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Alternative Vegetable Oil Sources for White Seabream (*Diplodus sargus*) Juveniles: Effects on Growth and Body Chemical Composition

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Abstract

In this study, the effects of different vegetable oil sources on growth and body chemical composition of white seabream (*Diplodus sargus*) juveniles were investigated. Four isonitrogenous (36%) and isolipidic (16%) experimental diets were formulated containing fish oil (FO) soybean oil (SO), canola oil (CO) and hazelnut oil (HO). Each experimental diet was fed to triplicate groups of 30 fish (initial mean weight 6 gram) for eight weeks. At the end of the study, final body weight and specific growth rate were found significantly different among groups ($P<0.05$). HO and CO groups had better growth rate when compared with other groups. The best feed utilization was found in group CO for all the experimental groups. CO and HO groups had the best protein and lipid utilization. The oil resources had an effect on fish whole body composition and hepato somatic index (HSI) values. Whole body lipid content in SO and HO groups were higher than that of FO group. The whole body fatty acid composition of fish reflected the fatty acid profiles of the feed. The results of this study suggest that SO, CO and HO can be used in fishmeal-based white seabream feed without any adverse effects in terms of growth and feed utilization.

Keywords: White seabream, soybean oil, canola oil, hazelnut oil, growth.

Sargoz (Diplodus sargus) Jüvenilleri İçin Alternatif Bitkisel Yağ Kaynakları: Büyüme ve Vücut Kimyasal Kompozisyonları Üzerine Etkileri

Özet

Bu çalışmada, farklı bitkisel yağ kaynaklarının sargoz (*Diplodus sargus*) jüvenillerinin büyüme ve vücut kimyasal kompozisyonları üzerine etkileri araştırılmıştır. Balık yağı (BY), soya yağı (SY), kanola yağı (KY) ve fındık yağı (FY) içeren izonitrojenik (%36) ve izolipidik (%16) dört deneysel yem formülize edilmiştir. Otuz adet balığın (başlangıç ortalama ağırlığı 6 gram) üç tekerrürlü grupları her bir deney yemi ile sekiz hafta beslenmiştir. Çalışmanın sonunda, son vücut ağırlığı ve spesifik büyüme oranı gruplar arasında önemli ölçüde farklı bulunmuştur ($P<0,05$). FY ve KY grupları diğer gruplara kıyasla daha iyi bir büyüme oranına sahip olmuştur. Tüm deney grupları için en iyi yem kullanımı KY grubunda bulunmuştur. KY ve FY grupları en iyi protein ve lipit kullanımına sahip olmuştur. Yağ kaynakları, balık tüm vücut kompozisyonu ve hepato somatik indeks (HSI) üzerine etkili olmuştur. SY ve FY gruplarında tüm vücut lipit içeriği BY grubundan daha yüksek olmuştur. Tüm vücut yağ asit kompozisyonu yemlerin yağ asit kompozisyonunu yansıtmaktadır. Bu çalışmanın sonuçları, SY, KY ve FY'nın balık unu bazlı sargoz yemlerinde büyüme ve yem kullanımı açısından herhangi bir olumsuz etki yaratmadan kullanılabileceğini göstermektedir.

Anahtar Kelimeler: Sargoz, soya yağı, kanola yağı, fındık yağı, büyüme performansı.

Introduction

The first studies about white seabream (*Diplodus sargus*) were done in the early 1990s (Cesaj *et al*., 1993; Divanach *et al*., 1993; Abellan and Garcia-Alcazar, 1995). In 2000s, it gained prominence among the new species in Mediterranean aquaculture. In recent years, it has come to be a preferred species due to its potential, high meat quality and market price. Its adaptation to culture, production stages, and technology used for established cultured marine species is seen as an advantage (Sa *et al*., 2006, 2007; Cardenas, 2010; Monfort, 2010; Basurco *et al*., 2011; Castro*et al*., 2013).

Despite this, there is still a need for research on the nutritional requirements of this species. Research

conducted on the protein and lipid requirements of white seabream has shown that they require lower protein and lipid compared to other sparid species (Sa *et al*., 2008a, 2008b). Additionally, some research about the carbohydrate needs of this species has been carried out (Sa *et al*., 2007, 2008c; Dimitroglou *et al*., 2010). However, there has been no research about the effect on this species of using different oil resources in the feed. The interaction of the species with the different oil and protein resources during intensive culture is a crucial research subject.

