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Effects of the Feeds Containing Hazelnut Meal as Plant Protein Source on Growth Performance and Body Composition of Siberian sturgeon (*Acipenser baeri*) and Economic Profitability Value

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Abstract: In this study, the effects of feeding with the diets containing hazelnut meal (HM) at different levels (0%, 15%, 30%, and 45%) on the growth performance and body composition of Siberian sturgeon were investigated. The study was carried out for 90 days with 3 replicates (n = 15; 283.1 ± 6.52 g fish weight). The highest weight gain (180.62 ± 2.84%) was observed in the control group followed by 15%, 30%, and 45% HM. When the groups were evaluated in terms of SGR, FCR, and PER, the control group was observed to have the best performance. The control group and the 15% HM group, which were statistically similar, were found to be different from the other groups ($P < 0.05$). The statistical difference between the control group and the 45% HM group of HSI values was significant ($P < 0.05$). CP, CF, and GE values were found to be similar in the control group and 15% HM groups and different from other groups ($P < 0.05$). Finally, it was concluded that adding 15% HM to the diet would positively affect fish growth in terms of growth performance, ECR, meat quality, and body composition, but considering the economic performance, it is determined that the rate of HM can be increased up to 45%.

Key words: Siberian sturgeon, *Acipenser baerii,* hazelnut meal, growth, feed conversion ratio, economic efficiency ratio, economic profit index

1. Introduction

Sturgeons are known as a species with high potential for aquaculture, as well as their high ecologic and economic value. Cultivation studies on sturgeons have been concentrated on issues such as growth, nutrition, and environmental requirements. Feeds used in the breeding of sturgeons are commercial trout feeds. Commercial feed production that can meet the nutritional requirements of this species is not available yet.

An important part of the cost of all operating expenses in aquaculture is feed costs. To ensure economical fish farming, it is necessary to reduce the cost of feed and prepare stable rations that contain nutritional requirements of fish and are easily digestible by fish. Fish meal is the most valuable feed ingredient for fish rations, with the ideal amino acids and fatty acids composition [1].

Fish meal is used not only in fish feed but also as a protein source in poultry and cattle feeds. However, in recent years, it has been understood that the amount of feed obtained from natural fish stocks cannot be increased further. The need to use more of the existing production in human nutrition has also reduced the amount of fish meal production. Thus, feed producers started to import fish meal. Moreover, researchers have sought to search for cheap, readily available supplemental or alternative protein sources that could meet protein needs instead of fish meal, which accounts for the vast majority of the ration. For this purpose, it is desired that any feed ingredient added to the ration does not have a harmful effect on fish growth, and has the necessary essential amino acid (EAA) content to provide optimum fish growth and high protein digestion [2–4].

Hazelnut is a type of crop that has a high economic value for Turkey. Hazelnut meal resulting from industrial production of oil as a by-product is impressive in terms of high protein content. Turkey ranks first in hazelnut production and exports in the world. Turkey accounts for 80% of world production and about 70% of the world exports. Hazelnut is a product that is readily available in the Black Sea region. Therefore, hazelnut meal is a convenient source of plant protein for aquaculture in Turkey. Research aiming to use hazelnut meal in the feeds of some fish species with different biological needs and dietary habits is present [5–11]. However, no study that

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focuses on the success of using hazelnut meal in the feed of Siberian sturgeon, a species with a high economical value and carnivorous feeding habit, could be found.

In this study, it was aimed to investigate the usability of hazelnut meal, a by-product of hazelnut oil industry, instead of fish meal, which is more expensive and can also be used as human food, in Siberian sturgeon (*A. baerii*) rations.

