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RESEARCH ARTICLE **ARAŞTIRMA MAKALESİ**

Evaluation of sesame (*Sesamum indicum*) seed meal as a replacer for soybean meal in the diets of rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792)

Gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) yeminde soya küspesi yerine susam (*Sesamum indicum*) tohumu küspesinin değerlendirilmesi

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Abstract: A 60-day feeding trial was conducted to asses the potential nutritive value of sesame seed meal as a dietary replacement for soybean meal in the diets of rainbow trout (*Oncorhynchus mykiss* Walbaum, 1792). All diets were prepared to be isonitrogenous (49% protein), isolipidic (19% lipid) and isoenergetic (22 kJ g^{-1}). Four different diets containing 0% (C), 10% (10SSM), 15% (15SSM) and 20% (20SSM) sesame seed meal were formulated for rainbow trout with a mean weight of 81.02±0.02 g and fish were hand fed feed twice a day to apparent satiety under a natural light regime. At the end of study, significant differences were found in final body weight, weight gain and specific growth rate (SGR, %) between control group (C) and the experimental groups (p<0.05). While there were no significant differences between the experimental groups in terms of feed conversion ratio (FCR) and protein efficiency rate (PER) (p>0.05), Apparent Net Protein Retention (ANPR) differed significant between C and 10SSM and 15SSM and 20SSM groups (p<0.05). The moisture, protein, lipid and ash contents in the body composition of the fish increased in all experimental groups. The moisture, lipid and ash content were not significantly differed among the groups (p>0.05) but protein contents of fish in 15SSM and 20SSM groups was significantly higher than fish in control and 10SSM groups (p<0.05). There were also no differences in the digestibility of crude protein among groups (p>0.05). Comparable performance in growth, nutrient utilization and crude protein deposition of rainbow trout fed by diet containing 15% sesame seed meal showed that these meals could be used as this rate.

Keywords: *Alternative plant protein source, amino acids, growth*

Öz: 60 günlük besleme denemesi, gökkuşağı alabalığı (*Oncorhynchus mykiss* Walbaum, 1792) diyetlerinde soya küspesi yerine susam tohumu küspesinin potansiyel besleme değerini değerlendirmek için yapılmıştır. Tüm diyetler izonitrojenik (%49 protein), isolipidik (% 19 yağ) ve isoenerjik (22 kJ g^{-1}) olarak hazırlanmıştır. %0 (C), %10 (10SSM), %15 (15SSM) ve %20 (20SSM) susam tohumu küspesi ihtiva eden dört farklı diyet ortalama ağırlığı 81.02 ± 0.02 g olan gökkuşağı alabalıkları için formüle edilmiştir ve balıklar doğal ışık rejimi altında görülebilir tokluğa ulaşıncaya kadar günde iki kez elle beslenmiştir. Çalışmanın sonunda, kontrol (C) ve diyet grupları arasında final vücut ağırlığı, ağırlık kazancı ve spesifik büyüme oranında (SGR,%) önemli farklılıklar bulunmuştur (p<0.05). Yem dönüşüm oranı (FCR) ve protein etkinlik oranı (PER) açısından deney grupları arasında anlamlı bir fark yokken (p>0.05), Görünen Net Protein Tutumu (ANPR) bakımından C-10SSM ve 15SSM-20SSM grupları arasındaki farklılıkların önemli olduğu belirlenmiştir (p <0.05). Balıkların vücut kompozisyonundaki nem, protein, lipit ve kül içerikleri tüm deneme gruplarında artmıştır. Nem, yağ ve kül miktarı bakumından farklılıklar gruplar arasında önemli bulunmamıştır (p> 0.05), fakat 15SSM ve 20SSM diyetleriyle beslenen balıkların protein içerikleri C ve 10SSM diyetleriyle beslenen balıklardan daha yüksek olduğu belirlenmiştir. Bu gruplar arasındaki farklılıklar önemli bulunmuştur (p<0.05). Gruplar arasında ham protein sindirilebilirlik oranında önemli farklılık tespit edilmemiştir (p>0.05). %15 susam tohumu küspesi içeren diyetle beslenen gökkuşağı alabalıklarının büyüme, besin kullanımı ve ham protein birikimindeki performans karşılaştırıldığında, susam tohumu küspesinin bu oranda kullanılabileceğini göstermiştir.

Anahtar kelimeler: *Alternatif bitkisel protein kaynağı, aminoasitler, büyüme*

INTRODUCTION

Given the current rapid development of fish farming in the world, intense future competition for limited global supplies of fish meal is expected (Sargent and Tacon, 1999). As a strategy to reduce the risk, the identification, development and use of alternatives to fish meal in aquafeeds remain in high priority (Hardy, 2008). Soybean meal is one of the most nutritious of all plant protein sources (Lowell, 1988). Due to its high protein content, high digestibility and relatively well balanced amino acid profile, it is widely used as feed ingredient for many aquaculture species (Storebakken et al., 2000). It is currently the most commonly used plant protein source in fish feed (El-Sayyed, 1999). Lim and Akiyama (1992) reported that soybean products have been used to replace a significant portion of fish meal in fish feed with nutritional, environmental and economic benefits. However, soybean meal is expensive (Brown, 2008) and wider utilization and availability of this conventional source for fish feed is limited by increasing demand for human consumption and by other animal feed industries (Siddhuraju and Pecker 2001; Fakunle et al., 2013). Therefore, the use of less expensive and easily available plant protein sources are needed to reduce dependence on fish meal and soybean meal as the fundamental protein sources for aquatic animal diets without reducing the nutritional quality of feeds (Reigh 2008; Barros et al., 2002).

