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Original Article

Assessment of growth performance and blood profile of *Clarias gariepinus* (Burchell, 1822) fed with maggot meal diets as a replacement for fish meal

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Abstract
This study assessed the impact of incorporating maggot meal diets at varied inclusion levels on the growth and health parameters of *Clarias gariepinus*. After a 14-day acclimatization period, a total of 225 juvenile fish were randomly assigned to 5 experimental groups with each group replicated 3 times (15 fish per replicate). Over an 84-day period, fish groups were fed diets containing varied levels of maggot meal: 0 (control), 25, 50, 75, and 100% in replacement for fish meal. Weight gain and specific growth rate (SGR) were determined, and blood samples were analyzed at the end of the experiment. Significant differences ($p<0.05$) were observed in final mean weight gain, with the highest gain at 50% maggot meal (49.77±9.16g) and the lowest at 100% (30.77±5.87g). Specific growth rate varied significantly ($p<0.05$), with lowest at 100% replacement level (2.42±0.36%/day) and highest at the 50% replacement level (3.22±0.36%/day). Packed cell volume was significantly higher at 25% inclusion (42.0±0.4%), and haemoglobin concentration were significantly similar at 25% (14.0±0.6g/dL) and 50% (12.7±0.5g/dL) replacement levels. Significant differences ($p<0.05$) of serum biochemical values emerged across replacement levels. In conclusion, maggot meal inclusion up to 50% improved growth performance without compromising fish health, suggesting its potential in juvenile fish aquaculture.

INTRODUCTION

Aquaculture is one of the food production techniques that is expanding the quickest globally, according to Morgane *et al*. (2016). Aquaculture is growing, particularly the growth of African catfish *(Clarias gariepinus*), which can withstand harsh rearing circumstances (a wide range of temperatures, low oxygen levels, and high salinity levels), as well as have high nutritional content, nice flavour, and few bones. Additionally, mainly in Africa, it has developed into a substantial commercial species as a result of its high fertility and growth rate (Gasco *et al.,* 2018). Due to its superior nutritional content to that of other

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animal proteins, fish has remained a source of optimism for the solution to the world's problem of protein deficiency.

It is imperative to produce acceptable diets to increase fish culture, either in new forms for ponds or as entire feed in tanks, in order to fulfill the ever-increasing demand for fish (Premalatha *et al.,* 2011). As aquaculture production gets more intense, fish feed plays a critical role in increasing productivity and profitability (Mogaji and Ibiyo, 2016).

Additionally, the least developed nations capture about 50% of the world's fish harvest, and a sizable amount of this catch is consumed domestically (Ibiyo, 2018). A consistent supply of nutritionally balanced feed with sufficient levels of all-important elements, such as protein, fat, carbohydrate, vitamins, and minerals, is required for productive and sustainable aquaculture (Zlaugotne *et al.,* 2022). Pathological illnesses and stunted growth may be brought on by an excess or deficiency of one or more nutrients in the diet. Aquatic species must meet certain dietary needs for optimum growth and to avoid developing a variety of deficiencies. Minerals, protein, and nutrition are haematological markers that reflect the general health of fish. Iron (Fe) is a mineral that all living things, including fish, require because it is a component of proteins (Zlaugotne *et al.,* 2022).

Haemato-biochemical analyses are one of the studies that consistently monitor the physiological condition and health status of cultured fish (Hrubec *et al.,* 2000; Fazio, 2019; Gbore *et al*., 2020), as morphological and biometric criteria alone do not always provide a complete picture (Tavares-Dias and Moraes, 2007). Haematological and biochemical indicators have been used to assess the health condition of fish in response to dietary changes (Ferreira *et al.,* 2007; Mohammed and Sambo, 2007, Gbore *et al*., 2010). Haematological analysis can also be used to evaluate the acceptability of innovative and unconventional feeds, investigate the effects of stressful situations, evaluate fish health, and evaluate the non-specific resistance of different fish breeds and strains (Adewole and Gbore, 2006; Azaza *et al.,* 2020). Studies on haematological and biochemical responses of *C. gariepinus* have concentrated on responses to different feeds, dietary inclusion and substitution levels, and culture systems like concrete tanks, tarpaulin tanks, water-recirculating aquaculture systems, earthen ponds, and reservoirs (Bake *et al.,* 2019; Afia and David, 2019). The purpose of this investigation was to examine the performance of *C. gariepinus* (Burchell, 1822) fed diets containing maggot meal to substitute fish meals, as well as the impact of this feed on the haematological and biochemical parameters of the fish.

