on initial live weight of 7.58 ± 0.13 g. Experimental feeds contained fish oil, soybean oil, sunflower oil, corn oil and olive oil. In the chemical analyses of the experimental feeds, total crude fat was 12.33 ± 0.24% and total crude protein was 57.42 ± 0.31%. According to fatty acid analyses EPA (7.57%) and DHA (11.91%) in the feed containing fish oil, linolenic acid (5.50%) in the feed containing soybean oil and oleic acid (62.69%) in the feed containing olive oil were found in higher levels than in the other feeds. However, linoleic acid (18:2n-6) levels were 40.66% in soybean oil, 44.58% in sunflower oil and 45.57% in corn oil added feeds ($P < 0.05$). At the end of the feeding trials, the highest live weight gain and the best feed conversion ratio (FCR) were achieved with feed containing fish oil. However, live weight gain and FCR were present in lower levels in the feed containing corn oil than in the other feeds ($P < 0.05$). According to the crude fat analyses of the fish carcasses at the end of the feeding trials, the highest carcass fat values were in the fish fed fish oil added diets. In the fatty acids analyses of the whole fish bodies, higher values of EPA and DHA were found in the fish fed fish oil added diets than in the others. Linolenic acid (18:3n-3) and linoleic acid (18:2n-6) levels were higher in the fish fed soybean oil added feeds than in the others, and oleic acid (18:1n-9) was present in higher levels in the fish fed olive oil added feeds than in the others. In the statistical analyses, the live weight gain and carcass fat content and fatty acid composition in the experimental groups were significantly different ($P < 0.05$).

Key Words: *Dicentrarchus labrax*, growth, vegetable oil, fatty acids composition

Diyette Yer Alan Bitkisel Yağların Levrek (*Dicentrarchus labrax* L., 1758) Yavrularında Büyüme Performansı, Vücut Kompozisyonu ve Yağ Asidi Profiline Etkisi

Özet: Bu araştırmada balık yağı yerine farklı bitkisel yağlarla beslenen levrek balıklarının vücut yağı kompozisyonu ve büyüme performansı incelenmiştir. Yemleme deneyleri başlangıç ağırlığı 7,58 ± 0,13 g olan 600 adet levrek (*Dicentrarchus labrax* L.) balığı ile sürdürülmüştür. Deney yemlerine sırasıyla balık yağı, soya yağı, ayçiçek yağı ve zeytin yağı ilave edilmiştir. Kimyasal analizlerde toplam ham yağ %12,33 ± 0,24 ve toplam ham protein %57,42 ± 0,31 bulunmuştur. Yağ asidi analizlerine göre balık yağı içeren yemlerde EPA (%7,57) ve DHA (%11,91), soya yağı içeren yemlerde linolenik asit (%5,50) ve zeytin yağı içeren yemlerde oleik asit (%62,69) diğer yemlerdekinden daha yüksek düzeyde bulunmuştur. Bununla birlikte, linoleik asit (18:2n-6) soya yağı içeren yemlerde %40,66, ayçiçek yağı içeren yemlerde %44,58 ve mısır yağı içeren yemlerde %45,57 oranında bulunmuştur ($P < 0,05$). Yemleme deneylerinin sonunda, en iyi canlı ağırlık artışı değeri ve en iyi yemden yararlanma oranı (YYO) balık yağı içeren yemle beslenen gruptan elde edilmiştir ($P < 0,05$). Bununla birlikte canlı ağırlık artışı ve YYO mısır yağı içeren yemlerde diğerlerinden daha düşük düzeyde bulunmuştur. Yemleme deneylerinin sonunda balık karkasındaki ham yağ analizlerine göre; balık yağı ilave edilen diyetle beslenen balıklarda, karkastaki yağ değeri en yüksek düzeyde bulunmuştur. Tüm vücuttaki yağ asidi analizlerinde en yüksek EPA ve DHA değerleri balık yağı ilave edilen yemlerle beslenen balıklarda bulunmuştur. Linolenik asit (18:3n-3) ve linoleik asit (18:2n-6) soya yağı ilave edilen yemle beslenen balıklarda en yüksek düzeyde bulunmuştur ve oleik asit (18:1n-9) zeytin yağı ilave edilen diyetle beslenen balıklarda en yüksek düzeyde bulunmuştur. İstatistiksel analizlerde, canlı ağırlık artışı, karkastaki yağ miktarı ve deney gruplarındaki yağ asidi kompozisyonları önemli derecede farklı bulunmuştur ($P < 0,05$).

Anahtar Sözcükler: *Dicentrarchus labrax*, büyüme, bitkisel yağlar, yağ asitleri kompozisyonu

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Introduction

Fish require lipids as an energy source, and in the maintaining the cell membrane permeability, material transporting and enzyme activity of the membrane are controlled by polyunsaturated fatty acids (PUFAs). In general, fish have more n-3 PUFAs, eicosapentaenoic acid (EPA, 20:5 n-3) and docosahexaenoic acid (DHA, 22:6 n-3) than terrestrial animals have. Aquaculture diets must include essential fatty acids (EFAs) for optimal fish growth. Furthermore, fat-soluble vitamins (A, D, E and K) are present in oil (1,2). Lipid metabolisms of fish were studied in recent works, and the EFA requirements of fish species were found to be different from each other. n-3 HUFA of marine fish lipids is present at higher levels than in freshwater fish. These fatty acids have a spearing effect of protein in fish, and fish need fatty acids for growth and a better feed conversion ratio (FCR) (1).