Sesame seed (*Sesamum indicum* L.) is an important source of oil and composed of about 47.8-52.2% oil, 26.9-25.8% protein and 4.7-5.6% ash. In the sesame oil industry, sesame seed is used as the raw material for oil extraction, either using organic solvents or by mechanical pressing. The sesame seed meal is a by-product after oil extraction. The extraction of oil has led to increased protein content of defatted sesame seed meal (Onsaard et al., 2010). This meal can be used as a protein source ingredient in the food industry (Onsaard, 2012). Sesame seed meal was represented as a source of plant protein replacing soybean meal in fish diets to reduce the feed costs by Tacon (1993).

In fish feeding, sesame seed meal tested as a plant protein supplement in livestock feed such as broiler chicken (Rama Roa et al., 2008) and in fish species such as *Clarias gariepinus* (Jimoh and Aroyehun, 2011), *Cyprinus carpio* (Hasan et al., 1997), *Huso huso* (Jahanbakhshi et al., 2012) and *Labeo rohita* (Mukhodadhyay, 2001). However, information about performance of sesame seed meal on fish is still limited. The purpose of the present study was to evaluate the effect of replacing soybean meal with graded levels of sesame seed meal without amino acid supplementation as a potential plant protein source in the diets of the rainbow trout.

MATERIALS AND METHODS

Fish and experimental conditions

The feeding trial was conducted at an indoor facility of the Faculty of Fisheries, University of Sinop (Sinop, Turkey). Experimental rainbow trout were obtained from a commercial trout farm (Kuzey Su Urunleri Inc.) in Samsun, Turkey. Fish were stocked in centrally drained three 1000 l rectangle fiberglass tanks in a flow-through water system in an indoor facility and acclimated for two weeks under experimental conditions prior to the experiment. During acclimation, the fish were fed with a commercial trout feed (Black Sea Feed) twice a day to apparent satiation. After acclimatization, fish (mean weight of 81.02±0.02 g) were fasted for a day, weighted and randomly distributed to twelve fiberglasses circular tanks (approximately, water volume of 300-L; 60 cm in high; 80 cm in diameter) at a density of 19 fish per tank. Water flow rate was adjusted to 4 L min^{-1} and supplemental aeration was provided via airstone diffusers. The water quality parameters were monitored on weekly basis and average temperature, dissolved oxygen and pH were 14.95±0.07°C, 9.09±0.04 mg^{-1} and 7.23. Five fish from each tank were removed for homogenization and fillet samples were analyzed at the end of the study.

Experimental diets

Sesame seed meal was obtained from a commercial firm (Filiz Şekerleme ve Gıda Inc., Samsun, Turkey). The rest of the ingredients were provided by a local fish feed manufacturer (Sibal Inc., Black Sea Feed, Sinop, Turkey). The experiment feeds containing sesame seed meal was prepared by chancing with different ratios of soybean meal. Four experimental diets containing 0% (Control diet; C), 10% (10SSM), 15% (15SSM) and 20% (20SSM) sesame seed meal were formulated. All diets were prepared to be iso-nitrogenous (49% protein), iso-lipidic (19% lipid) and iso-energetic (22 kJ g^{-1}). When the diet was formulated, fish oil rates added by taking into account of the amount of oil from raw materials. Formulation and chemical composition of experimental diets were summarized in Table 1. Amino acid composition of the experimental diets were shown in Table 2. Chromic oxide (Cr_2O_3) was submitted in the diets as an indicator at a concentration of 0.5% to assess the apparent digestibility of the diets. Feed ingredients were thoroughly mixed, homogenized, moistened by the addition of 35% water and pelleted (4.0 mm) in a mincing machine. The pellets were dried at 50°C for 8 h, cut into pieces approximately 5 mm in length. Amino acid composition of experimental diet and fillet were analysed in triplicate following acid hydrolysis using pressure liquid chromatography (Agilent 1100 Series HPLC System) on a dry weight basis (Faculty of Marine Sciences and Technology, Çanakkale Onsekiz Mart University, Çanakkale, Turkey) (Arrieta and Prats-Moya, 2012). All feeds were stored at -40°C in plastic bags until need for feeding.

Feeding and faecal collection

The study was conducted in triplicates in a randomly assigned tanks. During the trial, fish in all groups were fed by hand ad libitum twice a day (at 09:00 am and 16:00 pm) for 60 days. All possible care was taken during feeding so that no uneaten feed settled on the tank bottoms. Feed for each tank was weighed daily to a constant amount (100 g) and feed consumption in each tank was determined by subtracting unconsumed feed from the ration. Tanks were thoroughly cleaned after each feeding. Starting on day 7 of the experiment, faecal matter was collected after each feeding by slow siphoning with an 8-mm plastic tube. There were no fecal collections made on weekends. Faecal samples were immediately frozen and stored at -40°C pending analysis.

Chemical analyses

The analyses of chemical composition of feed ingredients, experimental diets, fish samples and faeces were performed by the standard methods of AOAC (1995). Dry matter was determined after drying at 105°C to constant weight; furter analyses included: crude protein (Kjeldahl method; acid digestion; Nx6.25); crude lipid (after extraction with petroleum ether, Soxhlet method) and crude ash (at 550°C in muffle furnace for 6 h). Chromic oxide in the diet and feces was determined spectophotometrically according to Petry and Rapp (1970). Apparent protein digestibility coefficients were calculated as ADC (%) = 100-[100 (% Cr_2O_3 in diet/ % Cr_2O_3 in faeces) x (% nutrient in faeces/% nutrient in diet)] as per Degani (2006). ADC of dry matter (%) = 100-[100 (% Cr2O3 in diet/ % Cr2O3 in faeces) as per De Silva and Anderson (1995). Gross energy of the diets was estimated assuming 23.6 kJ/g protein, 39.5 kJ/g lipid and 17 kJ/g nitrogen free extracts. All analyses were done in triplicate.

