STUDY ON THE DIFFERENTIAL EFFECTS OF INSECT-BASED FEEDING IN JUVENILE WELS CATFISH (*Silurus glanis* Linnaeus, 1758)

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Abstract

The need to secure food resources for a rapidly expanding global population necessitates solutions capable of replacing protein derived from increasingly limited aquatic resources. In this context, entomoculture-an essentially unlimited source of protein-emerges as a sustainable alternative with the potential to supply essential nutrients for both animal feed and human consumption. This study presents a comparative analysis of the effects of feeding juvenile wels catfish (Silurus glanis) with insect meals obtained from black soldier fly larvae (Hermetia illucens)-variant V1-and mealworm larvae (Tenebrio molitor)-variant V2. During the experiment, the V2 group exhibited a bacterial infection, whereas the V1 group showed no signs of disease. At the end of the experimental period, growth performance was 7% higher in the V2 group compared with V1. In conclusion, incorporating insect-meal mixtures into cultured fish diets is recommended, as they may induce a synergistic effect reflected in enhanced growth performance and an immunomodulatory response.

Key words: *nutrition, wels catfish juvenile, insect meal*

INTRODUCTION

As the global population continues to expand, identifying sustainable, efficient alternative protein sources has become essential to ensure long-term food security. Aquaculture has emerged as the most rapidly expanding sector in food production in recent years, contributing significantly to the availability of high-quality protein for human consumption [1]. Approximately 50–60% of the production costs in fish farming are represented by feed expenses [2]. In current feed formulations, fishmeal constitutes the primary protein source; however, due to declining natural fish stocks, this resource has become limited and unpredictable. Over the past decade, research has increasingly focused on insect farming, as insect protein offers a virtually unlimited, environmentally friendly source that recycles food waste [3, 4, 5].

The acceptability of fish in relation to this type of feed primarily pertains to digestibility rather than palatability [6]. Many cultured fish species naturally include terrestrial insects that fall into the water, aquatic insects (*Ephemeroptera, Trichoptera, Plecoptera*), or insect larvae in their diet. Species such as rainbow trout (*Oncorhynchus mykiss*), common carp (*Cyprinus carpio*), and sturgeons (*Acipenser stellatus, A. gueldenstaedtii, A. ruthenus, Huso huso*) consume insects during their juvenile stages, and in juvenile wels catfish (*Silurus glanis*), insects may account for 30–60% of the natural diet [7]. In addition to their good palatability, insects provide high-quality protein, containing 35–70% crude protein and 10–40% lipids. Their lipid profile is characterized by a high content of lauric acid (C12:0) in black soldier fly larvae (*Hermetia illucens*), oleic

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acid (C18:1) predominantly in mealworms (*Tenebrio molitor*), and linoleic acid (C18:2) in superworms (*Zophobas morio*). Compared with fishmeal, insect lipids contain lower levels of omega-3 polyunsaturated fatty acids. Carbohydrates account for 5–15% of the biomass, most of which are present as chitin and glycogen. Ash content ranges from 3–15%, and insects also contain Ca, P, Mg, Zn, Fe, and Cu-microelements essential for fish; the highest calcium content is found in black soldier fly larvae, with a Ca:P ratio of 2:1 [8]. Fiber content, mainly derived from chitin in the insect exoskeleton (5–12%), may reduce digestibility but enhances immunity by acting as a prebiotic and improving intestinal health [9].

The advantages of using insects in fish feed are largely attributed to the bioactive compounds they contain. Natural antimicrobial substances such as defensins and lauric acid help reduce the need for antibiotics in aquaculture treatments and enhance the disease resistance of fish [10,11,12]. Insects also represent an important source of melanin, sterols, and antioxidants-compounds with protective physiological roles that may further decrease antibiotic use and support the immune response of fish [13].

This comparative study aims to evaluate the palatability, acceptability, growth performance, disease resistance, and changes in blood parameters of juvenile wels catfish (*Silurus glanis*) fed diets in which aprox. 20% of the standard foder was replaced with black soldier fly (*Hermetia illucens*) larvae meal or mealworm (*Tenebrio molitor*) meal.

MATERIAL AND METHOD

The feeding experiment was conducted over 40 days (December 1, 2025 – January 10, 2026) at I.C.D.E.A.P.A. Galați, using 100 L aquaria equipped with aeration and filtration systems to maintain optimal water parameters, which were monitored throughout the study. The experiment was performed in duplicate, with each aquarium stocked with the same number of specimens and subjected to identical environmental conditions.

