

Partial replacement of soybean meal by peanut and sesame seed meals in practical diets for rainbow trout, *oncorhynchus mykiss*

Abstract

This study was conducted to evaluate the partial replacement of soybean meal by sesame seed and peanut meals in practical diets for rainbow trout (*Oncorhynchus mykiss*). Four isonitrogenous (44% protein) and isolipidic (19% lipid) diets were formulated. The trial diets were prepared to include 10% sesame seed meal (S_{10}), 10% peanut meal (P_{10}), 5% sesame seed meal+5% peanut meal mix (SP_{10}) and a control (C) with no replacement of soybean meal. There were four dietary treatments, with three replicates for each treatment. The fish (initial average weight; 79.86 ± 0.14 g) were hand-fed twice a day to apparent satiety under a natural light regime for 65 days. At the end of experiment, the best growth was determined in SP_{10} group ($p < 0.05$). The growth performance of S_{10} and P_{10} groups was significantly lower than control and SP_{10} groups ($p < 0.05$). The hepatosomatic index (HSI) and viscerosomatic index (VSI) values were not affected from the protein sources in the diets ($p > 0.05$). Comparing to the initial sample, the moisture, protein, lipid and ash contents in the body composition of the fish increased in all experimental groups and were not significantly differed among the groups ($p > 0.05$). In the crude protein digestibility was no differences in among groups ($p > 0.05$), but the highest apparent protein digestibility coefficients were determined for C (91.26%) and SP_{10} (91.93%) groups. The present results demonstrated that 10% sesame seed meal and peanut meal could be used in diets of rainbow trout without any negative effects on growth. The results showed that using these protein sources together may provide better results rather than using them alone.

Keywords: Feed formulation, Proximate composition, Sesame seed, Peanut, Alternative protein source

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Abbreviations: S_{10} , 10% Sesame Seed Meal; P_{10} , 10% Peanut Meal; SP_{10} , 5% Sesame Seed Meal+5% Peanut Meal Mix; C, Control; ANFs, Anti-Nutritional Factors; ADC, The Apparent Digestibility Coefficient; ADCprotein, Apparent Protein Digestibility Values; FBW, Final Body Weight; WG, Weight Gain; FCR, Feed Conversion Rate; SGR, Specific Growth Rate; PER, Protein Efficiency Rate; VSI, Viscerosomatic Index; HSI, Hepatosomatic Index; Cr_2O_3 , Chromic Oxide; EAA, Essential Amino Acids; NEAA, Non-Essential Amino Acids.

Introduction

The aquaculture sector is developing more effectively than other food production sectors. However, economic factors such as feed cost are inhibiting development. Fish meal has resulted in its wide inclusion as the main protein source in diets for fish culture, because of its high protein content, palatability and well balanced amino acid profile. Nevertheless, in the near future, the production of such protein will not be enough to cover the increasing demand of this ingredient for animal diets.^{1,2} In recent research, it has been shown that many plant protein sources has potential protein source in fish feed and was utilized successfully in many experimental aquaculture diets.³ Therefore, concerning the more common usage and usability of the fish meal for fish feed is restricted by increasing demand for human consumption and by other animal feed industries.⁴ This phenomenon has support the requirement search for cheaper alternative protein source for the improving of low-cost feed that can replace traditional feedstuff without reducing the nutritional quality of the diets.⁵

Soybean meal has high protein content, better amino acid composition and the best protein quality among other plant protein

feedstuffs used in fish feeds.⁶ Thus, it is among the most preferred plant protein sources in the diet poultry and swine all over the world⁷ and currently the most commonly used plant protein source in fish feed.⁸ But like fish meal, the soybean meal is also expensive⁹ and the usage of soybean meal increases greatly feed costs. More work is required to detect alternative protein-rich feed ingredients suitable for cultured fish.¹⁰

Due to increases in cost and global demand of fish meal and soybean meal, the usage of other vegetable proteins in fish diets has become more widespread in recent years.³ 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.^{4,11}

Despite the large number of studies carried out in this subject, in general made studies are based on the use of vegetable protein sources partially or totally replacement of fish meal. Therefore, the objective of the present study was to evaluate the effects of partial replacement of soybean meal by sesame seed and peanut meal in diets for rainbow trout (*Oncorhynchus mykiss*) on the growth performance, feed utilization and body composition.