Statistical analysis

Anderson-Darling and Levene's tests were used for homogeneity of variances and equality of variance of groups, respectively. The significance of differences in growth between control and experimental groups were analyzed using one-way ANOVA, followed by Tukey's method for multiple comparisons. Arcsine square root transformations of percentage data were conducted to achieve homogeneity of variances before statistical analysis. Differences were considered significant when p<0.05. Analyses were performed using the program Minitab 17 for Windows.

RESULTS

Chemical and amino acid compositions of experimental diets

Nutrient composition of the feed ingredients was shown in Table 1. The chemical composition of the experimental diets containing 0, 10, 15, 20% sesame seed meal was presented in Table 2. The essential amino acid profile of the diets meets the requirements for rainbow trout (NRC, 1993). The total essential amino acid composition of the C and 15SSM groups was higher than 10SSM and 20SSM groups (Table 3).

Table 1. Nutrient composition of the feed ingredients (as % dry matter)

	Parameter			
Feed Ingredients	**Moisture**	**Crude protein**	**Crude lipid**	**Crude ash**
Fish meal	9.20	73.12	13.7	9.75
Soybean meal	11.58	46	3.21	5.82
Sesame seed meal	9.40	31	36	8.90
Corn protein	9.86	58.5	1.93	2.89

Table 2. Formulation and chemical compositions of the control and experimental diets

	Experimental diets			
Ingredients (g kg^{-1})	**C**	**10SSM**	**15SSM**	**20SSM**
Fish meal	350	350	350	350
Extracted soybean meal	270	200	170	140
Wheat flour	101.5	101.5	101.5	101.5
Corn protein	160	160	160	160
Sesame seed meal	0	100	150	200
Fish oil	110	80	60	40
Vitamin premix(*)	2	2	2	2
Mineral premix(*)	1.5	1.5	1.5	1.5
Chromic oxide (Cr_2O_3)	5	5	5	5
Proximate Composition (%)				
Moisture	4.19	5.26	5.36	5.19
Protein	49.53	48.95	49.60	49.03
Lipid	19.40	19.80	19.65	20.36
Ash	7.00	7.50	7.99	7.96
NFE+Crude fiber[1]	19.88	18.49	17.40	17.46
Gross energy(kJ g^{-1})[2]	22.73	22.52	21.84	22.58

* Per kg feed: Vitamin A 12500 IU; Vitamin D3 2500 IU; Vitamin C 250 mg; Vitamin K3 10 mg; Vitamin B1 10 mg; Vitamin B2 20 mg; Vitamin B6 15 mg; Vitamin B12 0.03 mg; Niacin 200 mg; Biotin 1 mg; Folic acid 10 mg; Pantothenic acid 60 mg; Ca 1000mg; Magnesium 600 mg; Potassium 450 mg; Zinc 90 mg; Manganase 12 mg; Cu 5 mg

[1]NFE+Crude fiber=100-(%protein+ %lipid+ %ash+ %moisture)
[2]Gross energy is calculated according to 23.6 kJ g^{-1} protein, 39.5 kJ g^{-1} lipid and 17 kJ g^{-1} NFE

Table 3. Amino acid composition of the experimental diets (g/100g dry weight)

Essential Amino Acids (EAA, g/100g)	**Diet Groups**			
	C	**10SSM**	**15SSM**	**20SSM**
Histidine	1.83	2.28	1.90	1.84
Isoleucine	2.04	1.70	1.99	1.84
Leucine	4.50	3.51	4.40	4.06
Lysine	2.43	1.71	1.18	1.89
Methionine	0.84	0.59	0.76	0.60
Phenylalanine	2.31	1.80	2.23	2.11
Threonine	2.51	2.85	2.43	2.16
Valine	1.18	1.02	2.48	1.21
Total EAA	17.64	15.46	17.37	15.71
Non-essential amino acids(NEAA, g/100g)				
Alanine	3.44	3.37	3.18	3.27
Aspartic acid	5.73	5.89	5.37	5.37
Glutamic acid	9.84	7.40	8.56	8.94
Glycine	2.59	3.63	2.55	2.57
Serine	2.53	5.33	3.11	2.51
Tyrosine	1.99	1.81	2.05	1.88
Total NEAA	26.12	27.43	24.82	24.54

Growth performance

The fish accepted all experimental diets and no mortalities occurred during the study. There was a difference in feed intake among groups. Increasing levels of sesame seed meal had significant effect on final body weight (FBW), weight gain (WG) and specific growth rate (SGR) ($p<0.05$) (Table 4). The best FBW, WG and SGR were determined in C and 15SSM groups. However, feed conversion rate (FCR) and protein efficiency rate (PER) were not effected by the use of sesame seed meal among experiment groups ($p>0.05$). Apparent Net Protein Retention (ANPR, %) was statistically significant between C and 10SSM and 15SSM and 20SSM groups ($p<0.05$). The highest ANPR was obtained in 15SSM and 20SSM groups.

Table 4. Growth performance, feed efficiency parameters of rainbow trout fed by the experimental diets*

Parameters	**C**	**10SSM**	**15SSM**	**20SSM**
Initial body weight (g)	80.98±0.14^{a}	80.98±0.17^{a}	81.05±0.11^{a}	80.98±0.06^{a}
Final body weight (g)	210.89±3.28^{a}	185.83±10.97^{b}	202.16±13.49^{c}	190.95±7.54^{b}
Weight gain (g)[1]	129.91±13.29^{a}	104.52±10.80^{b}	121.56±13.54^{c}	110.00±7.56^{b}
FCR[2]	1.03±0.02^{a}	1.10±0.06^{a}	1.11±0.05^{a}	1.11±0.04^{a}
SGR (%)[3]	1.71±0.02^{a}	1.48±0.10^{b}	1.63±0.13^{c}	1.53±0.07^{b}
PER[4]	2.54±0.05^{a}	2.50±0.11^{a}	2.35±0.11^{a}	2.42±0.13^{a}
ANPR (%)[5]	36.03±0.96^{a}	36.13±1.03^{a}	38.26±1.82^{b}	38.61±0.76^{b}

*Values are the mean±SEM of triplicate groups (five fish for each group). Different superscripts within the row denote significant differences ($p<0.05$).