The biological material used in the experiment consisted of juvenile catfish (*Silurus glanis*), approximately 175 days old, distributed at a density of 14 specimens per aquarium across the two experimental groups, involving a total of 56 catfish. Two distinct experimental groups were established: V1, with a total biomass of 1325 ± 23.42 g, and V2, with a total biomass of 1372 ± 28.78 g.

In group V1, the range of individual body masses extended from a minimum of 74.6 grams to a maximum of 121.3 grams, with standard lengths varying from a minimum of 22.8 centimeters to a maximum of 26.4 centimeters. Conversely, in group V2, the individual body masses exhibited a range from a minimum of 72.8 grams to a maximum of 110.5 grams, while the standard lengths were recorded between a minimum of 21.9 centimeters and a maximum of 25.7 centimeters. The coefficient of variation indicated pronounced heterogeneity within both groups-25% in V1 and 29% in V2-reflecting the typical size variability observed in predatory fish species. By the end of the experiment, biometric variability increased to 29% in V1 and 40% in V2, suggesting intense competition for food and unequal access to resources, which favored larger individuals, a phenomenon frequently observed in predatory fish species.

The experimental protocol included two feeding variants, both formulated using the commercial base feed Aqua Garant Aqua Catch (40% crude protein, 21% lipids, 1.5% cellulose), into which insect meals were incorporated. In variant V1, the base feed was supplemented with black soldier fly larvae (BSFL) meal (*Hermetia illucens*), characterized by 37.5% crude protein, 19.82% lipids, 11.56% fiber, and 8.8% ash. In variant V2, the base feed was mixed with

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mealworm (TM) meal (*Tenebrio molitor*), containing 50% crude protein, 25% lipids, 3.6% fiber, and 3% ash.

To obtain isoproteic formulations, the V1 diet consisted of 80 g Aqua Garant Aqua Catch and 26.5 g *H. illucens* meal, a proportion determined according to the protein content of the ingredients. In V2, the formulation included 80 g base feed and 20 g *T. molitor* meal, with the amount of insect meal adjusted to compensate for the differences in crude protein between the two insect species. This adjustment ensures a consistent protein profile in the overall feed formulation. These quantitative adjustments ensured equivalent final protein levels, allowing a controlled comparison of the nutritional effects of the two alternative protein sources.

Feed administration was carried out using boilies produced from the insect meals and the commercial feed. To ensure physical cohesion and a uniform texture, the mixture was stabilized with 3.5% gelatin, hydrated and solubilized prior to final homogenization. The resulting feed mass was shaped and portioned into boilies of sizes appropriate for the developmental stage of the juveniles, facilitating consumption and maintaining particle integrity in the aquatic environment. In the conducted experiment, the dietary intake for the fish was regulated, with feeding protocols adjusted to provide between 2.5% and 3% of their body mass. This range was determined based on the specific nutritional requirements of the fish, ensuring optimal growth and health throughout the study.

The subsequent growth parameters, including Weight Gain (WG), Specific Growth Rate (SGR), Relative Growth Rate (RGR), Feed Conversion Ratio (FCR), and Protein Efficiency Ratio (PER), were calculated and presented as mean values ± standard deviation (SD). This approach ensures a comprehensive understanding of the growth performance associated with the differing feed amounts in both treatments.

Weight gain (WG) = (Final body weight − Initial body weight)

Specific Growth Rate (SGR, %/d) = (ln Final body weight − ln Initial body weight) / Number of experimental days × 100

Relative Growth Rate (RGR, %) = (Final body weight − Initial body weight) / Initial body weight × 100

Feed Conversion Ratio (FCR) = Feed intake / (Final fish weight − Initial fish weight)

Protein Efficiency Ratio (PER, %) = (Final body weight − Initial body weight) / (Feed intake × Crude protein content of feed) × 100

Survival Rate (SR, %) = (Final number of fish / Initial number of fish) × 100

Blood for hematological analyses was collected from the caudal vein using heparinized syringes, from four fish specimens in each experimental variant. Anticoagulated samples were used to determine erythrocyte (RBC) and leukocyte (WBC) counts using a Neubauer hemocytometer and an oil-immersion objective on a Euromex microscope equipped with a 3 MP video camera.