Fish oil (FO) is a commonly used oil resource in traditional commercial fish culture. It is well known that a drop in world fish oil production often leads to an increase in the price of fish oil due to increased demand. This condition leads to the seeking of new oil resource alternatives for commercial fish feeds (Turchini *et al*., 2009). Vegetable oils are preferred instead of fish oil since they have increased production, are highly available, variable and affordable compared to fish oil. Soybean and canola, which are the most commonly used ones, have poor amounts of n-3 highly unsaturated fatty acid (HUFA), but soybean oil is rich source of polyunsaturated fatty acid (PUFA), mainly linoleic (LA; 18:2 n-6) and canola oil is rich about monounsaturated fatty acid (MUFA) mainly oleic acid (OA; 18:1n-9) (Fountoulaki *et al*., 2009). For this reason they are considered as alternate oil sources for fresh water and marine fish species (Caballero *et al*., 2002; Izquierdo *et al*., 2005; Montero *et al*., 2005; Piedecausa *et al*., 2007; Fountoulaki *et al*., 2009; Turchini *et al*., 2009; Arslan *et al*., 2012; Francis *et al*., 2014).

In general, marine fish have a limited ability synthesize long chain (LC) PUFAs such as eicosapentaenoic acid (EPA; 20:5n-3), docosahexaenoic acid (DHA; 22:6n-3) and archidonic acid (ARA; 20:4n-6) from 18C fatty acids (linoleic acid, LA, 18:2n-6; linolenic acid, LNA, 18:3n-3) (Sargent *et al*., 2002; Montero *et al*., 2005; Wassef *et al*., 2009). Because of this reason, some researchers have focused on partial replacement of fish oil with vegetable oils for marine species such as European sea bass, *Dicentrarchus labrax*, (Mourente and Dick, 2002; Montero *et al*., 2005; Eroldoğan *et al*., 2012), gilthead sea bream, *Sparus aurata*, (Menoyo *et al*., 2004; Wassef *et al*., 2009; Taşbozan *et al*., 2011), red sea bream, *Pagrus major*, (Huang *et al*., 2007) and meagre, *Argyrosomus regius*, (Taşbozan *et al*., 2014a). The results of these studies were acceptable in terms of growth performance, in addition to this, their experimental diets contained sufficient amount of fish meal from 381 g to 500 g per kg. On the other hand, some promising results also were yielded from the studies in which total replacement of fish oil with vegetable oil were carried out using fishmeal-based diets (fish meal content from 383 g to 600 g per kg)in different fish species (Mourente *et al*., 2005; Piedecausa *et al*., 2007; Turchini *et al*., 2011; Altundağ *et al*., 2014; Francis *et al*., 2014; Yılmaz and Eroldoğan, 2015).

Other than the more commonly used vegetable oils, research into the potential of hazelnut oil is importantow ing to its desirable fatty acid profiles and availability. World total hazelnut production is 914 thousand tons of which Turkey has a 72% share (AEPDI, 2012). Studies that will be conducted in the following years will allow usage of hazelnut products in different areas, especially in fish feed.

This research is the first investigation of the usage of vegetable oils in omnivorous white seabream and is expected to provide important contributions to the scientific and commercial aspects of this product. In addition, there were a few studies on the potential of hazelnut oil as a source of alternative vegetable oil to fish oil in fish feed (Taşbozan *et al*., 2011; Arslan *et al*., 2012; Taşbozan *et al*., 2014a). Hence, more knowledge is needed about the effect of dietary hazelnut oil in feeds of different fish species. Therefore, the objective of the present study was to determine the effect of total replacement dietary fish oil with soybean, canola and hazelnut oil on white sea bream juveniles in terms of growth performance, feed utilization and whole body chemical composition.

Materials and Methods

Animals, Experimental Design and Feeding Trial

White seabream (*Diplodus sargus*) juveniles were obtained from Mediterranean Fisheries Research Production and Training Institute, Antalya, Turkey. Triplicate groups of 30 fish (initial mean weight 6 gram) were used for each tank. Water volume of tanks was 400 liters, water was supplied from a well at a rate of 2 L/min and during the experimental period water quality parameters were meticulously observed and natural photoperiod was used. Water quality parameters were measured daily such as temperature and dissolved oxygen (OxyGuard Handy Polaris 2) and pH (Lutron pH-207 HA) and salinity (portable refractometer, Brix FG-108) were measured weekly. During the experimental period average temprature, oxygen, pH and salinity were 27.5°C, 6.2 mg/L, 7.8 and 36.03 ppt, respectively. The fish were hand-fed to visual satiety three times a day ($08:^{00}$, $12:^{30}$ and $17:^{00}$) during 8 weeks of experiment.

