www.trjfas.org
ISSN 1303-2712
Turkish Journal of Fisheries and Aquatic Sciences 13: 819-825 (2013) DOI: 10.4194/1303-2712-v13_3_05

Partial Replacement of Fish Oil with Vegetable Oils in Diets for European Seabass (*Dicentrarchus labrax*): Effects On Growth Performance and Fatty Acids Profile

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Received 12 June 2013
Accepted 17 December 2013

Abstract

The study was conducted to determine the effects of alternative oil sources on growth, body composition and feed conversion of sea bass individuals. The tested oils used in the study were as follows: sesame oil (SO), canola oil (CO) and soybean oil (SBO). All tested oils were included at a 50% substitution level of fish oil and were compared with a control diet containing 100% fish oil (FO). There was no effect of diet on specific growth rate. The highest final weight was seen in fish fed SO and FO diets compared to that of fish fed CO diet and SBO diets ($P<0.05$). At the end of the experiment, no statistically significant difference was detected determined in whole body fatty acid composition in terms of saturated fatty acids (SFA) and polyunsaturated fatty acids (PUFA) contents ($P>0.05$). In the n-6 fatty acids, fish fed SBO diet contained significant amount of linoleic acids (LA, 18:2n-6) compared to that of fish other dietary treatments diets . Deposition of eicosapentaenoic acid (EPA, 20:5n-3) and docosahexaenoic acid (DHA, 22:6n-3) was identical among the dietary treatments. In conclusion, the result of the trial show that sesame oil could be used as an alternative to fish oil in European sea bass diet formulation while when fish meal content of the diet is kept relatively high as it was the case our present in this study (585 mg/g)

Keywords: Sea Bass, alternative vegetable oil sources, soybean oil, sesame oil, canola oil.

Balık Yağ Yerine Kısmı Bitkisel Yağların Avrupa Deniz Levreği (*Dicentrarchus Labrax*) 'nin Beslenmesine Büyüme Performansı ve Yağ Asitleri Profili Üzerine Etkileri

Özet

Bu çalışma alternatif yağ kaynaklarının; levrek bireylerinde büyüme, vücut kompozisyonu ve yem değerlendirmesi üzerine etkilerini belirlemek üzere yapılmıştır. Denemede kullanılan yağlar susam yağı, kanola yağı ve soya yağı. Denemede kullanılan tüm yağlar, %50'sini balık yağının oluşturduğu diyetlere %50 oranında dahil edilmiştir ve %100 balık yağından oluşan bir diyetle karşılaştırılmıştır. Diyetlerin Spesifik Büyüme oranı üzerinde hiçbir etkisi olmamıştır. Kanola yağı ve soya yağı ile beslenen balıklarla karşılaştırılınca, en yüksek final ağırlığı susam yağı ve balık yağı diyetleriyle beslenen balıklarda görülmüştür ($P<0,05$). Denemenin sonunda, tüm vücut yağ asit kompozisyonlarına bakıldığında doymuş yağ asitleri ve çoklu doymamış yağ asitleri bakımından istatistiksel açıdan bir fark bulunmamıştır ($P>0,05$). n-6 yağ asitlerinde, diğer diyetlere oranla soya yağı diyetinin önemli miktarda linoleik asit (LA, 18:2n-6) içerdiği gözlenmiştir.Diyet grupları arasında Eicosapentaenoic acid (EPA, 20:5n-3) ve docosahexaenoic acid (DHA, 22:6n-3)'nın depolandığı belirlenmiştir. Sonuç olarak, Avrupa deniz levreği diyetlerinde balık yağına alternatif, 585 mg/g balık unu içeren susam yağı kullanılabilir.

Anahtar Kelimeler: Deniz levreği, alternatif bitkisel yağ kaynakları, soya yağı, susam yağı, kanola yağı.

Introduction

Aquaculture is one of the fastest growing sectors of food industry in the world. It is reported that there has been about 10% growth achieved in aquaculture during the past 10 years to meet the food demand of the ever increasing world population. According to FAO data of 2006, the total aquaculture production reached 140 million tons, 95 million tons of which came from fishing and 45 million tons from farming (FAO, 2007).