Hematocrit (HCT) was determined using a DVAB microcentrifuge after centrifuging capillary tubes at 3000 rpm for 10 minutes, while hemoglobin (Hb) was analyzed via the Drabkin colorimetric method, with readings taken on a Specol 1300 spectrophotometer at a wavelength of 540 nm.

To determine the leukocyte formula, blood smears were prepared from fresh samples, then fixed and stained according to the standardized May-Grünwald–Giemsa protocol. After complete drying, the smears were examined microscopically, and leukocyte types were identified based on specific morphological characteristics (cell size, nuclear appearance, cytoplasmic granulation). A minimum of 200 cells were counted for each sample, and the percentage of each leukocyte cell type was calculated relative to the total number of cells analyzed.

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Biochemical blood analyses were performed using a Seamaty automated analyzer, following the standard protocol for fish. The hepatic parameters assessed included aspartate aminotransferase (AST), alanine aminotransferase (ALT), alkaline phosphatase (ALP), gamma-glutamyl transferase (GGT), total bilirubin (TB), and total bile acids (TBA). Renal function was assessed via creatinine (Crea), urea (UREA), and the urea/creatinine ratio (U/C). Metabolic status was characterized by measuring glucose (GLU), total cholesterol (TC), triglycerides (TG), total protein (TP), albumin (ALB), globulins (GLOB), and the A/G ratio. We evaluated tissue enzyme activity by measuring lactate dehydrogenase (LDH), creatine kinase (CK), amylase (AMY), and lipase (LPS).

Disease resistance testing was conducted upon the appearance of the first symptoms of illness in the group fed according to variant V2. Instead of imposing a quarantine, the same tools were used for both experimental groups for aquarium cleaning and fish handling during periodic biometric measurements. This procedure aimed to ensure uniform exposure to the pathogen *Aeromonas hydrophila*, facilitating a comparative assessment of disease resistance between the two groups subjected to different dietary regimens.

Microsoft Excel and Real Statistics software were used for the statistical processing of experimental data, enabling the calculation of descriptive parameters and the application of significance tests. Data normality was assessed using the Shapiro–Wilk test, and because the results indicated non-normal distributions, the Mann–Whitney test was applied for group comparison. In addition, Levene's test was used to evaluate the homogeneity of variances between the two groups. Hematological parameters, including leukocytes, were summarized as mean values and standard deviations.

RESULTS AND DISCUSSIONS

An episode of illness characterized by bacterial hemorrhagic septicemia was recorded, with a presumptive diagnosis of *Aeromonas hydrophila* infection. This ubiquitous Gram-negative bacterium is often associated with cutaneous and systemic pathologies in fish [14]. The onset of clinical signs was marked by distinct skin ulcerations (see Photo 1) observed in two catfish specimens, necessitating immediate therapeutic intervention. Treatment consisted of administering acriflavine in prolonged baths at a concentration of 5 ppm, with applications repeated at three-day intervals. Throughout the experiment, it is important to note that the tools used for aquarium maintenance and fish handling were shared between both experimental groups. Despite this potential transmission pathway, no individuals in group V1 exhibited symptoms consistent with the disease, suggesting that these fish may have demonstrated enhanced resistance to infection or reduced susceptibility attributable to their dietary treatment.



Photo No. 1 Skin ulcerations and subcutaneous hemorrhages in *S. glanis*- V2

The survival rate (SR) was 100% in both experimental groups. Zero mortality indicates excellent tolerance among juvenile catfish to both types of insect meal, even during the bacterial infection episode observed in the V2 group. Although clinical signs of disease appeared in this group, the immediate initiation of treatment prevented losses, resulting in no recorded mortality throughout the experiment. Biometric and gravimetric measurements collected

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throughout the experiment were compiled and analyzed to generate comparable information on the fish reared under the two experimental feeding regimes and to assess the effects of the distinct diets on their growth performance and overall health status. The growth parameters calculated for the two experimental groups, V1 and V2, are presented in Table 1, providing an integrated overview of the biological responses associated with each dietary treatment.