2. Materials and methods

2.1. Experimental fish and rearing system

The study was carried out at Recep Tayyip Erdoğan University Aquaculture Application and Research Center. Stream water was used in 12 rectangular fiberglass tanks with a volume of 500 L and dimensions of 1.15 × 1.15 × 0.6 m in three replicates. All of the tanks were run with equal water not less than 0.5 L/min per 1 kg of fish. The amount of dissolved oxygen in the water in the tanks was increased using airstones (aquarium bubblers). In addition, the physical and chemical parameters of the water used in tanks were ensured as shown by Gultekin et al. [12]. The mean water temperature, dissolved oxygen amount, pH, and conductivity values were 14.5 ± 1.03 °C, 10.5 ± 22.15 mg/L, 7.2 ± 14.06, and 135.3 ± 31.24 µS/cm, respectively. The fish placed in the experimental environment were fed with commercial trout feed for adaptation to the environment for a period of 6 days. At the beginning of the experiment, 180 fish with an average weight of 283.1 ± 6.52 g were randomly selected from the stock tank, and 15 fish were placed in each experimental tank. The experimental groups were fed at 2% of their live weight during 15-day periods. The prepared feeds were administered to the groups with a frequency of 3 meals/day (at 09:00 in the morning, at 13:00 at noon, and at 17:00 in the evening) by hand. Uneaten feed was removed from the tanks with siphoning, and the feed conversion ratios (FCR) in the groups were calculated based on the consumed feed.

The trial was conducted for 90 days. In order to determine the level of use of hazelnut meal in the feeds of Siberian sturgeon (*A. bareii*), a total of 4 different study groups were formed, one being the control group. Each group was studied in 3 replicates. Research rations were established using hazelnut meal (HM), with the rates of 0%, 15%, 30%, and 45% in the control, HM 15, HM 30, and HM 45 groups, respectively.

Fish development was followed at 15-day intervals. Individual weights were determined in tared containers with a precision of 1 g by digital scale. Fish sizes were measured using the Von Bayer method [13] with a precision of 1 mm.

At the beginning and end of the experiment, the slaughtering efficiency of the samples taken at random from each of the tanks was determined using the protocol given by Moccia et al. [14]. Head, fins, carcass weights, liver weights, and internal organ weights were measured in the order given. In addition, the data obtained by determining dry matter of muscle, crude ash, crude oil, crude protein, and moisture were evaluated. Amino acid and fatty acid analyses of the feed ingredients and the experimental feeds were carried out in Kazlıçeşme R&D Test Laboratory, İstanbul.

2.2. Experimental diets

In addition to fishmeal—the primary protein ingredient of rations—and hazelnut meal, corn gluten and bonkalit were used in the experiments.

Before preparing the feeds to be used in the study, the basic nutrient contents (dry matter, crude protein, crude lipid, crude cellulose, crude ash, and nitrogen-free extract) of each ingredient were analyzed, after the ingredients that would form the blend were homogenized (Table 1).

Using these values, 4 isonitrogenic (containing 43% crude protein) experimental feeds containing 0% (control), 15%, 30%, and 45% hazelnut meal were prepared (Table 2). The amino acid contents of the prepared feeds are given in Table 3.

During the preparation of the feed, the feed ingredients were ground and sieved through a mesh size of 500 µm. The ingredients were weighed with a digital scale accurate to ±1 g, and the prepared mixture was blended for 10 min. Fish oil was added into the mixture, and the

Table 1. Proximate analyses of fishmeal, hazelnut meal, bonkalit, and corn gluten (%).

Ingredients	Moisture	CP	CL	CC	CA	NFE[1]
Fish meal	10.0	67.0	13.35	0.1	9.0	0.55
Hazelnut meal	8.7	42.1	2.26	10.1	8.2	28.64
Bonkalit	9.1	13.4	3.13	9.3	1.9	63.17
Corn gluten	9.8	60.0	1.97	2.2	1.5	24.53

CP: Crude protein, CL: Crude lipid, CC: Crude cellulose, CA: Crude ash, NFE: Nitrogen free extracts
[1]Nitrogen free extracts = matter – (crude lipid + crude cellulose + crude ash + crude protein).

Table 2. Formulation, proximate composition, and energy content (kJ/g feed) of the experimental diets.

Ingredients (DM%)	Dietary protein level (%)			
	Control	HM 15	HM 30	HM 45
Fishmeal	60	45	30	15
Hazelnut meal (defatted)	0	15	30	45
Bonkalit	25.8	18.6	9.8	1
Corn gluten	0.2	7	15	23.4
Fish oil	10.8	11.2	12	12.4
[1]Vitamin mixture	0.2	0.2	0.2	0.2
[2]Mineral mixture	1	1	1	1
Methionine	0.4	0.4	0.4	0.4
Lysine	0.6	0.6	0.6	0.6
Molasses	1	1	1	1
Chemical composition				
Moisture (%)	9.1 ± 1.18	9.0 ± 1.85	9.1 ± 0.15	9.0 ± 1.63
Crude protein (%)	43.2 ± 0.22	43.2 ± 0.41	43.2 ± 0.18	43.2 ± 0.97
Crude lipid (%)	15.6 ± 0.05	15.5 ± 0.08	15.6 ± 0.37	15.5 ± 0.06
Crude ash (%)	8.2 ± 0.24	8.2 ± 0.15	8.1 ± 0.21	7.9 ± 0.18
[3]NFE (%)	22.8 ± 0.10	23.0 ± 0.07	24.1 ± 0.11	24.6 ± 0.05
[4]GE (kJ/g feed)	4.9 ± 0.11	4.8 ± 0.06	4.9 ± 0.12	4.9 ± 0.09

