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Peanut meal as a sustainable protein source in rainbow trout diets: Effects on fillet quality and nutritional values

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ABSTRACT

This study evaluated the effects of replacing soybean meal with peanut meal in rainbow trout diets on growth performance, biochemical composition, fatty acid profiles, nutritional quality indices, and fillet color. Fish were fed for 12 weeks with four experimental diets containing peanut meal at 0% (C; control), 50% (PNM50), 75% (PNM75), and 100% (PNM100) inclusion levels, along with a commercial feed (CF). All diets were formulated to be isonitrogenous, isolipidic, and isoenergetic. The C diet showed the best growth and specific growth rate, while the PNM50 diet resulted in the most favorable feed conversion ratio and survival. The commercial diet produced the lowest performance values. Protein content was highest in the C group, whereas lipid and ash contents were highest in CF and PNM100. Although PUFA levels were highest in CF, n-3PUFA, including EPA and DHA, were significantly higher in the experimental diets. Fillet lipid quality indices varied among treatments, with the highest FLQ and PI observed in the C group. Fillet color parameters were significantly improved in PNM100. Overall, peanut meal can partially or fully replace soybean meal in rainbow trout diets without compromising fillet quality, while enhancing fillet color and omega-3 content, contributing to more sustainable aquafeed formulations.

Keywords: Peanut meal, Nutrition quality indices, Color attributes, Fatty acids

Introduction

Aquaculture, identified by the FAO as the fastest-growing food production sector globally, plays a crucial role in meeting the increasing demand for high-quality protein (FAO, 2022). However, the industry's rapid expansion continues to raise concerns about its reliance on finite marine resources, particularly fishmeal. This dependence not only intensifies competition with other livestock sectors but also threatens the long-term sustainability of aquafeed production. As a result, developing cost-effective, sustainable, and nutritionally adequate alternatives to fishmeal remains a key priority in aquaculture research and practice (Naylor et al., 2021).

Among plant-based protein sources, soybean meal (SBM) has been extensively used due to its high protein content, digestibility, and balanced amino acid profile (El-Sayed, 1999). However, the growing global demand for soy across food and feed industries has limited its availability for aquaculture, contributing to rising feed costs (Siddhuraju & Becker, 2001). Therefore, identifying alternative plant protein sources that are affordable, accessible, and nutritionally sufficient is essential to ensure sustainable growth in aquaculture.

Peanut (*Arachis hypogaea* L.), the world's fourth-largest oilseed crop, has an annual global production of approximately 45.6 million tons (Yıldırım et al., 2014; Dernekbaşı et al., 2021). Peanut meal (PNM), a by-product obtained from the oil extraction process, is rich in protein (40.1–50.9%) and is more affordable compared to other plant protein sources (Batal et al., 2005; Acar & Türker, 2018). Its inclusion in aquafeeds not only helps reduce feed costs but also supports circular economy approaches by repurposing agricultural by-products, thus contributing to sustainability in feed formulation.

Recent research indicates that PNM offers more than just a protein source. It contains various beneficial bioactive compounds such as polyphenols, flavonoids, and resveratrol, along with a favorable fatty acid profile rich in monounsaturated (~50%) and polyunsaturated fatty acids (~33%) (Arya et al., 2016; Bimro et al., 2020). These components may positively influence fish health and growth performance and potentially enhance product quality traits such as fillet composition and color.

In rainbow trout (*Oncorhynchus mykiss*), fillet quality—including texture, color, and biochemical composition—is a major determinant of consumer acceptance and market value. Studies on aquatic food products show that consumers often associate flesh color with freshness, aroma, and overall product quality (Yağız et al., 2008). Color, in particular, has been highlighted as a primary driver of purchase decisions and pricing (Martinez et al., 2021).

Although many studies have focused on replacing fishmeal with various plant proteins in aquafeeds, limited research has been conducted on substituting SBM with PNM in rainbow trout diets. Previous trials using alternative protein sources such as lupin, cottonseed, and sunflower meal have shown promising results (Barros et al., 2002; Tibaldi et al., 2006); however, studies investigating PNM are still relatively scarce.

Given its nutritional richness and functional potential, PNM represents a promising candidate for sustainable aquafeed development. In aquaculture, where it is essential to provide diets rich in proteins, fatty acids, vitamins, and minerals to ensure optimal growth and health, the use of peanut by-products could contribute to both economic and environmental sustainability. Therefore, the present study aims to evaluate the effects of replacing SBM with PNM at different inclusion levels in the diets of rainbow trout, with a specific focus on changes in fatty acid profiles, biochemical composition, nutritional quality indices, and fillet color.

Materials and Methods

Experimental Conditions and Design

Rainbow trout were sourced from a commercial aquaculture facility (Kuzey Su Ürünleri Inc., Samsun, Turkey) and transported to the Fisheries Faculty Research and Application Center at Sinop University, where they were acclimated for four weeks prior to the feeding trial. During this period, fish were maintained in a rectangular fiberglass tank (4000 L) equipped with a central drainage system and supplied with a continuous flow-through freshwater supply.

Following acclimation, fish with an initial mean body weight of 89.73 ± 0.08 g were fasted for 24 h and randomly allocated to 15 circular fiberglass tanks (300 L; 60 cm height, 80 cm diameter), representing five dietary treatments with three replicates per treatment. Each tank was stocked with 20 fish. Water exchange was maintained at a rate of 4 L min^{-1}, and dissolved oxygen levels were supported using air diffusers.

Fish were individually weighed at the beginning and end of the experimental period using a digital scale with 0.01 g precision. Water quality parameters were monitored weekly throughout the experimental period. Mean values were recorded as 15.98 ± 0.02 °C for temperature, 6.12 ± 0.04 mg L^{-1} for dissolved oxygen, and pH 8.16. Continuous aeration was supplied using air diffusers to maintain adequate dissolved

oxygen levels during the trial. No abnormal mortality or stress-related behavioral changes were observed in the experimental groups.

At the start of the trial, 15 fish were sampled, filleted, and homogenized to determine baseline fatty acid composition. After 12 weeks, five fish from each replicate tank were collected for analysis. Fish were euthanized using an overdose of clove oil, and samples were stored at −80 °C (Wise-Cryo/WUF-D500-80°C) until further biochemical analyses.

Experimental Diets and Feeding

With a target protein content of 45%, four experimental diets were formulated: three with increasing levels of PNM substituting SBM (50%, 75%, and 100% substitution, denoted as PNM50, PNM75, and PNM100, respectively), and one control diet containing 0% peanut meal (C). In addition, a commercial feed (CF) commonly used in rainbow trout farming and likely containing SBM as the main plant-based protein source was used as a second control to compare with the experimental diets (Table 1). PNM was provided by a private corporation (Başpınar Fıstıkçılık Toprak Mah. ve Nak. Tic. Ltd. Şti., Osmaniye/Türkiye), while most of the other ingredients were supplied by a local fish feed manufacturer (SURSAN Inc., Samsun/Türkiye).