MATERIALS AND METHODS

Experimental procedure

The experiment was a completely randomized design of 5 treatments in triplicate. A total of 350 *C. gariepinus* juveniles, with average weight of 6.82±0.24g, were bought from a reputable Farm in Ondo State and acclimatized for 14 days prior to the commencement of the experiment. Fifteen plastic tanks with a 50-liter capacity and dimensions of 65 cm by 40 cm by 30 cm were stocked evenly with a total of 225 juveniles of *C. gariepinus* fish among the treatments, each at the stocking rate of 15 fish per tank. Before the

experiment, the fish were not fed for two days. They were fed to satiation twice daily (08:00 and 5:00 hours). The weight of the fish was monitored every two weeks and individual weighing of fish and measurement of standard length and total length were also recorded every two weeks for the period of 12 weeks. The quantities of feeds offered to the fish were weighed, and the quantity of dead fish in each tank during the feeding trial was counted in order to calculate the feed consumption. The water temperature, pH, dissolved oxygen (DO), conductivity and total dissolve solids (TDS) were determined weekly using HANNA Multi-parameter meter with GPS and 4m Cable Probe made in Romania. The ranges of water temperature, pH and DO were 23.22 - 28.04 °C, 6.32 - 6.91, 0.12 - 2.13 mg/L, respectively.

Diet Formulation

According to Ogunji *et al*. (2011), the larval stage of the semi-transparent housefly (*Musca domestica*) that thrived on poultry droppings was employed to create the housefly maggot meal used in this investigation. The formulation of five experimental diets resulted in a 40% dry matter protein content. The two main dietary protein sources were fish meal and maggot meal (Table 1). When the amount of maggot meal was increased from 0% (control) to 25, 50, 75, and 100% (coded as

Table 1. Composition of experimental diets formulated with varied maggot meal

Ingredient	MMD_0 Control (0%)	MMD_1 25%	MMD_2 50%	MMD_3 75%	MMD_4 100%
Maggot Meal	0	12.4	24.8	37.2	49.6
Fish Meal	40	30	20	10	0
Soya Bean Meal	30	30	30	30	30
Maize	12	12	12	12	12
DCP	0.5	0.5	0.5	0.5	0.5
Vitamin Premix*	0.5	0.5	0.5	0.5	0.5
Lysine	0.6	0.6	0.6	0.6	0.6
Methionine	0.4	0.4	0.4	0.4	0.4
Salt	0.1	0.1	0.1	0.1	0.1
Fish Oil	1.0	1.0	1.0	1.0	1.0
Vitamin C	0.5	0.5	0.5	0.5	0.5
Starch	14.1	11.7	9.3	6.9	4.5
Toxin Binder	0.3	0.3	0.3	0.3	0.3
Total	**100**	**100**	**100**	**100**	**100**

Key: MMD_0 = 0% maggot meal diet; MMD_1 = 25% maggot meal diet; MMD_2 = 50% maggot meal diet; MMD_3 = 75% maggot meal diet; MMD_4 = 100% maggot meal diet.
DCP = Di-Calcium Phosphate.
*Vitamin and Mineral premix: 2.5kg of premix contains Vitamin A 12,500,000.00 I.U., Vitamin D32, 500, 000.00 I.U., Vitamin E 40,000.00 mg., K3-2,000.00mg, B1-3,000.00mg, B2- 5,500.00mg,Niacin-55,000.00, Calcium Pantothenate-11,500.00mg, VitaminB6-5,000.00mg, B12-25.00mg, Choline chloride-450,000.00mg, Biotin-50.00mg, Manganese-120,000.00mg, Iron- 100,000.00, Zinc- 80,000.00mg, Copper-8,500.00mg, Iodine1,500.00mg, Cobalt-300.00mg, Selenium-120.00mg, Antioxidants-120,00.00mg.

MMD1, MMD2, MMD3, and MMD4, respectively), the amount of fish meal in the test diets dropped concomitantly. As a control, a diet devoid of maggot meal (MMD0) was used. In preparing diets, yellow maize, soyabeans, Starch, minerals and vitamin premix were obtained from a livestock feed store. Large ingredients were all blended together. Ingredients from dry diets, such as vitamin and mineral blends, were carefully combined with oil. The feed was pelletized into sizes with a 2 mm diameter after water was added. The pelletizer and mixer were locally fabricated. The wet pellets were dried for three days at room temperature, packaged in an air-tight container, and stored in the refrigerator until use.

