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UTILIZATION OF BLACK SOLDIER FLY MAGGOT (*Hermetia illucens*) AND CASSAVA PULP (*Manihot esculenta*) AS ALTERNATIVE FEED FOR THE GROWTH OF AFRICAN CATFISH (*Clarias gariepinus*)

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ABSTRACT

The high cost of commercial pellet feed represents a major constraint in African catfish *(Clarias gariepinus*) aquaculture, necessitating the development of alternative feeds derived from locally available organic waste sources. This study evaluated a combined feed formulation based on Black Soldier Fly larvae *(Hermetia illucens)* and cassava pulp *(Manihot esculenta)* at different proportions to assess its effects on the growth performance of African catfish. The experiment was conducted in Trimo Harjo Village, South Sumatra, from December 2024 to January 2025, using a Completely Randomized Design with four treatments and three replications. A total of 360 fish were used as the experimental units. Growth performance was evaluated based on absolute weight gain, weight gain percentage, absolute length, and feed conversion ratio (FCR), and water quality parameters were monitored as supporting variables. Data were analyzed using analysis of variance (ANOVA). The results showed that treatment P1 (75% maggot flour and 25% cassava pulp) produced the best growth performance, with an absolute weight gain of 8.66 g, weight gain of 28.88%, and FCR of 1.66, which was comparable to that of the control feed. The water quality parameters remained within acceptable ranges throughout the study. In conclusion, feed formulations based on organic waste, particularly the combination of maggot flour and cassava pulp, have strong potential as efficient and sustainable alternatives to commercial feed in the aquaculture of African catfish.

Keywords: *Clarias gariepinus;* Black Soldier Fly *(Hermetia illucens);* Cassava Pulp; Growth Performance; Feed Conversion Ratio

INTRODUCTION

Indonesia is a maritime country with great potential in the fisheries sector, including seawater, brackish water, and freshwater fish farming. Freshwater aquaculture makes a significant contribution to national fisheries production, accounting for around 1.1 million tons, while the rest comes from brackish ponds and marine waters. Aquaculture is also considered important in supporting national food security by providing sustainable protein sources (Wasik *et al*., 2025). Based on FAO data, global aquaculture production continues to increase and accounts for a large share of the world's total aquatic production, underscoring the need for freshwater fish for the global market and the need to increase supply (Sharma *et al*., 2024).

One of the leading commodities in freshwater fisheries cultivation in Indonesia is African catfish (*Clarias gariepinus*). This commodity has strong development prospects for supporting national food security due to its rapid growth rate, good adaptability, and relatively higher productivity compared to other freshwater fish (Indriastuti *et al*., 2022).

As market demand continues to increase, the aquaculture of African catfish (*Clarias gariepinus*) has expanded significantly. However, the high cost of commercial pellet feed remains a major challenge for fish farmers, as feed can account for more than 60% of total production costs. This situation increases operational expenses and may reduce the profitability of aquaculture operations. Therefore, improving production efficiency through the use of more economical alternative feed ingredients is necessary while still maintaining optimal fish growth (Mishbach *et al*., 2026; Patang *et al*., 2024).

High-quality feed must meet the physiological requirements of fish through a balanced composition of protein, lipids, carbohydrates, vitamins, and minerals. However, the high cost of fishmeal-based feed has become a major challenge in aquaculture, as feed can account for a substantial proportion of total production costs (Dirvariu *et al*., 2025). Therefore, the search for alternative protein sources that are more economical and sustainable has become increasingly important. One promising alternative is the larvae of *Hermetia illucens*, commonly known as the Black Soldier Fly (BSF), which contain high levels of protein and lipids. In addition, BSF larvae are capable of converting organic waste into high-protein biomass, making them an efficient and nutritionally valuable ingredient for aquaculture (Ghosh, 2025; Schneider *et al*., 2025; Su *et al*., 2025; Wang *et al*., 2025). The protein content of BSF larvae plays a crucial role in supporting fish growth as a structural component of body tissues and as an energy source, indicating that their inclusion in feed formulations may improve nutrient utilization efficiency in aquaculture systems (Karim & Bakali, 2025).

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In addition to having a high nutrient content, Black Soldier Fly maggots are also efficient in larval production because they can utilize organic substrate sources effectively and do not require large plots of land. On the other hand, cassava as tapioca agro-industrial waste has a high carbohydrate content, and although it has a low protein content and high crude fiber, it can be considered as an energy feed ingredient in feed formulation when combined with other protein sources (Riani *et al*., 2024).