All diets were formulated to be iso-nitrogenous (45% crude protein), iso-lipidic (17% crude lipid), and iso-energetic (20 kJ g^{-1}), based on the nutrient composition of the commercial feed. The diets were prepared by first mixing and homogenizing the dry ingredients, followed by the addition of approximately 35% water to moisten the mixture. The moist mash was then pelleted using a 4.0 mm die mincer. The resulting strands were cut into approximately 5 mm lengths and dried in a ventilated oven at 50°C for 10 hours. The duration and temperature were selected to ensure sufficient drying without compromising nutrient stability. After drying, all feeds were stored in sealed plastic bags at 4°C until use. To confirm complete drying, visual inspection and absence of moisture on storage surfaces were used, although no formal moisture measurement was conducted.

During the 12-week feeding trial, fish in all groups were fed *ad libitium* by hand twice a day (at 09:00 am and 15:30 pm). Feeding was carefully observed to ensure that all fish had equal access to the feed and that no uneaten pellets remained in the tanks.

Table 1. Formulation (g/kg) and proximate composition (%) of the experimental diet

	Experimental Diets				
	CF	**C**	**PNM50**	**PNM75**	**PNM100**
Fish meal	-	275	318	300	330
Extracted soybean meal	-	250	125	62.5	-
Corn protein	-	183	175	203	188
Wheat flour	-	130	110	110	100
Peanut meal (PNM)	-	-	125	187.5	250
Rice brain	-	50	50	50	20
Fish oil	-	110	95	85	80
Vitamin premix (*)	-	1	1	1	1
Mineral premix (**)	-	1	1	1	1
Proximate composition (%)					
Moisture	5.93	4.59	4.29	3.18	6.57
Protein	46.46	45.01	45.46	44.88	44.82
Lipid	17.11	17.65	18.15	17.87	18.13
Ash	12.97	13.95	14.82	13.33	13.10
NFE[1]	17.53	18.80	17.28	20.26	17.35
Gross energy (kJ g^{-1})[2]	20.70	20.84	20.84	19.92	19.96

[*] Vitamins (per kg premix): Vitamin A (210,000 IU), vitamin D_3 (35,000 IU), vitamin E (7,000 mg), vitamin K_3 (322 mg), vitamin B_1 (588 mg), vitamin B_2 (252 mg), vitamin B_6 (294 mg), vitamin B_{12} (826 µg), niacin (1,400 mg), biotin (7,583 µg), folic acid (182 mg), pantothenic acid (1,722 mg), inositol (17,220 mg), and vitamin C (933.31 mg)

[**]Minerals (per kg premix): Calcium (1,000 mg), magnesium (600 mg), potassium (450 mg), zinc (90 mg), manganese (12 mg), and copper (5 mg)

[1] NFE=100-(%protein+ %lipid+ %ash+ %moisture)

[2] Gross energy calculated as 23.6 kJ g^{-1} protein, 39.5 kJ g^{-1} lipid and 17 kJ g^{-1} NFE

Biochemical Composition

The biochemical composition of both diet and fish samples was determined following standard methods outlined by AOAC (1995). Dry matter was measured by drying the samples at 105 °C until a stable weight was obtained. Ash content was determined by combusting the samples in a muffle furnace at 550 °C for 6 hours. Crude protein levels were analyzed using the Kjeldahl method, whereas crude lipid content was quantified through Soxhlet extraction using petroleum ether as the solvent.

Fatty Acid Analysis

Total lipid content was analyzed using a modified version of the Bligh and Dyer extraction method (Hanson & Olley, 1963). In brief, 0.25 g of lipid obtained from fish fillets and feed samples was mixed with 4 mL of heptane and 0.4 mL of 2 N KOH. The mixture was vortexed for approximately 2 minutes and then centrifuged at 5000 rpm for 5 minutes. Following centrifugation, about 1.5–2 mL of the upper heptane layer was carefully collected and transferred into glass vials for subsequent GC/MS analysis.

Samples were introduced using an AI 1310 autosampler and analyzed with a Thermo Scientific ISQ LT gas chromatography–mass spectrometry system. The mass spectrometer was operated in electron ionization mode. Identification of fatty acids was achieved by comparing their retention times with those of a 37-component FAME standard mixture (Chem-Lab FAME Mix 370C standard solution; Art. No. CL40.13093; Lot No. 221.561.102.100).

Indices of the Nutritional Quality of Muscle Lipids

The formulas listed below were used in the study to determine the nutritional quality indices of the fillet lipids (Garaffo et al., 2011).

The Index of Atherogenicity (IA) =

[(4×C14:0)+C16:0+C18:0]/(ΣMUFA+n-6PUFA+n-3PUFA)

The Index of Thrombogenicity (IT) =

(C14:0+ C16:0+C18:0)/(0.5×ΣMUFA+0.5×n-6 PUFA+ 3×n-3 PUFA)+(n-3 PUFA/n-6 PUFA)

The Flesh Lipid Quality (FLQ) =

C20:5 n3 + C22:6 n3 / Σtotal FA

hypocholesterolemic/Hypercholesterolemic (h/H)=

(C18:1n-9+C18:2n-6+C20:4n-6+C18:3n-3+C20:5n-3+C22:5n-3+C22:6n-3)/(C14:0+C16:0)

The polyene index (PI), an equation previously reported by Lubis & Buckle (1990) that gives an idea of PUFA damage, was calculated using the following method.

Poliene index (PI)= (C20:5 n3 + C22:6 n3)/ C16:0

Color Analysis of Fish Fillet

The color values of the fish fillet (L*, a*, and b*, CIE, 1976) were determined using a Minolta Chroma Meter (CR-400, Konica Minolta Marunouchi, Tokyo, Japan) standardized for white plate (standard values for white plate L* = 91.97; a* = -1.4; b* = 2.0, Standard C2-22326). Three sites were used to gauge the fillet's color: the third position is in front of the caudal fin, the second position is underneath the dorsal fin, and the first position is between the back of the operculum. Lightness, redness, and yellowness are represented by the variables L*, a*, and b*. On a scale of zero to one hundred, L stands for color lightness; a and b represent the positions of red (+) and green (-) and yellow (+) and blue (-), respectively. Hue is how genuine color is typically seen, while Chroma (C*) refers to the intensity or saturation of the color. The following formulas were used to derive hue and C* angles using a* and b* values: $C* = \sqrt{a*^2 + b*^2}$ Hue=arctan (b*⁄a*)

Statistical Analysis

Statistical analyses were carried out using IBM SPSS Statistics (version 21). At the end of the experiment, the collected data were analyzed by one-way analysis of variance (ANOVA), and differences between treatment groups were further examined with Tukey's multiple comparison test. The assumption of normal distribution was checked using the Anderson–Darling test, while homogeneity of variances was assessed with Levene's test. When necessary, percentage values were subjected to arcsine square root transformation to satisfy ANOVA requirements. Regression analysis was applied to determine the relationship between dietary fatty acids and fillet fatty acid composition. Tables and figures were generated using Microsoft Office 2010. A significance level of $P < 0.05$ was used throughout the study.