Materials and methods

Fish maintenance and experimental planned

The experiment was conducted at an indoor facility of the Faculty of Fisheries, University of Sinop (Sinop/Turkey). Experimental fish were obtained from a commercial trout farm (Kuzey Fish Farm Inc.) in Samsun/Turkey and acclimated in three 1000 L rectangle fiberglass

tanks for two weeks before the experiment. During the acclimation, the fish were fed with a commercial trout feed (Black Sea Feed) two times a day by hand according to apparent satiation. After acclimatization, fish (initial mean weight of 79.86 ± 0.14 g) were fasted for a day, individually weighted to the nearest 1g, and randomly distributed twelve circular fiberglass tanks (water volume of 300 L) at 13 fish per tank with three replicates. Water flow rate was adjusted to 4 L min⁻¹ and additional aeration was supplied via air stone. The water quality parameters were monitored on weekly basis and average temperature, dissolved oxygen and pH were $15.92 \pm 0.09^{\circ}\text{C}$, 6.77 ± 0.77 mg /L and 8.15. At the beginning (20 fish) and at the end (5 fish from each tank) of the study, the fish were killed with overdose anaesthetics (clove oil). Fillet samples taken from the lower part of dorsal fin were removed for homogenization and analyzed.

Diet formulation and preparation

Feed ingredients were supplied by a domestic fish feed producer (Sibal Inc., Black Sea Feed, Sinop /Turkey). Sesame seed meal and peanut meal were obtained from commercial firms (Filiz Confectionery & Food Inc., Samsun/Turkey; Başpınar Peanuts, Crops and Transport Inc., Osmaniye/Turkey, respectively). Sesame seed meal and peanut meal in the experiment feeds was prepared by chancing with 10% of soybean meal. Nutrient composition of the feed ingredients was shown in Table 1. Four experimental diets (a control no containing peanut and sesame seed meal (C), 10% sesame seed meal (S₁₀), 10% peanut meal (P₁₀) and 5% sesame seed meal+5%peanut meal mix (SP₁₀)] were formulated (Table 2). Amino acid composition of the experimental diets was shown in Table 3. Chromic oxide (Cr₂O₃) was added into the diets as a marker at a concentration of 0.5% to detect the apparent digestibility of the diets. Feed ingredients were fully 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 almost 5 mm in length. Amino acid composition of experimental diet and muscles were analysed in triplicate following acid hydrolysis using pressure liquid chromatography (Agilent 1100 Series HPLC System) on a dry weight basis.¹² All feeds were stored -40°C in plastic bags until the feeding.

Feeding and faecal collection

The study was conducted in triplicates in a randomly assigned tanks. During experimental period, fish in all groups were fed by hand to satiation twice a day (at 09:00 am and 16:00 pm) under a natural light regime for 65 days. Fish were fed slowly and carefully so that no uneaten feed stayed on the tank bottoms. The tanks were completely cleaned after each feeding. Before the trial, the fish were subjected to a 1-week adaptation period. Faecal samples were gathered by slow siphoning with an 8 mm plastic tube after 1 h from each feeding and frozen quickly at -40°C until analysis.

Proximate composition

The proximate composition of feed ingredients, experimental diets, fish samples and faeces were analyzed as follows: dry matter after drying in an oven at 105°C until constant weight; crude protein (N x 6.25) by Kjeldahl method after acid digestion; crude lipid by petroleum ether extraction in a Soxhlet apparatus and crude ash by incineration in a muffle furnace at 550°C for 6 hours by the standard methods of AOAC.¹³ Chromium oxide in the diet and faeces was detected spectrophotometrically according to Petry and Rapp.¹⁴ Apparent protein digestibility coefficients were calculated as ADC (%) = $100 - [100 (\% \text{ Cr}_2\text{O}_3 \text{ in diet} / \% \text{ Cr}_2\text{O}_3 \text{ in faeces}) \times (\% \text{ nutrient}$

in faeces/% nutrient in diet)] as per Degani.¹⁵ Gross energy of the diets was forecasted supposing 23.6 kJ/g protein, 39.5 kJ/g lipid and 17 kJ/g nitrogen free extracts. All analyses were done in triplicate.