Table 1 Growth parameters obtained in the experiment on feeding catfish with *H. illucens* and *T. molitor*

E.V.	IBW (g)	FBW (g)	WG (g)	SGR (%/zi)	RGR	FCR	PCR
V1	95±22.98	146±41.78	51±24.19	1.05±0.40	53.77±23.7	2.34	1.07
V2	98±28.24	157±60.92	59±51.29	1.09±0.74	61.29±52	2.13	1.18

The total weight gain (WG) exhibited a significant divergence between the two feeding treatments. In treatment V1 (BSFL-fed), WG reached 718 ± 24.19 g, whereas in treatment V2 (TM-fed), the value increased to 827 ± 51.29 g. Specific growth rate (SGR) values indicated a favorable daily growth performance in both groups. The BSFL-fed catfish in V1 exhibited an SGR of 1.05 ± 0.40%/day, while the TM-fed catfish in V2 achieved 1.09 ± 0.74%/day, showing only minor differences that slightly favored V2. The results indicate that while the SGR in V2 was notably elevated, the extremely high standard deviation (SD=52) highlights considerable intra-group variability. This suggests the presence of an unstable cohort characterized by a mix of individuals exhibiting exceptionally high growth rates alongside others demonstrating significantly reduced performance. The observed variability in growth measurements prompts a critical examination of their consistency and reliability within the study group. Future analyses should aim to investigate the underlying factors that contribute to this discrepancy in growth performance. This exploration could provide valuable insights and enhance the understanding of growth dynamics in the examined cohort. The results suggest that the TM diet (V2) facilitated slightly more rapid growth compared to other conditions. Nonetheless, the significant variability observed, indicated by high standard deviation (SD) and coefficient of variation (CV), suggests a considerable degree of biological heterogeneity typical of predatory fish species. This variability is likely influenced by competition for food resources among individuals. The results align with previously reported values for African catfish (*Clarias gariepinus*), where SGRs of 1.93 ± 0.03%/day (BSFL-fed) and 1.91 ± 0.03%/day (control) have been documented [15], as well as with findings for *Silurus meridionalis*, which exhibited SGRs of 2.96%/day (BSFL-fed) versus 2.20%/day (control) [16].

Analysis of growth indices revealed moderate differences between the two experimental groups. Relative growth rate (RGR) was lower in V1 (53.77 ± 23.7%) compared with V2 (61.29 ± 52%), indicating a slightly higher relative growth response in the TM-fed group. Feed conversion ratio (FCR) values-2.34 for V1 and 2.12 for V2-further demonstrate that V2 converted feed more efficiently. These FCR values are favorable for juvenile wels catfish, as the literature frequently reports poorer feed conversion, such as 3.42 ± 0.10 (BSFL-fed) and 3.74 ± 0.10 (control) in African catfish [15].

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The PER values obtained for the two experimental groups were 1.07 for V1 and 1.18 for V2, indicating that the protein supplied through the *Tenebrio molitor*–based diet was utilized more efficiently in group V2. A PER greater than 1 is generally considered a very good outcome for catfish, particularly when compared with the considerably higher value reported in the international literature of 3.83 ± 0.04 [17].

The interpretation of the results is grounded in the observation that, although the mean values of the growth parameters were relatively similar between the two groups, the substantially higher standard deviation recorded in V2 reflects increased heterogeneity. This variability suggests pronounced individual differences in dietary response, potentially exacerbated by the infectious episode that occurred within this group.

The V1 group, which was fed *Hermetia illucens*, demonstrated stable growth metrics characterized by minimal variability and exhibited a higher feed conversion ratio (FCR) compared to the V2 group, suggesting a decrease in feed conversion efficiency. Notably, while growth rates were slower relative to V2, the V1 group maintained low variability and showed no signs of disease, even under environmental circumstances conducive to homogeneous pathogen transmission. This observed outcome may indicate an immunomodulatory effect associated with black soldier fly larvae (BSFL), which can be attributed to the presence of lauric acid, known for its bactericidal properties, and a high concentration of chitin, which is recognized for its prebiotic implications. Previous studies [16, 17] have substantiated these claims. Overall, the biological profile of group V1 was defined by uniformity, robust health, and consistent growth, though at a lower rate compared to the TM-fed group V2. The findings from Group V2, which was fed *Tenebrio molitor*, indicated a marked enhancement in several growth performance metrics, including weight gain (WG), specific growth rate (SGR), relative growth rate (RGR), feed conversion ratio (FCR), and protein efficiency ratio (PER). This group exemplified superior overall growth performance; however, it also manifested significant variability, indicative of heterogeneous growth patterns as individuals displayed differing responses to the dietary inputs provided. Notably, during the course of the experiment, Group V2 encountered a bacterial infection, which was subsequently addressed with prompt treatment. This incident resulted in a temporary attenuation of the accelerated growth rate and revealed a lower level of immune resilience.

