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Original Research Paper

Evaluation of *Moina micrura* meal as a Fish meal Substitute: Effects on Growth Performance, Feed Utilization and Whole-Body Composition of *Cyprinus carpio*

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Moina micrura, Cladoceran meal, Fish meal replacement, Growth performance.

Abstract

The increasing cost and limited availability of fish meal have prompted the search for alternative protein ingredients in aquaculture feeds. This study evaluated the potential of dried *Moina micrura* meal as a partial fish- meal substitute in diets for common carp (*Cyprinus carpio*). Three dietary treatments were evaluated over a 100-day feeding trial: a control diet without *M.micrura* meal, a diet containing 5% *M.micrura* meal (M5), and a diet containing 10% *M.micrura* meal (M10). Growth performance, feed utilization and whole-body proximate composition were assessed. The dried *M.micrura* meal contained 51.00 ± 0.50% crude protein and 17.60 ± 0.26% crude lipid, with moisture and ash contents of 14.33 ± 0.29% and 10.53 ± 0.06%, respectively. Dietary treatment significantly affected growth performance ($p < 0.001$). Final body weight increased from 2.67 ± 0.10 g in the control to 4.83 ± 0.15 g in M5 and 6.83 ± 0.15 g in M10. Similarly, weight gain increased from 1.11 ± 0.08 g in the control to 3.26 ± 0.15 g in M5 and 5.27 ± 0.16 g in M10. The M10 group exhibited the highest specific growth rate (1.333 ± 0.012% day^{-1}) and protein efficiency ratio (1.165 ± 0.045), together with the lowest feed conversion ratio (1.90 ± 0.06). Whole-body crude protein and lipid contents increased with increasing dietary *Moina* inclusion, whereas moisture content decreased. Overall, the results demonstrate the potential of dried *M.micrura* meal as an alternative protein ingredient in common carp diets. Among the treatments evaluated, 10% inclusion was associated with the most favourable growth performance and feed utilization. Further studies using nutritionally matched diets are warranted to distinguish the effects of *Moina* inclusion from those of differences in dietary protein content.

1. Introduction

Aquaculture is one of the fastest-growing food production sectors globally and plays an important role in ensuring food and nutritional security. According to the Food and Agriculture Organization, aquaculture has become a major contributor to global aquatic animal production. However, the continued expansion of aquaculture depends largely on the availability of nutritionally balanced and economically sustainable feeds. Common carp, *Cyprinus carpio* Linnaeus, 1758, is one of the most widely cultured freshwater fish species because of its rapid growth, omnivorous feeding habit, adaptability to