Parallel to the rest of the world, fishery production has demonstrated a rapid growth in Turkey totaling 623,191 tons of production value made in 2009 alone in Turkey, 158,000 tons (25.7%) of which came from farming of fresh, saltwater and brackish water aquatic species. Farmed European sea bass (*Dicentrachus labrax*) production values in Turkey

have steadily increased over the last decade reaching 38000 tons in 2008 ranking Turkey first in European production scale (TUIK, 2010). The oil source used in the feed of the cultured aquatic species and especially the fish species increases the growth performance, food and protein conversion rates (Bell *et al.*, 2000; Montero *et al.*, 2005). In the grow-out phase of sea fishes, the oil content and its use are quite important for the growth of fishes. As it is widely known, protein and oils are the most important energy sources in feed of carnivorous salt water fish species. These two important energy sources should be well balanced in all commercial aqua feeds. The recent studies have focused on balancing oil and protein contents in feeds of carnivore species, thus adjusting energy rates of feeds (Marti Palanca *et al.*, 1996; Vergara *et al.*, 1996; Santinha *et al.*, 1996, 1999; Company *et al.*, 1999; Fountoulaki *et al.*, 2005). The most important oil and energy source used in fish feeds is fish oil. Fish oil should be used in feed formula to preserve and balance energy balance of feeds.

There has been an increasing demand for aquaculture products by consumers throughout the world due to different reasons like healthy diet, which has, in turn, increased the production of these products. The rapid increase of aquaculture products in general and fish farming in particular results in increasing demand for fish meal and oil, which are the main contents of feeds used in aquaculture. It is quite important to find cheaper alternative oil sources to fish oil to meet the fatty acid requirements of fishes in aqua feeds for a sustainable and economically sound aqua feed industry thereby reducing ingredient cost and contributing to national economy (Dernekbaşı *et al.*, 2010).

Thus, the aim of the study was to investigate the effects of some vegetable oils (sesame oil, canola oil and soybean oil) included at a 50% substitution levels of fish oil in practical diet formulations for European sea bass.

Materials and Methods

Experimental Diets

Four diets containing equal amount of crude protein, energy and lipid concentration on a dry weight basis were formulated. Anchovy oil was the only added lipid source in fish oil diet (FO). All the other diets contained vegetable oils to substitute half of the fish oil used in the control diet by sesame (SO), canola (CO) and soybean oils (SBO) (Table 1).

Feeding Trial

European sea bass (*Dicentrarchus labrax*) juveniles used in this study were obtained from a commercial local farm (Akuvatur, Ltd., Adana, Turkey) and were transported to an indoor system where they were kept in fiberglass tanks for a period of four weeks prior starting of the experiment. 240 European sea bass individuals (45g initial body weight) were distributed randomly among 12 tanks of 500 L (20 fish/tank). These tanks were supplied with sea water (40 g/L) at a flow rate of approximately 2 L min^{-1}. Water parameters such as temperature, salinity, pH and dissolved oxygen were continuously monitored with YSI model salinometer (Yellow springs Instrument, Yellow springs, OH, USA), oxygenmeter and pH meter (pH 315i Set, WTW Measurement Systems, Germany). Individual fluorescent lighting was provided over each tank and was automatically controlled to provide12-h light/12-h dark ($07.^{00}$ to $19.^{00}$ h) photoperiod. Triplicate groups of fish were fed one of the four ~~s~~ dietary treatments by hand to apparent satiation three times daily ($09.^{00}$ h, $13.^{00}$ h and $18.^{00}$ h) for 90 days and the dietary treatments were assigned using a randomized block design.