The hematological analysis (Table 2) conducted during the experiment aimed to evaluate the physiological status of the catfish fed diets based on the two insect species. Table 2 presents the hematological parameters measured-RBC, WBC, Hct, Hb, MCV, MCH, and MCHC-providing insight into the systemic responses associated with each dietary treatment.

Table 2 Hematological values of fish with differentiated nutrition from the two experimental groups

	RBC	WBC	Hct	Hb	MCV	MCH	MCHC
	(X 10^6 µL)	(X 10^3 µL)	(%)	(g/dL)	fL	pg	(g/dL)
V 1	1.25±0.36	41.50±1.70	20.00±5.66	6.75±1.91	160.81±1.14	54.27±0.39	33.75±0.00
V 2	1.30±0.03	46.25±0.64	17.50±0.71	5.90±0.28	134.59±2.51	45.37±1.19	33.71±0.25

Group V1 (BSFL) exhibited a higher maximum RBC value of 1.50 × 10^6/µL compared to V2 (TM), which reached 1.32 × 10^6/µL. This suggests better oxygenation and a more stable physiological state in fish fed BSFL. According to the literature, RBC

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counts in *Silurus glanis* vary significantly depending on diet, and nutrient supplementation-specifically with vitamin C-can increase RBC levels [18]. In contrast, Group V2 exhibited higher white blood cell (WBC) counts, with a maximum value of 46.7 × 10^3/µL, compared to 42.7 × 10^3/µL in Group V1, which may indicate a more active immune response or a higher level of physiological stress. Studies show that WBC counts in juvenile *Silurus glanis* are highly variable and sensitive to diet and environmental conditions [19, 20]. Hematocrit (Hct) values were higher in Group V1, with a maximum level of 24%, compared with 18% in Group V2, indicating increased oxygen-carrying capacity and a better physiological state. Literature confirms that Hct is influenced by diet and nutrient levels, including vitamin C, which increases hematocrit in *S. glanis* [18, 20]. Hemoglobin (Hb) values in Group V1 were higher, reaching a maximum level of 8.1 g/dL, compared to 6.1 g/dL in Group V2. This aligns with the elevated RBC and Hct levels in V1, indicating more efficient oxygenation [20, 21]. Regarding erythrocyte indices, mean corpuscular volume (MCV) was significantly higher for maximum values, in V1 (162 fL) than in V2 (136 fL), suggesting the presence of larger and potentially more mature erythrocytes; the mean corpuscular hemoglobin (MCH) was higher in V1 (55 pg) than in V2 (46 pg), indicating higher hemoglobin content per erythrocyte; and the mean corpuscular hemoglobin concentration (MCHC)was similar between groups (33.9 g/dL), indicating stable hemoglobin concentration within erythrocytes, with no pathological differences. International studies show that erythrocyte indices in *S. glanis* have broad ranges that are influenced by diet and environmental factors [20]. In conclusion, the comparative analysis indicates that group V1 (BSFL) exhibits higher levels of RBC, Hct, Hb, MCV, and MCH, as well as lower WBC counts. This pattern suggests a better physiological condition, more efficient oxygenation, and reduced immune stress in Group V1. In contrast, Group V2 (TM) is characterized by elevated WBC counts and lower erythrocyte parameters, indicating a more pronounced immune activation and increased metabolic stress following the illness episode.

Table 3 Leukocyte formula of the fish from the two experimental groups

Cell type (%)	Lymphocytes (x10^3cel./mm^3)	Neutrophils (x10^3cel./mm^3)	Eosinophils (x10^3cel./mm^3)	Monocytes (x10^3cel./mm^3)	Basophils (x10^3cel./ mm^3)
V1	78.04±0.76	16.43±0.11	1.54±0.65	2.50±0.71	1.50±0.71
V2	80.0±1.4	17.8±1.1	1.5±0.7	0.8±0.4	-

Group V1 exhibited a normal lymphocyte profile with no signs of immune stress, unlike Group V2, where slightly higher values (up to 81%) were recorded (Table 3). This increase may indicate specific immune activation in response to bacterial infection and physiological stress, as elevated lymphocyte counts are common in chronic infections or during the later stages of an immune response. Neutrophils, which are key cells in acute bacterial infections, exhibited maximum values of 16.5% in Group V1 and 18.5% in Group V2. The higher neutrophil levels observed in Group V2 corroborate the previous mention of an illness episode, acting as an indicator of acute inflammation characterized by an active, non-specific immune response.