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diverse environmental conditions and tolerance to fluctuating water quality (Bănărescu and Coad 1991; Rahman *et al*. 2008). Feed represents a major proportion of aquaculture production costs, while dietary protein is one of the most expensive components of formulated feeds (Naylor *et al*. 2021). Fish meal has traditionally been used as a major protein source in aquafeeds because of its favourable amino-acid profile, high digestibility and palatability (Ye *et al*. 2011). Nevertheless, increasing demand, limited fishery resources and fluctuations in fish-meal availability have encouraged the search for alternative protein sources (Hua *et al*. 2019; Hossain *et al*. 2016). Plant-derived ingredients such as soybean meal have received considerable attention, but their use can be limited by anti-nutritional compounds, amino-acid imbalance and competition with other sectors for raw materials (Gatlin *et al*. 2007; Jayant *et al*. 2018). Consequently, alternative animal-derived protein ingredients with good nutritional quality and production potential are increasingly being investigated. Freshwater zooplankton constitute an important component of aquatic food webs and are widely used as live feed in aquaculture because of their favourable nutritional composition, digestibility and suitable size for fish larvae and juveniles (Das *et al*. 2012; Rasdi *et al*. 2020; Sultana *et al*. 2023). Freshwater cladocerans, particularly *Daphnia* and *Moina*, are recognised as nutritionally valuable organisms containing considerable amounts of protein, lipid, essential fatty acids, vitamins and minerals (Mayer and Wahl 1997; Das *et al*. 2012). Their rapid reproduction and suitability for mass culture make them attractive candidates for biomass production. Although cladocerans are commonly used as live feed, their potential as dried meal ingredients in formulated fish diets remains comparatively less explored. Previous studies have demonstrated that cladoceran biomass can contribute to growth and feed utilisation in cultured fish. For example, Abo-Taleb *et al*. (2024) reported favourable growth and feed-utilisation responses in hybrid red tilapia fed diets containing *Daphnia* meal, while El-Feky *et al*. (2024) demonstrated the potential of *Daphnia magna* biomass meal as a fish-meal replacement in Nile tilapia. Similar positive responses to cladoceran biomass have also been reported in grey mullet larvae (Abo-Taleb *et al*. 2021). The nutritional value of an alternative protein ingredient depends not only on its crude protein concentration but also on its lipid content, amino-acid profile, digestibility and availability of nutrients. *Moina micrura* is particularly interesting because it can be mass cultured under freshwater conditions and provides a source of animal protein and lipid biomass. However, information concerning the use of *M.micrura* meal in diets for common carp is still limited. Therefore, the present study evaluated the potential of dried *M.micrura* meal as a partial fish- meal substitute in diets for *C. carpio*. The study specifically examined its effects on growth performance, feed utilization and whole-body proximate composition.

2. Materials and Methods

2.1 Experimental fish

Juvenile common carp, *Cyprinus carpio*, were used for the feeding experiment. Fish were acclimated to laboratory conditions before the beginning of the feeding trial. Healthy and actively swimming individuals of relatively uniform size were selected and randomly distributed among the experimental aquaria. The experimental design consisted of five dietary treatments in the original feeding experiment. For the present *Moina*-focused manuscript, only the control, 5% *Moina* meal and 10% *Moina* meal treatments were considered. Each treatment consisted of three replicate aquaria with 20 fish per aquarium. The aquaria had a capacity of 100 L.

2.2 Culture and preparation of *Moina micrura* meal

Laboratory cultures of *Moina micrura* were maintained in the Department of Zoology, VHNSN College, Virudhunagar, Tamil Nadu, India. The cladoceran *Moina micrura* used in the present study was identified based on its morphological characteristics as shown in Figure 1. The cladocerans were cultured and harvested for preparation of the experimental feed ingredient. Harvested *M.micrura* biomass was collected and processed for incorporation into the experimental diets. The biomass was dried at 50 ± 2°C for 24 h and subsequently processed into meal.



Figure 1. Representative microscopic image of the cladoceran *Moina micrura* used in the present study.

2.3 Proximate composition of *Moina micrura* meal

Prior to diet formulation, the dried biomass of *Moina micrura* was analysed to determine its proximate composition and nutritional value. The proximate composition of the experimental diets was also determined after preparation. All analyses were performed in triplicate according to the standard methods of the Association of Official Analytical Chemists (AOAC, 2019). Moisture content was determined by oven-drying the samples at 105 °C until a constant weight was obtained (AOAC Method 934.01). Crude protein content was determined using the Kjeldahl method (AOAC Method 984.13), and the nitrogen content was converted to crude protein using a conversion factor of 6.25. Crude lipid content was determined by petroleum ether extraction using a Soxhlet extraction apparatus (AOAC Method 920.39). Ash content was determined by incinerating the samples in a muffle furnace at 550 °C for 6 h (AOAC Method 942.05).