All fish in each group were anaesthetized (2-phenoxyethanol at 0.5 ml/L) and then weighed individually, after removal of excess surface moisture, to the nearest 0.01 g at 10- day intervals during the study. On day 0, 15 fish from a common pool of fish were sampled randomly and stored at -20°C for subsequent chemical analyses. On day 90, 3 fish per tank were randomly culled from each replicate group (tank) for subsequent analyses. Whole body and fillet muscle samples were grounded and homogenized in a blender and the homogenate from each replicate tank was pooled (n=3/diet treatment) and stored at -20°C until analysis. A series of parameters were used to assess the effects of dietary treatments on the growth performance of the fish and were computed by the following equations:

Specific growth rate (SGR) (% body weight/day) = [(ln FW (g) − ln IW (g)) / time (days)] × 100

Feed conversion ratio (FCR) = total daily dry feed intake (g) / WG (g)

Protein efficiency ratio (PER) (g/g) = WG (g) / protein intake (g)

Survival (S) (%) = (number of fish in each group remaining on day 90 / initial number of fish) x 100.

Chemical Analyses

Determinations of moisture, ash, protein, and gross energy concentrations in the diets and fish samples were conducted as described below. Percent moisture samples were dried to constant weight at 103ºC. Ash content was determined by burning the samples at 450ºC for 5 h (AOAC, 1994). Crude protein concentration was determined by the Kjeldahl procedure using a Kjeltec 2200 (Foss Tecator, Högans, Sweden). Percent nitrogen was multiplied by 6.25 to obtain an estimate of percent crude protein in samples.

Lipids were extracted according to the procedure of Folch *et al.* (1957). Fatty acid methyl esters (FAME) were prepared according to Metcalfe and Schmitz (1961) and analyzed as described previously

Table 1. Ingredients, proximate composition (mg/g^{-1}) of experimental diets (3 mm) and growth parameters

	Experimental Diets			
	FO	SO	CO	SBO
Diet formulation (g kg^{-1})				
Fish meal [a]	585	585	585	585
Corn gluten [b]	143	143	143	143
Fish oil [c]	138	69	69	69
Sesame oil [d]	-	69	-	-
Canola oil [e]	-	-	69	-
Soybean oil [e]	-	-	-	69
Dextrin [b]	64	64	64	64
CMC [f]	50	50	50	50
Vitamin mix [c]	10	10	10	10
Mineral mix [c]	10	10	10	10
Proximate composition (mg g^{-1})				
Moisture	125.1	118.2	118.7	121.9
Protein	485.0	520.4	525.2	521.6
Lipid	238.1	232.3	229.5	221.1
Nitrogen free extract [f]	140.6	117.6	117.8	132.1
Ash	130.5	129.7	127.5	125.2
Gross energy (kJ g^{-1}) [g]	18.5	18.5	18.5	18.5
Growth parameters [h]				
Initial weight (g)	54.6 ± 0.48	54.7 ± 0.20	53.3 ± 0.68	53.9 ± 0.07
Final weight (g)	68.8 ± 1.91^{ab}	71.7 ± 0.35^{a}	66.5 ± 2.13^{b}	66.2 ± 3.29^{b}
SGR (% day^{-1}) [i]	0.26 ± 0.02	0.30 ± 0.01	0.25 ± 0.03	0.23 ± 0.06
PER [j]	0.29 ± 0.02^{ab}	0.34 ± 0.01^{a}	0.25 ± 0.04^{b}	0.24 ± 0.06^{b}
S [k]	100 ± 0.00	96.7 ± 2.89	100 ± 0.00	98.3 ± 2.89

Values in the same row with different superscripts are significantly different (P<0.05) as determined by ANOVA. Values are means ± S.E.M. (n=3)
[a] Supplied by Agromarine A.Ş., İzmir, Turkey.
[b] Supplied by Sunar Mısır A.Ş., Adana, Turkey.
[c] Supplied by Kılıç Deniz ürünleri üretim A.Ş.
[d] Supplied by Yeni Uğur A.Ş, Adana, Turkey.
[e] Supplied by Bizim yağ, Migros A.Ş., Adana, Turkey.
[f] Nitrogen free extract: 100-(protein+lipid+ash).
[g] Calculated based on the standard physiological fuel values: 19 kJ g^{-1} for protein, 36 kJ g^{-1} for lipid and 15 kJ g^{-1} for carbohydrate
[h] Values are mean ± SEM. (n = 3; number of thanks per treatment).
[I] Specific Growth Rate (SGR): [Ln(final weight) - Ln(initial weight)]/(number of days)/100.
[j] Protein efficiency ratio (PER) (g/g) = WG (g)/protein intake (g).
[k] Survival (S) (%) = (number of fish in each group remaining on day 60/initial number of fish)x100.

