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Effect of Black Soldier Fly Larvae Meal on African Catfish Growth

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ABSTRACT

The present study evaluated the partial replacement of fishmeal (FM) with black soldier fly (*Hermetia illucens*, BSF) larvae meal in the diets of the African catfish (*Clarias gariepinus*) juveniles under tank culture conditions. Two experimental diets were formulated: a control diet containing 30% FM and a test diet in which 50% of FM was replaced with BSF meal. A 30-day feeding trial was conducted using six concrete tanks with 45 fish in total. Growth performance, feed utilization, hematological parameters, and flesh composition were assessed. Results indicated that the final body weight (114.30 ± 0.77 g) and absolute weight gain (65.26 ± 1.43 g) of fish fed the BSF-based diet were significantly higher (P< 0.05) than those of the control group (95.72 ± 5.72 and 54.44 ± 2.15g, respectively). Daily weight gain was also improved in the BSF group (2.25 ± 0.05g vs. 1.87 ± 0.07g). Feed conversion ratio decreased slightly in the experimental group (1.38 ± 0.06) compared to the control (1.54 ± 0.14). No significant differences (P> 0.05) were observed in survival rate, hematological indices, or muscle composition, indicating that dietary BSF inclusion did not negatively affect fish health. These findings suggest that BSF larvae meal can serve as a sustainable alternative to fishmeal in African catfish diets, enhancing growth while maintaining physiological performance.

INTRODUCTION

Modern aquaculture is recognized as one of the most sustainable sources of animal protein, providing an alternative to limited capture fisheries and meeting the increasing global demand for fish and fish products **(Liland *et al*., 2021; FAO, 2022)**. In recent decades, the growth rate of aquaculture has significantly exceeded that of traditional fisheries; however, the further development of the sector is strongly dependent on solving feed-related challenges **(Ushakova *et al*., 2018)**. Fishmeal remains a key ingredient in aquafeeds due to its high protein content and balanced amino acid profile **(Mohan *et al*., 2022)**. Nevertheless, its production is limited, and the cost remains high as a result of declining fishery resources and competition with other livestock industries **(Tippayadara *et al*., 2021)**. Therefore, the search for alternative and sustainable protein sources is considered a strategic priority in aquaculture **(Liland *et al*., 2021; Uslu *et al*., 2023)**.

Insects, particularly the black soldier fly (*Hermetia illucens*) larvae, are among the most promising alternatives to fishmeal. Their biomass is rich in crude protein (40–45%), lipids, and minerals, while being produced cost-effectively in organic by-products **(Barragan-Fonseca *et al*., 2017; Maranga *et al*., 2022)**. Moreover, rearing *H. illucens* contributes to sustainable waste management, making this protein source both environmentally and economically viable **(Nguyen & Tran, 2025)**.

Previous studies on different fish species have demonstrated that incorporating H. *illucens* meal into diets can improve growth performance, feed conversion ratio, and survival without adverse effects on physiological status **(Fawole *et al*., 2020; Sanjaya *et al*., 2024; Hervé *et al*., 2025)**. However, high levels of replacement (above 50–75%) may reduce nutrient digestibility due to the presence of chitin **(Mulyani, 2023)**.

The African catfish (*Clarias gariepinus*) is one of the most important aquaculture species in Asia and Africa, valued for its hardiness, rapid growth, and adaptability to intensive rearing conditions **(Mundida *et al*., 2023)**. In Uzbekistan, this species is considered promising for aquaculture expansion; however, the use of black soldier fly larvae meal in its diet has not yet been sufficiently studied.

Therefore, the aim of the present study was to evaluate the effects of partial replacement of fishmeal with *Hermetia illucens* larvae meal on the growth, feed utilization, and hematological parameters of the African catfish (*Clarias gariepinus*) under tank culture conditions.

MATERIALS AND METHODS

The study was conducted in concrete tanks at the laboratory of “Fish Feed and Feeding” of the Tashkent Regional Scientific – Research Institute of Fisheries.

Black soldier fly (*Hermetia illucens*) larvae

Larvae of the black soldier fly (*Hermetia illucens*) were obtained from the insectary of the Institute, where the fly colony has been maintained for over three years. The larvae were reared on wheat bran at a substrate moisture of 70–75%. Five-day-old larvae were fed once daily for six days and harvested at 11 days of age for further processing. The total fresh biomass obtained was 50kg.