2.4 Experimental Diet Formulation

Five experimental diets were originally formulated; however, for the present analysis, only the diets containing *Moina micrura* meal were considered. Three diets were evaluated: a control diet containing fish meal as the primary animal protein source, and two experimental diets containing *M.micrura* meal at inclusion levels of 5% and 10% (M5 and M10, respectively). Fish meal, soybean meal, groundnut cake, rice bran, wheat bran and tapioca flour were procured from a commercial feed supplier in Virudhunagar, Tamil Nadu, India. A commercial vitamin–mineral premix was incorporated into all diets at 1%. All ingredients were accurately weighed according to the formulation presented in Table 1 and thoroughly mixed to obtain a homogeneous mixture. Water was gradually added to produce a uniform dough, which was steam-cooked for approximately 20 min. After cooling to room temperature, the vitamin–mineral premix was incorporated to minimise the thermal degradation of heat-sensitive vitamins. The prepared dough was passed through a laboratory pelletizer to produce pellets of approximately 2 mm diameter. The pellets were air-dried at room temperature, packed in airtight polyethylene bags and stored at 4 °C until use. The ingredient composition of the diets evaluated in the present M. micrura-based analysis is presented in Table 1.

Table 1. Ingredient composition of the experimental diets containing *Moina micrura* meal (g per 100 g diet)

Ingredient	Control	M5	M10
Fish meal	40	35	30
Moina micrura meal	0	5	10
Groundnut cake	10	10	10
Soybean meal	10	10	10
Rice bran	20	20	20
Wheat bran	10	10	10
Tapioca flour	9	9	9
Premix Supradin	1	1	1
Total	100	100	100

M5, diet containing 5% *Moina micrura* meal; **M10**, diet containing 10% *Moina micrura* meal. **Premix Supradin**-IP(as acetate) 20,000 IU; Cholecalciferol IP (vitamin-D3) 2,000 IU; thiamine mononitrate IP 200 IU; Riboflavin IP 20 mg; Pyridoxine Hydrochloride IP 6mg; Cyanocobalamin IP 30 mg; Nicotinamide IP 200 mg; Calcium pantothenate IP 32.6mg; Ascorbic acid ;IP 300 mg; α-iodophenyl acetate IP 50 mg; Biotin-USP0.50mg; Calcium phosphate IP 258 mg; Magnesium oxide light IP 120 mg; Dried ferrous sulphate IP 64.0mg; Manganese sulphate BP 4.06 mg; Total phosphorus in the preparation 51.60 mg copper sulphate IP 4.40; Sodium molybdate .5 mg and Sodium borate 1.76mg.

2.5 Experimental Fish, Rearing Conditions and Feeding Trial

Healthy juvenile common carp (*Cyprinus carpio*) were procured from a local fish farm in Virudhunagar, Tamil Nadu, India, and transported to the laboratory in oxygenated containers. Prior to the feeding trial, the fish were acclimatized to laboratory conditions for two weeks and fed the control diet. Following acclimation, the fish were disinfected by immersion in a 1% sodium chloride (NaCl) solution for 5 min to minimize the risk of external parasitic and bacterial infections before stocking. For the Moina meal feeding trial, the experimental fish were randomly distributed into glass aquaria of 100 L capacity. The dietary treatments consisted of a control diet and diets supplemented with Moina meal at graded inclusion levels, with three replicates for each treatment. Twenty fish, with an initial mean body weight of 1.50 ± 0.10 g and an initial mean total length of 4.83 ± 0.10 cm, were stocked in each aquarium. Fish were fed their respective experimental diets twice daily at 08:00 and 17:00 h at a feeding rate of 5% of body weight per day for 100 days. The feed ration was adjusted periodically based on changes in fish biomass during the experimental period. Continuous aeration was provided to all aquaria using air stones connected to an air pump to maintain adequate dissolved oxygen levels. Approximately 70% of the culture water in each aquarium was replaced weekly with dechlorinated freshwater to maintain suitable water quality throughout the feeding trial. Uneaten feed and faecal matter were removed regularly by siphoning to maintain hygienic rearing conditions. Fish were monitored daily for feeding behaviour, general health condition and mortality. Any dead fish were removed immediately, and survival was recorded for each treatment.