Assessment of fish growth, nutrient utilization and survival

After the 12-week feeding trial, the following parameters were calculated according to Akinwumi and Abiodun (2014) as shown in the formulae below:

i. **Specific growth rate (%/day)** = 100 (Ln FW - Ln IW)/Duration of experiment (days)

ii. **Nitrogen metabolism** = Duration of experiment (days) × (0.549) × (IW+FW)/2

iii. **Fish Survival (%)** = 100× (Number of survived fish/ quantity of fish initially stocked)

iv. **Relative Growth rate (RGR) (%)** = $\frac{W_2 - W_1}{W_1} \times 100$

Where, W_1 = initial average weight (g) at the start of experiment

W_2 = final average weight (g) at the end of experiment

v. **Feed Conversion Ratio** = $\frac{\text{Dry weight of feed fed (g)}}{\text{Fish weight gain (g)}}$

vi. **Protein Efficiency Ratio (PER)** = $\frac{\text{Wet body weight gain (g)}}{\text{Crude protein fed}}$

Proximate analyses of the formulated feeds were carried out using method of Association of Official Analytical Chemists (AOAC, 2012). The Soxhlet System HT (Tecator) to measure crude fat, while the Kjedahl System (The Kjedahl TM 2300 Analyzer Unit -FOSS Analytical, Hilleroed, Denmark) was used to measure protein (N 6.25). Burning at 550°C for 10 hours in a muffle furnace was used to calculate the ash content (Table 2) (AOAC, 2012).

Table 2. Proximate composition of the maggot meal diets

Parameter	MMD_0 0%	MMD_1 25%	MMD_2 50%	MMD_3 75%	MMD_4 100%
Moisture	9.84±0.84^{b}	8.49±0.78^{a}	10.72±0.08^{c}	10.54±0.10^{c}	11.68±0.56^{d}
Crude Protein	40.97±0.00^{a}	41.69±0.25^{a}	40.94±0.90^{a}	40.57±1.38^{a}	40.05±0.09^{a}
Ash	10.74±0.13^{c}	6.68±0.46^{ab}	6.18±0.80^{a}	6.15±0.12^{a}	7.61±0.1^{b}
Crude Lipid	6.68±0.19^{b}	4.90±0.29^{a}	4.65±0.25^{a}	7.18±0.68^{b}	8.77±0.17^{c}
Crude Fibre	10.40±0.07^{a}	11.41±1.38^{a}	12.29±0.23^{a}	12.53±1.61^{a}	11.24±0.34^{a}
NFE	21.37±0.16^{a}	26.82±1.21^{c}	25.21±0.21^{bc}	24.03±0.73^{b}	20.64±0.38^{a}

^{abcd}: Indicate that means on the same row but with different superscripts are statistically significant ($P<0.05$). NFE= Nitrogen Free Extract.

Blood collection and analysis

Following the 12-week feeding trial, blood was obtained from three fish taken from each replicate. Blood was drawn from the

caudal vein and put into two different types of bottles: heparinized bottles to prevent blood coagulation and non-heparinized bottles to allow blood to clot. These samples were used for hematological and serum biochemical analyses, respectively. The blood cell counts were counted using a Neubauer bright-line haemocytometer (Marienfeld, Agoda Company Pte. Ltd., Germany), following the method described by Dacie and Lewis (1991). To evaluate the variation in white blood cell count, blood smears were prepared on slides and examined using a microscope (Olympus, USA) and a blood cell differential counter (Durga, Miniscence, Inc., USA). The results for differential cells were expressed as percentages, as per the method outlined by Harikrishnan *et al*. (2010). In addition, the Al-Dohail *et al.* (2009) approach was used to compute the mean corpuscular volume, mean corpuscular hemoglobin, and mean corpuscular hemoglobin concentration as follows.