Experimental Feeds

Four isonitrogenous (36%) and isolipidic (16%) experimental diets were formulated containing fish oil (FO) soybean oil (SO), canola oil (CO) and hazelnut oil (HO) in Table 1. All the ingredients were finely-grind, well mixed and made into pellets (2 mm in dimension) with a laboratory pellet machine. Fish meal, fish oil and vit-min mixture were obtained from Sibal Fish Feed Company (Sinop, Turkey). Corn gluten and dextrin were obtained from Sunar Corn Company (Adana, Turkey). The other ingredients

Table 1. Formulation of the experimental diets

Ingredients (g/kg)	FO	SO	CO	HO
Fish meal	400	400	400	400
Corn gluten	80	80	80	80
Dextrin	335	335	335	335
Fish oil	100	0	0	0
Canola oil	0	100	0	0
Soybean oil	0	0	100	0
Hazelnut oil	0	0	0	100
CMC[a]	40	40	40	40
DCP[b]	25	25	25	25
Min-Mix	10	10	10	10
Vit-Mix	10	10	10	10
Proximate composition (% dry matter basis)				
Moisture	6.95	7.70	7.38	7.91
Protein	36.67	36.84	36.88	37.00
Ash	10.19	10.16	10.27	10.28
Lipid	16.18	16.22	16.39	16.55
Fiber	2.83	2.79	2.85	2.82
NFE[c]	34.13	33.99	33.61	33.35
Gross Energy (MJ/kg)[d]	18.55	18.55	18.54	18.53

Vit-Min Mix: Vit. Mix (in diet g/kg); tocopherol (E), 0.2; menadione $NaHSO_3$-$3H_2O$ (K3), 0.01; thiamine (B1), 0.015; riboflavin (B2),0.025; niacin (nicotinic acid), 0.2; Ca panthothenate, 0.024; pyridoxine-HCl (B6), 0.02; cyanocobalamine (B12), 0.00002; folic acid, 0.008;vitamin C, 0.21; inositol, 0.2; d-biotine, 0.0005; (in diet IU/kg) vit-A, 12.500; vitamin D3, 2.500. Min.
Mix (in diet g/kg); manganese, 0.02;zinc, 0.075; copper, 0.005; cobalt, 0.005; iodine, 0.003; selenium, 0.0003.
[a] CMC: carboxymethyl cellulose
[b] DCP: dicalcium phosphate
[c] NFE: nitrogen free extract = 100-(protein+ash+lipid+fiber)
[d] Calculated on the basis of 23.6, 39.5 and 17.2 MJ/kg of protein, fat and carbohydrate, respectively.

were obtained from local producers. The diets were air dried at room temperature for 24 hours. All diets were sealed in vacuum-packed bags and stored in freezer at -20°C until their used.

Sample Collection and Analytical Methods

An initial sample of 30 fish from stock pond was taken at the begining of the experiment. At the end of the experiment, a sample of 15 fish from each tank was taken randomly. Protein, moisture and ash content of experimental diets, diet ingredients and whole bodies of fish samples were determined according to standard AOAC methods (1990). Moisture content was determined by oven drying at 105°C until a constant weight, ash was determined by incineration at 550°C for 18 h and crude protein was done (N×6.25) by the Kjeldhal method. Total lipid content was determined according to the Bligh and Dyer (1959) method. Nitrogen free extract (NFE) was calculated by the difference, and gross energy (GE) was calculated on the basis of 23.6, 39.5 and 17.2 MJ/kg of protein, fat and carbohydrate, respectively.

The fatty acid methyl esters of experimental diets and whole body fish samples were prepared using the method described by Ichiara *et al.* (1996) with a minor modification–through transmethylation using 2 M KOH in methanol and *n*-heptane. The fatty acids were analysed by a GC Clarus 500 with autosampler (Perkin Elmer, USA) equipped with a flame ionization detector and a fused silica capillary SGE column (30 m × 0.32 mm, ID × 0.25 µm, BP20 0.25 UM, USA). The oven temperature was heated to 140°C, held for 5 min at this level, and raised to 200°C by 4°C.min^{-1} and to 220°C by 1°C.min^{-1}, while the injector and the detector temperature were set at 220 °C and 280°C, respectively. The sample size was 1 µl and the carrier gas was helium 16 psi with a split ratio of 1:100. Fatty acids were identified by comparing the retention times of FAME with a Standard 37 component FAME mixture (Supelco). All the analyses were performed three replicates.

Statistical Analysis

All data were subject to one-way analysis of variance (ANOVA) SPSS 15.0 Windows software package. Differences between the means were tested by Duncan's multiple range tests (Duncan, 1955). The level of significance was chosen at $P<0.05$ and the results are presented as mean±SD.

Results

Proximate and Fatty acid Composition of Experimental Diets

The formulation and the proximate composition of the experimental diets are presented in Table 1. The proximate compositions of the diets were similar for all the experimental groups. The fatty acid composition of the diets was representative of the fatty acid composition of the different oil sources (Table 2). The major fatty acid was 16:0 and it was followed by 18:1n-9 in the FO group. The fatty acids with the highest composition in the CO and HO group

were 18:1n-9 and in the SO group was 18:2n-6. The FO group had the richest content of saturated fatty acid (SFA) among groups. Total monounsaturated fatty acid (MUFA) levels were higher in hazelnut group and followed by canola group because of high percentage of oleic acid (18:1 n-9). EPA and DHA contents were higher in the FO group than that in the other groups. Therefore, the concentration of total n-3PUFA was higher in the FO group in comparison to vegetable oil groups. Due to the high 18:2n-6 content of soybean oil, the n-6 PUFA and total PUFA values in the SO group were higher than that in the other experimental groups.