2.6 Growth Performance, Feed Utilisation and Survival Indices

Fish growth performance, feed utilisation and survival were evaluated at the end of the feeding trial. Fish from each aquarium were individually weighed and measured to determine changes in body. The following growth and feed-utilisation indices were calculated:

Weight gain (WG, g):

$$\text{WG (g)} = \text{Final average weight (g)} - \text{Initial average weight (g)}$$

Percentage weight gain (WG, %):

$$\frac{\text{Average final fish weight} - \text{Average initial fish weight}}{\text{Average initial fish weight}} \times 100$$

Specific growth rate (SGR, % day^{-1}):

$$\text{Specific growth rate (SGR \%per day)} = \frac{\text{lnW2} - \text{lnW1}}{\text{T2} - \text{T2}} \times 100$$

Where, W1 = the initial average body weight (g) at time T1 (day); W2 =the final average body weight (g) at time T2 (day).

Feed conversion ratio (FCR):

$$\text{FCR} = \frac{\text{Total feed}intake\ \text{(g)}}{\text{Total weight gain of } fish\ \text{(g)}}$$

Protein efficiency ratio (PER):

$$\text{PER} = \frac{\text{Total weight gain (g)}}{\text{Total protein intake (g)}}$$

2.7 Whole-Body Proximate Composition Analysis

At the end of the feeding trial, fish were randomly collected from each replicate aquarium for whole-body proximate composition analysis. The collected fish were rinsed with distilled water to remove adhering debris, blotted dry using absorbent paper and homogenised to obtain representative whole-body samples. The moisture, crude protein, crude lipid and ash contents of the whole-body samples were determined in triplicate using the analytical procedures described in Section 2.3. The whole-body proximate composition of fish fed the different experimental diets was expressed as percentage moisture, crude protein, crude lipid and ash content.

2.8 Statistical Analysis

All experimental data were recorded and organised using Microsoft Excel and statistically analysed using IBM SPSS Statistics version 21.0. The data were subjected to one-way analysis of variance (ANOVA) to determine significant

differences among the experimental treatments. Homogeneity of variances was assessed using Levene's test. When a significant treatment effect was detected, Tukey's honestly significant difference (HSD) post-hoc test was performed for pairwise comparisons among treatment means. Statistical significance was accepted at $P < 0.05$.

3. Results

3.1 Proximate composition of *Moina micrura* meal

The high protein content indicates that *M.micrura* provides a substantial protein contribution when incorporated into formulated fish diets. The proximate composition of the dried *M.micrura* meal and experimental diets is presented in Table 2. The diets evaluated and their analysed proximate composition is presented in Table 3.

Table 2. Proximate composition of dried *Moina micrura* meals (%)

Component	Composition (%)
Moisture	14.33 ± 0.29
Crude protein	51.00 ± 0.50
Crude lipid	17.60 ± 0.26
Ash	10.53 ± 0.06

Table 3. Analysed proximate composition of the experimental diets containing *Moina micrura* meal (%)

Parameter	Control	M5	M10
Moisture	9.50 ± 0.10	8.40 ± 0.10	8.43 ± 0.06
Crude protein	39.47 ± 0.25	40.77 ± 0.64	45.27 ± 0.68
Crude lipid	8.40 ± 0.10	7.63 ± 0.51	8.40 ± 0.10
Ash	10.10 ± 0.53	9.93 ± 0.84	10.40 ± 0.10

3.2 Growth Performance

The growth performance of the experimental fish was significantly influenced by the dietary treatments. Initial body weight did not differ significantly among the treatments ($F_{2,6} = 0.219$, $p = 0.810$), indicating that the fish were comparable at the beginning of the feeding trial. The mean initial body weight ranged from 1.56 ± 0.020 g in the Control group to 1.57 ± 0.015 g in the Moina 5% group, while the Moina 10% group recorded 1.56 ± 0.021 g. Levene's test confirmed homogeneity of variances ($F = 0.176$, $p = 0.842$), and Tukey's HSD test showed no significant differences among the treatment groups. In contrast, final body weight differed significantly among the dietary treatments ($F_{2,6} = 708.305$, $p < 0.001$). The Moina 10% group recorded the highest final body weight (6.83 ± 0.150 g), followed by the Moina 5% group (4.83 ± 0.150 g), whereas the Control group showed the lowest value (2.67 ± 0.100 g). Levene's test indicated homogeneous variances ($F = 0.182$, $p = 0.838$). Tukey's HSD test revealed significant differences between all treatment pairs, with the Control, Moina 5%, and Moina 10% groups forming separate homogeneous subsets. Similarly, weight gain was significantly affected by dietary treatment ($F_{2,6} = 749.336$, $p < 0.001$). The highest weight gain was recorded