Results and Discussion

Fatty Acid Composition of the Diets

The CF group had the lowest total saturated fatty acids (ΣSFA) and the highest monounsaturated fatty acids (ΣMUFA). Total polyunsaturated fatty acids (ΣPUFA) were highest in CF, followed by C, PNM75, PNM50, and PNM100; however, CF had the lowest n-3 PUFA, while C and PNM groups had higher n-3 levels. The n-3/n-6 ratio, DHA, EPA, and DHA/EPA were lower in CF. Fatty acids

such as C18:1 n-9c, C18:2 n-6c, and C20:4 n-6 were particularly higher in CF compared to other diets (Table 2).

Growth Performance

Initial weights (IW) were similar across all groups ($p > 0.05$). Final weights (FW) differed significantly ($p < 0.05$), with the highest in the control group, followed by PNM100, PNM75, PNM50, and CF. Weight gain (WG) showed a similar trend, with the control group highest and CF lowest; among PNM diets, PNM100 and PNM75 performed better than PNM50. Specific growth rate (SGR) was highest in PNM50 and lowest in CF ($p < 0.05$). Feed conversion ratio (FCR) also differed significantly, with the best value in PNM50, followed by PNM75 and PNM100, all outperforming the control and CF groups. Survival rate was highest in PNM50, similar in the control, PNM75, and PNM100 groups, and lowest in CF (Table 3).

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

	Experimental Diets				
Fatty acids	**CF**	**C**	**PNM50**	**PNM75**	**PNM100**
C14:0	2.73±0.01	5.34±0.03	5.14±0.01	4.77±0.02	4.73±0.04
C15:0	0.33±0.00	1.26±0.04	1.23±0.01	1.11±0.01	1.10±0.01
C16:0	10.36±0.06	14.19±0.05	14.09±0.09	13.34±0.03	13.45±0.14
C17:0	0.58±0.00	1.48±0.02	1.46±0.01	1.32±0.01	1.29±0.00
C18:0	6.18±0.05	6.41±0.05	6.62±0.01	6.18±0.01	6.32±0.06
C20:0	1.29±0.01	1.60±0.05	1.92±0.01	1.95±0.01	1.96±0.01
C22:0	0.85±0.01	0.95±0.01	1.79±0.01	2.01±0.01	2.11±0.02
C23:0	0.06±0.01	0.05±0.01	0.06±0.01	0.06±0.01	0.05±0.00
C24:0	0.79±0.00	0.63±0.08	1.28±0.01	1.39±0.01	1.40±0.01
ΣSFA	23.16±0.08	31.92±0.11	33.58±0.09	32.12±0.06	32.40±0.26
C14:1	0.13±0.00	0.40±0.03	0.39±0.00	0.35±0.01	0.35±0.00
C15:1	0.05±0.00	0.19±0.01	0.20±0.01	0.17±0.01	0.16±0.00
C16:1	0.35±0.01	0.99±0.04	1.00±0.01	0.92±0.00	0.89±0.01
C17:1	0.74±0.00	0.77±0.01	0.82±0.01	0.76±0.02	0.74±0.01
C18:1 n-9t	3.29±0.03	2.74±0.02	2.28±0.03	2.21±0.01	2.18±0.03
C18:1 n-9c	19.67±0.11	13.88±0.25	14.24±0.08	14.94±0.06	15.56±0.07
C20:1	3.79±0.07	2.86±0.07	2.85±0.01	2.75±0.08	2.60±0.02
C20:1 n-9	2.70±0.02	1.73±0.05	1.79±0.01	1.66±0.01	1.57±0.02
C24:1	1.30±0.01	1.76±0.03	1.87±0.02	1.75±0.02	1.65±0.06
ΣMUFA	32.01±0.10	25.32±0.04	25.44±0.08	25.49±0.02	25.71±0.01
C18:2 n-6t	0.66±0.02	0.58±0.03	0.61±0.00	0.59±0.01	0.52±0.01
C18:2 n-6c	16.55±0.07	9.49±0.07	10.55±0.07	11.32±0.12	11.03±0.08
C18:3 n-3	6.87±0.02	2.95±0.06	2.81±0.00	2.79±0.01	2.52±0.03
C18:3 n-6	0.27±0.01	0.20±0.00	0.21±0.01	0.20±0.00	0.19±0.01
C20:2	1.77±0.00	0.67±0.02	0.74±0.01	0.67±0.01	0.62±0.01
C20:3 n-3	0.02±0.00	0.01±0.00	0.02±0.01	0.01±0.00	0.01±0.00
C20:3 n-6	0.73±0.01	0.49±0.01	0.55±0.01	0.53±0.00	0.43±0.01
C20:4 n-6	1.49±0.01	1.58±0.03	1.61±0.00	1.55±0.01	1.44±0.01
C20:5n-3	5.92±0.02	8.42±0.02	7.85±0.08	7.83±0.02	7.44±0.01
C22:2	0.15±0.01	0.28±0.02	0.33±0.01	0.31±0.00	0.32±0.01
C22:6 n-3	6.20±0.04	12.65±0.13	11.46±0.08	11.29±0.02	10.97±0.05
ΣPUFA	40.64±0.07	37.34±0.03	36.74±0.02	37.10±0.08	35.49±0.07
Σn-3 PUFA	19.02±0.05	24.04±0.11	22.14±0.10	21.92±0.03	20.94±0.17
Σn-6 PUFA	19.70±0.08	12.36±0.08	13.53±0.08	14.20±0.11	13.61±0.06
n-3/n-6	0.97±0.01	1.95±0.02	1.64±0.02	1.54±0.01	1.54±0.01
DHA/EPA	1.05±0.01	1.50±0.01	1.46±0.02	1.44±0.00	1.47±0.01

Values are means±standard errors of three determinations

Table 3. Growth performance of rainbow trout (*Oncorhynchus mykiss*)

	Experimental groups				
	CF	C	PM50	PM75	PM100
Initial weight (IW, g)	89.70±0.15[a]	89.50±0.12[a]	89.70±0.12[a]	89.70±0.25[a]	89.80±0.24[a]
Final weight (FW, g)	261.42±20.57[a]	274.90±9.52[c]	265.10±16.83[b]	266.74±8.04[b]	268.37±21.03[b]
Weight gain (WG, g)	171.67±16.99[a]	185.40±7.94[c]	175.45±13.86[d]	177.19±6.28[b]	178.37±17.42[b]
Specific growth rate (SGR, %)	1.21±0.08[a]	1.27±0.03[c]	1.42±0.10[d]	1.23±0.02[b]	1.23±0.08[b]
Feed conversion rate (FCR)	1.53±0.23[d]	1.39±0.27[c]	1.00±0.08[a]	1.16±0.12[b]	1.16±0.10[b]
Survival (%)	76.32±7.89[a]	84.21±15.79[c]	94.74±0.00[d]	81.58±2.63[b]	81.58±13.16[b]

Data are reported as mean ± standard errors of three replicates (3). Means with different superscript letters in a row are significantly different ($p>0.05$)

Biochemical Composition of Rainbow Trout

Moisture content decreased in all experimental groups compared to the initial samples, with no significant differences among groups ($P > 0.05$). Protein levels were similar across groups, except between PNM50 and PNM100; the lowest protein was observed in PNM50 and the highest in the C group. Lipid content increased compared to initial values, with the highest in CF and the lowest in PNM100. Ash content was equal in the C and PNM75 groups (2.43) and varied among the others, being highest in PNM100 and lowest in PNM50 (Table 4).