Growth Performance and Feed Utilization

There were no losses in fish throughout the study and the survival rate was recorded as 100% for all groups. The growth performance and feed utilization parameters are shown in Table 3. At the end of the experiment, there were significant differences in the final weight and in the specific growth rate (SGR) among the experimental groups ($P<0.05$). The best growth performance was found HO group and followed by CO group. The lowest feed conversion ratio (FCR) was determined for the CO group and HO group was the second best FCR

Table 2. Fatty acid composition of the experimental diets (% of total fatty acids)

Fatty Acid	FO	SO	CO	HO
C14:0	7.66±0.53	1.20±0.01	1.13±0.01	1.18±0.01
C16:0	25.22±1.27	13.72±0.06	8.52±0.31	8.92±0.03
C17:0	0.46±0.02	0.08±0.01	0.25±0.17	0.12±0.01
C18:0	4.93±0.06	4.14±0.03	2.54±0.12	2.48±0.05
C20:0	0.92±0.59	0.36±0.02	1.39±0.05	ND
C23:0	0.59±0.03	ND	0.19±0.03	ND
∑ SFA	39.80±1.37	19.50±0.01	14.03±0.27	12.71±0.04
C14:1n9	0.97±0.06	0.15±0.01	0.18±0.02	0.17±0.01
C16:1n9	8.58±1.13	1.55±0.16	1.33±0.15	1.46±0.01
C17:1	0.32±0.02	ND	0.05±0.01	0.05±0.01
C18:1n9	21.53±1.94	26.43±0.04	55.19±0.19	66.95±0.16
C20:1n9	0.15±0.01	ND	0.07±0.03	ND
C22:1n7	0.17±0.07	ND	ND	ND
∑ MUFA	31.72±1.11	28.13±0.12	56.82±0.30	68.63±0.16
C18:2n6	2.23±0.89	41.82±0.08	16.32±0.04	11.51±0.06
C18:3 n6	0.14±0.02	0.44±0.01	ND	ND
C18:3n3	1.05±0.07	4.27±0.01	4.68±0.03	0.27±0.01
C18:4n3	0.95±0.08	0.28±0.01	0.28±0.01	0.22±0.02
C18:4n6	1.01±0.34	0.38±0.02	0.10±0.05	0.35±0.11
C20:3n6	0.10±0.01	ND	ND	ND
C20:4n3	0.26±0.02	0.19±0.01	0.25±0.01	0.08±0.01
C20:4n6	1.15±0.07	ND	0.32±0.06	0.21±0.01
C20:5n3	5.84±0.35	1.59±0.02	1.67±0.07	1.67±0.01
C22:6n3	7.89±0.55	2.92±0.01	3.13±0.04	2.88±0.02
∑ PUFA	20.63±1.40	51.90±0.10	26.76±0.13	17.19±0.15
∑ n3	15.99±0.97	9.25±0.24	10.01±1.24	5.12±0.12
∑ n6	4.63±0.82	42.64±0.17	16.74±1,25	12.07±0.17
n3/n6	3,45±0.61	0.22±0.01	0.60±0.28	0.42±0.07

ND: not determined.

Table 3. Growth and feed utilization parametres

	FO	SO	CO	HO
Initial (g)	6.57±0.01	6.61±0.16	6.60±0.07	6.57±0.10
FW (g)	14.00 ± 0.34^{c}	15.36 ± 0.81^{b}	16.43 ± 0.70^{ab}	16.72 ± 0.79^{a}
SGR(%/day)[a]	1.35 ± 0.06^{c}	1.50 ± 0.07^{b}	1.63 ± 0.07^{ab}	1.67 ± 0.04^{a}
FCR[b]	1.74 ± 0.10^{a}	1.75 ± 0.09^{a}	1.58 ± 0.08^{b}	1.66 ± 0.13^{ab}
LER[c]	3.59 ± 0.08^{b}	3.58 ± 0.19^{b}	3.95 ± 0.19^{a}	3.76 ± 0.19^{ab}
LPV[d]	42.68 ± 0.48^{c}	58.36 ± 1.59^{b}	70.74 ± 3.88^{a}	54.07 ± 0.44^{b}
PER[e]	1.60 ± 0.76^{b}	1.59 ± 0.08^{b}	1.76 ± 0.08^{a}	1.67 ± 0.08^{ab}
PPV(%)[f]	24.64 ± 0.76^{b}	25.87 ± 0.78^{ab}	28.51 ± 1.02^{a}	25.60 ± 0.93^{b}