Mean corpuscular volume (fL)
= 10 × (haematocrits/ Red blood cell count)

Mean corpuscular haemoglobin (pg)
= 10 × (Haemoglobin/Red blood cell count)

Means corpuscular haemoglobin concentration (g/L)
= 100 × (Haemoglobin/haematocrits)

The blood collected in non-heparinized bottles was subjected to centrifugation (SE-CF-TDZ-WS, Labkits, U-Term International (Hong Kong) Limited) at 4000g for 10 minutes at room temperature. This process yielded serum samples, which were subsequently utilized to assess serum total protein, albumin, globulin, creatinine, urea nitrogen, alanine aminotransferase, aspartate aminotransferase, and alkaline phosphatase levels. These assessments were conducted using Randox kits (Randox Laboratories Ltd, United Kingdom), following the manufacturer's standard protocol.

Statistical Analysis of Data

One-way analysis of variance (ANOVA) was performed on the acquired data to detect the significant differences among the control and experimental groups ($p<0.05$) and Duncan multiple range test was used to compare differences among individual treatment means.

RESULTS

The proximate composition of the formulated diets is presented in Table 2. Notably, there was no significant differences ($p>0.05$) observed in crude protein and fiber contents between the control and experimental diets. However, significant differences were observed in moisture, ash, lipids, and nitrogen-free extract levels.

The data presented in Table 3 show the growth parameters and nutrient utilization indices. Among the fish groups that were fed the experimental diets, those given MMD_2 exhibited the highest values. These values were significantly distinct ($p<0.05$) from those of the other fish groups for all the measured growth performance indicators, such as final weight, protein intake, specific growth rate (SGR), and feed consumption. Additionally, a consistent pattern was observed in other parameters, of which there was little difference. However, there was no notable difference ($p>0.05$) in parameters like feed conversion ratio, gross energy feed conversion (GEFC), protein efficiency ratio, fat efficiency ratio, nutrient metabolism, and condition factor.

Table 3. Growth performance and nutrient utilization of *C. gariepinus* fed with maggot meal diets

Parameter	MMD_0 (0%)	MMD_1 25%	MMD_2 50%	MMD_3 75%	MMD_4 100%
Initial weight (g)	106.00±1.58	108.06±3.39	106.74±2.86	107.15±3.26	106.79±1.20
Final weight(g)	399.20±82.39^{ab}	483.94±146.14^{ab}	548.19±153.75^{b}	507.70±106.48^{ab}	303.31±53.14^{a}
FMWG (g)	35.01±4.39	45.16±8.64	49.77±9.16	45.63±17.74	30.77±5.87
PI (g)	21.93±3.66^{bc}	23.09±1.85^{bc}	25.39±1.58^{c}	19.88±2.47^{ab}	17.05±1.02^{a}
SGR(%/d)	2.66±0.22^{ab}	3.04±0.33^{ab}	3.22±0.36^{b}	3.01±0.60^{ab}	2.42±0.36^{a}
Feed Intake (g)	54.83±9.16^{bc}	57.71±4.64^{bc}	63.46±3.95^{c}	49.71±6.18^{ab}	42.64±2.55^{a}
FCR	1.60±0.42	1.31±0.27	1.31±0.28	1.17±0.36	1.43±0.38
GEFC	66.11±20.61	78.39±15.13	78.66±15.57	90.78±27.05	72.81±17.54
PER	0.88±0.11	1.41±0.21	1.28±0.24	1.13±0.44	0.77±0.15
FER	0.67±0.2	0.78±0.15	0.79±0.16	0.91±0.27	0.73±0.18
GFCR	66.11±20.61	78.40±15.13	78.66±15.57	90.78±27.05	72.81±17.54
RGR	395.90±67.37	526.48±115.57	601.71±142.86	538.21±246.31	332.78±86.69
NM	483.29±76.98	656.40±148.18	737.71±161.18	665.65±306.04	408.93±102.78
Survival Rate (%)	75.56±7.69	71.11±13.88	73.33±13.33	77.78±16.78	66.67±11.55
CF	0.92±0.07	0.81±0.05	0.91±0.02	1.11±0.18	1.22±0.63

^{abcd}: Superscript in same row with different letters are significant different ($p<0.05$) FMWG (Final mean weight gain) SGR (Specific Growth Rate), FCR (Feed Conversion Ratio), GEFC (Gross Efficiency of Feed Conversion), PI (Protein intake), PER (Protein Efficiency Ratio), FER (Feed Efficiency Ratio), GFCR (Gross Feed Efficiency Ratio), RGR (Relative Growth Rate), NM (Nitrogen Metabolism), CF (Condition Factor).