Agro-industrial waste utilization as feed ingredients is a potential strategy to reduce environmental pollution caused by the accumulation of high-moisture organic waste, which can lead to odor pollution and environmental degradation. The use of food and agro-industrial waste in feed formulations can reduce organic waste accumulation while increasing the added value of these materials through the implementation of a circular economy concept. This approach supports a more sustainable and environmentally friendly feed production system (Leyva-López *et al*., 2020; Sari *et al*., 2026; Yafetto *et al*., 2023; Yasmine *et al*, 2021). In addition, the utilization of organic waste such as cassava pulp is also aligned with the Sustainable Development Goals (SDGs), particularly Goal 12, which promotes responsible consumption and production (Ilalfiah & Agustina, 2024).

Based on this background, this study is important to address the high cost of commercial pellet feed through the utilization of organic waste, particularly Black Soldier Fly maggot (*Hermetia illucens*) and cassava pulp (*Manihot esculenta*), as alternative feed ingredients. Therefore, this study aims to evaluate the potential of Black Soldier Fly maggot and cassava pulp as alternative feed ingredients for improving the growth performance and feed efficiency of African catfish (*Clarias gariepinus*).

RESEARCH METHODS

Time This study was conducted from December 16, 2024, to January 16, 2025, in Trimo Harjo Village, Semendawai Suku III District, South Sumatra. African catfish (*Clarias gariepinus*) fingerlings were obtained from local fish farmers in the same area. Water quality parameters were monitored throughout the experimental period at the research site.

The study evaluated the use of maggot flour (*Hermetia illucens*) and cassava (*Manihot esculenta*) on the growth performance of African catfish (*Clarias gariepinus*) over a 30 days using four treatments and three replications. Growth performance was assessed based on absolute weight gain, weight gain percentage, absolute length, and feed conversion ratio (FCR). Environmental parameters, including pH and water temperature, were measured every 10 days.

Approaches and Types of Research

This research uses a quantitative approach, which focuses on numerical data. The method used in this study is an experiment, which is a study that involves manipulating independent variables, controlling bound variables, and measuring the effect of free variables on bound variables.

Research Design

The experimental design used in this study was a Completely Randomized Design (CRD) consisting of four treatments with three replicates each. The control treatment (P0) used 100% commercial feed (SAFIR HG-2). In contrast, treatments P1, P2, and P3 consisted of combinations of maggot flour derived from Black Soldier Fly (*Hermetia illucens*) and cassava pulp (*Manihot esculenta*) at different proportions. The maggots used in this study were fresh Black Soldier Fly larvae that were processed in-house into maggot flour. Prior to grinding, the larvae were cleaned and oven-dried at 60–70°C until a constant weight was achieved to reduce moisture content and partially lower fat instability. The dried larvae were then ground using a mechanical grinder to obtain a fine flour. This drying step is essential to improve shelf life and prevent rapid rancidity due to the naturally high fat content of the maggots.

Treatment P1 contained 75% maggot flour and 25% cassava pulp, P2 contained 50% maggot flour and 50% cassava pulp, and P3 contained 25% maggot flour and 75% cassava pulp. Each formulation was supplemented with 20 g tapioca flour as a binder, 20 g premix, and 10 g fish oil, resulting in a total feed weight of 1000 g for each treatment (Aisyah *et al*., 2021).

Since proximate analysis was not conducted in this study, the nutrient composition of the commercial feed (P0) was obtained from the manufacturer's specifications. Meanwhile, the nutritional characteristics of the experimental diets (P1–P3) were described based on the known composition of their ingredients from the literature. Maggot flour is generally reported to have high protein and lipid content, whereas cassava pulp is characterized by higher fiber and lower protein levels. Therefore, differences in nutrient composition among treatments were interpreted qualitatively based on ingredient proportions.

In the feed preparation process, maggot flour and cassava pulp were first weighed according to the formulation of each treatment and then thoroughly mixed in a container until evenly distributed. Subsequently, tapioca flour, premix, and fish oil were added and mixed until homogeneous. Water was gradually added while stirring until a uniform dough was formed. The dough was then molded into pellet-shaped feed using a manual pellet mold. The pellets were steamed for approximately 10–15 minutes to improve texture and binding stability, and then air-dried at room temperature until completely dry before being used as feed during the experimental period.