[a] Specific growth rate: SGR(%/day) = [Ln(final weight)-Ln(initial weight)] / (number of days) * 100.
[b] Food conversion ratio: FCR = (dry feed fed) / (wet weight gain).
[c] Lipid efficiency ratio: LER = (final weight- initial weight) / (mass of lipid fed).
[d] Lipid productive value: LPV = (final body lipid – initial body lipid) / (lipid intake) * 100.
[e] Protein efficiency ratio: PER = (final weight- initial weight) / (mass of protein fed).
[f] Protein productive value: PPV = (final body protein – initial body protein) / (protein intake) * 100.

value. FO and SO groups were similar values in terms of FCR. The protein efficiency ratio (PER) and the lipid efficiency ratio (LER) were significantly higher in CO than in the other groups (P<0.05). The lowest protein productive value (PPV) and lipid productive value (LPV) were found FO group (P<0.05). These two parameters were higher in CO group and followed by HO and SO groups.

Proximate Composition and Body Indices of Fish

Significant differences were observed among groups in terms of the nutritional composition and hepatosomatic index HSI values (P<0.05), but no significant differences was determined in visceral somatic index VSI (P>0.05) (Table 4). The whole body lipid composition was higher in the SO group in comparison to the other groups. The hepatosomatic index was higher in FO group and the lowest values were found in SO and CO groups (P<0.05).

Fatty Acid Composition of Fish

Whole body fatty acid compositions of fish including initial values are given in Table 5. The whole body fatty acid composition of white seabream was affected by the different oil sources of diets. The most dominant fatty acid in all groups including the data for the initial population was the fatty acid 16:0 among the total SFAs, followed by 18:0. The total SFA content was significantly higher in FO group and followed by the SO, CO and HO groups, respectively

Table 4. Nutritional composition[a], VSI[b] and HSI[c] of the fish

	Initial	FO	SO	CO	HO
Protein	16.47±0.35	16.14±0.20^{a}	16.33±0.22^{a}	15.97±0.06^{a}	16.36±0.35^{a}
Lipid	4.25±0.36	8.30±0.08^{d}	12.39±0.39^{a}	10.39±0.34^{c}	11.12±0.23^{b}
Ash	6.34±0.37	7.35±0.25^{a}	5.86±0.24^{c}	6.31±0.40^{b}	5.50±0.27^{c}
Moisture	73.69±0.37	69.09±0.80^{a}	66.31±0.26^{c}	67.70±0.35^{b}	66.85±0.41^{c}
VSI%	4.50±0.50	4.69±0.81^{a}	4.28±0.81^{a}	4.38±0.51^{a}	4.32±0.55^{a}
HSI%	0.93±0.25	1.68±0.50^{a}	1.25±0.48^{b}	1.24±0.31^{b}	1.39±0.18^{ab}

[a] Whole body nutritional composition (protein, lipid, ash and moisture) is based on a % wet weight basis.
[b]Visceral somatic index: VSI % = (weight of visceral area)/(total fish weight) × 100.
[c] Hepatosomatic index: HSI % = (weight of liver)/(total fish weight) × 100.

Table 5. Whole body fatty acid composition of the fish (% of total fatty acid)