HM: hazelnut meal
[1]Vitamin mixture: Included per kg; Vitamin A 20,000,000 IU, Vitamin D3 2,000,000 IU, Vitamin E 200,000 mg, Vitamin K 312,000 mg, Vitamin B1 20,000 mg, Vitamin B2 30,000 mg, Vitamin B6 20,000 mg, Vitamin B12 50 mg, Vitamin C 200,000 mg, Niacin 200,000 mg, Cal.D.Panth. 50,000 mg, Folic acid 6000 mg, D-Biotin 500 mg, Cholin Chloride 300,000 mg.
[2]Mineral mixture: Included per kg; 60 mg manganese, 80 mg zinc, 60 mg ferro, 5.000 mg copper, 2.000 mg iodine, 1.000 mg cobalt, 200 mg selenium, 50 mg magnesium.
[3]Nitrogen free extracts (NFE) = matter – (crude lipid + crude ash + crude protein) [15]
[4]Gross energy (GE), calculated according to 23.7 kJ/g protein, 39.5 kJ/g lipid, 17.2 kJ/g NFE [16]

mixture was blended for 10 more min. Water that was 35% of the total feed weight was then added into the mixture, and the mixture was mixed for 20 more min to obtain a homogenous mixture. After making the mixture homogenous, pellets of 3 mm in diameter were prepared by passing the mixture through a mincing machine. The prepared feeds were dried for 24 h in the oven set (POL-EKO APARATURA) at 60 °C. The dried test feeds were cooled in room temperature, placed in labeled bags, and kept in the refrigerator (at +4 °C) until use. During the study, feed was prepared every 15 days.

2.3. Meat sampling and analysis

At the end of the trial period, four random fish from each tank were sampled. Sampled fish were quickly killed using overdose concentration of anesthetic (MS-222, 250 mg/L). Meat samples for analysis were taken from the right dorsal part of the fish, and stored in the deep freeze (–20 °C) until analysis. Dry matter and moisture content in the fish meat were calculated according to “TS 1743” (110 ± 1 °C), crude protein according to the “Kjeldahl method,” crude lipids according to “ether extraction by the Soxhlet method”, and crude ash according to “TS 1746” (550 ± 1 °C) [18,19].

2.4. Economic calculations

Feed cost, economic conversion ratio (ECR) and economic profit index (EPI) values for Siberian sturgeon farming were calculated based on the 2015 values of feed supplements and feed conversion ratio values obtained from the experiment (Table 4).

2.5. Statistical analysis

At the end of the study, the experiments were carried out as three repetitions. The obtained findings are shown as the standard deviation of the mean. SPSS 22.0 package program was used to evaluate the findings of the present study. ANOVA test was used to determine the differences

Table 3. Amino acid content of feed ingredients and experimental diets (% of dietary protein).

Essential amino acids	Fishmeal[1]	Hazelnut meal	Experiment groups				EAA requirement[2]
			Control	HM 15	HM 30	HM 45	
Threonine	2.38	0.76	3.87	3.88	3.92	3.66	3.28
Methionine	1.78	0.55	2.05	1.90	2.70	1.76	2.03
Valine	2.93	1.47	4.43	4.45	4.46	4.42	3.28
Isoleucine	2.56	2.09	3.04	3.08	3.11	3.04	2.99
Leucine	4.70	1.93	4.56	4.80	4.61	4.57	4.27
Phenylalanine	2.47	2.10	5.08	5.08	5.12	5.01	2.98
Lysine	4.45	0.85	7.71	7.64	7.66	7.71	5.36
Histidine	1.54	1.01	3.65	3.58	3.54	3.2	2.25
Arginine	3.40	4.20	5.70	5.73	5.79	5.67	4.77
Nonessential amino acids							
Alanin	3.88	4.67	2.78	2.53	2.64	2.70	
Aspartik Acid	5.61	10.06	4.60	4.56	4.48	4.51	
Cystine	0.51	3.55	0.29	0.26	0.31	0.29	
Glutamic Acid	8.52	11.50	6.17	6.01	6.12	6.19	
Gylcine	4.12	3.99	2.25	2.27	2.30	2.29	
Proline	2.67	4.05	2.34	2.38	2.41	2.34	
Serine	2.43	3.21	2.02	1.19	2.04	2.05	
Tyrocine	1.77	-	1.31	1.60	1.33	1.30	