The commercial feed used as the control consisted of fish meal, wheat bran, soybean meal, rice bran, vitamins (A, C, D3, E, K, B2, B6, B12, and niacin), calcium D-pantothenate, and choline chloride, with a nutritional composition of 31–33% protein, 3–5% fat, 4–6% crude fiber, 10–13% ash, and 11–13% moisture (Aisyah *et al*., 2021). During the rearing period, the fish were fed three times daily at 09:00, 14:00, and 19:00 WIB, with a feeding rate of 5% of the fish biomass per day. The amount of feed provided was periodically adjusted based on the total fish biomass in each experimental unit. The formulation of the alternative feed was designed to evaluate the effectiveness of maggot meal and cassava pulp (onggok) as protein and energy sources for fish, while also providing a potential solution to reduce feed costs, which account for more than 60% of the total production cost (Noorsyafina *et al*., 2023).

Population

The population in this study consisted of African catfish (*Clarias gariepinus*) obtained from fish farmers in Trimo Harjo Village, Semendawai Suku III District, South Sumatra. A total of 360 fish were randomly assigned to 12 experimental units (30 fish per unit), with three replicates for each of the four treatments.

Sample

The sample used in this study was African catfish (*Clarias gariepinus*). Each experimental unit consisted of 30 fish. For growth observations, 3 fish were randomly sampled from each tank, with three replicates per treatment. However, for the calculation of feed conversion ratio (FCR), the total biomass was measured using all fish within each tank to ensure accuracy. Furthermore, the fish were observed based on the predetermined parameters.

Data Collection Techniques

In this study, the data collected included several parameters of fish growth, namely:

Absolute Weight GainAbsolute

Weight gain is calculated to determine the increase in fish weight during the study using the formula:

$$\Delta W = W_t - W_o \quad \text{.................................... (1)}$$

Absolute weight growth (ΔW) was calculated using the formula $\Delta W = W_t - W_o$, where ΔW represents the absolute weight growth (g), W_t is the final fish weight (g), and W_o is the initial fish weight (g) (Nisa *et al*., 2025).

Weight Gain (%)

Weight gain was used to determine the increase in fish body weight during the experimental period and was calculated using the following formula:

$$Weight\ Gain\ (\%) = \frac{W_t - W_o}{W_o} \times 100 \quad \text{........... (2)}$$

Where W_t is the final weight of fish (g), and W_0 is the initial weight of fish (g) (Margaretha *et al*., 2025).

Absolute Length Gain:

Absolute length growth was used to measure the increase in fish length during the study:

$$\Delta L = L_t - L_i \quad \text{.. (3)}$$

The change in fish length (ΔL) was calculated using the formula $\Delta L = L_t - L_i$, where ΔL represents the change in fish length (cm), L_t is the final fish length of fish (cm), and L_i is the initial fish length of fish (cm) (Ayuwandra *et al*., 2025).

d. Food Conversion Ratio (FCR)FCR is used to assess the efficiency of feed utilization by fish:

$$FCR = \frac{F}{W_t - W_o} \quad \text{.. (4)}$$

Where FCR represents the feed conversion ratio, F is the amount of feed given during the experimental period (g), W_t is the final fish weight (g), and W_o is the initial fish weight (g) (Sirley *et al*., 2026).

Water Quality Monitoring

Water quality was monitored by measuring pH and temperature periodically. The pH value was recorded using a digital pH tester by immersing the probe into the pond water for 10–15 seconds until a stable reading was obtained, and measurements were conducted every 10 days. Water temperature was measured using a digital or mercury thermometer by immersing the device in the water for about 2 minutes to avoid interference from air temperature. Each measurement was conducted three times a day at 09:00, 14:00, and 19:00 WIB. In addition, to maintain water quality, uneaten feed and organic residues accumulated at the bottom of the ponds were removed regularly using a siphoning method. This procedure was carried out during the rearing period to prevent the accumulation of organic waste and to maintain a stable aquatic environment for fish culture.