Processing of larvae

Prior to drying, the larvae were starved for 24h, washed with running water, and inactivated in hot water (100°C, 30min). Drying was performed in a 12L drum dryer at 100– 130°C for 1.5h with a rotation speed of 35rpm **(Aliyarov *et al*., 2024)**. Dried larvae were ground using a feed mill and further sun-dried to reduce microbial contamination. From 50kg of fresh larvae, 11.4 ± 0.067kg of dry meal was obtained. The chemical composition of the product was analyzed using a Sup NIR 2750 spectroscopic analyzer (Table 2).

Feed formulation

Experimental diets were formulated using *H. illucens* meal and locally available ingredients. Floating pellets were produced using an extruder W-70. The feed formulation is shown in Table (1), and proximate composition is presented in Table (2).

Table 1. Composition of experimental diets for African catfish (*Clarias gariepinus*) with different inclusion levels of black soldier fly (*Hermetia illucens*) meal

Ingredient	0% BSF meal (Control)	50% BSF meal
Corn meal	30.0	30.0
Fish meal	30.0	15.0
BSF meal	0.0	15.0
Rice bran	10.0	10.0
Soybean meal	10.0	10.0
Meat and bone meal	2.0	2.0
Wheat bran	18.0	18.0
Total	100	100

Table 2. Proximate composition and nutritional value of experimental diets for African catfish (*Clarias gariepinus*)

Parameter	100% Fishmeal diet	Diet with 50% BSF meal
Moisture (%)	2.54 ± 0.01	3.05 ± 0.01
Crude protein (%)	24.85 ± 1.53	25.66 ± 0.96
Crude lipid (%)	12.86 ± 2.54	12.63 ± 2.50
Crude fiber (%)	4.10 ± 0.08	3.84 ± 0.07
Crude ash (%)	5.53 ± 2.32	5.84 ± 2.36
Calcium (Ca, %)	1.28 ± 0.93	1.30 ± 1.00
Phosphorus (P, %)	2.08 ± 0.77	2.11 ± 0.81

Experimental design

African catfish (*Clarias gariepinus*) fingerlings were obtained from fish farms in the Tashkent region. Fish were acclimatized for one week on the control diet (without BSF meal). After acclimation, 45 fish were randomly distributed into six concrete tanks (6 × 1 × 0.3 m). All experimental treatments and analyses were carried out in triplicate (n = 3), ensuring the statistical reliability of the obtained results.Water quality parameters were maintained within the following ranges: temperature 24–26 °C, dissolved oxygen 6 mg/l, mineralization 0.28 g/l, total hardness 7.2 meq/l, and pH 7.7. The content of dissolved oxygen, temperature and pH were measured in the water using a portable device (model Pro1020), and hardness was measured according to GOST 4151-72. Fish were hand-fed three times daily (08:00, 12:00, 17:00) at a feeding rate of 4.87% of body weight for 30 days. The average initial weight and length of fish were 43.01 ± 3.36g and 16.9 ± 1.81cm, respectively.

Growth performance (Ushakova *et al*., 2018; Mulyani, 2023).

Growth performance was assessed using the following indicators:

- Absolute weight gain (AWG, g) = $W_f – W_i$
- Daily weight gain (DWG, g/day) = $(W_f – W_i)/t$
- Specific growth rate (SGR, %/day) = $[(\ln W_f – \ln W_i)/t] \times 100$
- Condition factor (CF) = $((W_f^{1/3} – W_i^{1/3}) \times 3)/t$
- Survival rate (SR, %) = $(N_f / N_i) \times 100$
- Feed conversion ratio (FCR) = F_I / W_G
- Length gain (cm) = $L_f – L_i$

Where, W_i and W_f are the initial and final body weights (g), L_i and L_f are the initial and final lengths (cm), N_i and N_f are the initial and final numbers of fish, F_I is the feed intake, W_G is the weight gain, and t is the duration of the trial (days).

Hematological parameters

Blood samples from fish were collected after placing them in well-aerated containers and subjecting them to anesthesia with quinaldine (25– 30mg/ L). Subsequently, blood was drawn from the caudal artery and analyzed.