[1] WG, Weight gain(g)= final weight- initial weight
[2] FCR, Feed conversion rate = total diet fed (g) /total weight gain (g)
[3] SGR, Specific growth rate (%)= [(ln final wet weight - ln initial wet weight)/days] x 100
[4] PER, Protein efficiency rate = weight gain (g)/protein intake (g)
[5] ANPR, Apparent Net Protein Retention (%)=[(final weight in g x final weight protein in %)-(initial weight in g x initial body protein in %)/protein intake in g]x100

Table 5. Chemical composition of fillet of rainbow trout fed by the experimental diets (% wet weight)*

Parameters	Initial	C	10SSM	15SSM	20SSM
Moisture (%)	76.07±0.09[a]	75.07±0.52[b]	74.97±0.37[b]	75.43±0.09[b]	75.24±0.13[b]
Protein (%)	10.52±0.16[a]	18.34±0.19[b]	18.28±0.18[b]	21.06±0.29[c]	20.77±0.21[c]
Lipid (%)	3.39±0.01[a]	3.64±0.10[a]	4.26±0.21[a]	3.37±0.10[a]	3.95±0.14[a]
Ash (%)	1.49±0.02[a]	1.64±0.01[b]	1.67±0.04[b]	1.72±0.03[b]	1.71±0.05[b]

*Values are the mean±SEM of three replicates (five fish from each group were pooled). Different superscripts within the row denote significant differences ($p<0.05$)

Chemical and amino acid composition of fillet

The moisture, lipid and ash contents of fish were not influenced by increasing sesame seed meal percentages in the diets (Table 6). There were no differences among the groups ($p>0.05$), but protein contents of fish in 15SSM and 20SSM groups was significantly higher than C and 10SSM groups ($p<0.05$). The amino acid composition of the fillet from rainbow trout fed by experimental diets was shown in Table 7.

Apparent digestibility of dry matter and protein

ADCprotein values were similar in C, 10SSM, 15SSM and 20SSM groups, but it was the highest in C (Table 5). There were no significant differences in the digestibility of protein among the experimental groups ($p<0.05$). ADCdry matter was significantly higher in C (%86.11) than in 10SSM, 15SSM and 20SSM groups ($p>0.05$).

Table 6. Apparent digestibility coefficients (ADCs) of dry matter and protein of experimental diets with varying sesame seed meal contents (%)*

Parameters	Diet Groups			
	C	10SSM	15SSM	20SSM
Dry matter (%)	86.11±0.48[a]	80.58±0.71[b]	80.96±0.38[b]	80.52±2.13[b]
Crude Protein (%)	93.63±0.92[a]	90.98±1.32[a]	91.45±0.43[a]	91.29±1.36[a]

*Values are the mean±SEM of triplicate groups (15 fish for each group). Different superscripts within the row denote significant differences

Table 7. Amino acid composition of fillet from rainbow trout fed by experimental diets (g/100g dry weight)*

Essential Amino Acids (EAA, g/100g)	Diet Groups				
	Initial	C	10SSM	15SSM	20SSM
Histidine	1.92	2.68	2.66	3.04	2.94
Isoleucine	3.69	2.60	3.03	3.77	3.58
Leucine	7.33	6.73	6.70	8.10	8.15
Lysine	3.01	7.55	5.94	5.73	4.87
Methionine	2.68	2.06	2.09	2.18	2.16
Phenylalanine	3.49	2.92	3.08	3.70	3.89
Threonine	5.03	3.55	4.58	5.02	5.35
Valine	2.59	2.32	2.18	2.62	2.35
Total EAA	29.74	30.41	30.26	34.16	33.29
Non-essential amino acids(NEAA, g/100g)					
Alanine	5.95	5.29	4.91	5.52	5.46
Aspartic acid	12.45	7.25	8.47	10.67	10.67
Glutamic acid	12.45	7.25	8.47	10.67	10.67
Glycine	3.14	4.49	3.86	4.11	3.92
Serine	3.47	3.43	3.25	4.19	4.17
Tyrosine	3.18	2.94	2.99	3.79	3.89
Total NEAA	40.64	30.65	31.95	38.95	39.08

*Values are the mean±SEM of triplicate groups (five fish for each group)

DISCUSSION

The present study was aimed to determine the appropriate ratio of sesame seed meal as a replacer for soybean meal in rainbow trout diet by comparing the effect of sesame seed meal at different ratios on the growth, chemical composition, amino acid content and protein digestion. Some studies showed that alternative vegetable protein sources (soy, canola, sunflower, safflower, nuts, peanut) could be used in the diets of some fish species like yellow perch (*Perca flavescens* in Sindelar, 2014), Nile tilapia (*Oreochromis niloticus* in Gabor, 2006), the African catfish (*Clarias gariepinus* in Sanz et al., 1994), carp (*Cyprinus carpio* in Atalayoğlu and Cakmak, 2010) and Mozambique tilapia fries (*Oreochromis mossambicus* in Yıldırım et al., 2014). Similarly, Sanz et al. (1994), Yiğit et al. (2012), Ustaoğlu Tırıl and Kerim (2015) and Bilgin et al., (2007) reported that vegetable protein sources used in the diets (soy, canola, safflower, nuts) of rainbow trout have no negative impact on growth.

