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Dietary Inclusion Levels of Almond (*Prunus amygdalus* Batsch 1801) Seed Meal On Growth Performance and Nutrient Utilization of Indian Carp (*Labeo rohita* Hamilton 1822) Fingerlings

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ABSTRACT

The nutritional value of feeding *Labeo rohita* fingerlings with different levels of *Prunus amygdalus* seed meal was evaluated for 56 days. Five isoproteic diets containing 40% crude protein were formulated by incorporating different levels of *Prunus amygdalus* seed meal (0.0, 0.5, 1.0, 1.5, and 2.0g/100g), and designated as PA1- PA5 respectively. A total of 225 *Labeo rohita* fingerlings with a mean weight of 5.76±0.10g were randomly allocated into 15 glass tanks (measuring 70 × 45 × 45 cm), each filled with 70 liters of water. Fish were stocked at a rate of 15 per tank, corresponding to five dietary treatments with three replicates each. The results revealed that significant differences ($P<0.05$) were observed in all the growth performances. Fish on PA4 had the best growth performance compared to other treatments and control. Fish fed PA4 had the highest survival (%) while PA1 (control) had the lowest survival (%). All water quality parameters (DO, temperature, and pH) remained within optimal and acceptable ranges for the fish during the experimental period. There were significant variations ($P < 0.05$) in the haematological profile of the experimental fish. Notably, the 1.5g inclusion level (PA4) yielded a well-balanced biochemical response, marked by increased protein and globulin, stable glucose levels, and reduced cholesterol, which indicates optimal metabolic and immune conditions at this concentration.

INTRODUCTION

Aquaculture has become an essential industry for addressing the rising global need for animal protein. Fish accounts for more than 40% of the total dietary protein intake in Nigeria and serves as a primary protein source in the typical Nigerian diet (Dada, 2003). Achieving sustainable aquaculture requires the formulation of nutritionally complete aquafeeds that include essential fatty acids (EFAs), amino acids, vitamins, and minerals (Zhou *et al.,* 2004). However, aquaculture growth in Nigeria faces challenges due to the limited availability and high cost of feed ingredients, particularly fish meal (Ayinla, 2005). This has prompted the search for affordable, locally sourced, and affordable plant-based protein options that do not compete with human food consumption.

Feed accounts for over 50 percent of the production cost. (FAO 2009). Feed additives play a crucial role in animal nutrition by improving the quality of feed, which in turn enhances the nutritional value of livestock and their by-products. They positively influence animal performance and health by aiding feed fermentation and nutrient absorption (Yee, 2012).

Labeo rohita, a commercially important fish species available year-round, is widely favored by consumers (Kaur *et al.,* 2021). Its popularity stems from its high market value, rapid growth, desirable meat texture, and suitability for formulated diets (Biswal *et al.,* 2021). The cost of fish feed affects aquaculture because of its higher nutritional value; consequently, the price of the feed affects the price of fish. The price of fish meal is increasing daily due to rising demand and a low production rate (Wang *et al.,* 2021). As a result, there is growing interest in identifying alternative, locally available, and cost-effective plant-based protein sources that do not compete with human food supplies.

Prunus amygdalus (almond) is rich in nutrients beneficial to heart health, including vitamin E, monounsaturated fats, polyunsaturated fatty acids (PUFAs), arginine, and potassium (USDA, 2004). Almond seeds are also a source of essential nutrients such as vitamin E, vitamin B2, calcium, magnesium, and potassium, which play vital roles in promoting fish growth and performance (USDA, 2009). Additionally, almonds have been linked to benefits such as supporting body weight management, regulating blood sugar levels, and improving bone density (Wien *et al.,* 2010). Almond trees are commonly found across West Africa, and their fruits are widely consumed, especially by children. The seeds are easily accessible and locally available (Burkill, 2000). Almond seeds also contain essential amino acids, making them an effective supplement to support the growth and overall health of farmed fish. Furthermore, the lipid profile of *P. amygdalus* seeds, which includes beneficial fatty acids, can help improve immune function and promote general fish well-being (Adewoye *et al.,* 2010). Research suggests that *Prunus amygdalus* seeds can serve as a sustainable alternative protein source, reducing reliance on traditional fish meal in aquaculture feeds. They also contain antioxidant and bioactive compounds that may provide health benefits

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beyond basic nutrition (Robbins *et al.,* 2011). This makes almond seed meal a strong candidate for use in aquaculture, particularly as a plant-derived additive in fish feed.