Hematological parameters of African catfish were determined using standard methods. Hemoglobin concentration was measured with a Sahli hemometer, while erythrocyte and leukocyte counts were performed in a Goryaev chamber. For hemoglobin analysis, 0.1 N HCl solution was added to a graduated tube up to the "2" mark, followed by 20μL of the studied blood sample, which was thoroughly mixed. After a 10-minute incubation, the solution was diluted with distilled water until the color matched the standard, and the results were expressed in g/L (1g% = 10g/ L). Hematocrit values were determined by centrifugation, followed by measuring the ratio of erythrocyte volume to total blood volume using a millimeter ruler, with the results expressed as percentages. **(Pishchenko, 2002)**.

Evaluation of protein, moisture, and ash content in African catfish (*C. gariepinus*)

Moisture content was determined using the AOAC 930.15 method, with samples analyzed in triplicate. Fish samples were dried at 130°C for 2 hours in a hot air oven, cooled in a desiccator, and reweighed to calculate moisture loss. Ash content was assessed following the AOAC 942.05 method, where samples were incinerated at 700°C for 2 hours in a muffle furnace, cooled, and reweighed to determine ash residue. Crude protein content was measured using the Kjeldahl method (ISO 1871), with samples analyzed in triplicate. Nitrogen content was determined using a Kjeldahl apparatus, involving digestion with sulfuric acid, distillation, and titration, and protein was calculated by multiplying nitrogen values by a factor of 6.25. All measurements were conducted in triplicate, and results are expressed as mean ± standard error (M ± SE). Statistical analysis was performed using Excel, with differences considered significant at $P < 0.05$.

Statistical analysis

All growth and hematological data were analyzed using Excel and ANOVA. Results are presented as mean ± standard error (M ± SE). Differences between groups were considered significant at $P< 0.05$.

RESULTS

A 30-day feeding trial was conducted to evaluate the effect of replacing 50% of fishmeal with black soldier fly larvae meal (*Hermetia illucens*, BSFL) in the diet of African catfish (*Clarias gariepinus*). The main findings on growth performance, hematological, and biochemical parameters are summarized in Tables (3–5).

Table 3. Aquaculture performance of African catfish (*Clarias gariepinus*) fed diets with and without *Hermetia illucens* meal

Parameter	**Control (T_0)**	**Experimental (T_1)**
Initial weight, g	43.01 ± 1.50	43.01 ± 1.50
Final weight, g	95.72 ± 5.72^a	114.30 ± 0.77^b
Initial length, cm	16.9 ± 0.81	16.9 ± 0.81
Final length, cm	21.63 ± 0.44	22.23 ± 0.86
Absolute weight gain, g	54.44 ± 2.15^a	65.26 ± 1.43^b
Daily weight gain, g	1.87 ± 0.074^a	2.25 ± 0.05^b
Specific growth rate (SGR), %	0.086 ± 0.02	0.071 ± 0.00038
Condition factor	0.0108	0.0103
Feed conversion ratio (FCR)	1.54 ± 0.14	1.38 ± 0.06
Survival, %	82.96 ± 14.81	91.85 ± 3.92
Duration, days	30	30

Note. Values are expressed as Mean ± SE (n = 3). Different superscript letters (a, b) within the same row indicate significant differences at $P< 0.05$.

Table 4. Hematological parameters of African catfish (*Clarias gariepinus*) fed experimental diets

Parameter	Control	Experimental
Hemoglobin, g/l	73.66 ± 0.13	76.66 ± 0.60
Erythrocytes ($\times10^6$/mm³)	1.45 ± 0.09	1.46 ± 0.13
Leukocytes ($\times10^3$/mm³)	40.27 ± 8.94	35.20 ± 4.15
Hematocrit, %	29.43 ± 1.95	25.41 ± 1.64

Note. No significant differences were observed between treatments ($P > 0.05$).

Table 5. Proximate composition of African catfish muscle tissue under different feeding regimes

Parameters	Control	Experimental
Moisture, %	75.21 ± 0.39^a	76.99 ± 0.01^b
Crude protein, %	16.72 ± 0.45^a	16.27 ± 1.52^a
Ash, %	1.53 ± 0.16^a	2.16 ± 0.09^b

Note. Note. Values are expressed as Mean ± SE (n = 3). Different superscript letters indicate significant differences ($P< 0.05$).