Fatty Acid Composition of the Fillets

The predominant fatty acids in the experimental fish fillets were C14:0, C16:0, C18:0, C20:0, C18:1 n-9, C20:1, C24:1, C18:2 n-6, C18:3 n-3, C20:3 n-6, C20:4 n-6, C20:5n-3 and C22:6 n-3. C18:2n-6 and C18:3 n-3 were significantly higher in the CF group compared to the other experimental groups ($p<0.05$). The lowest EPA, DHA, and ΣSFA were in the CF group. ΣMUFA was similar among all experimental groups. The highest ΣPUFA and the lowest n-3/n-6 were in the CF group. n-6 PUFA was higher in the CF group than in the C, PNM50, PNM75, and PNM100 groups (Table 5).

Indices of the Nutritional Quality of Fillet Lipids

At the end of the study, no significant differences were observed in the index of atherogenicity (IA) and the index of thrombogenicity (IT) between the groups ($p>0.05$). The hypocholesterolemic/Hypercholesterolemic (h/H) was higher than the other groups in the CF group and was statistically different from other groups ($p<0.05$). The highest flesh lipid quality (FLQ) was in the C group ($p<0.05$). This was followed by PNM50, PNM100, PNM75, and C groups, respectively. The highest polyene index (PI) was in group C, and the lowest was in group CF ($P<0.05$). It was equal in the PNM75 and PNM100 groups ($P>0.05$). It was 1.44±0.01 in the PNM50 group (Table 6).

In Figure 1, vectors indicate the contribution and direction of each parameter, while clustering reflects similarities among diet groups. The CF group is distinguished by higher PI and lower FLQ and h/H values. The PNM50 group is strongly associated with higher FLQ, indicating better lipid quality. PNM75 and PNM100 cluster closely due to similar h/H and FLQ values, with slight separation driven by PI differences. The C group forms a separate cluster with intermediate values. Overall, the biplot shows that increasing PNM levels affect fatty acid composition and nutritional quality, with PNM50 and PNM75 exhibiting more favorable profiles than CF and C groups.

Color Analysis of Fish Fillets

The highest L* (lightness) value was observed at the 3rd location in the C group, while the lowest mean L* occurred in the PNM50 group. Differences among locations and diet groups were significant ($p < 0.05$). For a* (redness), values at the 1st location ranged from -0.48 (PNM75) to -0.31 (C), with increasing order observed as PNM75 < CF < PNM100 < PNM50. The highest a* value was recorded at the 3rd location in the PNM100 group, which also showed the highest overall mean. The lowest b* (yellowness) value (8.02 ± 0.56) was found at the 1st location in PNM75. Significant differences were detected among groups and locations ($p < 0.05$), except between the 2nd and 3rd locations in the CF group. Mean b* values differed across groups, except between CF and PNM75. C* (chroma) was lowest in PNM75 (1st location) and highest in PNM100 (3rd location). Although C and PNM100 had the highest mean values, differences were not significant ($p > 0.05$). The hue angle was negative at the 1st location in CF and at the 1st and 2nd locations in PNM75. The highest Hue value (1.49 ± 0.05) was observed in the CF group (Table 7).

Table 4. Chemical compositions in the fillets of rainbow trout (*Oncorhynchus mykiss)*

	Chemical composition (% wet basis)			
	Moisture	**Protein**	**Lipid**	**Ash**
Initial	77.06±0.27	21.35±0.29	4.09±0.29	2.57±0.04
CF	73.56±0.40^{a}	21.64±0.44^{a}	7.51±0.19^{a}	1.99±0.14^{b}
C	73.56±0.70^{a}	22.45±0.51^{a}	5.96±0.31^{b}	2.43±0.09^{a}
PNM50	73.94±0.03^{a}	20.31±0.41^{b}	7.16±0.67^{a}	1.87±0.03^{b}
PNM75	73.84±0.44^{a}	21.94±1.12^{a}	6.96±0.26^{a}	2.43±0.42^{a}
PNM100	72.94±0.68^{a}	20.69±0.63^{b}	5.47±0.09^{b}	2.68±0.19^{a}

Data are mean ± SE. Means with different superscript letters in a column are significantly different (p>0.05)

Table 5. Fatty acid concentrations in the fillets of rainbow trout (*Oncorhynchus mykiss)*