(Czesny and Dabrowski 1998) with some modifications. Briefly, the FAME obtained were separated by gas chromatography (Agilent 6890 N), equipped with a flame ionization detector and fitted with a DB 23 capillary column (60 m, 0.25 mm i.d. and 0.25 µm) ejector and detector temperature program was 190°C for 35 min than increasing at 30°C per min up to 220°C where it was maintained for 5 min. Carrier gas was hydrogen (2 ml min^{-1} and split ratio was 30:1). The individual fatty acids were identified by comparing their retention times to that of a standard mix of fatty acids (Supelco 37 component FAME mix). Prior to transmethylation, nonadecanoic acid (C19:0) was added to the samples (0.8 mg per 50 mg of lipid) as the reference standard for the quantification of fatty acids.

Statistical Analysis

Data are reported as mean ± S.E.M (n=3). Percentage values were arcsine square root transformed and after normality and homogeneity of variance were confirmed, one-way variance (ANOVA; sigmastat 3.0, SPSS, Chicago, U.S.A) were used to determine differences between means. Differences were considered statistically significant at P<0.05.

Results

Mortality was low and unaffected by dietary treatments at the end of 90 days (P>0.05).

Dietary treatment influenced growth performance of European sea bass in the present study (Table 1). On the final day of the experiment, the highest final weight was found in fish fed SO diet, while the lowest final weight was obtained in fish fed the SBO diet. The values of FO group and CO group were close to each other, while the highest final weight of individuals was observed in fish fed SO diet. The mean weight of SO group was found as 71.70 g at the end of 90 days, which was the highest weight (Table 1). In terms of specific growth rate, there was no statistically significant difference among groups (P>0.05). Specific growth rate changed between 0.23 and 0.30% body weight/day. Considering the feed conversion values obtained in the experiment, there was no significant difference among groups (P>0.05). The mean feed conversion

rate of groups was determined as 3.48±0.89., There was no significant difference in the daily feed intake values obtained in the dietary treatments throughout the study (P>0.05). The fish fed on FO diet consumed 15.44 g/day on average, while the mean feed consumptions of fish fed SO diet and CO diet were 16.44 g/day and 16.01 g/day, respectively. There was a statistically significant difference among groups in terms of protein efficiency ratio (PER) (P<0.05). Accordingly, the highest PER was observed in fish fed SO diet (0.34±0.01), while the lowest protein efficiency was determined in fish fed SBO diet (0.23±0.06) compared to fish fed all the other diets. Proximate composition of the experimental diets is reported in Table 2. There was a statistically significant difference among groups in terms of MUFA and HUFA (P<0.05). The level of MUFA was highest in experimental diets SBO diet. On the other hand, the level of PUFA was highest in experimental diets SO diet.

Proximate composition of whole body is reported in Table 3. The fish fed SBO diet and FO diet (181.7±0.13 mg/g and 176.6±0.41 mg/g, respectively) had the highest whole body protein content across the 90 day experimentation period. Lipid content of the whole body varied between 86.8 mg/g and 91.0 mg/g and was unaffected by dietary treatments. There were no significant differences observed between dietary treatments for dry matter and ash content in fish fed the experimental diets (P>0.05).

The fatty acid compositions of whole body total lipid of European sea bass, following 90 days of feeding the experimental diets are shown in Table 4. As it would be expected, the fatty acid composition of the diet was mirrored in whole body of fish. The level of LA was highest in fish fed SBO diet and lowest in fish fed FO diet (15.3%) and CO diet (18.3%). On the

Table 2. Percent fatty acid composition (g/100g fatty acids) of the experimental diets of European sea bass