In this research, final body weight and ve weight gain of 10SSM and 20SSM groups were lower than C and 15SSM groups. The reduction in growth parameters recorded at the inclusion of sesame seed meal in the diet of rainbow trout could be due to dietary amino acid profile imbalance and presence of antinutritional factors in test ingredient (sesame seed). Sesame seed contains high amount of oxalate and phytic acid (Francis et al., 2001). Additionally, Francis et al. (2001) stated that the lowered growth performance of fish fed by sesame diets containing high phytate can be attributed to various factors, namely reduced bio-availability of minerals, impaired protein digestibility by formation of phytic acid-protein complexes and depressed absorption of nutrients due to damage to pyloric caeca region of the intestine. In the current experiment, while the total essential amino acid contents of C and 15 SSM groups were almost equal, the total essential amino acid contents of 10SSM and 20SSM groups were lower. A reduction in the growth of rainbow trout fed without any amino acid supplement is thought to be the cause of amino acid deficiency in the diet.

Not much studies were available for determining sesame seed meal ratio in fish feed. In these limited research, it was reported that the growth performance and the body composition of rainbow trout was not affected by replacing fish meal with sesame seed meal up to 39% (Nang Thu et al, 2011) and 20% (Emadi et al., 2014). Fabrengo et al. (2010) reported that sesame seed meal of 15% instead of fish meal in the African catfish diet could be used successfully without causing any decline in the growth. Jahanbakhshi et al. (2012) indicated that the substitution compliance of sesame seed meal and corn gluten could be between 16-48% for beluga (*Huso huso*) fingerlings. Generally accepted usage rates of the vegetable protein source identified for rainbow trout are 20% soybean meal (Teles et al., 1994), 56 g/kg concentrated potato protein (Xie and Jokumsen, 1998), 10% cotton seed meal (Cheng and Hardy, 2002), 20% canola and pea flour (Thiessen et al., 2003), 20% rice protein concentrate (Palmegiano et al., 2006), 30% lupine flour (Glencross et al., 2008) and 20% safflower meal (Ustaoğlu Tiril and Kerim, 2015).

The difference between control and treatment groups in terms of SGR was statistically significant ($p < 0.05$) in this study. While the highest SGR was in C and 15SSM groups, SGR obtained from the other groups were lower. The cause of this decrease is believed to be derived from a decrease in the amount of essential amino acids in the diet. El-Sayed (1987) reported that groups were fed by sesame seed meal showed lower performance in the growth rate in the usage of sesame seed meal instead of casein/gelatin as a replacement in tilapia fry and supplementation of lysine and zinc increased the growth rates. Mukhopadhyay and Ray (1999) indicated that the best growth performance was obtained in the group fed by synthetic lysine, cystine and methionine supplementation using mustard meal with sesame seed meal and synthetic lysine, cystine and methionine supplementation instead of fish meal in Indian carp fry. The increased incorporation ratio of mucuna seed meal (*Mucuna puriens* var. utilis) with different percentage (10, 20, 30 and 40%) brought a decline in the growth rate in carp (Siddhuraju and Becker, 2001).

In the present study, sesame seed meal ratio in feed significantly affected the feed intake ($p<0.05$). Lower feed consumption was observed in the groups fed by the diet containing sesame seed meal than control group. This situation was supported by the studies of Nang Thu et al. (2007) which shows that the participation of lysine to the vegetable originated diet increased the food intake and Deng et al. (2011) which reported that participation of lysine to the diet significantly increased the total feed consumption of carp. Feed conversion ratio (FCR) related with consumed feed amount and gained live weight of fish is an important parameter affecting producers' operating costs. FCR was not affected by increasing ratio of sesame seed meal in diet according to the studies of Emadi et al. (2014) in rainbow trout, Fagbenro et al. (2010) and Enyidi et al. (2014) in African catfish. Similarily, in the present study, increasing sesame seed meal ratio up to 20% in the diet did not affect the feed conversion ratio which was between 1.03 and 1.11. Unlike these studies, Palmegiano et al. (2006) indicated that increasing rice protein concentrate meal (RPCM) ratio (0, 20, 35 and 53%) in rainbow trout diet affected FCR. While better FCR was obtained in the group fed by diet containing 20% RPCM compared to the control group, FCRs of the other two groups were higher than the control and the group fed by diet containing 20% RPCM.

According to the present study there was no significant differences between the groups in terms of protein efficiency rate (PER) ($p > 0.05$). Similarly, Emadi et al. (2014) stated that increased rate of sesame seed meal did not influence PER ratio (1.72-2.55) in rainbow trout. Enyidi et al. (2014) reported that added sesame seed meal ratio to the diet did not provide any negative impact, quite the contrary, it gave quite good results. PER ratio (2.87-2.59) was slightly affected by rising sesame seed meal up to 52% in diet (Nang Tu et al., 2011), while increasing sesame seed meal to the ratio of 45% in African catfish decreased the PER ratio to 0.93 ± 0.15 (Fagbenro et al., 2010). In these studies, a decrease in PER value is an expected situation with increasing levels of sesame seed meal in the diet. Because reduced growth rate in the groups fed by diet including 30% and 45% of sesame seed meal was reported (Fagbenro et al., 2010; Namg Tu et al., 2011; Enyidi et al., 2014) and reduced growth is an indicator for underutilization of protein in feed. The reason for the differences seen between these researches could be explained by the amount and quality of fish meal contained in the diet, protein: energy ratio of the diet and also differences of the protein quality of sesame seed meal used in the diet. Received protein by diet is an important energy source for the fish. Fish provides energy needs mostly from fats and carbohydrates between protein and energy. The protein primarily was used for protein synthesis.

The sesame seed meal ratio in the diet affected the amount of protein retained in fish. At the end of the study, while the lowest protein amounts were obtained in 10SSM and C groups, the highest protein amounts were obtained in 20SSM and 15SSM groups. In parallel, the apparent net protein retention (ANPR) were higher in 15SSM and 20SSM groups than the C and 10SSM groups. While the values obtained in this study showed similarity with the study of Emadi et al. (2014) who determined the crude protein rate of fish fillet as 24.2% in the group fed by diet containing 20% sesame seed meal, they were higher than the studies of Mukhopadhyay and Kay (1999), Jimoh et al. (2014) and Jimoh and Aroyehun (2011) who detected it as between 8.01 and 8.90%, 17.42 and 17.70%, 13.7 and 13.9%, 16.00 and 16.86%, respectively.