Calculations

The following calculations were made:
Feed conversion rate (FCR) = total feed intake/weight gain
Specific growth rate (SGR) (% day⁻¹) = $[(\ln \text{ initial weight} - \ln \text{ final weight}) / \text{days}] \times 100$
Protein efficiency rate (PER) = wet weight gain/protein fed
Hepatosomatic index (HSI) (%) = (liver weight / body weight) x 100
Viscerasomatic index (VSI) (%) = (viscera weight/body weight) x 100

Statistical analysis

Statistical analysis included one-way analysis of variance (ANOVA) and Tukey's multiple significant difference tests using the software program (Minitab 13.0 for Windows). Arcsine square root transformations of percentage data were conducted for homogeneity of variances before statistical analysis. A p-value <0.05 was considered as significant.

Results

Biochemical and amino acid compositions of experimental diets

Nutrient composition of the feed ingredients was presented in Table 1. The chemical and amino acid composition of experimental diets were shown in Table 2 and Table 3, respectively. The best total essential amino acid composition of the experimental diets was determined in SP₁₀ diet. The highest lysine amount was also seen in SP₁₀ diet. The methionine amounts of the C and SP₁₀ diets were higher than the S₁₀ and P₁₀ diets.

Growth performance

The fish accepted all the experimental diets and no mortalities occurred during the experiment. The best final body weight (FBW), weight gain (WG) feed conversion rate (FCR), specific growth rate (SGR) and protein efficiency rate (PER) were determined in SP₁₀ and control (C) groups, respectively (p<0.05). The viscerasomatic index (VSI) and hepatosomatic index (HSI) values were not affected from the different plant protein sources in the diets (p>0.05). The highest HSI and VSI were in S₁₀ group (Table 4).

Digestibility

Apparent protein digestibility values (ADCprotein) was given in Table 5. ADCprotein values were similar in C, S₁₀, P₁₀ and SP₁₀ groups. There were no statistically significant differences in the digestibility of protein among the experimental groups (p>0.05).

Biochemical and amino acid composition of muscle

There was significant differences between the initial and final body composition of fish in all experimental groups in terms of moisture, protein, lipid and ash contents (Table 6) (p<0.05). There was no statistically significant differences among final body composition of fish in all experimental groups (p>0.05). Although protein contents of fish in C and SP₁₀ groups was higher than fish in S₁₀ and P₁₀ groups, there was no significant difference between them (p>0.05). The amino acid composition of muscle from rainbow trout fed experimental diets was shown in Table 7.

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	21	36	8.90
Peanut meal	5.7	30.6	10.35	7.52
Corn gluten	9.86	58.5	1.93	2.89

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

	Experimental Diets			
	C	S ₁₀	P ₁₀	SP ₁₀
Ingredients (g kg⁻¹)				
Fish meal	331.5	331.5	331.5	331.5
Extracted soybean meal	250	190	190	190
Wheat flour	130	130	110	120
Corn gluten	150	150	150	150
Sesame seed meal	0	100	0	50
Peanut meal	0	0	100	50
Fish oil	130	90	110	100
Vitamin premix(*)	2	2	2	2
Mineral premix(*)	1.5	1.5	1.5	1.5
Chromic oxide (Cr2O3)	5	5	5	5
Proximate Composition (%)				
Dry matter	95.71	94.74	94.64	94.81
Protein	44.28	43.93	44.45	44.45
Lipid	19.1	19.6	19.3	19.2
Ash	6.35	7.34	6.96	7.03
NFE+Crude fiber ¹	25.98	23.97	23.93	24.13
Gross energy(kJ g ⁻¹) ²	22.41	22.17	22.18	22.14

*Vitamin-mineral premix (mcg/kg premix): vitamin A, 210000 IU; Vitamin D₃, 35000 IU; vitamin E, 7000 mcg; vitamin K₃, 322 mcg; vitamin B₁, 588 mcg; vitamin B₂, 252 mcg; vitamin B₆, 294 mg; vitamin B₁₂, 826 mcg; niacin, 1400 mcg; biotin, 7583 mcg; 182 mcg folic acid, pantothenic acid, 1722 mcg; inositol, 17220 mcg; vitamin C, 933.31 mcg; Ca, 1414mcg.