The haematological indicators of *C. gariepinus*, which were fed a diet containing varied levels of maggot meal, are displayed in Table 4. Significant differences ($p<0.05$) were observed for all haematological parameters, with the exception of granulocytes and lymphocytes. Notably, there was an increase in both the packed cell volume (PCV) and the value of haemoglobin in fish fed with MMD_1, whereas a decrease was noted in those fed with MMD_3. The highest values for Mean cell volume (MCV), Mean corpuscular haemoglobin (MCH) and White blood cells (WBC) were associated with the fish fed diet containing MMD_2, while the lowest values were recorded in fish fed MMD_3. Fish fed MMD_4 had a

Table 4. Haematological parameters of *C. gariepinus* fed varied inclusion levels of maggot meal diet

Parameter	MMD_0 (0%)	MMD_1 25%	MMD_2 50%	MMD_3 75%	MMD_4 100%
PCV (%)	35.0±0.4^{c}	42.0±0.4^{e}	38.0±0.07^{d}	24.0±0.6^{a}	33.0±0.6^{b}
RBC (x 10^6/L)	9.4±0.5^{a}	12.4±0.4^{b}	8.9±0.4^{a}	13.2±0.7^{b}	17.7±0.5^{c}
MCHC (g/dL)	33.14±0.3	33.33±0.3	33.15±0.3	33.33±0.3	33.33±0.3
MCV (fl)	37.24±0.7^{c}	33.9±0.4^{b}	42.7±0.5^{d}	18.2±0.7^{a}	18.6±0.7^{a}
MCH (pg/cell)	12.4±0.08^{c}	11.3±0.3^{b}	14.2±0.4^{d}	6.1±0.5^{a}	6.2±0.5^{a}
HGB (g/dL)	11.7±0.9^{bc}	14.0±0.6^{d}	12.7±0.5^{cd}	8.0±0.9^{a}	11.0±0.7^{b}
WBC (x 10^6/L)	1.3±0.5^{ab}	2.2±0.2^{bc}	2.4±0.5^{c}	1.1±0.3^{a}	1.6±0.8^{abc}
Granulocytes (x 10^9/L)	0.5±0.3	0.4±0.3	0.8±0.3	0.3±0.1	0.5±0.3
Lymphocytes (x 10^9/L)	0.8±0.6	1.2±0.4	1.4±0.3	0.7±0.4	1±0.6
Monocytes (x 10^9/L)	0.0±0.0^{a}	0.1±0.1^{ab}	0.2±0.1^{b}	0.0±0.0^{a}	0.1±0.1^{ab}

^{abcd}: Indicate that mean on the same row but statistically significant ($p> 0.05$) are superscripts with different meanings. MCHC stands for Mean Corpuscular Haemoglobin Concentration. MCV stands for Mean Cell Volume. MCH stands for Mean Cell Haemoglobin. HGB stands for Haemoglobin. WBC stands for White Blood Cell.

significant increase in Red blood cells (RBC) values followed by fish fed MMD_3, with the lowest values observed in those fed MMD_2.

Table 5 displays the findings from the serum biochemical analysis for *C. gariepinus* that were fed maggot meal diets. The findings indicated a significant difference ($p<0.05$) in creatinine levels among *C. gariepinus* fed the experimental diets, with the highest level observed in fish fed MMD_0 and the lowest in those fed MMD_3. Aspartate aminotransferase (AST) level was highest in *C. gariepinus* fed MMD_0, whereas *C. gariepinus* fed MMD_2 had the lowest value. Additionally, *C. gariepinus* fed MMD_0 had the highest ALT level, while the lowest levels were observed in *C. gariepinus* fed MMD_2 and MMD_4. A significant ($p<0.05$) disparity was also observed in total protein levels across the treatment groups, with *C. gariepinus* fed MMD_0 having the highest level of total protein, followed by those fed MMD_1. In a similar vein, the highest level of albumin was recorded in *C. gariepinus* fed MMD_0, while the lowest value was recorded in those fed MMD_4. There was a significant difference ($p<0.5$) in globulin levels across the treatment groups, with *C. gariepinus* fed MMD_4 displaying the highest globulin value, while those fed MMD_2 had the lowest value. Variations were also observed in alanine aminotransferase (ALT) and urea levels across the treatment groups.