Eosinophils, which are involved in responses to parasites and allergens, showed similar values in both groups (1.08–2% in V1 and 1–2% in V2), indicating no significant differences. This suggests that neither group experienced notable parasitic infestation.

Monocyte levels, which typically rise during chronic infections, persistent inflammation, and tissue regeneration were recorded at maximum of 3% in Group V1

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and 1% in Group V2. For Group V1, these values indicate a mature immune response, normal phagocytosis, and a stable physiological state. In Group V2, the very low monocyte count may suggest monocyte depletion during the illness episode, as well as temporary immunosuppression and metabolic stress. Basophils, which are rare in fish and typically increase during allergic or parasitic inflammation, were found at 1–2% in Group V1 and at 0% in Group V2. In conclusion, group V1 showed normal values, whereas group V2 was characterized by an absence of basophils-a finding that may be attributed to severe immune stress, leukocyte redistribution during illness, or temporary immune suppression.

The overall conclusion is that group V1 (BSFL) exhibited a stable immune profile, with lymphocyte, neutrophil, monocyte, and basophil counts within normal physiological ranges and no signs of immune stress or infection. In contrast, Group V2 (TM) exhibited an immune profile affected by disease. This group had elevated neutrophil counts, indicating acute infection and inflammation, along with slightly elevated lymphocyte levels, which suggest specific immune activation. The very low monocyte counts indicated monocyte depletion and potential immunosuppression, while the absence of basophils likely stemmed from severe immune stress.

The leukocyte differential count clearly confirms the disease episode in Group V2, with values typical of an immune response. International literature states that lymphocytes predominate in *Silurus glanis*, comprising 60–80% of the total white blood cell count [18, 20, 21]. Neutrophil levels increase during bacterial infections and acute stress, whereas monocyte levels tend to decrease during severe infections or metabolic stress [18, 19, 20, 22]. Basophils are rare and are typically absent in states of immunosuppression.

In summary, the study's findings indicate that Group V1 aligns with a healthy immune profile, while Group V2 exhibits hematological changes characteristic of acute infections in catfish. The results of the blood biochemistry analysis can be found in Table 4.

Table 4 Blood biochemistry analyses for the experimental groups

Blood biochemical parameters	V1 (mean±stdev)	V1 (mean±stdev)
ALB (g/L)	9.8±1.5	11.4±0.6
TP (g/L)	40.6±4.9	41.1±4.2
GLOB (g/L)	30.8±3.4	28.7±3.7
A/G	0.3±0.0	0.4±0.1
TB (umol/L)	5.0±2.9	2.5±1.8
GGT (U/L)	2.0±0.1	2.0±0.0
AST (U/L)	650.0±0.0	607.5±60.1
ALT (U/L)	101.5±13.4	108.5±19.1
ALP (U/L)	170.5±24.7	217.5±20.5
TBA (umol/L)	28.9±9.7	24.7±29.1
AMY (U/L)	5.0±0.0	5.0±0.0
LPS (U/L)	120.5±3.5	111.5±41.7
LDH (U/L)	750.0±73.6	165.0±28.7
CK (U/L)	3622.0±34.6	2278.0±35.0
Crea (mmol/L)	128.0±28.4	108.0±67.0
UREA (mmol/L)	1.0±0.3	1.0±0,2
U/C	7.9±0.8	12.9±5.4
GLU (mmol/L)	7.2±1.2	7.2±0.7
TC (mmol/L)	4.7±0.8	4.9±0.2
TG (mmol/L)	10.0±0.0	11.0±0.2
tCO2 (mmol/L)	12.5±0.3	12.8±0.1
Ca (mmol/L)	2.8±0.2	3.0±0.0
PHOS (mmol/L)	4.0±0.5	3.3±0.4

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Blood biochemistry revealed clear differences between the groups fed *Hermetia illucens* (V1) and *Tenebrio molitor* (V2). Both groups showed elevated levels of total protein (TP) and globulin (GLOB); however, V2 group exhibited higher values and variability, indicating an intense immune response and a possible active inflammatory process. The A/G ratio, significantly low across all groups, indicates a predominance of globulins-a phenomenon often associated with systemic inflammation in fish [23]. Nevertheless, albumin stability in V1 group indicates that hepatic function is not severely impaired. In contrast, the V2 group exhibited significant fluctuations in total bilirubin (TB), indicating hemolysis and liver damage [24, 25].