Dada *et al.* (2019) investigated the dietary impact of *Prunus amygdalus* seed meal on the reproductive performance of male African catfish (*Clarias gariepinus*) broodstock. In addition to its nutritional value, the seed exhibits antioxidant properties that help enhance the health of aquatic organisms by reducing oxidative stress and inflammation. While almonds are extensively studied for their health benefits in humans, their application in aquafeeds has not been widely explored. Only a few studies have examined the nutritional content of *Prunus amygdalus* seeds (Seham *et al.,* 2014). This study aims to assess the impact of different inclusion levels of almond seed meal in the diet on the growth performance and nutrient utilization of *Labeo rohita* fingerlings. Evaluating these factors will provide insight into the potential of almond seed meal as a sustainable alternative feed ingredient and help reduce reliance on costly traditional feed components. If proven effective, this approach could support the development of more affordable feed formulations, thereby improving the profitability and sustainability of small- and medium-scale aquaculture enterprises.

MATERIALS AND METHODS

Experimental Area

This study was conducted at the Research Laboratory of the Department of Fisheries and Aquaculture Technology, The Federal University of Technology, Akure (FUTA), Ondo State.

Collection and Preparation of *P. amygdalus* Seeds

Mature, ripe, and unaffected fruits of *P. amygdalus* were collected on the premises of the School of Agriculture and Agricultural Technology, FUTA. The fruits were identified and authenticated by a botanist from the Department of Crop, Soil, and Pest Management at FUTA. The fruits were cut open, and the seeds were removed cleaned, dried at ambient temperature to avoid the loss of volatile compounds, milled into fine powder using an electric blender (Model ES 242) and stored at 4°C in a plastic container

Experimental Fish

Labeo rohita fingerlings (225 in total), with an average weight of 4.92 ± 0.10 g, were sourced from the fish farm at the Federal University of Technology, Akure, Ondo State. They were acclimated in the laboratory for a period of two weeks and fed a commercial diet twice daily throughout this period.

Preparation of Experimental Diets

Five isoproteic diets containing 40% crude protein were formulated by incorporating different levels of *Prunus amygdalus* seed meal (0.0, 0.5, 1.0, 1.5, and 2.0g/100g), and designated as PA1-PA5 as shown in Table 1. Diets were fan dried at room temperature for 48 hours, packed in airtight polyethylene bags, labeled according to their respective treatments, and stored in a cool, dry environment.

Experimental Design

A completely randomized design was adopted for the experiment. Following the acclimatization phase, *L. rohita* specimens were individually weighed, and a total of 225 fish with an average body weight of 5.76 ± 0.10 g were randomly distributed into 15 glass tanks (dimensions: 70 × 45 × 45 cm), each containing 70 liters of water. Each tank housed 15 fish, representing five distinct dietary treatments with three replicates per treatment. Initial body weights were recorded using an electronic balance (Mettler Toledo PB 3002) immediately after acclimation. Fish were re-weighed biweekly to monitor growth throughout the 56-day feeding trial. The fish were

Table 1: Gross composition of the experimental diets (g/100g) for *L. rohita*.