The chemical composition of fish flesh is affected by fish feed. Lipids in the feeds accumulate in the muscles, viscera and liver after energy metabolism in fish. Lipid profiles of fish flesh are reflected by fish feed lipids (3,4).

Fish, like all other vertebrates, require 3 long chain polyunsaturated fatty acids (PUFAs) for normal growth and development, including reproduction. These are docosahexaenoic acid (DHA, 22:6n-3), eicosapentaenoic acid (EPA, 20:5n-3) and arachidonic acid (AA, 20:4n-6) (5-9). These PUFAs play an essential role in maintaining the cell membrane structure and physiological functions. Fish require n-3 PUFA to be higher than AA. According to recent studies, arachidonic acid is essential for marine fish larvae (5,6,9-11). In particular 20:4n-6 in fish oil added feed is essential for sea bass larvae (9,10).

In marine fish farming these fatty acids are very important and must be present in marine fish feeds. When n-3 HUFA is deficient in the diet, linoleic acid (LA, 18:2n-6) and linolenic acid (LNA, 18:3n-3) partially substitute for n-3 HUFA. These fatty acids are essential for the survival of larvae, and the growth performance of fish (10,12-14).

The effects of soybean, sunflower, corn and olive oil, which include n-6 and n-9 PUFAs as a substitute for fish oil, which includes n-3 PUFA, on the growth performance, whole body composition, and fatty acids composition of sea bass (*Dicentrarchus labrax* L., 1758) juveniles were studied.

Materials and Methods

a. Feeding trials

The feeding trials were conducted in a commercial hatchery in the Aegean region over 75 days in 5 periods between 10 June and 25 August, 2000. Sea bass with an average initial weight of 7.58 ± 0.13 g were allocated 500 l of water (60 fish per tank) in duplicate fiberglass tanks. Filtered seawater was used. The daily feed level was adjusted to be 4% of live weight. Five groups of fish were fed 3 times a day according to the experimental diets. During the feeding trials, the temperature (°C), pH, and dissolved oxygen value of the water in the experimental tanks were measured daily, and seawater salinity was measured monthly.

Water temperature was measured between 21 ºC and 26 ºC, pH measured 7.5-8.3, average dissolved oxygen was 6.5 mg/l-11.3 mg/l and seawater salinity was 40‰ during the feeding trials. Water temperature, dissolved oxygen, pH and salinity were at optimal values during the feeding trials (15-18). In addition, the crude protein and crude lipid values of the experimental feeds were optimal for sea bass (19-21).

Experimental feeds were prepared at the Sapanca Inland Waters Research and Experiment Department of the İstanbul University Faculty of Fisheries. Ingredients of the experimental feeds were obtained from a commercial fish feed company in Turkey. Oil was added to experimental feeds at a level of 10%.

Dietary ingredients were milled in a grinder and thoroughly mixed and homogenized in a mixer when the feeds were prepared, and were pelleted in a laboratory pellet mill (KAHL-157) through 1 and 2 mm dies. In order to meet the amino acid requirements of the fish, fish meal was added in sufficient quantities to the experimental feeds (1,16). Fish oil in the control group and soybean oil, sunflower oil, corn oil and olive oil in the experimental groups were added to feeds at a level of 12.33%. Antioxidant (Oxistat) was added to the feeds at a level of 0.03% to prevent oxidation by the fish meal and unsaturated fatty acids (9). Feed formulations and nutrients in the experimental feeds are shown in Table 1.

b. Growth performance

Fish were weighed every 2 weeks according to the experimental groups, and live weight gain was recorded as the difference between final weight and initial weight.

Table1. Formulation of the experimental diets (% as dry weight basis).

Ingredients	%
Fish meal	63.68
Soybean meal	13.33
Corn meal	8.00
Oil[a]	10.0
Binder[b]	1.33
Vitamin mixture[c]	1.00
Mineral mixture[d]	0.13
Antioxidant[e]	0.03
Proximate analyses	**(Mean ± SD)**
Dry matter (%)	91.13 ± 0.09
Crude protein (%DW)	57.42 ± 0.31
Ether extract (%DW)	12.33 ± 0.20
Ash (%)	10.33 ± 0.24
Crude fibre (%DW)	1.57 ± 0.08
NFE (%DW)	9.48 ± 0.30

[a]Fish oil, soybean oil, sunflower oil, corn oil and olive oil were used in experimental feeds, respectively.

[b]Aquacub was used as binder.

[c]Vitamin mixture (I.U. or mg/kg); Vitamin A 5,000,000 (I.U. kg^{-1} diet), Vitamin D_3 5,000,000 (I.U. kg^{-1} diet), Vitamin E 44,000, Vitamin B_1 4,400, Vitamin B_2 6,400, Vitamin B_6 3,600, Vitamin B_{12} 10, Vitamin K_3 2,000, Folic acid 1,200, Niacin 50,000, Biotin 60, D-Calcium pantothenate 6,800, Choline chloride 350,000, Ascorbic acid 60,000, Inositol 50,000, Antioxidant (oxistat) 1,000.

[d]Mineral mixture (mg/kg); Manganese 6,2000, zinc 40,000, cobalt 900, iodine 1,240, copper 4,000, iron 20000, Selenite 100.