	Experimental Diets			
	FO	SO	CO	SBO
14:0	3.5 ± 0.00^{a}	2.3 ± 0.01^{c}	2.6 ± 0.08^{b}	2.6±0.08^{b}
14:1	0.1 ± 0.00	0.1 ± 0.02	0.1 ± 0.01	0.1±0.01
15:0	0.3 ± 0.01	0.2 ± 0.06	0.3 ± 0.08	0.2±0.01
15:1	0.1 ± 0.01	0.1 ± 0.01	0.1 ± 0.04	0.1±0.02
16:0	13.7 ± 0.04^{a}	11.9 ± 0.35^{b}	13.8 ± 0.04^{a}	11.7±0.51^{b}
16:1n-7	5.0 ± 0.01	3.0 ± 0.39	3.3 ± 0.16	3.4±0.07
17:0	0.1 ± 0.00	0.1 ± 0.04	0.2 ± 0.01	0.1±0.03
16:2n-4	0.6 ± 0.00	0.6 ± 0.13	0.4 ± 0.02	0.4±0.03
16:3n-4	0.7 ± 0.00	0.5 ± 0.16	0.6 ± 0.00	0.6±0.02
17:1	0.6 ± 0.00	0.5 ± 0.09	0.4 ± 0.01	0.4±0.02
18:0	3.3 ± 0.06	4.2 ± 0.16	4.1 ± 0.36	3.4±0.23
18:1n-9	25.6 ± 0.0^{c}	31.4 ± 1.38^{b}	23.7 ± 0.43^{c}	38.1±0.26^{a}
18:2n-6	17.4 ± 0.03^{c}	25.4 ± 0.79^{b}	28.2 ± 1.52^{a}	16.6±0.66^{c}
18:3n-6	0.1 ± 0.00	0.1 ± 0.06	0.00 ± 0.00	0.1±0.07
18:3n-3	2.9 ± 0.05^{c}	1.6 ± 0.19^{b}	3.6 ± 0.21^{a}	3.9±0.14^{a}
18:4n-3	0.3 ± 0.00	0.1 ± 0.08	0.1 ± 0.02	0.2±0.02
20:0	1.2 ± 0.02	0.7 ± 0.11	0.7 ± 0.02	0.7±0.00
20:1n-11	0.4 ± 0.00	0.4 ± 0.10	0.3 ± 0.24	0.4±0.08
20:1n-9	2.5 ± 0.00^{a}	1.8 ± 0.20^{b}	1.8 ± 0.10^{b}	2.6±0.14^{a}
20:2n-6	0.6 ± 0.01	0.4 ± 0.03	0.3 ± 0.05	0.3±0.06
20:3n-6	0.4 ± 0.00	0.2 ± 0.12	0.1 ± 0.00	0.1±0.09
20:4n-6	0.6 ± 0.04	0.5 ± 0.20	0.5 ± 0.49	0.5±0.18
20:3n-3	0.3 ± 0.00	0.1 ± 0.04	0.1 ± 0.05	0.1±0.02
20:4n-3	0.8 ± 0.00	0.5 ± 0.19	0.5 ± 0.11	0.4±0.01
20:5n-3	6.9 ± 0.01^{a}	5.1 ± 0.15^{b}	5.1 ± 0.17^{b}	4.8±0.19^{b}
22:0	2.1 ± 0.00	0.8 ± 0.23	0.8 ± 0.23	1.4±0.59
22:1n-11	0.2 ± 0.00	0.3 ± 0.31	0.1 ± 0.04	0.00±0.06
22:2n-6	0.1 ± 0.01	0.2 ± 0.01	0.2 ± 0.06	0.1±0.60
22:4n-6	0.3 ± 0.00	0.2 ± 0.15	0.1 ± 0.11	0.1±0.03
22:1n-9	0.3 ± 0.00	0.1 ± 0.04	0.1 ± 0.14	0.1±0.00
22:5n-3	1.8 ± 0.00	1.3 ± 0.52	1.3 ± 0.10	1.1±0.02
22:6n-3	7.3 ± 0.00^{a}	5.3 ± 0.88^{b}	6.2 ± 0.69^{ab}	5.3±0.58^{b}
ΣSFA	24.2 ± 0.01^{a}	20.3 ± 0.05^{c}	22.6 ± 0.54^{b}	20.1±0.26^{c}
ΣMUFA	35.9 ± 0.00^{c}	38.8 ± 1.42^{b}	30.9 ± 0.01^{d}	46.2±0.38^{a}
ΣPUFA	39.8 ± 0.00^{b}	40.9 ± 1.47^{b}	46.5 ± 0.55^{a}	33.7±0.11^{c}
Σn3	20.3 ± 0.00^{a}	14.0 ± 1.75^{c}	16.8 ± 0.37^{b}	15.9±0.71^{bc}
Σn6	19.5 ± 0.00^{c}	26.9 ± 0.28^{b}	29.7 ± 0.92^{a}	17.8±0.60^{d}
n3/n6	1.0 ± 0.00^{a}	0.5 ± 0.07^{c}	0.6 ± 0.03^{c}	0.9±0.007^{b}