Ingredients	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
Fish meal 65%	23.3	23.3	23.3	23.3	23.3
Soybean meal 45%	25.4	25.4	25.4	25.4	25.4
Groundnut cake 45%	28.1	28.1	28.1	28.1	28.1
Yellow maize 10%	13.3	13.3	13.3	13.3	13.3
Methionine	0.30	0.30	0.30	0.30	0.30
Lysine	0.20	0.20	0.20	0.20	0.20
Fish oil	6.00	6.00	6.00	6.00	6.00
Vitamin premix	2.40	2.40	2.40	2.40	2.40
Starch	1.00	1.00	1.00	1.00	1.00
Prunus amygdalus Seed meal	0.00	0.5	1.0	1.5	2.0

Vitamin premix- A Pfizer livestock product containing the following per kg of feed: A = 4500 I, U, D = 11252 I.U, E = 71I.U, K3=2mg, B12=0.015mg, pantothenic acid = 5mg, nicotinic acid = 14 mg, folic acid = 0.4mg, biotin = 0.04 mg. choline = 150mg, cobalt = 0.2 mg, copper = 4.5 mg, iron = 21 mg, manganese = 20mg, iodine = 0.6 mg, selenium = 2.2 mg, zinc = 20 mg, antioxidant = 2 mg offered the respective experimental diets twice daily, from 08:00–09:00 and 16:00–17:00 GMT, until apparent satiety. Uneaten feed and waste were removed daily via siphoning at 08:00 and 14:00 h before feeding sessions, and partial water exchange was performed to maintain water quality.

Determination of Physico-Chemical Parameters

Water quality parameters such as temperature, dissolved oxygen, and pH were recorded biweekly during the experimental period. Temperature readings were taken with a mercury thermometer (Jenway 3150 Dual Purpose Meter), pH values were measured using a digital pH meter (JENWAY 1960), and dissolved oxygen concentrations were evaluated with a DO test kit (HANNA HI-9142), in accordance with APHA (2005) guidelines.

Growth and Nutrient Utilization Parameters

Growth performance metrics were calculated based on the method described by Iheanacho *et al.* (2017). At the conclusion of the feeding trial, the fish were counted and weighed. The indices for growth and feed utilization were then determined using the following formulas:

Weight Gain (g) = Final weight- initial weight

Specific Growth Rate (SGR)

This was calculated from data on changes of body weight over a given time interval.

SGR (% per day) = ((Ln final weight - Ln initial weight)/(Time (Days))× 100

Feed Intake

This was determined by summing the daily average feed intake (DFI) of the fish in each treatment group over the entire experimental period.

Feed Conversion Ratio (FCR)=Feed intake (g)/Weight gain (g)

Feed Efficiency Ratio (FER)=Weight gain (g)/Feed intake (g)

Survival (%) = (Number of fish harvested /Number of fish stocked)× 100.

Fish Blood Collection and Analyses

Blood was drawn from fish in each glass tank using the cardiac puncture technique. Approximately 1 ml of blood was collected into separate 5 ml disposable syringes treated with ethylene diamine tetraacetic acid (10 ml EDTA) as an anticoagulant. Standard haematological methods outlined by Svobodana *et al.* (2006) were employed to determine the differential white blood cell (WBC) count, red blood cell (RBC) count, haemoglobin (Hb) concentration, and packed cell volume (PCV).

Serum Biochemical Analysis

Biochemical parameters were assessed using an automated analyzer equipped with veterinary-specific software (Cobas-Mira, ABX-Diagnostics, Tokyo, Japan).

Proximate Composition

The proximate composition of *P. amygdalus* seed, experimental diets and fish was analyzed for moisture, crude protein, ash, crude fibre, and fats according to the methods of AOAC (2023). Gross Energy was calculated as (5.65 Kcal/g x %CP) + (9.45 Kcal/g x %Lipid) + (4.11 Kcal/g x %NFE) according to NRC (2011)

Data Analysis

The experimental data were subjected to one-way analysis of variance (ANOVA) to evaluate differences among the treatment group means. To identify statistically significant variations between treatments, Tukey's multiple comparison test was applied. All statistical procedures were performed using SPSS software (Version 23, Statistical Package for the Social Sciences), with the significance threshold set at $p < 0.05$.