[e]Oxistat was used as antioxidant (mg/kg); Butylated hydroxytoluene 99,000 mg, Butylated hydroxyanisole 9,000 mg, Ethoxyquin 9,800 mg, Sodium citrate 39,200 mg, Silicilic acid 18,620 mg, Calcium carbonate 821,000 mg.

The feed conversion ratio (FCR) was calculated according to the equation FCR = feed intake (dry weight) (g)/live weight gain (g), and specific growth rate (SGR) was calculated according to the equation SGR = (ln final weight–ln initial weight) x 100/time in days (3,22).

c. Chemical analyses

Proximate compositions of nutrients in the experimental feed and fish samples were collected on the initial and 45th days and at the end of the feeding trial, and were analyzed according to the AOAC (23). Chemical analyses for body composition were completed in parallel in 10 fish samples obtained on the initial and 45th days and at the end of the feeding trials in the control and experimental groups. Dry matter, crude protein, crude lipid, fiber and ash in the experimental feed were analyzed. Dry matter, crude protein, crude lipid and ash were analyzed in the homogenized fish samples obtained at the start, on the 45th day and at the end of the feeding trials. Chemical analyses of the experimental fish were performed using the following procedures: dry matter in an oven at 105 ºC for 12 h; ash by incineration in a muffle furnace at 550 ºC for 16 h; crude protein (N x 6.25) by the Kjeldahl method after acid digestion; crude lipid by petroleum ether extraction in a Soxtec system (23).

d. Fatty acids analysis

Fatty acids analyses were performed on the same 10 fish samples as used for chemical analyses, and all analyses were conducted in parallel for the control group and experimental groups. Total lipid was extracted after homogenization in chloroform/methanol (2:1, v/v) containing 0.01% BHT (butylated hydroxytoluene) as antioxidant, basically according to the method of Folch et al. (24). Fatty acid methyl esters of diets and fish samples were obtained by esterification with 1% sulfuric acid in methanol (25), and the fatty acid analysis of the feed and fish samples was performed on a Perkin Elmer Auto System XL capillary gas chromatography (column 30 x 0.25mm, FID detector, CP-2330 Supelco). Flame-ionization detection temperature was 220 ºC, helium was used as the carrier gas, the split rate was 1/50, the oven temperature was programmed to rise from 120 ºC/2 min to 220 ºC/15 min at a rate of 5 ºC/min. The injector temperature was 240 ºC and the detector temperature was 250 ºC. Individual fatty acid methyl esters were identified by reference to known standards (Sigma).

e. Statistical analyses

Statistical analysis of data was performed by one-way ANOVA and Duncans test for multiple comparisons of means with a 5% significance level (26,27).

Results

Dry matter levels of 91.13 ± 0.09%, crude protein of 57.42 ± 0.31%, crude lipid of 12.33 ± 0.20%, ash of 10.33 ± 0.24% and, fiber of 1.57 ± 0.08% were determined in the proximate analysis of the experimental feeds, and were calculated as N-free extract at 9.48 ± 0.30.

Growth performance of sea bass juveniles fed experimental feeds including fish oil, soybean oil, sunflower oil, corn oil and olive oil is shown in Table 2.

Initial fish weights in the control and experimental groups were similar ($P > 0.05$), but the best weight gain at the end of feeding trials was determined the control group (fish oil), with lower and similar levels in the experimental groups (vegetable oils) ($P < 0.05$). Specific growth rate (SGR) values in the experimental groups fed on vegetable oils were similar and lower than those in the control group (fish oil) ($P < 0.05$). However, feed conversion ratio (FCR) values were best in the control group (fish oil), worst in group III (corn oil) and similar in the other experimental groups (soybean oil, sunflower oil and olive oil) ($P < 0.05$).

Whole body composition (dry matter, crude protein, crude lipid and ash) of sea bass juveniles fed experimental diets determined at the initial, 45th and final days of the feeding tried is shown in Table 3.

Table 2. Growth performance and nutrient utilization of sea bass juveniles fed the experimental diets[1].

Growth performance	Control Group (*Fish oil*)	Experimental Group I (*Soybean oil*)	Experimental Group II (*Sunflower oil*)	Experimental Group III (*Corn oil*)	Experimental Group IV (*Olive oil*)
Mean initial body weight (g)	7.54 ± 0.25^{a}	7.40 ± 0.23^{a}	7.61 ± 0.25^{a}	7.75 ± 0.27^{a}	7.75 ± 0.27^{a}
Mean final body weight (g)	38.78 ± 0.64	33.44 ± 0.62	32.40 ± 0.61	32.08 ± 0.71	33.36 ± 0.62
Final weight gain (g)	31.27 ± 0.62^{a}	26.04 ± 0.77^{b}	24.79 ± 0.60^{bc}	24.34 ± 0.99^{c}	25.76 ± 0.70^{bc}
Specific growth rate (SGR)	2.20 ± 0.06^{a}	2.01 ± 0.05^{b}	1.94 ± 0.04^{b}	1.90 ± 0.08^{b}	1.98 ± 0.04^{b}
Total feed intake (g/fish)	47.02 ± 0.98	42.58 ± 1.02	42.60 ± 0.90	42.62 ± 1.07	43.74 ± 0.97
Feed conversion ratio (FCR)	1.59 ± 0.09^{d}	1.78 ± 0.12^{cd}	1.86 ± 0.14^{b}	1.94 ± 0.14^{a}	1.81 ± 0.13^{bc}

[1]Values are means ± SD n = 60. Values in each row with different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.
Specific growth rate calculated as: SGR = (ln final weight – ln initial weight) X 100/days.
Feed conversion ratio calculated as: FCR = Feed intake/Whole fish weight gain.