The highest average crude lipid ratios were between 3.37 ± 0.10% and 4.26% ± 0.21. While the highest lipid ratio was obtained in 10SSM group, there was a decrease in the crude lipid of fish fillet in 15SSM and 20SSM groups. While the values obtained from the study showed similarity with the study of Mukhopadhyay and Kay (1999) who determined the crude lipid rates of fish fillet as 4.29 to 5.24%, they were lower than the studies of Emadi et al. (2014), Jimoh et al. (2014) and Mohanta et al. (2007) who detected the crude lipid rates of fish fillet as 7.4%, between 5.73 and 5.87% and between 6.5 and 6.7%, respectively. In the above-mentioned studies, a visible reduction occurred in the crude lipid of fish fillet with increasing amount of sesame seed meal in the diet but the differences were not statistically significant (p>0.05).

Considering the amount of essential amino acids in fish fillet at the end of the study, the highest lysine amount was in the control group and the increasing level of sesame seed meal in the diet resulted decreased lysine amount. The lowest lysine amount was in 20SSM group. Methionine in all groups were almost at the same rate. The highest total essential amino acid amount was in 15SSM group. Emadi et al. (2014) reported that while the lysine amount was 2.38% in the group fed by the diet containing 20% sesame seed meal, which showed the best growth rate, comparing the control group (2.50%), the methionine amount of 1.53% in the same group was equal to the control group in rainbow trout.

The importance of the origin of the nutrients given to the fish as well as digestion rate of nutrients is great in aquaculture practice. Food digestion is important in terms of reducing production costs as it is effective on the development of the most appropriate way and as soon as possible time in the livings. Considering the values regarding to the digestibility of nutrients in the study, it was changed between 93.63 and 90.98% and differences between groups were not significant (p> 0.05). In the parellel line of the present study, Mukhopadhyay (2001) reported that protein digestion rate, which was changed between 82.51 and 88.97%, was not affected by sesame seed meal ratios in the diet. Mohanta et al. (2001) indicated that digestibility rates were between 85.51 and 90.91% in their study used sesame seed meal in the diet of Indian carp. Protein digestibility rates were between 85.51 and 90.91% in the study of Mukhopadhyay and Ray (1999). The differences in protein digestion ratios in different studies may rise due to faecal collection methods. Except this, there are also many factors such as water temperature, fish size and species.

The inclusion of sesame seed meal in the diet of rainbow trout generally produced worse result when compared to soybean based diet, although it does not negatively affect growth. However, inclusion of sesame seed meal in the diet at 15% dietary level produced similar results and the fish grew relatively well. It was thought that new studies must be considered related to the use of sesame seed meal in order to put forward the more detailed results. In particular, the anti-nutrients of sesame seed meal should be determined, new methods should be developed to reduce them and sesame seed meal treated by these methods must be re-evaluated on fish.

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REFERENCES

Arrieta, M.P. & Prats-Moya, M.S. (2012). Free amino acids and biogenic amines in Alicante Monastrell wines. *Food Chemistry,* 135:1511–1519. doi: 10.1016/j.foodchem.2012.06.008

Atalayoğlu, G. & Çakmak, M.N. (2010). Pullu Sazan (*Cyprinus carpio* L. 1843) Yemlerinde fındık küspesinin kullanılma olanaklarının araştırılması. *Fırat Üniv. Fen Bilimleri Dergisi*, 22(2):71-78.

AOAC. (1995). *Official Methods of Analysis*. 16th ed. Association of Official Analytical Chemists, Arlington, VA.

Barros, M.M., Lim, C. & Celcius, P.H. (2002). Effect of soybean meal replacement by cottonseed meal and iron supplementation on growth, immune response and resistance of channel catfish (*Ictalurus punctatus*) to *Edwardsiella ictaluri* challenge. *Aquaculture*, 207:263-279.

Bilgin, Ö., Türker, A. & Tekinay, A.A. (2007). The use of hazelnut meal as a substitute for soybean meal in the diets of rainbow trout (*Oncorhynchus mykiss*). *Turkish Journal of Veterinary and Animal Science*, 31(3):145-151.

Brown, P.B. (2008). Utilization of soy products in diets of freshwater fishes. In: Lim, C., Webster, C.D. & Lee, C.-S. (Eds), Alternatives Protein Sources in Aquaculture Diets, pp. 225-260. The Howarth Press, New-York, USA.

Caballero, M.J., Lopez-Calero, G., Socorro, J., Roo, F.J., Izquierdo, M.S. & Fernandez, A.J. (1999). Combined effect of lipid level and fish meal quality on liver histology of gilthead seabream (*Sparus aurata*). *Aquaculture,* 179:277-290.

Cheng, Z.J. & Hardy, R.W. (2002). Apparent digestibility coefficients and nutritional value of cottonseed meal for rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 212:361-372. doi: 10.1016/S0044-8486(02)00260-0

Degani, G. (2006). Digestible energy in dietary sorghum, wheat bran and rye in common carp (*Cyprinus carpio* L.). *Israeli J. Aquac.-Bamidgeh*, 58:71-77.

Deng, J., Zhang, X., Tao, L., Bi, B., Kong, L. & Lei, X. (2011). D-lysine can be effectively utilized for growth by common carp (*Cyprinus carpio*). *Aquaculture Nutrition*, 17:467-475. doi: 10.1111/j.1365-2095.2010.00783.x

De Silva, S.S. & Anderson, T.A. (1995). *Fish Nutrition in Aquaculture*. Chapman and Hall, London, 319 pp.