[1]Liu et al. (15); [2]Ng and Hung [17].

between the groups. When the difference was statistically significant, the Duncan multiple comparison test was used to determine the difference between the groups. The differences between the groups were evaluated according to the degree of importance $P < 0.05$

3. Results

In this study, growth parameters, economic profitability ratio, and meat yield characteristics of Siberian sturgeon (*A. baerii*) fed with feeds that were mixed with hazelnut meal at different ratios were investigated.

3.1. Growth performance

Individual weights of fish were measured at the beginning of the experiment and at 15-day intervals. At the end of the study, mean individual live weights were 789.6 ± 3.58 g in the control group, 734.6 ± 5.83 g in HM 15, 689.1 ± 5.27 g in HM 30, and 645.0 ± 2.74 g in HM 45. At the end of the study, it was determined that the difference between the mean individual live weights of the groups was significant ($P < 0.05$). During the experiment, no fish deaths were observed in any of the groups. Table 4 shows the values of average body weight, weight gain rate (WGR), specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), and condition factor (CF) that were obtained at the end of the experiment.

According to the statistical analysis results based on the weight gain rate, the control group with the highest weight gain rate and specific growth rate at day 90 was similar to HM 15 but different from HM 30 and HM 45 ($P < 0.05$). At the end of the experiment, the best average feed conversion ratio and protein efficiency ratio were found in the control group. These ratios were similar to those of HM 15 and different from those of the other groups ($P < 0.05$). At the end of the study, it was determined that the difference between the average condition factor values calculated for the groups was not significant ($P < 0.05$).

3.2. Economic profitability values

Economic parameters were calculated for the cost and profitability of the prepared experimental feeds (Table 4). When the ECR values were taken into account, there was a statistically significant difference between the control group and HM 45 ($P < 0.05$). Neither HM 15 nor HM 30 was statistically different from the control group. In terms of the EPI data, there was no statistically significant difference between the control group and HM 15, whereas there was a statistically significant difference between the

Table 4. Growth and economic parameters obtained from the experimental groups.

Parameters	Experiment groups			
	Control	HM 15	HM 30	HM 45
W_i (g)	281.38 ± 6.22	283.60 ± 3.5	281.60 ± 5.51	285.96 ± 11.47
W_f (g)	789.6 ± 3.58 ^{a}	734.6 ± 5.83 ^{ab}	689.1 ± 5.27 ^{bc}	645.0 ± 2.74^{cd}
[1]WGR(%)	180.6 ± 2.4^{a}	159.0 ± 1.18^{b}	144.7 ± 1.22^{c}	125.6 ± 0.89^{d}
[2]SGR(%)	1.1 ± 0.04^{a}	1.0 ± 0.05^{ab}	0.9 ± 0.07^{b}	0.9 ± 0.09^{b}
[3]FCR	1.5 ± 0.07^{a}	1.6 ± 0.08^{b}	1.8 ± 0.06^{c}	1.9 ± 0.04^{d}
[4]FI (% per day)	689.3 ± 1.27 ^{a}	706.9 ± 1.52 ^{b}	742.0 ± 1.33 ^{c}	741.7 ± 1.24 ^{c}
[5]PER	1.9 ± 0.56^{a}	1.7 ± 0.42^{a}	1.5 ± 0.28^{bc}	1.4 ± 0.23^{c}
[6]CF (%)	0.3 ± 0.03^{a}	0.3 ± 0.03^{a}	0.3 ± 0.03^{a}	0.3 ± 0.04^{a}
Cost of diets (€/kg)	1.653 ^{a}	1.483 ^{a}	1.3267 ^{ab}	1.163 ^{b}
[7]ECR (€/kg)	2.562 ^{a}	2.477 ^{a}	2.388 ^{a}	2.245 ^{ab}
[8]EPI (€/fish)	6.593 ^{a}	6.228 ^{ab}	5.918 ^{ab}	5.643 ^{b}

Values are mean ± standard error. Values in the same row with different superscripts are significantly different ($P < 0.05$). Initial: i, Final: f.