RESULTS AND DISCUSSION

Physico-Chemical Parameters

The physico-chemical parameters recorded throughout the experimental period for *Labeo rohita* fed with the experimental diets showed variation as presented in Table 2. Temperature remained fairly consistent across all treatments, ranging between 27.05°C and 27.22°C. Dissolved oxygen (DO) levels varied from 6.31 to 6.79 mg/L, indicating sufficient oxygen levels for fish growth throughout the trial period. The pH values showed some variation, with the lowest pH recorded in PA1 and the highest in PA3.

Table 2: Water qualities parameter measured during the experimental period

Parameters	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
DO (mg/L)	6.33 ± 0.03^a	6.79 ± 0.02^a	6.31 ± 0.14^a	6.52 ± 0.03^a	6.35 ± 0.02^a
Temperature (°C)	27.16 ± 0.35^a	27.22 ± 0.00^a	27.05 ± 0.04^a	27.20 ± 0.00^a	27.17 ± 0.05^a
pH	7.12 ± 0.02^a	7.51 ± 0.05^b	7.65 ± 0.003^b	7.36 ± 0.04^b	7.42 ± 0.00^b

Means in same row with different superscripts are significantly different (P<0.05)

Proximate Composition of the Experimental Diets

The proximate composition of the experimental diets fed to *L. rohita* during the study is presented in Table 3. The crude protein content of all the experimental diets fell within the range 39.24 to 39.62%. Ash content ranged between 7.91% and 8.53%, PA2 diet had the lowest Ash content while PA1 diet (control) had the highest Ash content. Lipid content ranged between 12.6% for PA4 diet to 13.1% for PA1diet. Crude fibre content ranged between 5.10 and 6.02% (mean, 5.7%). PA3 diet had the highest value while PA1 diet had the least value. Moisture content of the experimental diets ranged between 11.5 to

12.6%. PA2 had the lowest moisture content while PA1 had the highest moisture content.

Table 3: Proximate Composition of experimental diets

Parameters (%)	PA (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
Protein	39.24	39.62	39.43	39.36	39.47
Ash	8.53	7.91	8.28	8.12	8.40
Lipid	13.1	12.8	12.9	12.6	12.8
Fibre	5.10	5.87	6.02	5.68	5.99
Moisture	12.6	11.5	11.7	11.9	12.3
Nitrogen free extract	21.43	22.30	21.67	22.34	22.04

Growth Performance

The growth parameters and nutrient utilization results for *Labeo rohita* fed diets supplemented with *Prunus amygdalus* seed are shown in Table 4. Both mean final weight and mean weight gain followed a similar pattern by the end of the experiment. Significant differences ($P < 0.05$) were observed in the mean final weight across treatments. Fish fed the PA4 diet recorded the highest mean final weight (70.6g), while those on the PA1 (control) diet had the lowest (53.9g). Additionally, fish receiving PA3, PA4, and PA5 diets showed significantly ($P < 0.05$) greater specific growth rates (SGR) compared to the control group (PA1). The least SGR was recorded in the PA1 at a rate of 3.99% per day, which showed that the rate of growth of fish in the control group was Lower than fish fed with almond seed meal. The feed intake (FI) recorded for fish fed PA3, PA4 and PA5 was significantly higher ($P < 0.05$) than the control diet PA1 and PA2, and the highest FI was recorded in the PA4, 108.7g, which was reflective of the enhanced growth performance in those fish groups. The FCR was lowest in PA4 (1.68) and considered excellent because the fish fed this treatment had the highest feed conversion, the poorest FCR (1.77) was established in PA1. FER shows fish fed PA4 and PA3 diet were higher ($P < 0.05$) with 0.60 and 0.59, respectively indicating that the almond seed enhanced feed conversion. Fish fed PA4 had the highest survival rate (100%) while the control had the lowest survival rate.

Table 4: Growth performance of *Labeo rohita* fed experimental diets.