	Experimental Groups						
	Initial	**CF**	**C**	**PNM50**	**PNM75**	**PNM100**	***R²***
C14:0	2.73±0.03^{b}	2.21±0.02^{a}	4.06±0.04^{d}	3.90±0.01^{c}	3.83±0.02^{c}	3.57±0.01^{c}	*0.98*
C15:0	0.44±0.01^{d}	0.27±0.01^{a}	0.90±0.01^{b}	0.87±0.01^{c}	0.90±0.01^{b}	0.79±0.01^{c}	*0.97*
C16:0	11.18±0.12^{a}	12.63±0.10^{b}	14.34±0.03^{d}	14.34±0.05^{d}	13.24±0.04^{c}	13.31±0.04^{c}	*0.91*
C17:0	0.69±0.02^{a}	0.46±0.01^{a}	1.17±0.02^{b}	1.16±0.02^{b}	1.20±0.02^{b}	1.12±0.01^{b}	*0.95*
C18:0	7.11±0.09^{c}	5.88±0.03^{a}	6.79±0.01^{b}	6.67±0.02^{b}	6.42±0.04^{b}	6.25±0.03^{b}	*0.42*
C20:0	0.92±0.01^{b}	0.50±0.02^{a}	1.03±0.03^{b}	1.14±0.^{01bc}	1.31±0.02^{c}	1.28±0.03^{c}	*0.89*
C22:0	0.53±0.03^{a}	0.75±0.02^{b}	0.67±0.02^{ab}	1.07±0.01^{c}	1.37±0.02^{d}	1.25±0.03^{d}	*0.95*
C23:0	0.45±0.11^{c}	0.42±0.02^{c}	0.26±0.01^{a}	0.24±0.02^{a}	0.33±0.01^{b}	0.34±0.01^{b}	*0.15*
C24:0	0.64±0.03^{a}	0.53±0.01^{a}	0.69±0.02^{a}	0.76±0.01^{b}	0.93±0.01^{c}	0.88±0.01^{bc}	*0.71*
ΣSFA	**24.69±0.25^{b}**	**23.66±0.04^{a}**	**29.91±0.10^{c}**	**30.16±0.06^{c}**	**29.52±0.13^{c}**	**28.79±0.13^{c}**	***0.97***
C14:1	0.16±0.00^{b}	0.09±0.01^{a}	0.27±0.00^{c}	0.25±0.00^{c}	0.27±0.00^{c}	0.23±0.00^{c}	*0.93*
C15:1	0.06±0.00^{a}	0.04±0.01^{a}	0.12±0.00^{b}	0.12±0.01^{b}	0.13±0.00^{b}	0.11±0.00^{b}	*0.87*
C16:1	0.23±0.01^{b}	0.12±0.00^{a}	0.30±0.01^{c}	0.28±0.00^{c}	0.31±0.01^{c}	0.27±0.01^{c}	*0.96*
C17:1	0.71±0.01^{b}	0.46±0.01^{a}	0.80±0.01^{b}	0.72±0.00^{b}	0.82±0.02^{b}	0.70±0.02^{b}	*0.16*
C18:1n-9t	1.32±0.26^{a}	2.25±0.07^{d}	2.38±0.06^{d}	2.20±0.05^{d}	1.66±0.01^{b}	1.98±0.02^{c}	*0.72*
C18:1n-9c	20.61±0.94^{a}	22.41±0.14^{b}	19.93±0.02^{a}	21.32±0.04^{b}	20.97±0.10^{a}	22.05±0.08^{b}	*0.57*
C20:1	3.71±0.05^{d}	0.39±0.00^{a}	0.50±0.01^{c}	0.48±0.01^{b}	0.52±0.01^{c}	0.46±0.00^{b}	*0.64*
C20:1 n-9	0.09±0.01^{a}	0.07±0.04^{a}	0.11±0.00^{a}	0.12±0.00^{a}	0.10±0.00^{a}	0.11±0.00^{a}	*0.29*
C24:1	1.02±0.02^{a}	0.98±0.02^{a}	1.33±0.12^{b}	1.28±0.04^{b}	1.31±0.02^{b}	1.33±0.01^{b}	*0.71*
ΣMUFA	**27.90±0.88^{c}**	**26.99±0.12^{b}**	**25.74±0.10^{a}**	**26.77±0.02^{b}**	**26.10±0.15^{b}**	**27.24±0.08^{c}**	***0.16***
C18:2n-6t	0.84±0.01^{d}	0.55±0.02^{b}	0.56±0.02^{b}	0.49±0.01^{a}	0.61±0.01^{c}	0.53±0.01^{b}	*0.01*
C18:2n-6c	13.69±0.14^{c}	18.53±0.01^{d}	11.13±0.09^{a}	12.34±0.02^{b}	13.06±0.04^{c}	13.60±0.01^{c}	*0.98*
C18:3 n-3	4.42±0.08^{b}	5.72±0.03^{c}	2.89±0.02^{a}	2.75±0.01^{a}	2.82±0.03^{a}	2.91±0.02^{a}	*0.76*
C18:3 n-6	1.40±0.01^{c}	0.88±0.02^{a}	0.80±0.02^{a}	0.80±0.01^{a}	1.00±0.01^{b}	0.93±0.01^{ab}	*0.99*
C20:2	3.00±0.04^{b}	3.01±0.02^{b}	2.10±0.02^{a}	2.24±0.01^{a}	2.44±0.02^{a}	2.46±0.01^{a}	*0.01*
C20:3 n-3	2.39±0.03^{d}	0.99±0.01^{b}	1.06±0.38^{b}	0.60±0.01^{a}	1.47±0.39^{c}	0.67±0.01^{a}	*0.18*
C20:3 n-6	2.17±0.03^{c}	1.60±0.01^{b}	1.20±0.02^{a}	1.28±0.01^{a}	1.50±0.02^{b}	1.42±0.01^{b}	*0.34*
C20:4 n-6	2.36±0.02^{b}	1.68±0.03^{a}	1.79±0.02^{a}	1.60±0.00^{a}	1.75±0.02^{a}	1.67±0.01^{a}	*0.00*
C20:5n-3	5.03±0.06^{b}	4.42±0.02^{a}	5.78±0.09^{c}	5.30±0.02^{c}	5.24±0.10^{c}	4.85±0.07^{b}	*0.85*
C22:2	0.12±0.00^{a}	0.14±0.04^{a}	0.17±0.02^{a}	0.17±0.00^{a}	0.18±0.00^{a}	0.16±0.00^{a}	*0.03*
C22:6 n-3	11.70±0.13^{a}	11.71±0.11^{a}	16.66±0.26^{c}	15.33±0.03^{c}	14.14±0.01^{b}	14.62±0.06^{b}	*0.88*
ΣPUFA	**47.11±0.56^{c}**	**49.23±0.15^{d}**	**47.70±3.70^{c}**	**42.90±0.04^{a}**	**44.20±0.26^{b}**	**43.80±0.10^{ab}**	***0.36***
n-3 PUFA	**23.54±0.32^{b}**	**22.85±0.12^{a}**	**26.39±0.36^{c}**	**23.98±0.03^{b}**	**23.06±0.30^{a}**	**23.04±0.11^{a}**	***0.74***
n-6 PUFA	**20.45±0.20^{c}**	**23.23±0.07^{d}**	**19.04±3.44^{c}**	**16.52±0.01^{a}**	**17.93±0.09^{b}**	**18.14±0.02^{bc}**	***0.40***
n-3/n-6	**1.15±0.01^{b}**	**0.98±0.01^{a}**	**1.46±0.21^{e}**	**1.45±0.00^{e}**	**1.32±0.02^{d}**	**1.27±0.01^{c}**	***0.58***
DHA/EPA	**2.33±0.00^{a}**	**2.65±0.02^{b}**	**2.88±0.07^{c}**	**2.89±0.01^{c}**	**2.70±0.05^{b}**	**3.02±0.03^{d}**	***0.39***

Data are reported as mean ± standard errors of three replicates (3). Means with different superscript letters in a row are significantly different (p>0.05)

Table 6. The nutritional quality indices of the fillet lipids of rainbow trout (*Oncorhynchus mykiss)*

Diets groups	IA	IT	FLQ	h/H	PI
Initial	0.41±0.01^{a}	0.22±0.00^{a}	16.78±0.23^{a}	4.16±0.08^{b}	1.50±0.00^{c}
CF	0.37±0.00^{a}	0.22±0.00^{a}	16.15±0.12^{a}	4.34±0.01^{b}	1.28±0.01^{a}
C	0.53±0.02^{a}	0.24±0.01^{a}	21.77±0.83^{d}	3.32±0.15^{a}	1.56±0.02^{d}
PNM50	0.54±0.00^{a}	0.26±0.00^{a}	20.67±0.03^{c}	3.21±0.01^{a}	1.44±0.01^{b}
PNM75	0.52±0.00^{a}	0.25±0.00^{a}	19.41±0.10^{b}	3.40±0.01^{a}	1.46±0.00^{bc}
PNM100	0.49±0.00^{a}	0.25±0.00^{a}	19.50±0.13^{b}	3.54±0.02^{a}	1.46±0.01^{bc}