[1] Values in the same row with different superscripts are significantly different (P< 0.05) as determined by ANOVA. Data for each parameter (n=3/diet treatment with each mean based on the analysis of 3 fish).

other hand, fish fed CO diet (1.9%) had significantly higher linolenic acid than the other treatments. The whole body percentages of oleic acid (18:1n-9) were highest in fish fed CO diet. Total monounsaturated fatty acid content significantly higher in fish fed CO diet ($P<0.05$). In addition, there was no difference among groups considering arachidonic acid (20:4n-6) content. Whole body EPA, DHA, PUFA, total n-3 and total saturated fatty acids content was not different between dietary treatments. The saturated fatty acid level in whole body ranged from 21.8% and 23.9% and there was no significant affect of the dietary treatment. No statistical differences were observed in polyunsaturated fatty acids in whole body different between treatments, with values ranging between 37.8±1.47% (CO) and 39.5% (SO).

Discussion

Most of the recent studies conducted on feeding of carnivore fish species have focused on the effects of vegetable oils as alternatives to fish oil, one of the basic raw nutrient material in aqua feeds, on growth performance and whole body and tissue fatty acid composition of fishes. It is known that oils used as energy sources in fish diets have effects on growth, survival rate and body composition (Yıldız and Şener, 2004; Almaida and Pagan, 2007). In this study, no significant difference was detected considering specific fish growth rates whereas final weight of the fish fed SO and FO diet was higher than that of the fish fed on other diets. A number of recent studies on the marine species have reported growth retardation when dietary oil was replaced with different plant oils (Izquierdo *et al.*, 2003; Yıldız and Şener, 2004; Figuerede-Silva *et al.*,2005; Izquierdo *et al.*, 2005; Eroldoğan *et al.*, 2012; Eroldoğan *et al.*, 2013). In a study with two marine species seabream (*Sparus aurata*) and sharpsnout seabream (*Diplodus puntazzo*), Hernandez *et al.* (2007) used linseed oil and soybean oil as alternative oil sources. These authors found that the best results growth parameters and least nutrient composition change in whole body and tissue were observed in fish fed FO diet. In the present study, FO treatment demonstrated a better growth performance than fish fed SBO diet. In contrast to the results of the present and other studies, the growth and feed utilization of the fish were unaffected by use of the vegetable oils in some previously conducted studies but significant changes in muscle fatty acid composition were reported in the European sea bass (Figuerede-Silva *et al.*, 2005). Hung *et al.* (2007) also examined the use of canola oil as a replacement in diets fed to red coral (*Pagrus major*). These authors found that the sources of lipid used did not affect the weight gain, feed intake, feed conversion and survival of the fish, but tissue fatty acid composition largely reflected that of the diets. Therefore, the results obtained in the present study were supported by previous studies showing that replacing high levels of fish oil affected growth and fatty acid composition of the fish. Importantly, the level of the fish meal and fish oil in the present study was 60 and 50% on a dry matter basis in diets, respectively. Thus, all experimental diets contained some n-3 LC-PUFA, which could help explain the lack of any major detrimental effect on fish growth. This is in accordance with data reported in previous studies conducted in the same species (Eroldoğan *et al.*, 2012; 2013).