The experiment lasted for 30 days and was conducted in triplicate (n= 3). The average final weight of fish in the control group (T_0) was 95.72 ± 5.72g, whereas in the experimental group (T_1) it reached 114.30 ± 0.77g (P< 0.05). Absolute weight gain was 54.44 ± 2.15g in T_0 and 65.26 ± 1.43g in T_1 (P< 0.05). Daily weight gain was 1.87 ± 0.074g in T_0 and 2.25 ± 0.05g in T_1 (P< 0.05). No significant differences were observed for the other growth parameters (P> 0.05). Final body weight in T_1 was higher by 19.4%, absolute weight gain by 19.9%, and daily weight gain by 20.3% compared to T_0.

The enhanced growth rates in the experimental group are likely attributed to the high crude protein (40–45%) and lipid content of BSFL meal, which improves nutrient availability and digestibility. Importantly, fish survival was not negatively affected: survival rate was 82.96 ± 14.81% in the control group and 91.85 ± 3.92% in the experimental group.

Hematological parameters remained within the normal range (Table 2). Hemoglobin concentration was 73.66 ± 0.13g/ l (T_0) and 76.66 ± 0.60 g/l (T_1); red blood cell counts were 1.45 ± 0.09 and 1.46 ± 0.13 million/mm³, and white blood cell counts were 40.27 ± 8.94 and 35.2 ± 4.15 thousand/mm³, respectively. Hematocrit values were 29.43 ± 1.95% in the control group and 25.41 ± 1.64% in the experimental group. No significant differences were found between groups (P > 0.05), suggesting that BSFL meal did not adversely affect the physiological condition of fish.

The chemical composition of fish muscle tissue is presented in Table (3). Moisture content was slightly higher in the experimental group (76.99 ± 0.01%) compared to the control (75.21 ± 0.39%; P< 0.05). Crude protein content remained comparable between treatments: 16.72 ± 0.45% (control) and 16.27 ± 1.52% (BSFL diet), with no significant differences (P> 0.05). Ash content, however, was significantly higher in the experimental group (2.16 ± 0.09%) compared to the control (1.53 ± 0.16%; P< 0.05). Muscle moisture in the experimental group increased by 2.4%, while ash content rose by 41.2% compared to the control. Crude protein levels did not differ significantly (> 0.05). Therefore, inclusion of *Hermetia illucens* meal in catfish diets enhanced the mineral profile of muscle tissue without compromising protein content.

Overall, the findings demonstrate that partial replacement of fishmeal with black soldier fly larvae meal enhances growth performance of African catfish without adverse effects on hematological parameters, while maintaining optimal protein levels in muscle tissue.

DISCUSSION

The results of this study demonstrated that partial replacement of fishmeal with *Hermetia illucens* larvae meal significantly improved the growth performance of the African catfish (*Clarias gariepinus*), with higher final weight, absolute and daily weight gain compared to the control group. These findings are consistent with those reported by

Fawole *et al.* (2019), who observed the highest growth rate and weight gain in catfish when 50% of fishmeal was substituted with BSFL meal, without adverse impacts on hematological indices. Similarly, **Maranga *et al.* (2022)** found that up to 75% substitution of fishmeal with BSFL meal in aquaponic systems did not compromise survival or feed conversion efficiency, confirming the nutritional adequacy of insect meal in aquaculture diets.

In terms of feed efficiency, the lower feed conversion ratio (FCR) in the experimental group compared to the control aligns with the results of **Sanjaya *et al*. (2024)**, who demonstrated improved feed utilization at substitution levels up to 50%. Likewise, **Mulyani (2023)** and **Mundida *et al*. (2023)** reported that diets containing BSFL meal enhanced protein utilization and reduced FCR, supporting the idea that insect meal can serve as a cost-effective and sustainable protein source for aquaculture.

Regarding hematological parameters, the present study confirmed that hemoglobin concentration, erythrocyte and leukocyte counts, as well as hematocrit values remained within normal physiological ranges, consistent with earlier studies **(Fawole *et al*., 2019; Sanjaya *et al*., 2024)**, which reported no adverse hematological effects of BSFL inclusion. This indicates that BSFL meal does not compromise the immune or physiological status of catfish.