Variable Operational Definition and Test Analysis

In this study, the independent variables were in the form of alternative feed treatment, namely Black Soldier Fly maggot (*Hermetia illucens*) and cassava pulp (*Manihot esculenta*). Maggot is a larva that can decompose organic waste into a source of high protein, while cassava pulp is a tapioca industrial waste that is rich in carbohydrates. The study-bound variable was the growth of African catfish (*Clarias gariepinus*), both weight gain (grams) and length (cm), which was measured in response to feed treatment. Before the hypothesis test, a prerequisite test was carried out: a normality test to ensure the data followed a normal distribution (p-value >0.05) and a homogeneity test to check the similarity of variations between samples. Data analysis was carried out using ANOVA to determine the effect of treatment on fish growth. If there is a significant difference, it is followed by the Duncan Multiple Range Test (DMRT) at the 5% significance level.

RESULT AND DISCUSSION

Growth Performance of African Catfish (*Clarias gariepinus*)

The growth performance results are presented in Table 1. Treatment P1 consistently showed the best performance among the substitution feeds, with values approaching those of the control (P0). The FCR value of P1 (1.66) was relatively close to that of the control feed (P0, 1.00), indicating good feed efficiency. This can be explained by the high protein content and balanced amino acid profile of maggot flour, which is comparable to that of fishmeal. Maggot protein contains essential amino acids such as lysine, methionine, and threonine in proportions similar to fishmeal, allowing fish to efficiently utilize nutrients for growth rather than as an energy source (Dirvariu *et al*., 2025; Gasco *et al*., 2022). The combination of 75% maggot flour and 25% cassava thus provided a nutrient balance that supported near-optimal feed conversion, making P1 an effective alternative to conventional fishmeal-based feed.

The prerequisite tests for analysis (normality and homogeneity) using *SPSS 26* showed that all parameters were normally distributed (significance value > 0.05) and homogeneous (significance value > 0.05). The One-Way ANOVA results indicated a significant effect of the mixture of maggot flour and cassava on fish weight growth (significance value 0.000 < 0.05). Further analysis was carried out using Duncan's Multiple Range Test (DMRT) at a 5% significance level. DMRT (Duncan's Multiple Range Test) with a significance level of 5% show in Table 2.

Table 1. Mean Growth Performance of African Catfish

Treatment	Absolute Weight (g)	Weight Gain (%)	Absolute Length (cm)	FCR
P0	10,66	35,55	6,23	1,00
P1	8,66	28,88	5,33	1,66
P2	6,00	20,00	3,33	2,33
P3	4,33	14,44	2,33	3,00

Description: Weight Gain (%) represents total weight gain percentage; FCR (Feed Conversion Ratio); P0 (control feed); P1–P3 (treatment feeds).

Table 2. The Duncan Absolute Weight Test

Treatment	Standard Deviation
P0	10.66 ± 0.57a
P1	8.66 ± 1.15a
P2	6.00 ± 1.00b
P3	4.33 ± 0.57b

Remarks: Numbers followed by the same letter mean that they do not differ significantly, SD (Standard Deviation), P0 (Control feed), P1-P3 (Treatment feed)

Based on Duncan's Multiple Range Test (DMRT) results for absolute weight gain (Table 2), the highest performance among the substitution feeds was observed in treatment P1 (75% maggot flour *Hermetia illucens* and 25% cassava *Manihot esculenta*), with an average absolute weight of 8.66 ± 1.15 g. This value was not significantly different from the control feed (P0, 10.66 ± 0.57 g), indicating that P1 effectively supports growth comparable to commercial feed. Treatments P2 (50% maggot flour and 50% cassava) and P3 (25% maggot flour and 75% cassava) showed significantly lower weight gains of 6.00 ± 1.00 g and 4.33 ± 0.57 g, respectively. The lower growth in P3 is likely due to the high crude fiber content of cassava, which reduces feed digestibility and slows nutrient absorption, resulting in suboptimal growth (Alifka *et al*., 2025; Restu *et al*., 2025). Maggot flour, on the other hand, provides high protein content (35–45%) and essential amino acids that support tissue growth (Dirvariu *et al*., 2025; Gasco *et al*., 2022), while cassava contributes carbohydrates as an energy source, allowing proteins to be used efficiently for growth rather than energy. These results emphasize that a balanced combination of animal protein and energy sources is critical for optimal growth in dumbo catfish.