Data are mean ±SD. Means with different superscript letter in a column are significantly different (p>0.05)

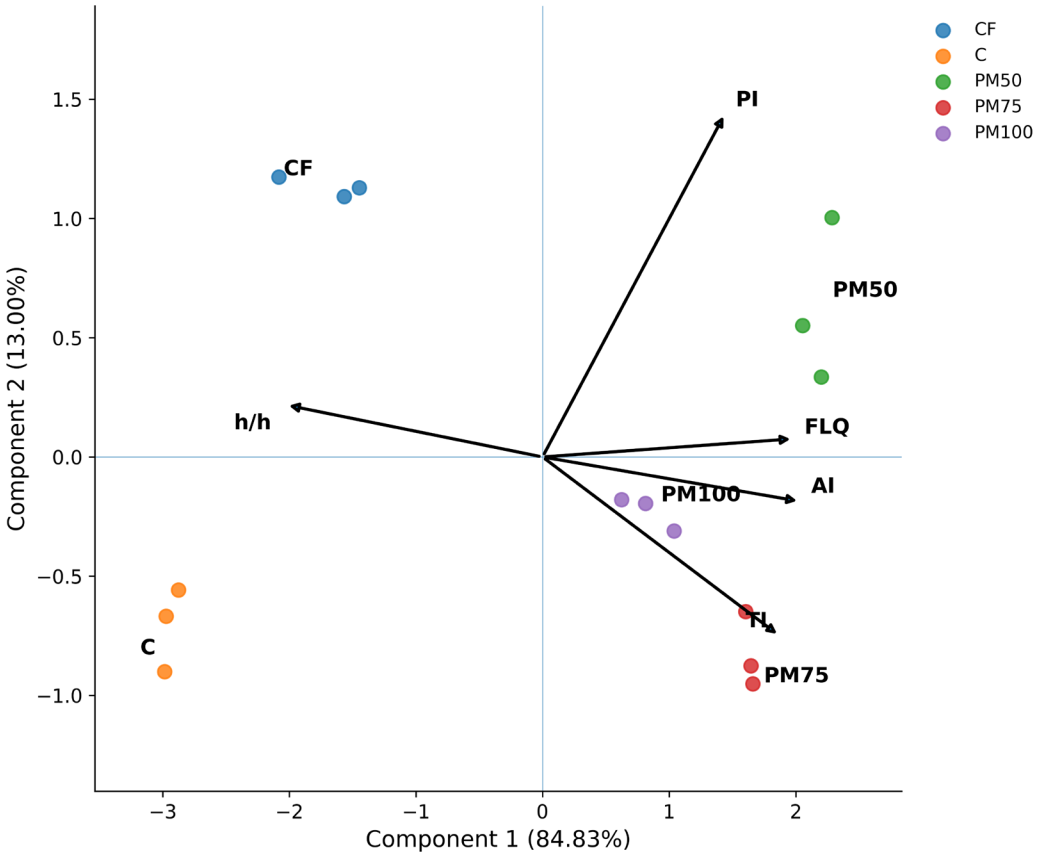

Figure 1. Principal component analysis (PCA) biplot, graph showing the relationships between experimental diet groups (CF, C, PNM50, PNM75, PNM100) and the evaluated parameters (PI, h/H, FLQ, TI)

From fishmeal, which has long served as the primary protein source in aquaculture, to alternative ingredients such as plant-based proteins, aquaculture by-products, and insect meals, selecting an appropriate protein source to meet the nutritional needs of fish remains a complex and evolving challenge. Due to declining fish stocks, reduced fishmeal availability, and increasing competition for its use in other sectors, alternative protein sources are being explored with increasing urgency. Among these, plant-based meals are widely studied for their cost-effectiveness and availability. The current study investigated the potential of PNM to replace SBM, another commonly used plant protein source in fish feeds. Different inclusion levels of PNM were tested alongside a commercial feed, and their effects on fillet biochemical composition, fatty acid profiles, nutritional quality indices, and fillet coloration were evaluated.

In addition to biochemical and quality parameters, growth performance was also evaluated to assess the overall effectiveness of replacing SBM with PNM. The results showed that all diets were well accepted by the fish. In particular, the PNM50 group exhibited the highest FCR (1.00 ± 0.08) and the highest SGR (1.42 ± 0.10%). Although the FCR values of

the PNM75 and PNM100 groups were slightly higher than the PNM50 group, they remained significantly better than diets C and CF. This supports the conclusion that PNM is not only acceptable but also potentially beneficial in trout feeds at moderate to high addition levels. These findings are in line with several previous studies reporting that PNM can be used as a viable alternative protein source in aquaculture feeds without negatively affecting growth performance (Acar & Türker, 2018; Yıldırım et al., 2014). While some previous studies have noted palatability issues or growth suppression beyond 20% addition (Garduño-Lugo & Olvera-Novoa, 2008), the successful use of up to 100% PNM in this study can be attributed to careful isonitrogenous and isolipidic diet formulation that ensured balanced nutrient provision. All groups were fed under identical husbandry conditions following the same feeding protocol until apparent satiation, and no differences in feeding management among tanks were applied throughout the experiment. Furthermore, this study provides a new perspective by demonstrating that even complete replacement of SBM with PNM did not compromise growth, supporting the suitability of PNM as a sustainable plant protein alternative in trout diets.

Table 7. Fillet color parameters were measured from 3 different regions at the end of the trial of rainbow trout (*Oncorhynchus mykiss*)