The most notable differences between the two groups appear in tissue and hepatic enzyme levels. Elevated CK and LDH values in the TM-fed group (reaching maximum values of 4000 U/L and 1297 U/L) are characteristic of severe muscle damage, acute stress, or systemic infections, far exceeding ranges reported for healthy fish. In contrast, V1 group showed elevated yet much more stable values, indicating moderate-rather than pathological-metabolic stress. Hepatic enzymes ALT and ALP were significantly higher in V2 group, suggesting hepatocellular damage and intestinal inflammation, while the values in V1 group remained within the limits of intense but physiological metabolism. Nitrogenous metabolites (creatinine, urea, uric acid) showed marked differences between the groups. The extreme variability of creatinine and urea in V2 group suggests renal dysfunction and pronounced protein catabolism, phenomena frequently associated with disease in fish [26, 27].

In conclusion, fish in group V2 exhibited elevated levels of albumin, total protein, and cholesterol, indicating superior nutritional status and intense metabolism consistent with higher growth performance. At the same time, significant deviations in globulin, LDH, TB, and TBA levels suggest an inflammatory response and increased hepatic stress associated with the infectious episode observed in this group. These results align with meta-analyses showing that *T. molitor*-based diets can improve growth performance but may also lead to greater physiological variability and sensitivity to stress. Despite these biochemical changes, the V2 group achieved 7% higher growth than V1 group. This can be attributed to the higher energy density of *Tenebrio molitor* meal, which has been recognized in the literature for its lipid and protein profile that can stimulate rapid fish growth, even under metabolic stress conditions [27, 28]. In contrast, although group V1 displayed lower growth, it maintained a stable biochemical profile with consistent hepatic and renal values; this supports literature indicating that *Hermetia illucens* meal can provide immunomodulatory benefits and sustain metabolic homeostasis [29, 30]. This finding confirms literature indicating that *H. illucens* meal can have immunomodulatory effects and help maintain metabolic homeostasis [31]. These results align with existing studies showing that *Hermetia illucens* meal benefits fish gut health and immunity, largely due to its lauric acid content and prebiotic chitin [32]. Overall, the biochemical data and growth performance indicate that while a *Tenebrio molitor* diet can stimulate rapid growth, it could also induce metabolic stress and physiological alterations associated with disease. In contrast, a *Hermetia illucens* diet supports stable growth and optimal health, making it more suitable for maintaining homeostasis in juvenile *Silurus glanis*.

Because Shapiro–Wilk indicated non-normal distributions non-parametric methods were applied. Mann–Whitney U was used for group comparison and Levene's test confirmed unequal variances. Taken together, the non-parametric analyses indicate that weight gain values in

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the two experimental groups do not differ significantly at the distributional level. The Mann–Whitney U test confirmed the absence of a significant difference between group s(α=0.05 and p=0,79). However, Levene's test demonstrated a significantly higher variance in Group V2, reflecting pronounced heterogeneity and the presence of extreme values. This indicates that, although the central tendency of weight gain does not differ statistically between the two groups, the biological response in V2 is considerably more variable, and was expressed as a percentage.

CONCLUSIONS

The study highlights that both types of insect meals can support the growth of juvenile *Silurus glanis*. However, *Hermetia illucens* is beneficial due to its lauric acid content and high level of chitin, which exerts a prebiotic effect. This combination plays an immunomodulatory role that promotes metabolic stability and overall health. In contrast, *Tenebrio molitor* enhances growth performance due to its lower chitin content, which optimizes nutrient absorption. However, this also limits the stimulation of gut microbiota, and without lauric acid, it increases the fish's susceptibility to disease. Further experiments using blends of insect meals are recommended to evaluate the potential synergistic effects on the growth and health of farmed fish. The study suggests that future experiments incorporating insect-meal mixtures are needed to determine whether synergistic effects may occur.

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