The weight gain percentage data (Table 3) also support these findings. Treatment P1 showed a value (28.88 ± 3.83%) that was not significantly different from the control feed P0 (35.55 ± 2.11%), while P2 and P3 were significantly lower, with values of 20.00 ± 3.33% and 14.44 ± 1.92%, respectively. The high weight gain in P1 reflects the balanced nutrient composition of maggot flour and cassava, where maggot protein provides essential amino acids for muscle development, and cassava supplies energy to optimize protein utilization (Dirvariu *et al*., 2025; Gasco *et al*., 2022; Islam *et al*., 2024). Conversely, the lower value in P3 results from the excessive proportion of cassava, increasing crude fiber levels, and reducing nutrient digestibility (Alifka *et al*., 2025; Restu *et al*., 2025). These results indicate that feed composition directly influences growth performance, and the P1 formulation offers an effective alternative feed for supporting near-optimal growth.

Table 3. Duncan Weight Gain Test

Treatment	Standard Deviation
P0	35.55 ± 2.11a
P1	28.88 ± 3.83a
P2	20.00 ± 3.33b
P3	14.44 ± 1.92b

Remarks: Values followed by the same superscript letter are not significantly different ($p > 0.05$). SD = Standard Deviation.

The absolute length data (Table 4) further demonstrate that P1 provided the most favorable growth, with an average gain of 5.33 ± 1.52 cm, followed by P2 at 3.33 ± 1.15 cm and P3 at 2.33 ± 0.57 cm. Treatment P1 did not differ significantly from the control (6.23 ± 1.07 cm), suggesting that the 75% maggot and 25% cassava formulation supplies a more balanced nutrient profile for linear growth. High protein and essential amino acids from maggot flour, combined with minerals such as calcium and phosphorus, support skeletal development and linear growth (Jahan *et al*., 2021; Wang *et al*., 2025). In contrast, the low protein content and high carbohydrate proportion in P3 limited growth, consistent with studies showing that excessive plant-based feed without proper protein balance reduces growth performance (Negara *et al*., 2026; Restu *et al*., 2025; Rizki *et al*., 2021).

Table 4. Absolute Length Duncan Test

Treatment	Standard Deviation
P0	6.23 ± 1.07a
P1	5.33 ± 1.52a
P2	3.33 ± 1.15b
P3	2.33 ± 0.57b

Remarks: Numbers followed by the same letter mean that they do not differ significantly, SD (Standard Deviation), P0 (Control feed), P1-P3 (Treatment feed).

Feed Utilization Efficiency

Feed utilization efficiency was evaluated using the Feed Conversion Ratio (FCR), as presented in Table 5. The Feed Conversion Ratio (FCR) results indicate that P1 achieved the most efficient feed utilization among the substitution treatments, with an FCR of 1.66 ± 0.57, not significantly different from the control (1.00 ± 0.50). Treatments P2 and P3 recorded higher FCR values of 2.33 ± 0.57 and 3.00 ± 0.00, respectively. A lower FCR indicates better feed efficiency, meaning that a greater proportion of the feed consumed is converted into biomass (Akwuaka, 2025). The superior efficiency of P1 is attributed to the optimal balance of protein and energy, with maggot flour providing highly digestible protein and cassava supplying energy (Wang *et al*., 2025). In contrast, the high cassava proportion in P3 reduced protein content and feed efficiency, as excessive carbohydrates without sufficient protein limit the energy available for tissue growth (Negara *et al*., 2026). ANOVA and DMRT analysis confirmed that the composition of maggot flour and cassava significantly affects FCR and overall growth performance.

Overall, the study demonstrated that feed formulations combining maggot flour and cassava significantly influenced the absolute weight, SGR, absolute length, and FCR of dumbo catfish. Among the treatments, the formulation of 75% maggot flour and 25% cassava (P1) consistently yielded the best growth performance, approaching that of commercial feed, thereby highlighting its potential as an effective alternative feed for sustainable aquaculture.

Table 5. Duncan FCR Test

Treatment	Standard Deviation
P0	1.00 ± 0.50a
P1	1.66 ± 0.57a
P2	2.33 ± 0.57b
P3	3.00 ± 0.00b

Remarks: Numbers followed by the same letter mean that they do not differ significantly, SD (Standard Deviation), P0 (Control feed), P1-P3 (Treatment feed)

Water Quality Parameters

The water pH in the research ponds was measured every 10 days using a digital pH meter, and the results are presented in Figure 2. During the study, the pH value remained constant at 7.5 for all treatments (P0, P1, P2, and P3).