Fatty acids	Initial	FO	SO	CO	HO
C14:0	3.97±0.08	5.05±0.11^{a}	1.56±0.03^{b}	1.49±0.01^{b}	1.49±0.04^{b}
C15:0	0.45±0.01	0.65±0.01^{a}	0.26±0.01^{b}	0.25±0.01^{c}	0.24±0.01^{c}
C16:0	16.37±0.35	21.73±0.16^{a}	15.20±0.16^{b}	12.71±0.10^{c}	12.51±0.04^{c}
C17:0	0.41±0.04	0.68±0.03^{a}	0.24±0.01^{b}	0.20±0.01^{c}	0.21±0.01^{bc}
C18:0	4.50±0.07	6.86±0.12^{a}	5.95±0.09^{b}	4.00±0.09^{c}	3.46±0.19^{d}
C20:0	3.03±0.54	1.86±0.40^{bc}	1.63±0.01^{c}	2.56±0.03^{a}	2.19±0.02^{b}
C23:0	2.34±0.04	0.79±0.01^{a}	0.63±0.01^{b}	0.59±0.01^{c}	0.58±0.01^{c}
∑ SFA	31.06±0.14	37.64±0.25^{a}	25.47±0.26^{b}	21.79±0.05^{c}	20.67±0.21^{d}
C14:1n9	0.04±0.02	0.08±0.01^{b}	0.05±0.01^{c}	0.06±0.01^{c}	0.24±0.01^{a}
C15:1	0.07±0.01	0.13±0.01^{a}	0.04±0.01^{b}	0.03±0.01^{b}	0.03±0.01^{b}
C16:1n9	0.65±0.16	0.95±0.05^{a}	0.61±0.06^{c}	0.72±0.07^{bc}	0.79±0.07^{b}
C16:1n7	5.16±0.21	7.40±0.65^{a}	2.26±0.06^{b}	2.49±0.23^{b}	2.59±0.27^{b}
C17:1	0.18±0.01	0.25±0.01^{a}	0.07±0.01^{b}	0.07±0.01^{b}	0.06±0.01^{c}
C18:1n9	20.19±0.33	32.92±0.58^{c}	29.35±0.58^{d}	48.67±0.23^{b}	56.38±0.28^{a}
C20:1n9	0.13±0.05	0.84±0.05^{a}	0.33±0.03^{d}	0.57±0.04^{c}	0.68±0.01^{b}
C20:1n7	0.04±0.01	0.24±0.02^{d}	0.80±0.04^{a}	0.38±0.01^{b}	0.29±0.01^{c}
C22:1n9	0.06±0.01	0.05±0.01^{b}	0.12±0.01^{a}	0.06±0.02^{b}	0.03±0.01^{c}
C22:1n7	0.37±0.01	0.09±0.01^{a}	0.06±0.01^{b}	0.06±0.01^{b}	0.06±0.01^{b}
C24:1n9	1.06±0.01	0.63±0.11^{a}	0.32±0.01^{b}	0.44±0.06^{b}	0.34±0.01^{b}
∑ MUFA	27.94±0.16	43.59±0.19^{c}	33.99±0.51^{d}	53.53±0.14^{b}	61.49±0.05^{a}
C18:2n6	8.59±0.17	4.53±0.07^{d}	28.58±0.45^{a}	12.64±0.10^{b}	9.48±0.06^{c}
C18:3 n6	0.13±0.01	0.15±0.04^{a}	0.05±0.01^{b}	0.05±0.01^{b}	0.04±0.01^{b}
C18:3n3	1.78±0.04	0.77±0.10^{c}	2.76±0.01^{b}	3.04±0.01^{a}	0.26±0.01^{d}
C18:4n3	0.89±0.01	0.44±0.01^{a}	0.31±0.01^{b}	0.30±0.01^{b}	0.25±0.01^{c}
C18:4n6	0.14±0.01	0.02±0.01^{d}	0.39±0.01^{b}	0.43±0.01^{a}	0.04±0.01^{c}
C20:3n6	0.18±0.01	0.09±0.01^{b}	0.12±0.01^{a}	0.12±0.01^{a}	0.04±0.01^{c}
C20:4n3	0.09±0.01	0.15±0.03^{ab}	0.13±0.01^{b}	0.18±0.01^{a}	0.09±0.01^{c}
C20:4n6	2.58±0.05	0.85±0.41^{a}	0.12±0.01^{b}	0.46±0.31^{ab}	0.27±0.01^{b}
C20:5n3	4.74±0.09	1.81±0.03^{a}	1.35±0.02^{b}	1.28±0.01^{c}	1.24±0.01^{d}
C22:6n3	12.01±0.22	4.45±0.08^{a}	3.91±0.06^{b}	3.71±0.02^{c}	3.34±0.12^{d}
∑ PUFA	31.12±0.60	13.26±0.43^{d}	37.72±0.39^{a}	22.21±0.22	15.05±0.16^{c}
∑n3	19.51±0.37	7.62±0.38^{b}	8.46±0.12^{a}	8.51±0.35^{a}	5.15±0.15^{c}
∑n6	11.62±0.18	5.74±0.09^{d}	29.26±0.41^{a}	13.70±0.10^{b}	9.87±0.05^{c}
n3/n6	1.68±0.06	1.33±0.11^{a}	0.29±0.01^{d}	0.62±0.05^{b}	0.52±0.03^{c}

(P<0.05). The total MUFA content was determined to be significantly higher in HO group in comparison to that in the other experimental groups (P<0.05). The highest 18:1n-9 value was determined for the HO group and followed by CO, FO and SO groups, respectively. The highest 18:2 n-6 content was found in SO and all groups were reflected their feed compositions. Total polyunsaturated fatty acid (PUFA) content and n-3 PUFA values were significantly different among groups (P<0.05). The highest total n-3 PUFA was found in SO, the lowest total PUFA content was determined in FO group. The n-6 PUFA content and n3/n6 ratios were the same as experimental feed composition for whole body fatty acid in all groups.

Discussion

This study showed that fish oil can be replaced 100% with soybean, canola or hazelnut oil without any adverse effect on growth and body chemical compositions in white seabream juveniles. After the eighth week of study, growth performance, especially in terms of SGR values, were in agreement with previous studies (Piedecausa *et al*., 2007; Sa *et al*., 2008a,b; Arslan *et al*., 2012; Wassef *et al*., 2014). Results in terms of growth and feed utilization were similar to those of previous studies of fish oil replacement with soybean oil and canola oil (Rosenlund *et al*., 2001; Caballero *et al*., 2002; Piedecausa *et al*., 2007; Fountoulaki *et al*., 2009; Arslan *et al*., 2012; Han *et al*., 2013; Glencross *et al*., 2003; Stubhaug *et al*., 2007; Huang *et al*., 2007; Fountoulaki *et al*., 2009; Karayücel and Dernekbaşı, 2010; Taşbozan *et al*., 2014b) on different fish species. Arslan *et al*. (2012) did not achieve a better growth with the usage of hazelnut oil instead of fish oil in brown trout. However, usage of hazelnut oil instead of fish oil in this study showed a better performance on growth and feed utilization as in previous studies carried out on gilthead seabream (Taşbozan *et al*., 2011) and meagre (Taşbozan *et al*., 2014a).