Muscle proximate composition analysis further showed slight differences between groups. The crude protein content of catfish muscle in the experimental group (16.27%) was comparable to values reported by **Mulyani (2023)**, who found protein contents ranging from 15.8 to 17.5% in catfish fed BSFL-based diets. Similarly, the ash content (2.16%) observed in this study closely matched the results of **Mundida *et al*. (2023)**, who reported higher ash deposition in fish fed insect meal diets, likely due to the elevated mineral content of BSFL meal. Moisture content was slightly higher in the experimental group (76.99%) compared to the control, which is consistent with data presented by **Hervé *et al*. (2025)**, suggesting that dietary lipid composition may influence water retention in muscle tissues. One of the key aspects influencing the nutritional value of *Hermetia illucens* larvae meal is its relatively high chitin content, which may affect nutrient digestibility in fish. Chitin, a structural polysaccharide present in the exoskeleton of insects, is known to reduce the bioavailability of proteins and amino acids due to its binding properties and resistance to enzymatic degradation in the gastrointestinal tract **(Barragan-Fonseca *et al*., 2017; Liland *et al*., 2021)**. Several studies have demonstrated that increasing levels of BSFL meal in fish diets can lead to reduced digestibility when the chitin fraction is not properly managed **(Tippayadara *et al*., 2021; Uslu *et al*., 2023)**.

In our experiment, the inclusion of 50% BSFL meal (T_1) did not significantly impair growth performance compared to the control (T_0). However, the slight reduction in final body weight observed in T_1 may be partially explained by the chitin fraction, which could limit feed efficiency at higher inclusion levels. Similar observations have been reported in carp and tilapia when insect meal was used to replace fish meal **(Doğan & Turan, 2021)**.

On the other hand, chitin may also play a functional role in stimulating the immune system. Previous reports suggest that moderate amounts of dietary chitin can enhance non-specific immunity and improve resistance against bacterial infections in fish **(Mohan *et al*., 2022; Linh *et al*., 2024)**. Thus, while chitin can restrict nutrient utilization, it may simultaneously contribute to improved health and resilience of cultured fish.

According to the findings of **Bartucz *et al*. (2023)**, the inclusion of 33%–66% BSFL meal in the diet of the African catfish demonstrated the most favorable results; therefore, in our experiment, a 50% replacement level of BSFL meal was selected as the basis. Overall, our findings support the growing body of evidence that partial substitution of fishmeal with *Hermetia illucens* larvae meal enhances growth performance and feed utilization efficiency of *Clarias gariepinus*, while maintaining normal hematological profiles and muscle proximate composition. However, as noted by **Nguyen and Tran (2025)**, excessive inclusion levels may impair growth due to chitin-related digestibility issues, highlighting the need to optimize inclusion levels in practical aquafeeds.

CONCLUSION

The results of this study demonstrated that partial replacement (50%) of fishmeal with black soldier fly (*Hermetia illucens*) larvae meal in the diet of theAfrican catfish (*Clarias gariepinus*) significantly improved growth performance, absolute and daily weight gain, while reducing feed conversion ratio. Hematological indicators and muscle proximate composition remained within normal ranges, indicating no adverse effects on fish health or flesh quality. These findings confirm the potential of black soldier fly larvae meal as a sustainable alternative protein source in aquaculture feed formulations.

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الملخص

تمت دراسة تأثير استبدال 50% من مسحوق السمك بمسحوق يرقات ذبابة الجندي الأسود (*Hermetia illucens*) في علائق يافعات القرموط الإفريقي (*Clarias gariepinus*) لمدة 30 يومًا. أظهرت النتائج أن متوسط الوزن النهائي للأسماك في المجموعة التجريبية بلغ 114.30 ± 0.77 جم مقابل 95.72 ± 5.72 جم في مجموعة الضابطة، مع زيادة معنوية في الزيادة الوزنية المطلقة (65.26 ± 1.43 جم مقارنة بالضابطة 54.44 ± 2.15 جم). كما ارتفع معدل النمو اليومي بنسبة 20.3% في المعاملة. لم تُسجل فروق معنوية في مؤشرات الدم (الهيموغلوبين، الكريات الحمراء والبيضاء، والهيماتوكريت) بين المجموعتين ($P > 0.05$). تشير هذه النتائج إلى أن مسحوق يرقات *H. illucens* يمثل بديلًا بروتينيًا مستدامًا يُحسن أداء النمو دون تأثير سلبي على صحة الأسماك.