El-Sayed, A.F.M. (1987). Protein and energy requirements of *Tilapia zillii*. Ph.D. Thesis, Michigan State University, East Lansing, Michigan, USA.

El-Sayed, A.F.M. (1999). Alternative dietary protein sources for farmed tilapia, *Oreachromis* spp. *Aquaculture*, 170:149-168. doi: 10.1016/S0044-8486(99)00159-3

Emadi, H., Mokhayer, B. & Faal, M. (2014). Alternative role of sesame seed replacing fish meal in the diet of rainbow trout (*Oncorhynchus mykiss*) fingerlings. *Iranian Journal of Fisheries Sciences*, 13(3):608-620.

Enyidi, U.D., Pirhonen, J., Vielma, J. (2014). Effects of sesame seed meal and bambaranut meal on growth, feed utilization and body composition of juvenile African catfish *Clarias gariepinus*. *Iranian Journal of Fisheries Sciences,* 13(4):998-1013.

Facunle, J.O., Alatise, S.P., Effiong, B.N. & Tiamiyu, K. (2013). Effects of replacing Sayabeans meal with graded levels of boiles jatropha kernel meal in diets of *Clarias gariepinus* fingerlings. *Bulletin of Environment, Pharmacology anf Life Sciences*, 2(9): 112-117.

Fagbenro, O.A., Adeparusi, E.O. & Jimoh, W.A. (2010). Nutritional evaluation of sunflower and sesame seed meal in *Clarias gariepinus*: An assessment by growth performance and nutrient utilization. *African Journal of Agricultural Research*, 5(22):3096-3101.

Fagbenro, O.A., Adeparusi, E.O. & Jimoh, W.A. (2013). Haematological profile of blood of African catfish (*Clarias gariepinus* Burchell,1822) fed sunflower and sesame meal based diets. *Journal of Fisheries and Aquatic Science*, 8(1):80-86. doi: 10.3923/jfas.2013.80.86

Francis, G., Makkar, H.P.S. & Becker, K. (2001). Anti-nutritional factors present in plant derived alternative fish feed ingredients and their effects in fish. *Aquaculture*, 199:197-227.

Gaber, M.M. (2006). Partial and complete replacement of fish meal by broad bean meal in feeds for Nile tilapia, *Oreochromis niloticus*, L., fry. *Aquaculture Research*, 37:986-993. doi: 10.1111/j.1365-2109.2006.01517.x

Glencross, B., Hawkins, W., Evans, D., Rutherford, N., Dods, K., Mccafferty, P. & Sipsas, S. (2008). Evaluation of the influence of *Lupinus angustifolius* kernel meal on dietary nutrient and energy utilization efficiency by rainbow trout (*Oncorhynchus mykiss*). *Aquaculture Nutrition*, 14:129-138. doi: 10.1111/j.1365-2095.2007.00512.x

Hasan, M.R., Macintosh, D.J. & Jauncey, K. (1997). Evaluation of some plant ingredients as dietary protein sources for common carp (*Cyprinus carpio* L.) fry. *Aquaculture*, 151:55-70. doi: 10.1016/S0044-8486(96)01499-8

Hardy, R. (2008). Farmed fish diet requirements for the next decade and implacations for global availability of nutrients. In: Lim, C., Webster, C.D. & Lee, C.-S. (Eds), Alternatives Protein Sources in Aquaculture Diets, pp. 1-15. The Howarth Press, New-York, USA.

Jahanbakhshi, A., Imanpuor, M., Taghizadeh, V. & Shabani, A. (2012). Effects of replacing fish meal with plant protein (sesame oil cake and corn gluten) on growth performance, survival and carcass quality of juvenile beluga (*Huso huso*). *World Journal of Fish and Marine Sciences,* 4(4):422-425. doi: 10.5829/idosi.wjfms.2012.04.04.63107

Jimoh, W.A. & Aroyehun, H.T. (2011). Evaluation of cooked and mechanically defatted sesame (*Sesamum indicum*) seed meal as a replacer for soybean meal in the diet of African catfish (*Clarias gariepinus*). *Turkish Journal of Fisheries and Aquatic Sciences*, 11:185-190. doi: 10.4194/trjfas.2011.0202

Jimoh, W.A., Fagbenro, O.A. & Adeparusi, E.O. (2014). Response of African catfish, *Clarias gariepinus* (Burchell 1822), fingerlings fed diets containing differently timed wet-heat-treated sesame (*Sesamum indicum*) seed meal. *Agricultural Sciences*, 5:1159-1171. doi: 10.4236/as.2014.512126

Lim, C. & Akiyama, D.M. (1992). Full-fat soybean meal utilization fry fish. *Asian Fisheries Science,* 5:181-197.

Lowell, R.T. (1988). Use of soybean products in diets for aquaculture species. *J. Aqua. Prod.*, 2:27-52.

Mohanta, K.N., Mohanty, S.N., Jena1, J. & Sahu, N.P. (2007). Effect of different oil cake sources on growth, nutrient retention and digestibility, muscle nucleic acid content, gut enzyme activities and whole-body composition in silver barb, *Puntius gonionotus* fingerlings. *Aquaculture Research*, 38:1702-1713. doi: 10.1111/j.1365-2109.2007.01836.x

Mukhopadhyay, N. & Ray, A.K. (1999). Improvement of quality of sesame Seasamum indicum seed meal protein with supplemental amino acids in feeds for rohu *Labeo rohita* (Hamilton) fingerlings. *Aquaculture Research*, 30:549-557.

Mukhopadhyay, N. (2001). Effect of fermentation on apparent total and nutrient digestibility of sesame (*Sesamum indicum*) seed meal in rohu, *Labeo Rohita* (Hamilton) fingerlings. *Acta Ichthyol. Piscat.,* 31:19–28.