In our study on white seabream juveniles, protein and lipid utilization values were found to be better for canola and hazelnut oils compared to others. Values of the soybean group were similar to the FO group. In previous studies, use of canola and soybean on gilthead seabream (Izquierdo *et al*., 2003, 2005; Fountoulaki *et al*., 2009), use of soybean and flaxseed oil on sharpsnout seabream (Piedecausa *et al*., 2007) use of canola on rainbow trout (Karayücel and Dernekbaşı, 2010) and on tilapia (Taşbozan *et al*., 2014b) and use of hazelnut oil on gilthead seabream (Taşbozan *et al*., 2011) showed similarly better results in terms of protein and lipid utilization. Sa *et al*. (2007, 2008a,b,c) reported that white seabream can easily adapt to feed prepared with different feed raw material resources and hence is considered to have good feed utilization capacity. In the present study, it was observed that the white seabream could adapt easily to different vegetable oil sources. Therefore, it can be speculated that the FCR values of CO and HO groups demonstrated better values comparing the control group (FO).

In this study, different oils in the feed had an effect on fish whole body composition except protein content and HSI values. Amongst the groups including vegetable oil, lipid content in SO and HO groups were higher than FO group. Similar results were reported from previous studies on different species (Piedecause *et al*., 2007; Fountoulaki *et al*., 2009; Turchini *et al*., 2009; Arslan *et al*., 2012). The results of this and other studies show that alternative vegetable oil resources cause different results based on the fish species, fish size, duration of the study and culture conditions.

The use of SO, CO and HO with the fishmeal-based diets in this study did not lead to any negative effects on growth and feed utilization. It is suggested that this situation may have resulted because of fish meal (400 g fish meal in per kg feed) in the experimental feeds. In spite of total vegetable oil replacement, this adequate fish meal content of the feeds of vegetable oil groups were effective on growth and feed utilization. Similar results were reported with fishmeal-based diets for red sea bream (Huang *et al*., 2007), sea bream (Izquierdo *et al*., 2003; Montero *et al*., 2003; Izquierdo *et al*., 2005; Wassef *et al*., 2009; Wassef *et al*., 2014), European sea bass (Izquierdo *et al*., 2003; Martins *et al*., 2006; Eroldoğan *et al*., 2012; Yılmaz and Eroldoğan, 2015) and sharpsnout seabream (Piedecausa *et al*., 2007).

Vegetable oil usage as an alternative to fish oil affected fish body fatty acid composition and reflected the composition of the feed (Turchini *et al*., 2003). This is more obvious in marine fish species because of they have limited ability to convert 18C fatty acids into 20-22C fatty acids compared to freshwater fish (Watanabe, 1982). Most of the vegetable oils are rich sources of n-6 and n-9 fatty acids, mainly LA and OA, respectively (Turchini *et al*., 2009). In this study, the fish body composition in SO group had the highest n-6 PUFA due to the rich content of LA in their diet. At the same time, LA and n-6 PUFA levels in whole body fatty acid composition showed a similar tendency with LA and n-6 PUFA levels of the feed. These results are consistent with some previous studies on similar fish species such as European sea bass (Montero *et al*., 2005; Mourente *et al*., 2005; Eroldoğan *et al*., 2012), sea bream (Montero *et al*., 2003; Menoyo *et al*., 2004; Wassef et al., 2009; Fountoulaki *et al*., 2009; Wassef *et al*., 2014), sharpsnout sea bream (Piedeceusa *et al*., 2007) and red sea bream (Huang *et al*., 2007). As previously reported, reviewed by Turchini *et al*. (2009), most of the vegetable oils are poor sources of n-3 fatty acids when compared to marine oils. In addition, the importance of n-3 LC-PUFA, especially EPA and DHA, in marine fish species for optimum

performance has been demonstrated by some researchers (Sargent *et al*., 1989; Ibeas *et al*., 1996; Oliva-Teles, 2000; Skalli and Robin, 2004). In this study, although EPA and DHA contents of the feeds in SO, CO and HO groups were lower as compared to FO group, the growth performance of fish in vegetable oil groups were better than that of the FO group. On the other hand, all the experimental diets contained 400 g/kg fish meal, and thus sufficient amount of n-3 L-C PUFA in our study. This amount of fish meal had a favorable effect in terms of growth performance. This result is quite consistent with some earlierstudies (Piedecausa *et al*., 2007; Huang *et al*., 2007; Wassef *et al*., 2009; Turchini *et al*., 2011; Eroldoğan *et al*., 2012; Wassef *et al*., 2014; Yılmaz and Eroldoğan, 2015).