In general, dietary fatty acid composition is mirrored by the fish's organs and lipid stores (Bell *et al.*, 2001; Izquierdo *et al.*, 2003; Yıldız and Şener, 2004; Eroldoğan *et al.*, 2012)

In the present study, the fish fed on SBO diet were found to have the highest value of whole body monounsaturated saturated fatty acids due to high concentration of oleic acid in soybean oil. However, SFA level was found to be similar in all dietary treatments. The highest SFA was determined in fish fed FO and CO diets. In all dietary treatments, LA content was found lowest in fish fed FO diet, while the highest were observed in fish fed SBO diet. Similar to our study, Skalli and Robin (2004) reported that sea bass fed on diets containing n-3 highly unsaturated fatty acids (n-3 HUFA level in the diet up to 1.9%) had higher LA levels in their body than the fish fed control diet containing 100% cod liver oil. Similar to our study and latter study, Bell *et al.* (2001) also reported that increasing LA content of Atlantic salmon (*Salmo salar*) correlated with canola oil inclusion in the diet. The concentration of LA and linolenic acid increased with canola oil in the diet whereas EPA and DHA levels relatively decreased with increasing canola oil the experimental diet formulated for red coral (Satoh *et al.*, 2007). Interestingly, in the present study, there was no statistically significant difference among groups considering EPA content of fish whole body. Generally, even though European sea bass uses 18-carbon fatty acids and turns it into EPA and DHA

Table 3. The proximate composition (mg/g) of whole body of sea bass fed the four experimental diets over a 90 days period

	Experimental Diets			
	FO	SO	CO	SBO
Whole-body				
Protein	176.6 ± 0.41^{ab}	175.0 ± 0.24^{b}	173.1 ± 0.36^{b}	181.7 ± 0.13^{a}
Lipid	91.0 ± 1.15	83.3 ± 0.28	86.8 ± 0.17	87.6 ± 0.19
Dry Matter	312.1 ± 1.0	291.1 ± 1.94	290.1 ± 3.06	302.2 ± 0.58
Ash	67.3 ± 0.93	64.0 ± 1.55	60.2 ± 2.96	65.1 ± 0.43

Table 4. Percent fatty acid composition (g/100g fatty acids) of the whole body of sea bass fed the experimental diets