Table 3. Whole body composition of sea bass juveniles fed the experimental diets[1].

Experimental groups and periods	Dry matter (%)	Crude protein (%)	Crude lipid (%)		Ash (%)
			Carcass	Muscle	
Initial	23.46 ± 0.06^{c}	20.68 ± 0.03^{a}	4.88 ± 0.05^{d}	1.85 ± 0.14^{d}	3.49 ± 0.03
Control group (*Fish oil*)					
Day 45	24.67 ± 0.05^{b}	21.03 ± 0.03^{a}	4.83 ± 0.07^{de}	2.43 ± 0.12^{b}	3.78 ± 0.02
Final	23.73 ± 0.03^{c}	20.96 ± 0.01^{a}	4.55 ± 0.03^{e}	2.64 ± 0.08^{a}	4.10 ± 0.01
Experimental group I (*Soybean oil*)					
Day 45	24.83 ± 0.07^{b}	20.72 ± 0.04^{a}	5.34 ± 0.08^{c}	1.69 ± 0.18^{de}	3.69 ± 0.03
Final	24.82 ± 0.05^{b}	20.83 ± 0.01^{a}	5.03 ± 0.01^{cd}	1.87 ± 0.16^{d}	3.97 ± 0.01
Experimental group II (*Sunflower oil*)					
Day 45	24.71 ± 0.03^{b}	20.97 ± 0.03^{a}	5.12 ± 0.03^{cd}	2.07 ± 0.15^{c}	3.75 ± 0.04
Final	25.12 ± 0.04^{bc}	21.05 ± 0.02^{a}	4.99 ± 0.05^{cd}	1.61 ± 0.12^{e}	4.03 ± 0.02
Experimental group III (*Corn oil*)					
Day 45	24.79 ± 0.08^{b}	20.28 ± 0.05^{a}	5.96 ± 0.04^{b}	1.74 ± 0.14^{de}	3.62 ± 0.01
Final	25.97 ± 0.07^{a}	20.56 ± 0.01^{a}	6.38 ± 0.03^{ab}	1.84 ± 0.13^{d}	3.83 ± 0.03
Experimental group IV (*Olive oil*)					
Day 45	24.52 ± 0.02^{b}	20.83 ± 0.04^{a}	6.27 ± 0.02^{ab}	2.05 ± 0.17^{c}	3.71 ± 0.02
Final	25.63 ± 0.03^{bc}	20.74 ± 0.03^{a}	6.11 ± 0.06^{ab}	1.77 ± 0.19^{de}	3.91 ± 0.01

[1]Values are means ± SD, n = 10. Values in each row with different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 3 shows that according to the chemical analyses of fish samples for the initial, 45th and final days of the trials crude protein differences were not significant ($P > 0.05$). Carcass fat values of the control and experimental groups for the initial, and 45th days and the end of the trials were not significantly different ($P > 0.05$). However, the end of trials differences between the groups were significant ($P < 0.05$). Fat values in fish muscle were also significantly different ($P < 0.05$) at the initial, 45th and final days of the trial. However, the best value was found in the control group.

Fatty acid composition and whole fish body fatty acid composition of sea bass juveniles fed the experimental diets determined at the initial, 45th and final days of the feeding trial are shown in Tables 4, 5 and 6.

Table 4. Fatty acid composition of the experimental diets (% by weight of total fatty acids)[1].