Parameters	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
MIW (g)	$5.78±0.12^a$	$5.76±0.19^a$	$5.79±0.14^a$	$5.77±0.01^a$	$5.76±0.01^a$
MFW (g)	$53.9±12.4^a$	$57.4±8.25^{ab}$	$68.1±3.35^b$	$70.6±7.45^c$	$65.7±1.90^b$
MWG (g)	$48.1±12.5^a$	$51.6±8.40^{ab}$	$62.3±3.50^b$	$64.8±7.45^c$	$60.0±1.85^b$
SGR (%/day)	$3.99±0.46^a$	$4.11±0.32^{ab}$	$4.40±0.13^b$	$4.47±0.19^b$	$4.35±0.05^b$
TFI (g/fish)	$85.0±11.0^a$	$89.8±4.30^b$	$105.9±4.30^c$	$108.7±10.2^c$	$105.3±5.65^c$
FCR	$1.77±0.25^b$	$1.74±0.22^b$	$1.70±0.16a^b$	$1.68±0.03^a$	$1.76±0.15^{ab}$
FER	$0.57±0.08^a$	$0.57±0.03^a$	$0.59±0.05^b$	$0.60±0.02^b$	$0.57±0.05^a$
Survival (%)	$85.0±15.0^a$	$95.0±5.00^a$	$90.0±10.0^a$	$100.0±0.00^a$	$90.0±10.0^a$

Mean in the same row with different letter are significantly different at P<0.05.
Key: MIW= Mean initial weight, MFW= Mean final weight, MWG= Mean weight gain, SGR= Specific growth rate (%/day), FI= Feed intake, FCR= Feed conversion ratio, FER= Feed efficiency ratio

Haematological Profile

The Impact of *P. amygdalus* seed supplementation on the haematology of *L. rohita* is presented in table 5. PA2, PA3, PA4 and PA5 diets exhibited higher levels of haemoglobin (Hb), packed cell volume (PCV), and red blood cell count (RBC) compared to those in the PA1 (control) group. The highest Hb value was recorded in group PA4 (2.0g), reaching 6.63 g/100 ml, along with a significantly elevated PCV of 19.7% in the same group. These findings suggest a positive effect of almond seed at higher inclusion levels. White blood cell (WBC) counts varied across the treatment groups. The lowest values were recorded in PA4 ($6.53 \times 10^3/mm^3$) and PA2 ($8.06 \times 10^3/mm^3$), possibly indicating an immunomodulatory role of almond seeds, especially at lower inclusion rates. In line with RBC trends, another blood parameter peaked in PA4 at $2.01 \times 10^3/mm^3$, suggesting enhanced erythropoiesis with higher almond seed supplementation. Significant differences ($P < 0.05$) were observed among all groups for mean corpuscular volume (MCV), mean corpuscular hemoglobin (MCH), and mean corpuscular hemoglobin concentration (MCHC). MCV and MCH values increased particularly in groups PA2 and PA4, whereas MCHC values showed more fluctuation—28.5% in PA2 and 37.9% in PA1—indicating a less consistent effect on haemoglobin concentration within red cells.

Table 5: Haematological profile of *L. rohita*

Parameters	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
PCV (%)	11.7±0.88^{a}	15.8±1.00^{b}	16.3±1.33^{b}	19.7±1.76^{c}	16.4±1.15^{b}
WBC (×103 /mm3)	7.37±0.26^{b}	8.06±0.15^{c}	7.67±0.15^{bc}	6.53±0.16^{a}	7.50±0.17^{b}
RBC (×103 /mm3)	1.54±0.06^{a}	1.57±0.03^{a}	1.79±0.03^{ab}	2.01±0.25^{b}	1.83±0.09^{ab}
Hb (g/100ml)	4.43±0.13^{a}	4.50±0.31^{a}	5.20±0.11^{b}	6.63±0.12^{c}	5.57±0.18^{b}
MCHC (%)	37.9±3.82^{c}	28.5±2.34^{a}	31.9±1.91^{ab}	33.7±2.27^{b}	34.0±3.49^{b}
MCH (pg)	28.8±1.38^{a}	28.7±2.00^{a}	29.1±0.35^{a}	33.0±2.05^{b}	30.4±2.37^{a}
MCV (fl)	76.0±8.60^{a}	100.6±8.81^{c}	91.1±5.80^{b}	98.0±9.30^{c}	89.6±6.30^{ab}

Key: WBC- White Blood Cell, RBC- Red Blood Cell, Hb- Haemoglobin, PCV - Pack Cell Volume, MCV- Mean cell Volume, MCH-Mean Cell Haemoglobin, MCHC- Mean Cell Haemoglobin Concentration.