[1] Weight gain rate WGR (%) = 100 × (Wf – Wi) / Wi

[2] Specific growth rate, SGR ($\%day^{-1}$) = ((Ln Wf - Ln Wi) / days) × 100

[3] Feed conversion ratio, FCR = dry feed intake (g) / weight gain (g)

[4] FI, Feed intake = 100 × feed consumption / (($W_i + W_f$) / 2) / feeding days [20]

[5] Protein efficiency ratio (PER) = wet weight gain / protein intake [21]

[6] Condition factor, CF (%) = (W / L^3) × 100

The raw material and fish prices used were the average prices in 2015: Fish meal = 2.27 €/kg, hazelnut meal = 0.72 €/kg, wheat meal = 0.36 €/kg, corn gluten = 0.90 €/kg, fish oil = 2.63 €/kg, vitamin mixture = 4.0 €/kg, mineral mixture = 2.18 €/kg, methionine = 3.63 €/kg, lysine = 2.18 €/kg, molasses = 0.18€/kg. Siberian sturgeon sale price is calculated at 15.3 €/kg.

[7] Economic efficiency ratio, ECR, (€/fish) = feed conversion ratio × feed cost (€/kg)/weight gain (kg) [22]

[8] Economic profit index (€/fish), EPI = final weight (kg/fish) × fish sale price (€/kg) - ECR (€/ kg) × weight increase (kg) [23]

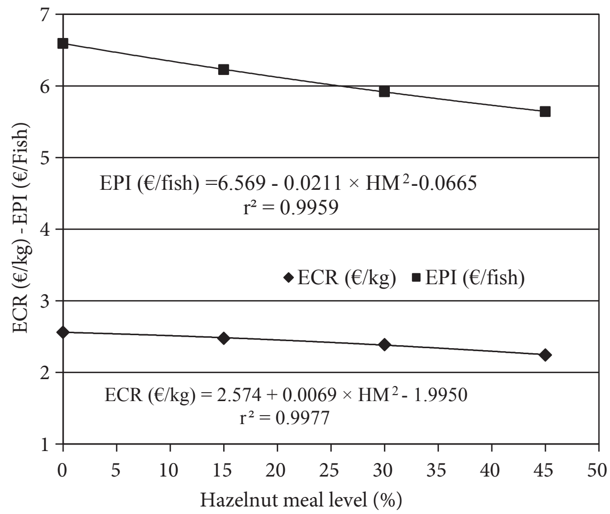

Figure. Second-order polynomial fitting of economic parameters and optimum dietary hazelnut meal level (HM).

control group and HM 30 as well as between the control group and HM 45 ($P < 0.05$).

The lowest EPI value was calculated in HM 45 with a value of 5.643 €/fish, whereas the highest EPI value was in the control group with a value of 6.593 €/fish (Table 4, Figure). Thus, it was determined that the feed prepared for HM 45 did not have a significant effect on the improvement of the growth performance but had a significant effect in reducing ECR and EPI values.

3.3. Body composition

At the end of the experiment, hepatosomatic index (HSI), viscerosomatic index (VSI), moisture, crude protein, crude lipid, crude ash, and total energy amount were determined in the fish sampled from the groups. The results are given in Table 5.

At the end of the study, the highest HSI was found in the control group, and the lowest in HM 45. Considering the mean HSI values, the control group did not significantly

Table 5. Effect of hazelnut meal level on biometric parameters and whole-body composition of Siberian sturgeon at the end of the trial.