Fatty acids	Control Group (*Fish oil*)	Experimental Group I (*Soybean oil*)	Experimental Group II (*Sunflower oil*)	Experimental Group III (*Corn oil*)	Experimental Group IV (*Olive oil*)
Saturated					
14:0	0.15 ± 0.01^{a}	0.05 ± 0.01^{b}	0.04 ± 0.01^{b}	0.05 ± 0.01^{b}	0.03 ± 0.00^{b}
16:0	19.47 ± 0.10^{a}	14.67 ± 0.17^{b}	11.26 ± 0.08^{d}	14.59 ± 0.20b^{c}	14.29 ± 0.13^{c}
18:0	3.93 ± 0.01^{b}	4.30 ± 0.15^{a}	3.70 ± 0.11^{b}	2.77 ± 0.14^{d}	3.12 ± 0.14^{c}
21:0	1.24 ± 0.06^{a}	0.25 ± 0.03^{b}	0.23 ± 0.03^{b}	0.20 ± 0.03^{b}	0.19 ± 0.03^{b}
23:0	0.42 ± 0.04^{a}	0.02 ± 0.00^{c}	0.09 ± 0.01^{b}	0.10 ± 0.01^{b}	0.02 ± 0.00^{c}
Unsaturated					
16:1	6.24 ± 0.07^{a}	1.44 ± 0.10^{b}	1.34 ± 0.06^{b}	1.34 ± 0.10^{b}	1.59 ± 0.13^{b}
17:1	0.84 ± 0.07^{a}	0.26 ± 0.04^{b}	0.20 ± 0.03^{b}	0.20 ± 0.04^{b}	0.26 ± 0.06^{b}
n-9					
18:1n-9	23.91 ± 0.15^{d}	23.29 ± 0.20^{e}	29.69 ± 0.10^{b}	26.04 ± 0.21^{c}	62.69 ± 0.20^{a}
20:1n-9	0.93 ± 0.12^{a}	0.31 ± 0.04b^{c}	0.24 ± 0.03^{c}	0.36 ± 0.07^{bc}	0.46 ± 0.06^{b}
24:1n-9	0.53 ± 0.06^{a}	0.21 ± 0.04^{b}	0.18 ± 0.04^{b}	0.17 ± 0.03^{b}	0.16 ± 0.04^{b}
n-6					
18:2n-6	4.29 ± 0.27^{d}	40.66 ± 0.51^{b}	44.58 ± 0.56^{a}	45.70 ± 0.71^{a}	9.50 ± 0.42^{c}
20:2n-6	0.24 ± 0.07^{a}	0.14 ± 0.03^{ab}	0.15 ± 0.04^{ab}	0.14 ± 0.01^{ab}	0.12 ± 0.00^{b}
18:3n-6	0.82 ± 0.06^{a}	0.45 ± 0.06^{b}	0.37 ± 0.03^{b}	0.49 ± 0.07^{b}	0.50 ± 0.06^{b}
20:4n-6	1.23 ± 0.11^{a}	0.22 ± 0.07^{b}	0.19 ± 0.03^{b}	0.20 ± 0.04^{b}	0.17 ± 0.01^{b}
20:3n-6	0.28 ± 0.04^{bc}	0.39 ± 0.06^{b}	0.54 ± 0.10^{a}	0.21 ± 0.04^{c}	0.18 ± 0.01^{c}
n-3					
18:3n-3	1.08 ± 0.14^{b}	5.55 ± 0.21^{a}	0.55 ± 0.14^{c}	0.91 ± 0.14^{bc}	0.75 ± 0.07^{bc}
20:5n-3	7.57 ± 0.24^{a}	1.11 ± 0.08^{b}	0.88 ± 0.13^{b}	0.85 ± 0.07^{b}	0.76 ± 0.08^{b}
22:6n-3	11.91 ± 0.44^{a}	1.95 ± 0.28^{b}	1.61 ± 0.30^{b}	1.60 ± 0.14^{b}	1.43 ± 0.18^{b}
Total n-3	20.56 ± 0.79^{a}	8.61 ± 0.58^{b}	3.04 ± 0.14^{c}	3.36 ± 0.14^{c}	2.94 ± 0.06^{c}
Total n-6	6.62 ± 0.31^{d}	41.72 ± 1.02^{b}	45.68 ± 1.41^{a}	46.60 ± 0.85^{a}	10.35 ± 0.28^{c}
Total n-9	25.37 ± 0.52^{d}	23.81 ± 0.43^{e}	30.11 ± 0.15^{b}	26.57 ± 0.57^{c}	63.31 ± 0.44^{a}
DHA/EPA	1.57 ± 0.14^{b}	1.76 ± 0.08^{ab}	1.83 ± 0.11^{ab}	1.88 ± 0.11^{a}	1.88 ± 0.08^{a}

[1]Values are means ± SD, n = 10. Values in each row with different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 5. Whole fish body fatty acid composition on the initial and 45th days of the feeding trial (% by weight of total fatty acids)[1].