in the Moina 10% group (5.27 ± 0.156 g), followed by the Moina 5% group (3.26 ± 0.146 g), while the Control group showed the lowest weight gain (1.11 ± 0.080 g). The homogeneity of variance assumption was satisfied (Levene's F = 0.640, p = 0.560), and Tukey's HSD test confirmed significant differences among all treatment pairs. Percentage weight gain also differed significantly among treatments ($F_{2,6}$ = 631.406, p < 0.001). The Moina 10% group exhibited the highest percentage weight gain (338.83 ± 12.502%), followed by the Moina 5% group (208.30 ± 9.019%) and the Control group (71.12 ± 4.220%). Levene's test showed homogeneous variances (F = 2.950, p = 0.128), and Tukey's HSD test indicated that all treatment groups differed significantly from one another. Specific growth rate (SGR) was also significantly influenced by dietary treatment ($F_{2,6}$ = 2276.305, p < 0.001). The highest SGR was observed in the Moina 10% group (1.33 ± 0.012% day^{-1}), followed by the Moina 5% group (1.01 ± 0.010% day^{-1}), while the Control group recorded the lowest SGR (0.48 ± 0.022% day^{-1}). Levene's test indicated homogeneous variances (F = 0.656, p = 0.553), and Tukey's HSD test demonstrated significant differences among all treatment groups. Feed conversion ratio (FCR) showed a significant difference among the dietary treatments ($F_{2,6}$ = 287.672, p < 0.001). The Moina 10% group recorded the lowest FCR (1.90 ± 0.060), followed by the Moina 5% group (3.07 ± 0.140), whereas the Control group showed the highest FCR (9.04 ± 0.660). Since a lower FCR indicates better feed conversion efficiency, the Moina 10% group exhibited the most efficient utilization of feed. Levene's test confirmed homogeneity of variances (F = 2.776, p = 0.140), and Tukey's HSD test showed significant differences between all treatment pairs. Protein efficiency ratio (PER) also differed significantly among the dietary treatments ($F_{2,6}$ = 536.715, p < 0.001). The Moina 10% group exhibited the highest PER (1.17 ± 0.045), followed by the Moina 5% group (0.80 ± 0.031), whereas the Control group recorded the lowest PER (0.28 ± 0.018). Levene's test indicated homogeneous variances (F = 0.661, p = 0.550), and Tukey's HSD test confirmed significant differences among all treatment groups. Overall, the results demonstrate a clear improvement in growth performance and nutrient utilization with Moina supplementation. The Moina 10% diet consistently produced the highest final body weight, weight gain, percentage weight gain, SGR, and PER, while also exhibiting the lowest FCR. The Moina 5% diet showed intermediate performance, whereas the Control group recorded the poorest growth and feed utilization. Thus, among the dietary treatments evaluated, Moina 10% was the most effective diet for promoting growth, improving feed conversion efficiency, and enhancing protein utilization in the experimental fish. Body weight was highest in common carp fed 10% *Moina micrura* meal, followed by the 5% Moina group and the control throughout the 16-week culture period (Figure 2). The growth performance of the experimental fish fed diets supplemented with different levels of *Moina micrura* is presented in Table 4.