Biochemical Profile

The present study evaluated the biochemical profile of *L. rohita* fingerlings fed varying inclusion levels of *P. amygdalus* seed meal. Fish fed diets containing 0.5g, 1.0g, and 2.0g almond seed meal showed a noticeable increase in glucose levels, whereas no substantial difference was observed between the control group (PA1) and the inclusion level of 1.5g (PA4). Total protein, globulin, and albumin levels were significantly increase in fish that received 0.5g, 1.5g, and 2.0g almond seed meal when compared to the PA1(control). Cholesterol levels were decreasing at 0.5g and 1.5g inclusion level and high at PA3(1.0g), PA5(2.0g) and PA1 control group.

Table 6: Biochemical profile of *L. rohita*

Parameters	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
Glucose (mg/dl)	31.0±1.15^{a}	41.7±0.88^{b}	40.5±0.66^{b}	32.3±0.28^{a}	44.3±0.73^{c}
Cholesterol (mg/dl)	40.2±0.58^{ab}	38.6±1.19^{a}	42.3±0.88^{b}	37.9±1.76^{a}	41.0±1.15^{ab}
Total protein (g/dl)	5.37±0.12^{b}	5.93±0.07^{b}	4.80±0.12^{a}	5.43±0.09^{b}	6.09±0.18^{c}
Globulin (g/dl)	3.22±0.06^{ab}	3.53±0.20^{b}	3.11±0.09^{a}	3.37±0.18^{b}	3.65±0.12^{c}
Albumin (g/dl)	2.20±0.09^{b}	2.43±0.15^{c}	2.05±0.12^{a}	2.16±0.12^{b}	2.41±0.15^{c}

Mean in the same row with different letters are significantly different (P<0.05)

Carcass Composition

The inclusion of *P. amygdalus* seed meal in the diet of *L. rohita* significantly influenced carcass composition, as shown in table 7. The moisture content was relatively consistent across various treatments, whereas the ash content decreased as the inclusion levels increase, suggesting a decrease in mineral deposition at the 2.0g inclusion level. A significant decrease in crude lipid content occurred with the increasing levels of almond seed meal, indicating a lipid-lowering impact, while crude protein content steadily increased, reaching the highest levels at a 2.0g inclusion. Nitrogen-Free Extract (NFE) showed slight variations but was generally lower at 0.5g and 2.0g inclusion levels.

Table 7: Carcass composition of *L. rohita*

Parameters (%)	PA1 (0.0)	PA2 (0.5)	PA3 (1.0)	PA4 (1.5)	PA5 (2.0)
Moisture	2.93±0.04^{a}	2.78±0.07^{a}	2.32±0.02^{a}	3.04±0.03^{b}	2.84±0.03^{a}
Ash	18.2±0.02^{c}	18.9±0.06^{c}	16.7±0.03^{b}	15.6±0.02^{ab}	13.9±0.04^{a}
Crude lipid	13.2±0.01^{c}	11.5±0.09^{ab}	12.3±0.06^{b}	10.6±0.04^{a}	10.4±0.06^{a}
Crude protein	59.4±0.14^{a}	61.8±0.03^{b}	61.9±0.02^{b}	64.8±0.02^{c}	67.3±0.06^{d}
NFE	6.23±0.10^{b}	5.31±0.01^{a}	6.98±0.03^{b}	6.51±0.00^{b}	5.82±0.06^{a}

Mean in the same row with different superscripts are significantly different at P<0.05
Key: NFE – Nitrogen Free Extract

Discussion

Physico-Chemical Parameters

The physico-chemical parameters recorded during the experiment were found to be in the standard range suitable for the normal physiological performance of *L. rohita.* These parameters are in concordance with Bhatnagar and Devi's, 2013, Md Hosen *et al.* (2019) and Malik *et al.* (2020). This suggests that the environmental conditions during the experimental period were within an appropriate range for the culture of *Labeo rohita* and similar fish species.