Fatty acids	Initial	Control Group (*Fish oil*)	Experimental Group I (*Soybean oil*)	Experimental Group II (*Sunflower oil*)	Experimental Group III (*Corn oil*)	Experimental Group IV (*Olive oil*)
Saturated						
14:0	4.41 ± 0.30^{b}	6.72 ± 0.31^{b}	2.68 ± 0.25^{d}	3.23 ± 0.32^{cd}	3.62 ± 0.31^{c}	3.36 ± 0.23^{cd}
16:0	17.61 ± 0.86^{e}	28.80 ± 1.13^{a}	18.74 ± 0.48^{de}	22.38 ± 0.54^{c}	25.48 ± 0.42^{b}	20.13 ± 0.18^{d}
18:0	3.46 ± 0.37^{d}	5.51 ± 0.28^{bc}	5.10 ± 0.14^{c}	6.35 ± 0.42^{a}	5.96 ± 0.37^{b}	4.19 ± 0.14^{d}
21:0	1.71 ± 0.15^{a}	0.06 ± 0.01^{b}	0.06 ± 0.00^{b}	0.03 ± 0.01^{b}	0.05 ± 0.01^{b}	0.04 ± 0.00^{b}
23:0	0.56 ± 0.08^{a}	0.07 ± 0.01^{bc}	0.17 ± 0.04^{b}	0.05 ± 0.01^{c}	Trace	0.07 ± 0.00^{bc}
Unsaturated						
16:1	5.15 ± 0.21^{b}	8.17 ± 0.38^{a}	3.20 ± 0.31^{d}	3.66 ± 0.23^{cd}	3.89 ± 0.27^{cd}	4.08 ± 0.11^{c}
17:1	0.88 ± 0.11^{a}	0.96 ± 0.11^{a}	0.16 ± 0.04^{c}	0.57 ± 0.14^{b}	1.06 ± 0.08^{a}	0.23 ± 0.06^{c}
n-9						
18:1n-9	15.10 ± 0.21^{f}	29.20 ± 0.28^{d}	25.18 ± 0.47^{e}	33.35 ± 0.49^{c}	34.40 ± 0.56^{b}	46.04 ± 0.25^{a}
20:1n-9	3.26 ± 0.24^{a}	2.51 ± 0.15^{b}	1.79 ± 0.20^{c}	2.01 ± 0.15^{c}	2.53 ± 0.18^{b}	2.66 ± 0.08^{b}
22:1n-9	Trace	0.32 ± 0.08^{a}	0.05 ± 0.00^{c}	0.19 ± 0.04^{b}	0.25 ± 0.06^{ab}	0.06 ± 0.01^{c}
24:1n-9	0.56 ± 0.14^{a}	0.63 ± 0.11^{a}	0.40 ± 0.07^{a}	0.45 ± 0.11^{a}	0.49 ± 0.10^{a}	0.51 ± 0.08^{a}
n-6						
18:2n-6	5.17 ± 0.24^{e}	2.31 ± 0.28^{f}	23.24 ± 0.34^{a}	15.09 ± 0.39^{b}	10.03 ± 0.04^{c}	6.28 ± 0.40^{d}
20:2n-6	0.39 ± 0.09^{bc}	0.15 ± 0.03^{d}	0.81 ± 0.11^{a}	0.50 ± 0.08^{b}	0.38 ± 0.10^{bc}	0.26 ± 0.03^{cd}
18:3n-6	0.27 ± 0.10^{b}	0.07 ± 0.00^{c}	0.41 ± 0.08^{a}	0.16 ± 0.04^{bc}	0.12 ± 0.00^{c}	0.09 ± 0.03^{c}
20:3n-6	0.15 ± 0.04^{b}	0.14 ± 0.03^{b}	0.25 ± 0.06^{ab}	0.29 ± 0.07^{a}	0.14 ± 0.04^{b}	0.15 ± 0.01^{b}
20:4n-6	3.31 ± 0.14^{a}	1.96 ± 0.23^{b}	1.44 ± 0.11^{c}	1.36 ± 0.20^{c}	1.49 ± 0.13^{c}	1.95 ± 0.21^{b}
n-3						
18:3n-3	1.17 ± 0.10^{b}	1.02 ± 0.03^{b}	2.41 ± 0.15^{a}	0.15 ± 0.03^{c}	0.07 ± 0.00^{c}	0.27 ± 0.10^{c}
20:5n-3	9.16 ± 0.28^{a}	7.64 ± 0.34^{b}	3.92 ± 0.17^{c}	2.08 ± 0.11^{e}	2.74 ± 0.20^{d}	2.94 ± 0.20^{d}
22:6n-3	16.53 ± 0.75^{a}	14.21 ± 0.30^{b}	5.73 ± 0.54^{c}	4.14 ± 0.20^{d}	3.85 ± 0.28^{d}	4.12 ± 0.17^{d}
Total n-3	26.86 ± 0.66^{a}	22.87 ± 0.80^{b}	12.06 ± 0.08^{c}	6.37 ± 0.52^{de}	6.66 ± 0.37^{d}	7.73 ± 0.47^{d}
Total n-6	8.90 ± 0.56^{d}	4.48 ± 0.39^{e}	25.34 ± 0.39^{a}	16.90 ± 0.56^{b}	11.88 ± 0.42^{c}	8.47 ± 0.20^{d}
Total n-9	18.92 ± 1.05^{e}	32.66 ± 1.22^{c}	27.42 ± 0.59^{d}	36.00 ± 1.27^{b}	37.67 ± 0.95^{b}	49.27 ± 1.80^{a}

[1]Values are means ± SD, n = 10. Values in each row with different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

Table 6. Whole fish body fatty acid composition at the initial and final days of the feeding trial (% by weight of total fatty acids)[1].