	Fish Fillet			
	First location (Behind the operculum)	Second location (Below the dorsal fin)	Third location (In front of the caudal fin)	Average
CF				
*L**	49.47 ± 0.20^{xA}	52.36 ± 0.81^{xA}	$50.78\pm0.1.11^{yA}$	50.87 ± 0.50^{x}
*a**	0.79 ± 0.39^{yB}	3.01 ± 0.78^{xA}	3.69 ± 0.53^{yA}	2.50 ± 0.40^{y}
*b**	10.25 ± 1.07^{yB}	11.42 ± 2.26^{zAB}	11.82 ± 0.57^{xA}	11.16 ± 0.55^{y}
*C**	10.33 ± 1.09^{yC}	11.87 ± 2.33^{yB}	12.39 ± 0.70^{yA}	11.53 ± 0.58^{y}
Hue	-0.07 ± 0.49^{yB}	1.31 ± 0.03^{yA}	1.27 ± 0.03^{xA}	0.84 ± 0.25^{y}
C				
*L**	48.81 ± 0.30^{xB}	48.28 ± 0.70^{xyB}	54.17 ± 0.04^{xA}	50.42 ± 1.88^{x}
*a**	-0.31 ± 0.62^{yC}	1.22 ± 0.69^{yB}	3.29 ± 0.00^{yA}	1.40 ± 1.04^{z}
*b**	11.64 ± 0.10^{xC}	14.35 ± 0.02^{xB}	16.54 ± 2.13^{xA}	14.18 ± 1.42^{x}
*C**	11.68 ± 0.07^{xC}	14.42 ± 0.04^{xB}	16.91 ± 2.07^{xA}	14.34 ± 1.51^{x}
Hue	0.03 ± 0.47^{yB}	1.49 ± 0.05^{xA}	1.37 ± 0.03^{xA}	0.96 ± 0.47^{y}
PNM50				
*L**	45.70 ± 1.36^{xB}	47.10 ± 1.00^{yA}	42.33 ± 19.40^{zC}	45.05 ± 2.74^{y}
*a**	3.29 ± 2.51^{xA}	3.25 ± 0.63^{xA}	3.26 ± 3.90^{yA}	3.27 ± 0.99^{x}
*b**	10.64 ± 0.80^{yB}	13.06 ± 0.83^{yA}	9.83 ± 11.74^{zC}	11.35 ± 1.69^{x}
*C**	11.71 ± 0.63^{xB}	13.49 ± 0.81^{xA}	10.36 ± 12.37^{zC}	12.04 ± 1.75^{y}
Hue	1.28 ± 0.22^{xAB}	1.33 ± 0.05^{yA}	1.25 ± 0.00^{xB}	1.29 ± 0.07^{x}
PNM75				
*L**	49.82 ± 0.30^{xA}	50.33 ± 1.18^{xyA}	53.83 ± 0.49^{xB}	51.33 ± 0.64^{x}
*a**	-0.48 ± 0.05^{yB}	-0.44 ± 0.10^{zB}	3.54 ± 0.19^{yA}	0.87 ± 0.48^{t}
*b**	8.02 ± 0.56^{zB}	12.18 ± 0.51^{yzA}	13.09 ± 2.01^{yA}	11.09 ± 0.76^{x}
*C**	8.04 ± 0.57^{zB}	12.19 ± 0.52^{yA}	13.59 ± 1.89^{yA}	11.27 ± 0.79^{y}
Hue	-1.51 ± 0.00^{zC}	-0.48 ± 0.01^{zB}	1.30 ± 0.05^{xA}	-0.23 ± 0.34^{z}
PNM100				
*L**	47.01 ± 1.79^{xB}	47.00 ± 0.42^{yB}	50.24 ± 1.06^{yA}	48.08 ± 0.72^{xy}
*a**	2.92 ± 0.71^{xB}	3.23 ± 1.11^{xB}	6.37 ± 0.90^{xA}	4.18 ± 0.58^{x}
*b**	10.41 ± 0.11^{yC}	14.02 ± 0.32^{xB}	16.08 ± 1.36^{xA}	13.50 ± 0.92^{x}
*C**	10.83 ± 0.09^{yC}	14.49 ± 0.00^{xB}	17.42 ± 0.89^{xA}	14.25 ± 0.99^{x}
Hue	1.30 ± 0.07^{xA}	1.35 ± 0.08^{yA}	1.19 ± 0.08^{yB}	1.28 ± 0.03^{x}

x, y, z, and t: Values within the same column bearing different superscript letters differ significantly ($P < 0.05$)
A, B, and C: Values within the same row bearing different superscript letters differ significantly ($P < 0.05$)

One of the common challenges in the use of plant-based proteins in aquafeeds is feed palatability, which can affect voluntary feed intake. In most previous studies incorporating PNM, inclusion levels were limited to 40% or less to maintain feed acceptance (Garduño-Lugo & Olvera-Novoa, 2008; Yıldırım et al., 2014; Dernekbaşı & Karayücel, 2017; Acar & Türker, 2018). However, in the present study, all experimental diets—including the one with 100% PNM inclusion—were readily accepted by the fish. This can be attributed to the balanced formulation of the trial diets, which were designed based on the nutrient composition of the commercial feed. Notably, while the CF diet was rich in oleic acid, linoleic acid (LA), linolenic acid (ALA), and n-6 PUFAs, it contained lower levels of SFA, EPA, DHA, and n-3 PUFAs. In contrast, the experimental diets were characterized by higher proportions of EPA and DHA, resulting in a significantly improved n-3/n-6 PUFA ratio compared to the commercial feed.

Although the protein content of fish varies depending on species, feeding environment, age, sex, and fat and moisture levels, it generally ranges from 18 to 22 g per 100 g of edible muscle tissue (Dean, 1990). An inverse relationship exists between lipid and moisture contents in fish meat. Moreover, fish proteins include all essential amino acids required for tissue maintenance and development (Turan et al., 2006). Therefore, in fishmeal replacement studies, it is essential to evaluate not only the crude protein levels but also the amino acid profile to assess nutritional adequacy. In the present study, the crude protein content of rainbow trout fillets ranged from 20.72% to 22.45%, with the highest value observed in the C group. These values are within the normal range and comparable across all dietary treatments, including the commercial feed, indicating that all experimental diets provided sufficient protein for muscle growth. Although slight variations in gross energy content were present among the experimental diets, including approximately a 5% difference between the C and PNM50 groups, these differences did not result in marked changes in fillet biochemical composition. The comparable crude protein, lipid, and ash contents observed among treatments suggest that the diets were nutritionally adequate and relatively balanced despite minor formulation differences. This also suggests that partial or full replacement of SBM with PNM did not impair the protein deposition capacity of the fish. Similarly, the highest crude lipid content (7.51%) was recorded in the CF group, while the highest ash content (2.68%) was measured in the PNM100 group. Although minor numerical variations were observed between groups in ash content, these differences were not statistically significant, consistent with the findings reported in the results and summary sections. Previous studies have also reported similar trends. Acar & Türker (2018) found no significant changes in crude protein, lipid, or ash content in rainbow trout fillets fed diets containing different levels of PNM as a fishmeal replacement. Likewise, Yıldırım et al. (2014) reported no adverse effects of PNM inclusion on the meat protein and ash content of Mozambique tilapia. However, other studies have reported contradictory findings; for instance, Garduño-Lugo & Olvera-Novoa (2008) observed a decline in protein, lipid, and ash content with increasing PNM levels in Nile tilapia, likely due to reduced digestibility of plant proteins. Lopes da Silva et al. (2017) also noted a decrease in whole-body protein content in Nile tilapia when more than 25% PNM was used to replace SBM. In the current study, the consistent protein content across diets suggests that up to 100% replacement of SBM with PNM can be achieved without negatively affecting the biochemical composition of rainbow trout fillets. These findings align with studies in other species where PNM was used as a substitute for SBM, such as in poultry and ducks (Pesti et al., 2003; Xia et al., 2022; Lu et al., 2013).