¹NFE+Crude fiber=100-(%protein+ %lipid+ %ash+ %moisture)

²Gross 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)

	Diet Groups			
	C	S ₁₀	P ₁₀	SP ₁₀
Essential Amino Acids (EAA, g/100g)				
Histidine	1.89	1.40	2.41	2.29
Isoleucine	1.84	1.53	1.41	1.73
Leucine	4.35	3.64	3.13	3.95
Lysine	1.00	1.12	0.88	1.85
Methionine	0.79	0.44	0.60	0.72
Phenylalanine	2.24	1.82	1.70	2.01
Threonine	1.96	1.98	2.85	3.00
Valine	1.23	0.94	1.15	0.98
Total	15.3	12.87	14.13	16.53
Non-essential amino acids(NEAA, g/100g)				
Alanine	3.22	2.33	3.45	3.23
Aspartic acid	5.30	6.90	5.16	4.53
Glutamic acid	9.51	11.07	7.58	7.90
Glycine	1.63	1.04	2.88	2.08
Serine	2.96	1.98	4.18	2.52
Tyrosine	1.90	1.97	1.78	1.71
Total	24.52	25.29	25.03	21.97

Table 4 Growth performance, feed efficiency and other body parameters in rainbow trout fed the experimental diets

Parameters	C	S ₁₀	P ₁₀	SP ₁₀
Initial body weight (g)	79.79±0.33	79.87±0.40	79.54±0.63	80.23±0.49
Final body weight (g)	200.72±7.97 ^a	184.41±3.55 ^b	183.94±16.42 ^b	213.54±6.31 ^c
Weight gain (g)	120.92±8.24 ^a	104.54±3.17 ^b	104.40±16.87 ^b	133.31±6.49 ^c
FCR	1.16±0.02 ^a	1.30±0.04 ^b	1.23±0.14 ^b	1.10±0.04 ^a
SGR (% day ⁻¹)	1.64±0.08 ^a	1.49±0.03 ^b	1.48±0.17 ^b	1.75±0.06 ^c
PER	2.73±0.19 ^a	2.38±0.07 ^b	2.36±0.38 ^b	3.01±0.14 ^c
HSI (%)	1.61±0.10	1.66±0.16	1.68±0.10	1.56±0.12
VSI (%)	10.45±0.24	10.67±0.45	11.20±0.30	10.74±0.20

Different superscripts within the row denote significant differences.

Table 5 Apparent digestibility coefficients (ADCs) of dry matter and protein in diets

Parameters	Diet groups			
	C	S ₁₀	P ₁₀	SP ₁₀
Dry matter (%)	77.12±2.38 ^a	72.38±3.64 ^b	73.84±2.40 ^b	77.92±0.79 ^a
Crude Protein (%)	91.29±0.80 ^a	89.76±1.50 ^a	89.97±0.94 ^a	91.93±0.24 ^a

Table 6 Chemical composition of muscle of rainbow trout fed the experimental diets (% wet weight)

Parameters	Initial	C	S ₁₀	P ₁₀	SP ₁₀
Moisture (%)	78.09±0.29 ^a	73.58±0.41 ^b	73.75±0.07 ^b	74.61±0.25 ^b	74.28±0.13 ^b
Protein (%)	18.24±0.01 ^a	21.39±0.05 ^b	20.49±0.03 ^b	20.49±0.04 ^b	21.19±0.46 ^b
Lipid (%)	3.39±0.01 ^a	4.70±0.28 ^b	4.46±0.33 ^b	4.04±0.03 ^b	4.51±0.22 ^b
Ash (%)	1.36±0.01 ^a	1.73±0.04 ^b	1.68±0.07 ^b	1.68±0.02 ^b	1.73±0.04 ^b

Different superscripts within the row denote significant differences.

Table 7 Amino acid composition of muscle from rainbow trout fed experimental diets (g/100g dry weight)

Diet Groups					
	Initial	C	S ₁₀	P ₁₀	SP ₁₀
Essential amino acids (EAA, g/100g)					
Histidine	2.09	2.31	2.15	2.58	2.63
Isoleucine	3.54	3.80	3.63	3.41	3.86
Leucine	7.65	7.25	7.15	7.10	7.62
Lysine	3.55	2.93	5.12	5.85	2.74
Methionine	1.73	1.99	2.35	1.37	2.01
Phenylalanine	3.43	3.70	3.17	3.36	3.82
Threonine	6.50	4.59	4.41	6.03	6.30
Valine	2.73	2.62	2.73	1.92	3.24
Total	31.22	29.19	30.71	31.62	32.22
Non-essential amino acids(NEAA, g/100g)					
Alanine	6.64	5.32	5.41	5.79	6.53
Aspartic acid	11.18	11.67	13.02	11.55	11.07
Glutamic acid	14.78	13.70	13.41	13.15	13.07
Glycine	3.69	3.01	2.49	3.90	3.05
Serine	4.05	3.69	3.75	3.71	3.97
Tyrosine	3.10	3.33	3.04	2.10	3.19
Total	43.44	40.72	41.12	40.20	40.88