Growth Performance and Nutrient Utilization

The growth performance results showed that fish fed the PA4 diet achieved the highest mean final weight and mean weight gain, indicating that a 1.5g inclusion level of *Prunus amygdalus* best promotes the growth of *Labeo rohita*. Growth declined in the group fed the highest inclusion level (PA5, 2.0g), suggesting reduced feed intake and poorer feed utilization. This aligns with Bekibele (2005), who reported increased mean weight gain in *Clarias gariepinus* fed mucuna bean meal-based diets up to an optimal inclusion level. Similarly, Jackson *et al.* (1982) observed improved growth in *Sparus mossambicus* fingerlings fed sunflower seed meal as a protein replacement. The highest specific growth rate (SGR) found here agrees with Akhtar *et al.* (2015), who noted increased SGR in *L. rohita* fed plant-based diets. Mean weight gain and SGR are commonly regarded as key indicators of diet productivity (Omitoyin and Faturoti, 2000). The lowest feed conversion ratio (FCR) was recorded in fish fed PA4, indicating better feed conversion and utilization, which are crucial for successful aquaculture growth (Nadeem *et al.,* 2021). The highest total feed intake (TFI) in the PA4 group suggests this diet was the most palatable and acceptable to the fish. Feed palatability and acceptability are influenced by factors such as feed appearance, taste, and the acceptability of individual feed ingredients (Tacon, 1985). Survival rates were generally good, ranging from 85.0% to 100%. Lower survival rates may indicate starvation due to poor feed intake, while higher survival rates could result from adequate feed consumption.

Haematological Parameters

Fish hematological parameters serve as reliable tools of assessing general health (Tavares-Dias, 2006). The hematological parameters of *L. rohita* fed experimental diet improved when compared with the control group. At the end of the experiment, PCV, RBC, Hb, MCV, and MCHC levels significantly increased compared to the control diet. The observed decrease in white blood cell (WBC) count suggests that *Prunus amygdalus* seed meal may possess antimicrobial properties. The rise in RBC values across the treated groups relative to the control could indicate enhanced cellular immunity, consistent with findings by Sahu *et al.* (2007), who noted that increased RBC counts in *Labeo rohita* fingerlings fed Mangifera indica reflected improved cellular immunity. The increase in hemoglobin (Hb) with higher inclusion levels suggests more efficient oxygen transport, which supports better growth and overall health in *L. rohita*. Red blood cell indices—MCV, MCH, and MCHC—are important in diagnosing anemia and lead poisoning in humans and animals (Ahilan *et al.,* 2004). The significant difference in MCHC values observed in the experimental groups may be linked to a defensive response (Ahilan *et al.,* 2004). Additionally, MCV values across all inclusion levels remained within the normal range (normocytic), indicating that the extracts do not induce microcytic anemia in the fish.