Almost all neutral fatty acids in developed animal tissues contain pairs of carbon atoms, with chain lengths of 14-22 carbons being common. Compared to plants, animal tissues have a more limited ability to unsaturate fatty acids. Therefore, the nutritional environment and thus the feeding in aquaculture have special importance (Aras et al., 2002). Hove & Nielsen (1991) reported that fatty acids 14:0, 14:1n-5, 16:0, 20:1n9, 20:2n-6, 22:1n-11 increased significantly at the end of the larval period, while the relative amounts of 18:1n-9, 18:2n-3, 20:3n-6, 20:5n-3 and 22:6n-3 decreased at the end of the larval period due to 7 different diets used in the initial feeding of salmon (*Salmo salar*) larvae. These results show the variability of fatty acids in fish and also show that one of the most important factors is nutrition. In the present study, it was determined that the fatty acid profiles of the fish were shaped according to the feeds they were fed. Namely, it was determined that CF feed had the lowest SFA, EPA, and DHA and the highest OA, MUFA, LA, and ALA, and this was reflected in fish meat.

Fatty acids play an important role in the human diet. Some fatty acids can be supplied by plants, but essential fatty acids such as EPA and DHA need to be taken into the body from outside. The best source of these is fish. Today, in response to the decreasing fish stocks, feed formulations, which constitute a very important part of the increasing aquaculture, should be made well, and the most suitable fish should be offered to the consumer. It is a known fact that cold-water fish have very high n-3 fatty acid percentages. In the present study, it was determined that all experimental groups had higher levels of EPA and DHA compared to CF. The highest

EPA and DHA were in group C, followed by the PNM50, PNM75, and PNM100 groups, respectively.

In this study, the highest LA and ALA were detected in the CF group, respectively. High LA and ALA content in meat has been reported to have anti-atherogenic (IA) and anti-thrombogenic (IT) effects (Ulbricht & Southgate, 1991). IA and IT are defined as indicators of the nutritional quality of fats in foods, since they are indices that can show whether foods are suitable for preventing cardiovascular diseases (Gil, 2010). Woloszyn et al. (2020) reported that a healthy animal product can be characterized by low IA and TI and high FLQ and h/H index. Since IA and IT are defined as the relationship between prothrombogenic (saturated) and anti-thrombogenic fatty acids (ΣMUFA, ΣPUFA n-6, and Σ PUFA n-3), the smaller these values are, the greater their protective potential against coronary artery disease. Therefore, it is recommended that IA and IT should be below 1.0 and 0.5, respectively, in diets for human health (Fernandes et al., 2014). Since IA and IT values were determined to be very low in this study, there was no significant difference between them. Fillet Lipid Quality (FLQ) indices are directly related to EPA and DHA ratios (URL2, 2016) as they indicate the global dietetic quality of lipids and their potential impact on coronary disease development (Senso et al., 2007). A relatively high FLQ value was obtained in this study. The ratio between hypocholesterolemic and hypercholesterolemic fatty acids (h/H index) indicates the effects of specific fatty acids on cholesterol metabolism. In terms of nutrients, higher FLQ and h/H values are considered to be more beneficial for human health (Woloszyn et al., 2020). The h/H indices obtained in this study ranged between 3.21 and 4.34, and the highest h/H was determined in the CF group. The PI refers to the ratio of the sum of EPA and DHA to palmitic acid (C16:0). PI is used as a measure of PUFA damage (Lubis & Buckle, 1990), while IA and IT are used to assess the nutritional quality of fish (Ulbricht & Southgate, 1991). PI has also been reported to be a good indicator of lipid oxidation (Tenyang et al., 2019). In the present study, the highest PI value was recorded in group C, and the lowest PI value was recorded in group CF. In groups PNM50, PNM75, and PNM100, PI values were found at levels close to each other. This shows that the lowest PUFA damage was in group CF, followed by groups PNM50, PNM75, and PNM100, and the highest PUFA damage was in group C. Because high PI indicates that the nutritional value of lipids is high, it also means that the risk of oxidation and PUFA damage may increase.

Color in fish is much more than a superficial effect; it is an important characteristic of fish freshness quality and is also used as an indirect estimate of the chemical composition and sensory properties of food (Cheng et al., 2015). For example, muscle pigmentation in farmed trout is recognized as the most important quality parameter after freshness. Studies have reported that measurement location has a very significant effect on fish fillet color (De Francesco et al., 2004). In the present study, some differences were observed in fillet color at each of the three locations measured. Redness, yellowness, and hue attributes were different between the groups. In the present study, the highest mean a* value of fillets was in the PNM100 group with 4.18±0.58, which is lower than previous studies on rainbow trout color parameters (Regost et al., 2001; Poontawee et al., 2007; Kaya Öztürk et al., 2019). In previous studies, this difference in a* value was reported to depend on the amount of carotene, pigment types, lipid source, and level in fish feed (Marty-Mahé et al., 2004; Lerfall et al., 2017). In previous studies with trout and salmon fed with synthetic pigments, it was reported that carotenoid concentration in fish muscles increased, a* and b* values increased, and L* values decreased (Smith et al., 1992; Ingle de la Mora et al., 2006; Yeşilayer & Erdem, 2011). Some studies reported that the L* value determined in fish fillets is related to the moisture content of fish fillets (Hernández et al., 2009; Fuentes et al., 2010), but no such relationship was found in this study. Offer et al. (1989) stated that higher moisture content contributes to the formation of refractive indices within the food matrix, resulting in a lighter color. The chroma (C*) of a color directly indicates color intensity by describing the purity of the color relative to neutral gray (Yeşilayer et al., 2020). In the present study, the highest C* was in the PNM100 group in the 2nd and 3rd location measurements made from the bottom of the dorsal fin and the posterior part of the caudal fin, followed by the C group measurements. If all measurements had shown the groups with PNM addition, it could be said that these color changes were due to PNM addition. However, since the raw material affecting the color of fish fillets, such as corn protein, was used in the experimental feeds, it cannot be clearly stated that the addition of PNM instead of SBM to the feeds affected the color of fish fillets. Since there is no literature on the effect of PNM added to fish feeds on fish fillet color, this deficiency can be filled by conducting research on this subject.

Conclusion

This study demonstrates that peanut meal (PNM) is a viable alternative to soybean meal in rainbow trout diets, influencing biochemical composition, fatty acid profiles, and fillet coloration. PNM-based diets supported favorable EPA and DHA levels and improved lipid quality indices, indicating their nutritional suitability for human consumption. Complete replacement of SBM with PNM was feasible under the tested conditions, supporting the use of PNM as a sustainable plant protein source in aquafeeds. This substitution may contribute

to more sustainable aquaculture by reducing dependence on conventional plant proteins and promoting diversification of feed ingredients, in line with UN Sustainable Development Goal 12.

Compliance with Ethical Standards

Conflict of interest: The author(s) declare no actual, potential, or perceived conflict of interest for this article.

Ethics committee approval: This study was conducted in compliance with the rules for animal experiments for scientific purposes, and permission was given by the Sinop University Animal Experiments Local Ethics Committee with permission No. 2020/02 on February 17th, 2020.

Data availability: The data will be made available upon request from the author.

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