Discussion

Although a significant amount of research was conducted on the replacement of fish meal with soybean meal or other plant meals as a protein source in feeds for rainbow trout, this research was regulated on the replacement of soybean meal by sesame seed meal and peanut meal in rainbow trout diet. The results of the present study indicated that sesame seed meal, peanut meal and sesame seed+peanut meals mix could be united in the diets of rainbow trout at a level of 10% as a replacer for soybean meal, without having any significant negative effect on growth or feed utilization.

It is reported that inclusion of higher levels of vegetable ingredients in salmonids diets has adverse effect on fish performance.^{16,17,18} Plant protein meals contain anti-nutritional factors (ANFs) and these cause reduce in growth performance and feed efficiency,¹⁹ and affect digestive enzyme activity and digestion/absorption capacity of animal.²⁰ In the present study, reduction in growth and high feed conversion ratios were observed in fish of S₁₀ and P₁₀ groups. This reduction in the growth could be related, not only to dietary amino acid profile, but also to the presence of ANFs. Additionally, it is probably that the lower weight gain observed in the fish of S₁₀ and P₁₀ groups may have been resulted from lower consumption of those diets. This observation agrees with

the findings of Jimoh and Aroyehun⁵ for African catfish (*Clarias gariepinus*) fed sesame seed meal-based diet. Davies et al.²¹ declared that high participation levels of some oilseed meals resulted in poor growth and feed utilization by Nile tilapia (*Oreochromis niloticus*). Also, in the current study, comparing with the control, the best growth and FCR were obtained from SP₁₀ group. At the same time, the highest SGR and PER were also observed in SP₁₀ group.

HSI is an index that is used to investigate the effects of feeding on the liver, which is a key organ for metabolism and the standard HSI value for Osteichthyes is 1-2%²² In this study, fish fed different diets did not show any significant differences in HSI which agreed with some existing literature on rainbow trout.^{23,17,24,18} In present study, no significant differences in VSI were present among fish of different dietary groups. Similar results were reported by Francesco et al.,¹⁶ Palmegiano et al.¹⁷ and Jalili et al.¹⁸ Although the study period is the same as the current study, the VSI results of the present study were low from those of Jalili et al.¹⁸ who reported that may have been due to the short experimental period (60 days). However, our results were similar with those of Francesco et al.¹⁶ and Palmegiano et al.¹⁷ although the trial periods were longer than those of the present study (24 weeks and 96 days, respectively). Therefore, the VSI value could be associated with the content and effective use of the feed, not the length or shortness of the trial period.

The proximate analysis of this study indicated that moisture, lipid, protein and ash content of muscle samples were not affected by the dietary plant protein levels. In previous studies with rainbow trout and other fish species, it has been shown that the partial or total replacement of soybean meal with plant protein sources (canola meal, sunflower meal, cotton seed meal, hazelnut meal, safflower meal, DDGS (distillers dried grains with solubles) or faba beans) had no adverse effects on the body composition.²⁵⁻³⁰

The apparent digestibility coefficient (ADC) of the in all diets were quite high (ranging from 72.38 to 77.92%), but the ADC values in fish of C and SP₁₀ groups were the highest than S₁₀ and P₁₀ groups. The ADC of protein in the present study were same and quite high (89.76-91.93%), indicating efficiency of the ingredients in the experiment diets. Digestibility values in fish normally range 75-95% for protein.⁶ The rates in the present study were within these limits. The results of this study on the protein digestibility were similar to previous studies using other plant protein sources, e.g. with pea and canola meal,²³ groundnut oil cake, soybean, mustard, sesame seed and sunflower meal,³¹ hazelnut meal,^{25,32} casava leaf meal, soybean meal, groundnut cake and sesame husk meal,³³ sunflower and sesame seed meal,³⁴ canola meal, soybean meal, DDGS, corn gluten feed, corn germ meal.³⁵

Consequently, results of this study showed that coexistence of sesame seed and peanut meals in rations could replace with soybean meal without any adverse effects on growth rates and feed efficiency.

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Conflicts of interest

None.

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