In many studies, when fish oil was replaced with vegetable oils, significant changes to fatty acid composition were observed (Turchini *et al*., 2003; Izquierdo *et al*., 2003; Mourente *et al*., 2005; Eroldoğan *et al*., 2012; Arslan *et al*., 2012; Francis *et al*., 2014). In general, the composition of n-3LC-PUFAs such as EPA and DHA of vegetable oil fed fishes is lower than in fish oil fed fishes (Tocher *et al*., 2001). In our study, in vegetable oil groups, EPA, DHA and arachidonic acid (ARA) levels were found to be lower than the FO group. The similar observations have been reported in different fish species such as Atlantic salmon (Bell *et al*., 2002, 2003) trout (Caballero *et al*., 2002), African catfish (Ng *et al*., 2003), turbot (Regost *et al*., 2003), sea bass (Mourente *et al*., 2005), sea bream (Izquierdo *et al*., 2005) and sharpsnout seabream (Piedecausa *et al*., 2007). Dietary fatty acids influence the fish body fatty acid composition (Turchini *et al*., 2009; Eroldoğan *et al*., 2012). On the other hand, some specific fatty acids are selectively retained or utilized (Bell *et al*., 2001; 2002). An increase in DHA levels observed in fish fatty acid composition with respect to feed fatty acid composition was observed. Similar results were observed in sharpsnout seabream (Piedecausa *et al*., 2007) brown trout (Arslan *et al*., 2012), sea bass (Mourente *et al*., 2005; Eroldoğan *et al*., 2012; Yılmaz and Eroldoğan, 2015), rainbow trout (Caballero *et al*., 2002), African catfish (Ng *et al*., 2003) and turbot (Bell *et al*., 1994; Regost *et al*., 2003). The reason of the deposition of DHA is prefentially retained in phospholipid fraction of lipid to maintain cell membran structure (Bell *et al*., 2003). In addition, the selective deposition mechanism should be evaluate include the high specifity of fatty acyl transferases for DHA and complex catabolism of DHA due to its relative resistance to β-oxidation (Bell *et al*., 2001).

Total SFA and MUFA values of the whole body composition were the same as the feed in this study. Palmitic acid (16:0) was the primary saturated fatty acid and it was higher level in fish body compared to the levels observed in diets. Similar tendency was detected for stearic acid (18:0). The high level of these fatty acids in fish body comparing to diets may reflect production by lipogenic activity (Dias *et al*., 1998; Skalli and Robin, 2004). On the other hand, oleic acid (18:1 n-9) levels were higher in FO and SO group in fish body compared to their diets. This observation can be evaluate that an active biosynthesis (liponegenesis) of oleic acid as reported by Eroldoğan *et al*. (2012). Our result supports similar reported for sea bream (Izquierdo *et al*., 2003; Menoyo *et al*., 2004) for sea bass (Izquierdo *et al*., 2003; Montero *et al*., 2005; Eroldoğan *et al*., 2012). CO and HO are rich sources for oleic acid (Turchini *et al*., 2009; Arslan *et al*., 2012). This fatty acid is involved in energy storage (Skalli and Robin, 2004). In our experiment, the oleic acid levels of fish body tissue in CO and HO groups were relatively lower when compared to experimental diets. However, high deposition of this fatty acid in body tissue of the fish was observed. This observation was consistent with the previous studies with canola oil on sea bass (Skalli and Robin, 2004; Mourente *et al*., 2005; Montero *et al*., 2005; Huang *et al*., 2007; Yılmaz and Eroldoğan, 2015), on sea bream (Montero *et al*., 2003), on red sea bream (Hang *et al*., 2007), with HO on brown trout (Arslan *et al*., 2012), on sea bream (Taşbozan *et al*., 2011), on meagre (Taşbozan *et al*., 2014a). In addition to these, MUFA rich diets more efficiently transformed into energy by the process of β-oxidation than n-6 PUFA rich diets, thus MUFA rich oil diets are more digestible than n-6 PUFA rich oils (Turchini *et al*., 2011; Eroldoğan *et al*., 2013; Yılmaz and Eroldoğan, 2015). This explanation was support the better growth performance and feed utilization in CO and HO groups compared to FO and SO groups.

The results of this study suggest that SO, CO and HO oil resources can be used in fishmeal-based white seabream feed without any adverse effects in terms of growth and feed utilization. This was the first study about vegetable oil resources conducted on this species. Obtaining further results from different life cylcles studies of this species and with the usage of different oil resources will provide further positive contributions to aquaculture.

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