Fatty acids	Initial	Control Group (*Fish oil*)	Experimental Group I (*Soybean oil*)	Experimental Group II (*Sunflower oil*)	Experimental Group III (*Corn oil*)	Experimental Group IV (*Olive oil*)
Saturated						
14:0	4.41 ± 0.42^{b}	6.44 ± 0.57^{a}	2.58 ± 0.14^{cd}	2.74 ± 0.34^{cd}	2.85 ± 0.21^{c}	1.89 ± 0.13^{e}
16:0	17.61 ± 0.70^{e}	27.56 ± 0.79^{a}	23.47 ± 0.66^{c}	20.55 ± 0.57^{d}	25.45 ± 0.35^{b}	17.60 ± 0.56^{e}
18:0	3.46 ± 0.42^{c}	5.27 ± 0.38^{b}	7.09 ± 0.27^{a}	6.13 ± 0.35^{ab}	6.59 ± 0.57^{a}	3.93 ± 0.47^{c}
21:0	1.71 ± 0.44^{a}	0.11 ± 0.00^{b}	0.05 ± 0.01^{b}	0.09 ± 0.03^{b}	0.07 ± 0.01^{b}	0.07 ± 0.00^{b}
23:0	0.56 ± 0.15^{a}	0.08 ± 0.03^{b}	0.05 ± 0.00^{b}	0.05 ± 0.01^{b}	0.03 ± 0.00^{b}	0.06 ± 0.01^{b}
Unsaturated						
16:1	5.15 ± 0.28^{b}	8.03 ± 0.28^{a}	2.82 ± 0.17^{c}	2.91 ± 0.16^{c}	3.01 ± 0.18^{c}	2.59 ± 0.20^{c}
17:1	0.88 ± 0.25^{b}	0.19 ± 0.04^{c}	0.73 ± 0.18^{b}	0.87 ± 0.10^{b}	1.37 ± 0.21^{a}	0.08 ± 0.00^{c}
n-9						
18:1n-9	15.10 ± 0.28^{d}	31.19 ± 0.34^{c}	30.82 ± 0.85^{c}	37.75 ± 1.06^{b}	37.26 ± 0.51^{b}	57.04 ± 0.48^{a}
20:1n-9	3.26 ± 0.38^{a}	0.18 ± 0.04^{c}	1.45 ± 0.21^{b}	1.68 ± 0.25^{b}	1.74 ± 0.20^{b}	1.78 ± 0.23^{b}
22:1n-9	Trace	0.06 ± 0.00^{bc}	0.09 ± 0.03^{b}	0.19 ± 0.03^{a}	0.04 ± 0.01^{cd}	0.02 ± 0.00^{cd}
24:1n-9	0.56 ± 0.20^{a}	0.57 ± 0.13^{a}	0.39 ± 0.07^{a}	0.39 ± 0.13^{a}	0.41 ± 0.08^{a}	0.28 ± 0.11^{a}
n-6						
18:2n-6	5.17 ± 0.24^{c}	2.84 ± 0.20^{d}	16.93 ± 1.13^{a}	15.59 ± 0.70^{a}	9.59 ± 0.57^{b}	6.54 ± 0.42^{c}
20:2n-6	0.39 ± 0.13^{bc}	0.16 ± 0.01^{d}	0.61 ± 0.08^{a}	0.43 ± 0.07^{ab}	0.31 ± 0.06^{bcd}	0.23 ± 0.06^{cd}
18:3n-6	0.27 ± 0.10^{a}	0.08 ± 0.00^{b}	0.19 ± 0.04^{ab}	0.14 ± 0.03^{ab}	0.11 ± 0.04^{b}	0.16 ± 0.04^{ab}
20:4n-6	3.31 ± 0.28^{a}	1.02 ± 0.13^{b}	0.72 ± 0.11^{bc}	0.80 ± 0.11^{bc}	0.70 ± 0.10^{bc}	0.59 ± 0.07^{c}
n-3						
18:3n-3	1.17 ± 0.14^{a}	0.28 ± 0.08^{cd}	0.82 ± 0.19^{b}	0.07 ± 0.00^{cd}	0.04 ± 0.00^{d}	0.32 ± 0.08^{c}
20:3n-3	Trace	0.17 ± 0.04^{b}	0.28 ± 0.07^{ab}	0.36 ± 0.08^{a}	0.17 ± 0.03^{b}	0.15 ± 0.03^{b}
20:5n-3	9.16 ± 0.23^{a}	8.15 ± 0.35^{b}	4.07 ± 0.35^{c}	3.03 ± 0.18^{d}	2.78 ± 0.39^{d}	2.51 ± 0.15^{d}
22:6n-3	16.53 ± 0.75^{a}	15.11 ± 0.37^{b}	6.13 ± 0.45^{c}	4.72 ± 0.71^{d}	3.84 ± 0.20^{d}	5.12 ± 0.15^{d}
Total n-3	26.86 ± 1.22^{a}	23.71 ± 1.00^{b}	11.30 ± 0.56^{c}	8.18 ± 0.39^{d}	6.83 ± 1.17^{d}	8.10 ± 0.42^{d}
Total n-6	8.90 ± 0.99^{bc}	3.94 ± 0.34^{d}	17.84 ± 1.19^{a}	16.53 ± 0.75^{a}	10.40 ± 0.57^{b}	7.29 ± 0.41^{c}
Total n-9	18.92 ± 1.13^{d}	32.63 ± 1.14^{c}	32.75 ± 1.06^{c}	40.01 ± 1.41^{b}	39.45 ± 0.64^{b}	59.12 ± 0.42^{a}

[1]Values are means ± SD, n = 10. Values in each row with different superscript differ at $P < 0.05$. Means were tested by ANOVA and ranked by Duncan's multiple range test.

As shown in Table 4, the best total linolenic acid (n-3) levels in experimental feeds were found (20.56 ± 0.79%) in the control group (fish oil), the other groups following with 8.61 ± 0.58% in soybean oil, 3.04 ± 0.14% in sunflower oil, 3.36 ± 0.14% in corn oil and 2.94 ± 0.06% in olive oil ($P < 0.05$). EPA (20:5n-3, 7.57 ± 0.24%) and DHA (22:6n-3, 11.91 ± 0.44%) were the highest n-3 fatty acid values in feeds including fish oil. The 18:3n-3 (5.55 ± 0.21%) fatty acid level was the highest of the n-3 fatty acids in the diet including soybean oil. 18:2n-6 fatty acid had the highest value of the total n-6 fatty acids in the diets including soybean oil, sunflower oil and corn oil. Finally, 18:1n-9 (63.31 ± 0.44%) was the highest value for n-9 in the diet including olive oil ($P < 0.05$).