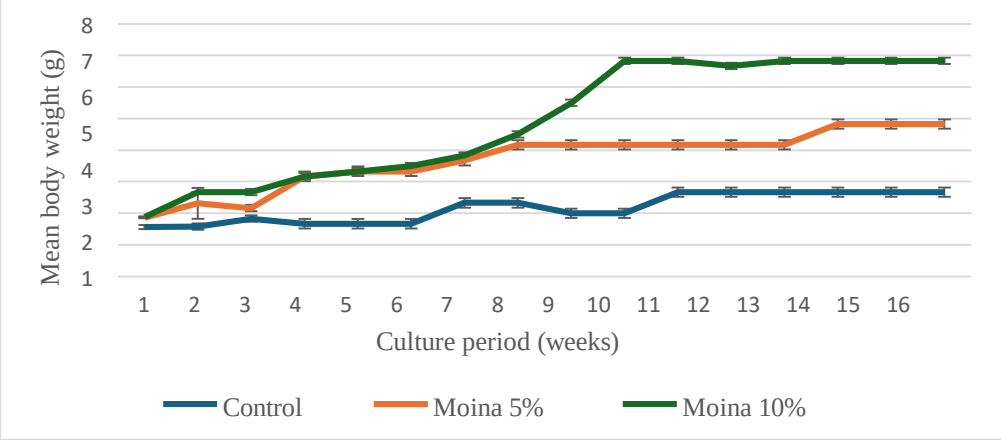

Figure 2. Changes in mean body weight (g) of common carp (*Cyprinus carpio*) fed diets supplemented with *Moina micrura* meal at 0% (control), 5%, and 10% inclusion levels over 16 weeks. Data are presented as mean ± SD (specify the actual error-bar measure) for three replicate aquaria per treatment.

Table 4. Effect of Moina supplementation on growth performance of experimental fish

Parameter	Control	Moina 5%	Moina 10%	$F_{2,6}$	p
Initial weight (g)	1.560 ± 0.020^{a}	1.567 ± 0.015^{a}	1.557 ± 0.021^{a}	0.219	0.810
Final weight (g)	2.670 ± 0.100^{a}	4.830 ± 0.150^{b}	6.830 ± 0.150^{c}	708.305	<0.001
Weight gain (g)	1.110 ± 0.080^{a}	3.263 ± 0.146^{b}	5.273 ± 0.156^{c}	749.336	<0.001
Weight gain (%)	71.12 ± 4.22^{a}	208.30 ± 9.02^{b}	338.83 ± 12.50^{c}	631.406	<0.001
SGR (% day^{-1})	0.484 ± 0.022^{a}	1.006 ± 0.010^{b}	1.333 ± 0.012^{c}	2276.305	<0.001
FCR	9.040 ± 0.660^{c}	3.070 ± 0.140^{b}	1.900 ± 0.060^{a}	287.672	<0.001
PER	0.281 ± 0.018^{a}	0.801 ± 0.031^{b}	1.165 ± 0.045^{c}	536.715	<0.001

Values are expressed as mean ± SD**.** Different superscript letters within the same row indicate significant differences among treatments according to Tukey's HSD test ($p < 0.05$).

3.3 Whole-body proximate composition

Whole-body proximate composition showed a nutritional response to *Moina* meal supplementation. The control group had the highest moisture content, whereas *Moina*-fed fish showed lower moisture and increased crude protein and lipid deposition. The available treatment values indicate that crude protein increased from 14.00 ± 0.82% in the control to 17.00 ± 0.82% in M5 and 18.50 ± 1.22% in M10. Crude lipid increased from 2.50 ± 0.41% in the control to 4.50 ± 0.41% in M5 and 5.50 ± 0.41% in M10. The whole-body proximate composition of *Cyprinus carpio* fed diets supplemented with different levels of *Moina micrura* is presented in Table 5. The increase in whole-body protein and lipid contents with increasing *Moina* inclusion indicates improved deposition of organic nutrients in fish receiving the supplemented diets.