Nang Thu, T.T., Parkouda, C., Saeger, S., Larondelle, Y. & Rollin, X. (2007). Comparison of the lysine utilization efficiency in different plant protein sources supplemented with l-lysine HCl in rainbow trout (*Oncorhynchus mykiss*) fry. *Aquaculture*, 272: 477-488. doi: 10.1016/j.aquaculture.2007.06.032

Nang Thu, T.T., Bodin, N., Saeger, S., Larondelle, Y. & Rollin, X. (2011). Substitution of fish meal by sesame oil cake (*Sesamum indicum* L.) in the diet of rainbow trout (*Oncorhynchus mykiss* W.). *Aquaculture Nutrition*, 17:80-89. doi: 10.111/j.1365-2095.2009.00732.x

NRC (National Research Council) (1993). *Nutrient requirement of fish.* National Academy Press, Washington D.C.

Onsaard, E., Pomsamud, P. & Audtum, P. (2010). Functional properties of sesame protein concentrates from sesame meal. *Asian Journal of Food and Agro-Industry,* 3(4):420-431.

Onsaard, E. (2012) Sesame proteins. *International Food Research Journal*, 19(4):1287-1295.

Palmegiano, G.B., Dapra, F., Forneris, G., Gai, F., Gasco, L., Guo, K., Peiretti, P.G., Sicuro, B. & Zoccarato, I. (2006). Rice protein concentrate meal as a potential ingredient in practical diets for rainbow trout (*Oncorhynchus mykiss*). *Aquaculture*, 258:357-367. doi: 10.1016/j.aquaculture.2006.04.011

Petry, H. & Rapp, W. (1970). Zur problematik der chromixidbestimmung in verdauunsversuchen. *Z. Tierphysiol. Tieremahrung u. Futtermittelkunde,* 27:181-189.

Rama Roa, S.V., Raju, M.V.L.N., Panda, A.K., Poonam, N.S., Shyam Sunder, G. & Sharma, R.P. (2008). Utilization of sesame (*Sesamum indicum*) seed meal in broiler chicken diets. *British Poultry Science*, 49(1):81-85. doi: 10.1080/00071660701827888

Reigh, R.C. (2008). Underutilized and unconventional plant protein supplements. In: Alternatives Protein Sources in Aquaculture Diets (Lim, C., Webster, C.D. & Lee, C.-S. Eds), pp. 433-474. The Howarth Press, New-York, USA.

Sargent, J.R. & Tacon, A.G.J. (1999). Development of farmed fish: a nutritionally necessary alternative to meat. *Proc. Nutr. Soc.*, 58:377-383.

Sanz, A., Morales, A.E., Higuera, M. & Cardenete, G. (1994). Sunflower meal compared with soybean meal as substitutes for fish meal in rainbow trout (*Oncorhynchus mykiss mykiss)* diets: protein and energy utilization. *Aquaculture*, 128:287-300. doi: 10.1016/0044-8486(94)90318-2

Siddhuraju, P. & Becker, K. (2001). Preliminary nutritional evaluation of mucuna seedmeal (*Mucuna pruriens var. utilis*) in common carp (*Cyprinus carpio* L.): an assessment by growth performance and feed utilization. *Aquaculture*, 196:105-123. doi: 10.1016/S0044-8486(00)00577-9

Sindelar, S.C. (2014). Utilisation of soybean products as fish-meal protein replacements in yellow perch *Perca flavescens* feeds. Master Thesis, South Dakota State University, South Dakota, USA.

Storebakken, T., Refstie, S. & Ruyter, B. (2000). Soy-product as fat and protein sources in fish feeds for intensive aquaculture. In: Drackly, J.K. (Ed), soy in Animal Nutrition_Federation of Animal Science Societies Savoy II. P. 127-170.

Tacon, A.G.J. (1993). Feed ingredients for warm water fish. Fish meal and other processed feedstuffs. FAO Fisheries Circular no. 856. FAO, Rome.

Teles, A.O., Gouveia, A.J., Gomes, E. & Rema, P. (1994). The Effect of processing treatments on soybean meal utilization by rainbow trout, *Oncorhynchus mykiss. Aquaculture,* 124(1-4):343-349. doi: 10.1016/0044-8486(94)90407-3

Thiessen, D.L., Campbell, G.L. & Adelizi, P.D. (2003). Digestibility and growth performance of juvenile rainbow trout (*Oncorhynchus mykiss*) fed with pea and canola products. *Aquaculture Nutrition*, 9:67-75. doi: 10.1046/j.1365-2095.2003.00203.x

Ustaoglu Tiril, S. & Kerim, M. (2015). Evaluation of safflower meal as a protein source in diets of rainbow trout [*Oncorhynchus mykiss*, Walbaum, 1792)]. *Journal of Appl. Ichthyol.*, 31:895–899. doi: 10.1111/jai.12807

Xie, S. & Jokumsen, A. (1998). Effects of dietary incorporation of potato protein concentrate and supplementation of methionine on growth and feed utilization of rainbow trout. *Aquaculture Nutrition*, 4:183-186. doi: 10.1046/j.1365-2095.1998.00066.x

Yıldırım, Ö., Acar, Ü., Türker, A., Sunar, M.C. & Kesbiç, O.S. (2014). Effects of replacing fish meal with peanut meal (*Arachis hypogaea*) on growth, feed utilization and body composition of Mozambique tilapia fries (*Oreochromis mossambicus*). *Pakistan J. Zool.,* 46(2):497-502.

Yiğit, N.Ö., Bahadır Koca, S., Bayrak, H., Dulluç, A. & Diler, I. (2012). Effects of canola meal on growth and digestion of rainbow trout (*Oncorhynchus mykiss*) fry. *Turk. J. Vet. Anim. Sci.,* 36(5):533-538. doi: 10.3906/vet-1101-705