Water pH is an important environmental factor affecting the growth of African catfish (*Clarias gariepinus*), as it influences physiological processes such as metabolism, respiration, and feed utilization efficiency. Extreme deviations in pH can induce physiological stress and reduce growth performance (Siagian & Situmorang, 2021). The observed pH of 7.5 falls within the optimal range for catfish cultivation according to the Indonesian National Standard (SNI), which is 6.5–8.5, and provides favorable conditions for metabolic activity and growth (Maziyan *et al*., 2025).

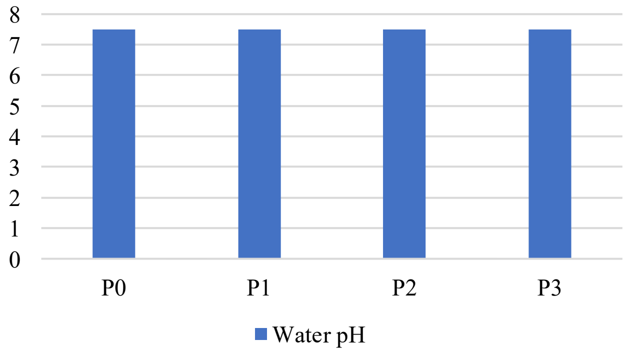

Figure 2. Graph Average Water pH Measurement

pH values below 5 can cause physiological disorders, including gill mucus accumulation, impaired respiration, and increased mortality risk, while pH values above 9 can reduce a and disrupt ionic balance in fish (Siagian & Situmorang, 2021). Additionally, pH fluctuations outside the optimal range can increase oxidative stress and decrease growth efficiency in cultured fish (Ali, 2025). The stable pH throughout the study indicates that water acidity was not a limiting factor, and differences in fish growth can be attributed primarily to feed treatments.

The water temperature in the research ponds was measured using a digital thermometer every 10 days, and the results are presented in Figure 3. During the study, the water temperature ranged from 26°C to 28°C across treatments: P0 at 28°C, P1 at 27°C, P2 at 27°C, and P3 at 26°C.

Water temperature is a critical environmental factor influencing the activity, metabolism, and appetite of African catfish (*Clarias gariepinus*) juveniles. Within the optimal tolerance range, an increase in temperature enhances metabolic rate, which in turn promotes feed consumption and growth (Pertiwi *et al*., 2021). The optimal temperature for dumbo catfish seed growth is between 25°C and 30°C, where enzyme activity and metabolic processes occur efficiently to support optimal development (Maziyan *et al*., 2025; Siagian & Situmorang, 2021).

Based on the results (Figure 3), the water temperature during maintenance remained within this optimal range and showed no extreme fluctuations that could inhibit growth. Therefore, environmental temperature did not act as a confounding factor, and the differences in growth observed among treatments can be attributed primarily to variations in feed formulation.

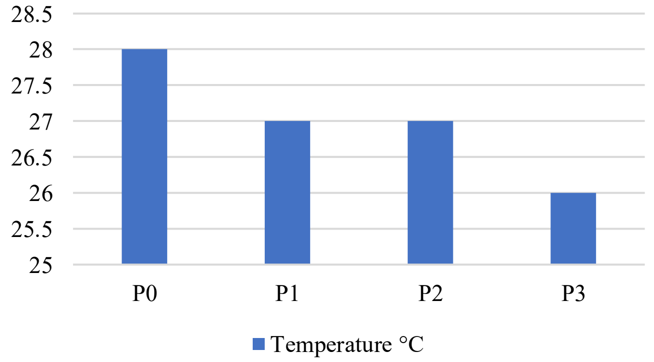

Figure 3. Graph Average Water Temperature Measurement

CONCLUSION

Based on the results of this study, alternative feed formulations consisting of maggot flour (*Hermetia illucens*) and cassava pulp (*Manihot esculenta*) significantly influence the growth performance of African catfish (*Clarias gariepinus*), as indicated by absolute weight gain, weight gain percentage, absolute length, and feed conversion ratio (FCR). The most optimal formulation was observed in treatment P1, with a composition of 75% maggot flour and 25% cassava pulp, which produced growth performance comparable to the control feed. Further research is recommended to determine the proximate composition of the formulated feeds, optimize feeding frequency and dosage, and improve the nutritional quality of cassava-based ingredients to enhance their effectiveness in supporting catfish growth.

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