Table 5. Whole-body proximate composition of *Cyprinus carpio*

Component (%)	Control	M5	M10
Moisture	79.00 ± 0.82	76.00 ± 0.82	74.00 ± 0.82
Crude protein	14.00 ± 0.82	17.00 ± 0.82	18.50 ± 1.22
Crude lipid	2.50 ± 0.41	4.50 ± 0.41	5.50 ± 0.41
Ash	1.50 ± 0.41	1.50 ± 0.41	1.75 ± 0.20

4. Discussion

4.1 Growth performance

The present study demonstrated a clear improvement in the growth performance of *C. carpio* following dietary incorporation of *M.micrura*meal. Final body weight increased from 2.67 g in the control to 4.83 g and 6.83 g in the M5 and M10 groups, respectively. Similarly, weight gain, percentage weight gain and SGR increased with increasing *Moina* inclusion. The improved growth observed in the *Moina*-supplemented groups may be associated with the favourable nutritional composition of the meal. The dried *M.micrura*biomass contained approximately 51% crude protein and 17.60% crude lipid, providing both protein and energy to the experimental diets. Adequate dietary protein availability is essential for tissue synthesis and growth in cultured fish. Previous studies have demonstrated that alternative protein ingredients can influence growth according to their

nutritional composition, inclusion level and digestibility (Mugwanya *et al*. 2023; Serra *et al*. 2024). Dietary protein level has also been shown to influence weight gain and specific growth rate in common carp (Zhang *et al*. 2024). The present results are consistent with previous studies investigating cladoceran biomass as an alternative feed ingredient. Abo-Taleb *et al*. (2024) reported favourable growth performance in hybrid red tilapia receiving diets containing *Daphnia* meal. El-Feky *et al*. (2024) similarly reported that *Daphnia magna* biomass meal could replace fish meal while maintaining or improving growth performance in Nile tilapia. Although these studies involved *Daphnia* rather than *Moina*, they support the broader potential of cladoceran biomass as an alternative animal-derived feed ingredient. In the present experiment, the M10 diet produced greater growth than M5, suggesting that the higher inclusion level supplied a greater quantity of *Moina*-derived nutrients under the conditions of the experiment. However, the optimum inclusion level of cladoceran meal may vary with fish species, dietary formulation, processing conditions and nutritional composition of the biomass.

4.2 Feed conversion and protein utilization

The marked reduction in FCR in the *Moina*-supplemented diet indicates improved conversion of dietary feed into fish biomass. The M10 group recorded an FCR of 1.900 ± 0.060 compared with 9.040 ± 0.660 in the control. Similarly, PER increased from 0.281 ± 0.018 in the control to 1.165 ± 0.045 in M10. The improvement in feed utilization may be related to the relatively high protein and lipid content of *M. micrura*. Protein efficiency depends not only on crude protein concentration but also on protein quality, amino-acid composition, digestibility and nutrient availability. Alternative aquafeed proteins are considered more suitable when they provide adequate essential nutrients and are efficiently utilized by fish (Serra *et al*. 2024). The present findings are also consistent with the general observation that alternative protein ingredients can improve feed utilization when appropriately incorporated into formulated diets (Mugwanya *et al*. 2023; Serra *et al*. 2024). However, feed intake and apparent nutrient digestibility were not directly measured in the present experiment. Therefore, the improved FCR and PER should not be attributed solely to enhanced protein digestibility. Further studies involving apparent digestibility coefficients, amino-acid profiles and nitrogen retention would help clarify the mechanisms responsible for the improved feed utilization observed with *M.micrura* meal.