Table 5. Serum biochemistry of *Clarias gariepinus* fed with varied inclusion levels of maggot meal diets

Parameters	MMD_0	MMD_1	MMD_2	MMD_3	MMD_4
Creatinine (mmol/l)	135.7±0.3^e	118.6±0.2^b	121.0±0.3^c	113.7±0.3^a	128.0±0.3^d
AST (IU/L)	162.6±0.3^d	151.4±0.4^b	148.6±0.3^a	161.6±0.3^c	151.8±0.3^b
ALT (IU/L)	33.7±0.4^d	27.8±0.4^b	25.2±0.3^a	29.6±0.3^c	27.8±0.3^b
Total Protein (g/dl)	64.5±0.3^e	60.0±0.2^d	52.1±0.3^a	55.6±1.5^b	57.8±0.3^c
Albumin (g/dl)	28.1±0.3^d	25.9±0.2^e	25.7±0.3^c	23.8±0.3^b	20.2±0.3^a
Globulin (g/dl)	36.4±0.3^d	34.2±0.3^c	26.4±0.3^a	32.8±0.3^b	37.6±0.3^e
Urea (mg/dl)	7.1±0.3^b	7.3±0.3^b	7.3±0.3^b	6.8±0.3^b	6.2±0.3^a
ALP (IU/L)	20.0±0.3^a	28.5±0.3^b	29.9±0.3^c	30.4±0.3^c	31.0±0.3^d

^{abc}: Superscripts with different letters in same row are significant different ($p<0.05$)
AST: Aspartate aminotransferase, ALT: Alanine aminotransferase; ALP: Alkaline phosphatase

DISCUSSION

Proximate composition of the maggot meal diets

The moisture contents of the feed, with the highest value observed at 100% maggot meal inclusion level and the lowest at 25% inclusion level, are in line with previous studies on insect-based diets for animal feed that reported varied moisture levels depending on the inclusion rate of insect meal (Qurat *et al.,* 2023). The significant difference in moisture content between the control diet and the experimental diets suggested that maggot meal inclusion affected the overall moisture content.

The range of crude protein content did not exhibit a significant difference among the different inclusion levels. This stability in protein content aligns with the generally recognized high protein content of insect-

based meals (Liceaga, 2022). The higher ash content in maggot meal-based diets was, perhaps, due to the natural mineral composition of insects (Sohail, 2018; Shah *et al*., 2022).

The variation in lipid content may be due to the dietary composition of maggot meal and its fatty acid profile (Ahmad *et al.,* 2022; Akinwole *et al.,* 2020). The non-significant difference in crude fibre contents between the control and experimental diets suggested that maggot meal inclusion did not substantially alter the fibre content of the feed. The variations in NFE content are likely due to the carbohydrate composition of the maggot meal (Abraham *et al.,* 2015).

Growth performance and nutrient utilization of C. gariepinus fed with varied maggot meal diets

The results of growth performance and nutrient utilization indicated that *C.gariepinus* exhibited varied growth performance when fed different diets containing maggot meal. This finding is consistent with studies that have demonstrated the positive influence of maggot-based diets on the growth of fish species (Akinwole *et al.,* 2020; Xu *et al.,* 2022) The outcome in protein intake as observed in this study aligns with research indicating that the protein content of diet strongly influences the growth and protein utilization in fish (Kim *et al.,* 2012; Olaniyi and Salau, 2013). The significantly highest and lowest SGR observed among the fish fed MMD_2 and MMD_4, respectively suggested that MMD_2 was the most preferred diet for promoting rapid growth in *C. gariepinus*. These findings corroborate previous studies that have linked the composition of dietary protein sources to SGR in fish (Li *et al.,* 2023; Nazir *et al.,* 2023). The statistical similarities observed in GEFC across the treatment groups was an indication that the feed conversion efficiency remained consistent across these two inclusion levels. This aligns with studies that reported similar trends in feed conversion efficiency with different dietary compositions (Kim *et al.,* 2021). The non-significantly higher nitrogen metabolism recorded at 50% inclusion level of maggot meal as compared to other groups containing higher inclusion levels suggested that a moderate inclusion level of maggot meal optimized nitrogen metabolism in *C. gariepinus*. Nitrogen metabolism is a key factor in fish growth and overall health (Lall and Kaushik, 2021). Condition factors are important indicators of the overall health and well-being of fish. The consistent k values across the treatment groups suggested that incorporating maggot meal did not significantly impact the condition of *C. gariepinus*, as reported by Ahmad *et al.* (2023).