As shown in Tables 5 and 6, total linolenic acid (n-3) values in the fish meat were higher on the initial day than on the 45th day and at the end of the trial ($P < 0.05$). Total n-3 fatty acid values in fish meat were highest in the control group. The groups fed the feeds including fish oil and the other feeds including vegetable oil (sunflower oil, corn oil and olive oil) in descending order followed ($P < 0.05$). Similarly, total linoleic acid (n-6) levels were best in the experimental groups fed the feeds including soybean oil, sunflower oil and corn oil, and total oleic acid (n-9) levels were best in the group fed the feed including olive oil ($P < 0.05$).

Discussion

Lipids are used as an energy source in feeds, especially in the larval phase of the fish, and affect growth performance, survival and whole body composition (4,6,10,13). In this study, the effect of the different vegetable oils added to starter feeds on the growth performance and fatty acid composition of sea bass (*Dicentrarchus labrax* L.) juveniles was studied. As it represents the main expense (40%-70%) in aquaculture, and feeds used in fish farms are very important in terms of profits.

At the end of the feeding trials the highest live weight gain, specific growth rate (SGR) and feed conversion ratio (FCR) were found in the group fed fish oil added feed. This is in agreement with previous results for this species ($P < 0.05$) (Table 2). According to the specific growth rate (SGR) and feed conversion ratio (FCR), feed including fish oil was more effective than the feeds including vegetable oils ($P < 0.05$) (1,6,13,19,21).

However, in some recent research it has been reported that the growth performance of the sea bass was not affected by fish oil obtained from different fish species or extracted from different kinds of vegetable oil (28,29).

According to the proximate analyses of the fish samples, the crude protein values of the fish were similar in all experimental groups because the crude protein level in the feeds was similar and high (57.42%) (19,21).

n-3 HUFA in fish oil is utilized more easily than the linoleic acid (n-6) and oleic acid (n-9) in vegetable oil. Therefore, the total fat content of the whole body of the fish was low (4.55%), but was high (2.64%) in the muscle ($P < 0.05$) (Table 3) (30).

According to the results of fatty acids in the diets, fish oil and soybean oil were sufficient to meet the n-3 requirement of sea bass juveniles, but the other diets including vegetable oils were insufficient. n-6 and n-9 fatty acid values in the experimental diets were sufficient and higher in the diets including vegetable oils than in the diets including fish oil. EPA and DHA in the diets included vegetable oils because of the fish meal in the diets (10,11,28,29).

As the results of fatty acid analysis of experimental feeds show, EPA (20:5n-3) and DHA (22:6n-3) levels in the fish oil added feed were 7.57% and 11.91%, respectively. These are the highest values for all the experimental feeds. Linolenic acid levels (18:3n-3) in the soybean oil added feed were 5.5%, and oleic acid (18:1n-9) levels in the olive oil added feed were 62.69%. These values were higher than those of the experimental feeds. The linoleic acid (18:2n-6) level was 40.66% in the soybean oil added feed, 44.58% in the sunflower oil added feed and 45.47% in the olive oil added feed. Arachidonic acid levels were 1.23% in the fish oil added feed and 0.17-0.22% in the vegetable oil added feeds. Vegetable oils do not contain arachidonic acid (20:4n-6), but the arachidonic acid values in the experimental feeds including vegetable oils were reflected in fish meal. The DHA/EPA ratio of the experimental feeds lay between 1.57 and 1.88 (Table 4). Although the fish oil used in the feed met the requirement of sea bass juveniles for fatty acid, some vegetables oils were also sufficient for n-6 and n-9 fatty acids; however, other vegetable oils, except for soybean oil were not sufficient for n-3 fatty acids (9,10,28,31,32).

In general, fatty acids in the diets are reflected in fish meat (Tables 4, 5 and 6). n-3 fatty acids values in the diets, except for the control group including fish oil, were insufficient. In a comparison of the 45th day and the end of the feeding trials, n-3 fatty acid values increased to the end of the feeding trials, but n-6 fatty acids values decreased, except for fish fed diets including corn oil. This is a result of the carbon chain elongation capacity of fish. In addition, n-9 fatty acid values also increased to the end of the feeding trials and this is a result of high n-9 fatty acid values in the diets (1,3,5,6).

According to all the results of whole fish body fatty acids composition, EPA and DHA values were higher in the fish group fed fish oil added feed than in the other groups. However, linolenic acid (18:3n-3) levels were best in fish fed soybean oil added feed, and oleic acid (18:1n-9) levels were best in the fish group fed olive oil added feed. Linoleic acid (n-6) was found in higher levels in the fish group fed soybean oil and sunflower oil added feeds than in the other groups. Arachidonic acid (20:4n-6) levels were highest in the fish group fed fish oil added feed (1.02%), and the lowest value was found in fish groups fed vegetable oil added feeds (0.59-0.80%) (Tables 5 and 6) (1,3,4,6,11,28,33). Differences between the fatty acid composition of fish at the beginning of the feeding trials, at the 45th day and at the end of the feeding trial were significant ($P < 0.05$), but were not different at the 45th day and the end of the feeding trials.

In conclusion, the live weight gain, specific growth rate and feed conversion ratio of sea bass (*Dicentrarchus labrax* L., 1758) juveniles were different in fish groups fed soybean oil, sunflower oil, corn oil and olive oil added feeds instead of fish oil ($P < 0.05$). However, in the whole fatty acid profile of the fish, n-6 levels were highest in the soybean, sunflower and corn oil groups, n-9 levels in the olive oil group and n-3 levels in the fish oil group. Similarly, differences between the fat contents of the carcass and muscle of the fish were found ($P < 0.05$).

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