4.3 Whole-body proximate composition

Dietary *Moina* supplementation was associated with changes in whole-body proximate composition. Moisture content decreased from 79.00% in the control to 76.00% and 74.00% in M5 and M10, respectively. In contrast, whole-body crude protein increased from 14.00% in the control to 17.00% in M5 and 18.50% in M10. The increase in body protein suggests enhanced deposition of dietary nutrients in fish receiving *Moina* based diets. Kim *et al*. (1995) reported that dietary protein and energy levels influenced whole-body nutrient composition in common carp, with dietary protein availability contributing to carcass protein deposition. Zhang *et al*. (2024) also demonstrated that dietary protein level can significantly affect weight gain and growth performance in common carp. The present increase in body protein with increasing *Moina* inclusion is therefore consistent with the established relationship between dietary protein supply, growth and tissue nutrient deposition. Whole-body lipid also increased from 2.50% in the control to 4.50% in M5 and 5.50% in M10. The lipid contribution of *M. micrura*, which contained 17.60% crude lipid, may have contributed to the greater lipid deposition observed in the supplemented fish. Fan *et al*. (2021) demonstrated that dietary lipid supply can influence whole-body protein and lipid deposition in common carp. The increase in body lipid should nevertheless be interpreted as a nutritional response rather than evidence of improved lipid digestibility, because apparent nutrient digestibility was not directly measured in the present study.

4.4 Overall significance of *Moina micrura* meal supplementation

The present results demonstrate that incorporation of *M.micrura* meal was associated with improved growth performance, feed utilization and whole-body nutrient deposition in *C. carpio*. The M10 diet produced the highest final body weight, weight gain, percentage weight gain and SGR among the three groups considered. The improvement in growth was accompanied by improved feed conversion and protein efficiency, together with increased whole-body crude protein and lipid contents. These responses indicate that *M.micrura*biomass can provide nutritionally useful nutrients for common carp. The results should, however, be interpreted within the conditions of the present feeding experiment. The study did not directly determine apparent digestibility, amino-acid availability or nitrogen retention. Consequently, further nutritional studies are required to identify the mechanisms responsible for the observed improvement in feed utilization. Overall, the findings

support the potential of *M.micrura* meal as a partial fish-meal substitute in diets for common carp. The 10% inclusion level showed the most favourable response among the *Moina* based treatments evaluated.

5. Conclusion

The present study demonstrated that dried *Moina micrura* meal has potential as an alternative animal-protein ingredient in diets for *Cyprinus carpio*. Dietary supplementation with *M.micrura* meal improved final body weight, weight gain, percentage weight gain and specific growth rate compared with the control diet. The 10% *Moina* meal treatment produced the highest growth response among the *Moina*-based diets. Feed utilization was also improved, as indicated by the lower FCR and higher PER observed in the M10 group compared with the control. In addition, *Moina* supplementation increased whole-body crude protein and lipid deposition while reducing moisture content. The results indicate that *M.micrura* meal can contribute valuable protein and lipid nutrients to formulated diets for common carp and may serve as a promising partial substitute for conventional fish- meal protein. Further studies should evaluate higher numbers of fish, apparent nutrient digestibility, amino-acid composition and long-term economic performance to determine the optimum inclusion level of *M.micrura*meal.

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Author Contributions

S. Robinson Davidraj: Performed the field and laboratory experiments, analysed the data, and prepared the original draft of the manuscript.

M. Kannan: Conceived the study, designed the research, supervised the work, and critically reviewed the manuscript.

N. Alagumanikumaran: Provided expertise in laboratory analyses and contributed to data interpretation.

S. Palpperumal: Reviewed and edited the manuscript.

K.Susithra: Assisted in preparing the initial manuscript framework and organization.

K. Muthulakshmi: Performed the statistical analyses and assisted in data interpretation.

R. Renugadevi: Interpreted the results and contributed to manuscript revision.

K. Madhavan: Contributed to manuscript revision.

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Data Availability: The datasets generated and analysed during the current study are available from the corresponding author on reasonable request.

Conflict of Interest: The authors declare that they have no conflict of interest.

Ethics statement: The fish used in this study were maintained and handled following standard aquaculture husbandry and animal welfare practices. All experimental procedures were conducted in accordance with applicable institutional and national guidelines for the care and use of animals in research. No procedures causing unnecessary pain, distress, or suffering were performed during the study.

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