Haematology of C. gariepinus fed diets containing varied levels of maggot meal diet

The significant differences observed in several haematological parameters among the different dietary treatments, shed light on the potential effects of maggot meal inclusion on the haematological profile of *C. gariepinus*. There was increase in the PCV and haemoglobin (Hb) levels in fish fed the diet containing the least level of maggot meal (MMD_1). This increase suggested that maggot meal might have a positive impact on the oxygen-carrying capacity of the blood, which is crucial for the overall health and performance of fish. Similar observations regarding the enhancement of haematological parameters by dietary supplements have been reported

in other studies (Ogunji *et al.,* 2008; Xu *et al.,* 2022). Conversely, a significant decrease in PCV and Hb levels was noted in fish given the diet with the highest maggot meal content (MMD_4). This decrease might be related to the limited availability of essential nutrients in the diet, highlighting the importance of proper dietary composition for maintaining optimal haematological parameters (Ahmed and Haboubi, 2010).

The study also revealed variations in red blood cell (RBC) counts among the different dietary treatments. The results which showed the highest RBC count in fish fed MMD_4 and the lowest in those fed MMD_2 suggested that the level of maggot meal inclusion might have differential effects on erythropoiesis, possibly due to variations in nutrient composition and digestibility (Attivi *et al.,* 2020). Significantly higher values of mean corpuscular volume, mean corpuscular haemoglobin, and white blood cell count were observed in fish fed MMD_2. This result could indicate an enhanced immune response and the presence of essential nutrients that supported the synthesis of these blood components (Tacon and Metian, 2013). Conversely, fish fed MMD_3 showed the lowest values for these parameters, suggesting potential dietary deficiencies that may compromise immune function. This consistency in immune cell numbers across the treatments might indicate that the presence of maggot meal had no effect on these particular immune characteristics (Xu *et al.,* 2022).

Monocyte counts were uniformly low across most treatments, with the highest value recorded in fish fed MMD_2. The fish fed the control diet and MMD_3 had the lowest monocyte counts. Monocytes are essential components of the immune system, and their low counts in some treatments warrant further investigation to understand their implications for fish health and disease resistance (Cain *et al.,* 2017).

Serum biochemistry of C. gariepinus fed with varied maggot meal diets

The significant difference in creatinine levels among the treatment groups suggested varied degrees of kidney function or metabolism in *C. gariepinus*. Elevated creatinine levels can indicate renal stress or dysfunction (Sayed *et al.,* 2022), and it is notable that the highest creatinine levels were seen in the group that was fed MMD_0. This may warrant further investigation into the potential negative effects of this diet on renal function. Aspartate aminotransferase and ALT are enzymes indicative of liver function. The elevated levels of these enzymes in fish fed MMD_0 and MMD_3 might signify hepatic stress or damage (Rastiannasab *et al.,* 2016). Conversely, the lower levels of these enzymes in fish in the MMD_2 group may suggest improved liver health in this treatment group.

Variations in levels of total protein, albumin, and globulin reflected the overall nutritional status and health of the fish (Tomori *et al.,* 2023). The higher total protein and albumin levels in fish fed MMD_0 could indicate better overall nutritional status, whereas lower levels in the MMD_4 group may be linked to dietary deficiencies or impaired protein synthesis. Elevated urea levels, as seen in the MMD_1 group, may suggest increased protein catabolism or poor dietary utilization (Tomori *et al.,* 2023). Conversely, the lower urea levels in the MMD_4 group could

indicate efficient protein metabolism. Elevated ALP levels, particularly in the MMD_4 group, might be associated with hepatic or biliary tract disorders (Arrington *et al.,* 1999). This finding raises questions about the impact of the MMD_4 diet on liver and gallbladder health.

CONCLUSION

The results of this study suggested that maggot meal has a number of qualities that could effectively supplement fish meal in the diet of *C. gariepinus*. When maggot meal was included at higher levels (50 - 75%) in the *C. gariepinus* diet, parameters relating to growth significantly improved. Furthermore, the blood profiles of *C. gariepinus* improved when they were fed diet with 50% inclusion level of maggot meal, consistent with the observed growth parameters at the same level. In summary, a 50% replacement of fish meal with maggot meal is recommended as the most suitable. Therefore, substituting fish meal with maggot meal to a considerable extent can reduce cost and meet the growth and haematological requirements of *fish*.

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