Parameter	Experiment groups			
	Control	HM 15	HM 30	HM 45
[1]HSI (%)	3.07 ± 0.27^{a}	2.89 ± 0.49^{ab}	2.76 ± 0.44^{ab}	2.48 ± 0.64^{c}
[2]VSI (%)	4.98 ± 0.94^{a}	4.95 ± 0.76^{a}	4.58 ± 0.80^{ab}	4.36 ± 0.22^{b}
Moisture (%)	77.44 ± 0.01	76.80 ± 0.02	75.65 ± 0.01	75.01 ± 0.03
Crude protein (%)	18.82 ± 0.11^{a}	18.30 ± 0.10^{a}	17.45 ± 0.09^{b}	17.06 ± 0.12^{b}
Crude lipid (%)	2.89 ± 0.06^{a}	2.70 ± 0.20^{a}	2.41 ± 0.06^{ab}	2.03 ± 0.06^{b}
Crude ash (%)	0.92 ± 0.15	0.87 ± 0.13	0.73 ± 0.11	0.6 ± 0.11
*GE (kJ/g feed)	6.33 ± 0.40^{a}	5.90 ± 0.53^{a}	4.41 ± 0.4^{b}	4.09 ± 0.57^{b}

Values are mean ± standard error. Values in the same row with different superscripts are significantly different (P < 0.05).
[1]HSI, hepatosomatic index; [2]VSI, viscerosomatic index
*Gross energy (GE), calculated according to 23.7 kJ/g protein, 39.5 kJ/g lipid, 17.2 kJ/g NFE [16]

differ from HM 15 and HM 30 (P < 0.05), whereas the difference between the control group and HM 45 was statistically significant (P < 0.05). However, the addition of different amounts of hazelnut meal to the experimental groups did not have a significant effect on the VSI values (P < 0.05). Considering the fish meat findings of the groups, it was determined that the difference among the groups HM 15, HM 30, and HM 45 was insignificant in terms of crude protein, crude lipid, and total energy (P < 0.05).

4. Discussion

In our study, the parameters of 4 experimental feeds including hazelnut meal at different ratios (0% HM (Control), 15% HM, 30% HM, and 45% HM) and affecting the growth performance, economic profitability rate, and chemical composition of fish meat in Siberian sturgeon (*A. baerii*) were evaluated and examined, and the findings were compared with the findings in the literature.

Bilgin et al. [5], Atalayoglu and Cakmak [9], Karabulut et al. [10], and Dogan and Bircan [11] used hazelnut meal in their studies (30% HM in rainbow trout, 40% HM in common carp, 50% HM in rainbow trout, 45% HM in *Acipenser gueldenstaedtii*, respectively) and reported that growth was adversely affected when the rate of hazelnut meal was increased. In our study, the best values for the relative live weight gain, SGR, FCR, and PER were found in the control group and HM 15, whereas the worst values were found in HM 45 where the hazelnut meal was used at the highest level. It was observed that if the amount of hazelnut meal in diet rise was above the specified ratios, growth decreased and the feed conversion ratios increased. Our results are similar to those of the studies by Bilgin et al. [5], Atalayoglu and Cakmak [9], Karabulut et al. [10], and Dogan and Bircan [11].

This can be attributed to the lack of essential amino acid content of the hazelnut meal as in all plant protein sources. These differences are thought to be due to the different species and sizes of fish, the length of the experimental period, and the different feed ingredients that were added in the ration. During the study, no deaths were observed in the fish in the groups, and the rate of survival in all groups was 100%.-

In terms of feed conversion ratio, the best FCR values were calculated in the control group as 1.55. It has been reported that any increase in the proportion of plant protein in sturgeon diets results in worsening of FCR values [10,24,25].

In this study, the highest value of PER was obtained in the control group as 1.88 ± 0.56, and the lowest in HM 45 as 1.36 ± 0.23. Compared with the other studies in which plant feed ingredients (corn starch, spirulina, soy protein concentrate, rape meal) were added to sturgeon diet, the present experimental values of PER were determined to be lower than those found by Mohseni et al. [21], Mazurkiewicz et al. [24], and Palmegiano et al. [26]. The PER values were similar to those found by Sicuro et al. [27] and Lee et al. [28], and higher than those found by Mohseni et al. [21]. When compared with the studies that were carried out using hazelnut meal, the PER values of the present study were lower than those reported by Bilgin et al. [5], Ergun et al. [7], and Dogan and Bircan [11]. The PER values of our study were similar to the values found by Buyukcapar and Kamalak [6], and higher than those by Emre et al. [8] and Karabulut et al. [10].