Body Composition

Significant differences were recorded only at PA4, the overall variation in moisture content was minimal across the diet groups. This suggests that almond seed meal had a limited direct effect on water retention in the muscle tissue. The slightly higher moisture at PA4 may reflect a compensatory metabolic response or increased lean mass associated with improved protein deposition. The highest protein content observed in this study at PA5 (2.0g) may be attributed to the fish's more efficient utilization of available protein for growth at this inclusion level compared to other groups. Similar findings regarding body protein content in relation to species-specific protein requirements have been reported for other fish (Kim *et al.,* 2002; Yang *et al.,* 2002; Lin *et al.,* 2010). Kim and Lee (2009) noted that body protein content responds to dietary protein levels in a dose-dependent manner, with maximum protein content coinciding with the dietary protein level that produces the highest growth rate. Whole-body fat content decreased progressively as inclusion levels increased, with the lowest fat content found in fish fed the highest protein diet (PA5). This reduction in fat may be linked to the dietary fiber or bioactive compounds present in almonds, which could influence lipid metabolism and reduce fat accumulation (Richardson *et al.,* 2009; Robbins *et al.,* 2011). Lower fat content is often preferred for health reasons and consumer acceptance, suggesting a potential advantage of including almonds in aquafeeds. Except at lower dietary protein levels, body ash content showed no significant differences across treatments. The highest ash content at marginal protein levels might result from reduced fish weight and consequently impaired muscle growth at lower protein concentrations. Additionally, diets low in protein have been associated with muscle hypertrophy (Yamashiro *et al.,* 2016).

Biochemical Profile

Biochemical analysis offers important insights for assessing the health status of fish. These biochemical changes vary based on factors such as the species, age, sexual maturity cycle, and overall health condition of the fish. Additionally, examining serum biochemical components has proven helpful in identifying and diagnosing metabolic disorders and diseases in fish (Ferrari *et al.,* 2007). The findings revealed significant variations in serum biochemical indicators across the treatment groups. Fish that were given diets containing 0.5g, 1.0g, and 2.0g almond seed meal (PA2, PA3, PA5) showed a noticeable increase in glucose levels, whereas no substantial difference was observed between the control group (PA1) and the inclusion level of 1.5g (PA4). This pattern suggests that moderate supplementation (1.5g) helped maintain glucose equilibrium, while both higher and lower inclusion levels may have induced a slight stress response or heightened carbohydrate metabolism. Similar patterns have been reported by El-Sayed (1999), who found that excessive inclusion of plant-based meals in tilapia diets led to increased glucose levels due to nutritional stress. Likewise, Zaki *et al.* (2012) observed that moderate inclusion of lupin meal stabilized glucose in Nile tilapia. Importantly, cholesterol levels were significantly diminished with 0.5g and 1.5g inclusion, indicating a possible cholesterol-lowering effect of almond seed meal at these concentrations, which might be attributed to the presence of unsaturated fatty acids or phytosterols recognized for reducing cholesterol. Total protein, globulin, and albumin levels were significantly elevated in fish that received 0.5g, 1.5g, and 2.0g almond seed meal (PA2, PA4, PA5) when compared to the control group. Comparable results were obtained by Omoregie and Ofojekwu (2002), who reported increased protein levels in fish fed soybean-based diets, and Harikrishnan *et al.* (2011), who reported that plant based-meal supplements can elevate immunological markers in fish. This enhancement suggests improved protein synthesis and a stronger immune response, as globulin acts as an essential marker for immune competence. Conversely, fish that were supplemented with 1.0g almond seed meal (PA3) exhibited lower levels of total protein and globulin, implying potential differences in the effectiveness of protein utilization or absorption at this inclusion level. A similar non-linear trend was reported by Adeparusi and Famurewa (2011), where certain inclusion levels of Moringa seed meal led to suboptimal biochemical responses in C. gariepinus. Notably, the 1.5g inclusion level (PA4) yielded a well-balanced biochemical response, marked by increased protein and globulin, stable glucose levels, and reduced cholesterol, which indicates optimal metabolic and immune conditions at this concentration.

CONCLUSION

The results of this study demonstrated that the best growth performance and nutrient utilization in *Labeo rohita* were achieved with the PA4 diet, containing 1.5 g/100g inclusion of *Prunus amygdalus* Therefore, *Prunus amygdalus* seed can be effectively incorporated at 1.5 g/100g in the diet of *L. rohita* without negatively affecting growth or nutrient utilization. Additionally, *P. amygdalus* seed supplementation shows beneficial balance that boosts protein and immune functions, stabilizes glucose and cholesterol levels, and improve growth performance. However, further research is needed to evaluate its effectiveness under pond culture conditions, as this study was conducted in a controlled laboratory setting.

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