	Experimental Diets			
	FO	SO	CO	SBO
14:0	3.0 ± 0.02[a]	2.7 ± 0.19[b]	2.7 ± 0.10[b]	2.7±0.11[b]
14:1	0.1± 0.02	0.1 ± 0.00	0.1 ± 0.04	0.1 ±0.01
15:0	0.3 ± 0.01	0.3 ± 0.05	0.3 ± 0.01	0.4 ±0.07
15:1	0.3 ± 0.14	0.3 ± 0.13	0.3 ± 0.07	0.3±0.14
16:0	13.9 ± 0.32	12.8 ± 0.80	13.2 ± 0.35	14.2±0.85
16:1n-7	4.7 ± 0.23[a]	4.1 ± 0.31[b]	4.1 ± 0.26[b]	4.2±0.03[b]
17:0	0.2 ± 0.04	0.2 ± 0.10	0.2 ± 0.01	0.2± 0.04
16:2n-4	0.3 ±0.03	0.3 ± 0.03	0.3 ± 0.05	0.3 ±0.02
16:3n-4	0.4 ±0.03	0.4 ± 0.04	0.4 ± 0.03	0.4±0.04
17:1	0.2 ±0.13	0.2 ± 0.07	0.3 ± 0.02	0.3±0.21
18:0	3.3 ±0.10	3.5 ± 0.35	3.2 ± 0.04	3.5±0.17
18:1n-9	28.8 ±2.06[ab]	27.5 ± 1.01[b]	30.7 ± 0.69[a]	27.2±0.34[b]
18:2n-6	15.3 ± 0.36[c]	16.80 ± 0.30[b]	15.0 ± 0.32[c]	18.3±1.06[a]
18:3n-6	0.1 ± 0.02	0.1 ± 0.07	0.1 ± 0.08	0.00±0.04
18:3n-3	2.5 ± 0.10[a]	1.9 ± 0.32[b]	2.6 ± 0.17[a]	2.5±0.20[a]
18:4n-3	0.2 ± 0.02	0.3 ± 0.14	0.3 ± 0.33	0.2±0.17
20:0	0.6 ± 0.02	0.7 ± 0.11	0.4 ± 0.31	0.6±0.01
20:1n-11	0.2 ± 0.01	0.3 ± 0.07	0.2 ± 0.08	0.1±0.14
20:1n-9	4.2 ± 0.06	3.6 ± 0.34	3.8 ± 0.41	3.7±0.29
20:2n-6	0.7 ± 0.04	0.9 ± 0.14	0.7 ± 0.06	0.7±0.22
20:3n-6	0.2 ± 0.05	0.2 ± 0.06	0.1 ±0.08	0.1±0.09
20:4n-6	0.8 ± 0.17	1.1 ± 0.42	0.7 ± 0.08	0.8±0.31
20:3n-3	0.2 ± 0.05	0.2 ± 0.14	0.1 ± 0.08	0.3±0.34
20:4n-3	0.7 ± 0.11	0.6 ± 0.13	0.5 ± 0.07	0.6±0.09
20:5n-3	4.7 ± 0.19	4.4 ± 0.22	4.2 ± 0.32	4.2±0.24
22:0	2.4 ± 0.31	2.5 ± 0.65	1.8 ± 0.56	2.3±0.41
22:1n-11	0.0 ± 0.04	0.2 ± 0.29	0.1 ± 0.11	0.1±0.06
22:2n-6	0.1 ± 0.10	0.3 ± 0.19	0.1 ± 0.05	0.2±0.01
22:4n-6	0.1 ± 0.12	0.3 ± 0.30	0.2 ± 0.09	0.1±0.06
22:1n-9	0.2 ± 0.03	0.7 ± 1.04	0.2 ± 0.17	0.2±0.06
22:5n-3	2.2 ± 0.18[bc]	2.4 ± 0.04[ab]	2.5 ± 0.09[a]	2.0±0.24[c]
22:6n-3	10.1 ± 0.29	10.0 ± 0.38	10.6 ± 1.66	9.1±0.47
ΣSFA	22.6 ± 1.86	22.6 ± 0.04	21.8 ± 0.99	23.9±0.95
ΣMUFA	39.6 ± 2.10[ab]	37.9 ± 0.[15cb]	40.4 ±1.06[a]	37.0±0.62[c]
ΣPUFA	37.9 ± 0.24	39.5 ± 0.19	37.8 ± 1.47	39.1±1.38
Σn3	20.5 ± 0.35	19.8 ± 0.68	20.9 ± 1.75	18.8±1.02
Σn6	17.3 ± 0.34	19.7 ± 0.73	17.0 ± 0.32	20.3±1.18
n3/n6	1.2 ± 0.04	1.0 ± 0.07	1.2 ± 0.13	0.9±0.08

[1] Values in the same row with different superscripts are significantly different (P< 0.05) as determined by ANOVA. Data for each parameter (n=3/diet treatment with each mean based on the analysis of 3 fish).

limitedly, Eroldoğan *et al.* (2013) noted that deposition of the DHA were significantly high in the fish fed canola diet. The remarkable higher deposition rates of the some LC-PUFA compared to other fatty acids is also in accordance with previous result on European sea bass (Mourente and Bell, 2006; Eroldoğan *et al.*, 2012; Eroldoğan *et al.*, 2013). Reports on DHA deposition in marine species have been contradictory, showing both significant increase (Mourente and Bell, 2006; Eroldoğan *et al.*, 2012; Eroldoğan *et al.*, 2013) and decrease (*Sparus aurata*, Fountulaki *et al.*, 2009; *Diplodus puntazzo*, Piedecausa *et al.*, 2007). This is probably due to the fact that interaction between fatty acids from different oil sources is complex and tissues (liver and flesh) do not necessarily assimilate or catabolize fatty acids from different oil sources in the same way.

In conclusion, the present study has demonstrated that the effects of dietary vegetable oil inclusion on fatty acid profile, which generally reflected the profile of the diets used. In particular, sesame oil is an effective substitute for fish oil in European sea bass as long as the fish-meal based diet contains a relatively large amount of fish meal.

Acknowledgments

This study was supported the Resource Fund of the University of Cukurova, (Turkey) for their financial support (with SÜF 2009 YL11).

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