At the end of the study, the mean CF values of the groups changed between 0.29% and 0.30%, and there was no statistically significant difference between the groups. Based on their 107-day growth study conducted on *A. ruthenus* and *A. baerii* species, Prokes et al. [29] reported that the condition factors of fish under experimental conditions varied between 0.30% and 0.45% (with a mean of 0.38%). The CF values that were obtained were similar to those of other research studies [15,28].

At the end of the experiment, economic efficiency ratio (ECR) and economic profitability index (EPI) values were calculated to determine the cost of the groups. The best group in terms of ECR values was HM 45, and the worst group was the control group. The lowest EPI value was calculated in HM 45 while the highest EPI value was obtained from the control group.

Martinez-Llorens et al. [23] fed sea breams from 15 to 350 g using soybeans at different rates. They found an ECR value of 1.07 €/kg and an EPI value of 1.28 €/fish for 30% soybean use, the rate at which they obtained the best growth. Hernández et al. [30] added soybean flour at certain ratios, as an alternative to fish meal, to the feed of sharpsnout seabream (*Puntazzo puntazzo*). They found that feed costs were 0.84 €/kg in the control group and 0.68 €/kg in the group containing 40% soybean. They calculated the EPI value as 1.75 €/fish in the control group and 1.59 €/kg in the group containing 40% soybean. Lozano et al. [31] used sunflower seeds meal at different rates for gilthead seabreams (*Sparus aurata*). They found the ECR value to be 1.75 €/kg in the control group and 1.90 €/kg in the 36% sunflower meal group. They found the EPI value to be 1.27 €/fish in the control group and 1.15 €/fish in the 36% sunflower meal group. Most of the studies mentioned here were research on different fish sizes and different species, studied with diets including soybean, sunflower, and plant oil. The use of sturgeon in this study makes it different from the studies mentioned above in that sturgeons are more costly than other fish in terms of price. Nevertheless, the economic calculations in the experiment revealed that increasing the hazelnut meal rate would be economical in terms of fish feed and fish meat cost without adversely affecting the growth performance of the fish.

Looking at the HSI and VSI values calculated in the study, the findings on the values of HIS and VSI obtained from the groups were evaluated. Accordingly, when the effect of the hazelnut meal additions at different ratios was evaluated in terms of HSI among the groups, it was found that the index value was the highest in the control group and the lowest in HM 45. The values of HSI and VSI in this study were similar to those observed by Zhu et al. [20] and Xue et al. [25], who added animal protein to diets in their studies, and Palmegiano et al. [26], who used spirulina in diets of Siberian sturgeon. These two values found in the present study were higher than those found by Dogan and Bircan [11], who added hazelnut meal in rainbow trout feed, Sicuro et al. [27], who added corn gluten and pea flour in hybrid sturgeon feed, Ustaoglu and Kerim [32], who added safflower meal, and Aybal [33], who used canola meal in tilapia feed.

At the end of the study, moisture, crude protein, crude lipid, crude ash, and total energy amount were determined.

As a result of the crude protein analysis performed on the fish meat, the highest values were obtained from the control and HM 15 groups with 18.82 ± 0.11% and 18.30 ± 0.10%, respectively. In the same way, the highest crude lipid ratios were 2.89 ± 0.06 and 2.70 ± 0.20 in the control and HM 15 groups, respectively, and the highest total energy (GE) amounts were in the control and HM 15 groups with 6.33 ± 0.40 kcal/g and 5.90 ± 0.53 kcal/g, respectively. When the CP, CL, and GE values in the current study were compared with those of other studies, the results were generally similar, except for some differences due to damp and dry specimens. These values were similar to those found by Zhu et al. [20], Mazurkiewicz et al. [24], Xu et al. [25], and Palmegiano et al. [26] in the studies conducted on Siberian sturgeons. The values were similar to those obtained by Buyukcapar and Kamalak [6], Ergun et al. [7], Emre et al. [8], Atalayoglu and Cakmak [9], and Dogan and Bircan [11], who used hazelnut meal in diets.

In conclusion, it was determined that adding 15% hazelnut meal to the ration that was prepared to feed Siberian sturgeon weighing 280–300 g can be used without adversely affecting fish growth performance. In addition, the use of hazelnut meal, a by-product of the hazelnut oil industry, which is easily available and inexpensive and has 43% protein content, as a feed additive for Siberian sturgeon will help to increase the added value of hazelnuts.

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