

Effect of Goat Weed Leaf Meal (*Ageratum conyzoides*) as a Partial Dietary Replacement for Maize in the diet of African Catfish (*Clarias gariepinus*) Juveniles

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Research Article

Keywords: *Ageratum conyzoides*, Conventional feed, Fish nutrition, Serum enzyme

Posted Date: February 27th, 2024

DOI: <https://doi.org/10.21203/rs.3.rs-3975853/v1>

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Additional Declarations: No competing interests reported.

Abstract

It is crucial to find ways to employ less expensive conventional materials in fish farming to lower production costs without adversely affecting the general performance of the fish. Consequently, certain neglected plants, such as goat weed leaves that have been reported to have the potential to serve as a partial substitute for maize (energy source) must be considered. Therefore, this research evaluated the effects of partially replacing maize with goat weed leaf meal (*Ageratum conyzoides*) (GWLM) on the growth, haematology, and serum enzyme indices of *Clarias gariepinus* juveniles. A 56-day feeding trial was conducted with a total of 500 juveniles with an average weight of 13.7 g. After sterilizing in a mixture of potassium permanganate and water to reduce stress, a one-week acclimatization period was ensured using commercial feed (2 mm). Subsequently, they were randomly stocked in quadruplets of 25 fish per culture tank measuring 1.2 m x 1.2 m x 0.9 m each (labeled Ai-iv, Bi-iv, Ci-iv, Di-iv, and Ei-iv) based on the diet to be fed. A total of five (5) different diets with varying levels of dietary inclusion (0%, 2%, 4%, 6%, and 8%) of goat weed leaf meal (GWLM) as a partial replacement for maize were formulated to contain a minimum crude protein level of 40%. The test diets were administered twice daily (7:00 hrs. and 18:00 hrs.) and the sampled fish were adequately fed (5% body weight) with proper follow-up to monitor feeding behavior. The data collected from the research were subjected to a one-way analysis of variance (ANOVA) using the SPSS version 23 analysis package. Furthermore, a Duncan multiple-range test was employed to separate the means. There were notable ($p < 0.05$) variations in various parameters (proximate composition, digestibility of nutrients, growth performance, haematological and serological profiles, and water quality) observed in all treatments as the inclusion of the test ingredient in the diet increased. However, as the inclusion levels of the test ingredient increased above 4%, a steady decline was observed between treatments. At a 4% dietary inclusion level, the best performance indices (weight gained (36.52g), feed conversion ratio (2.15), specific growth rate (2.31) and survival rate (95%)), and blood profile (haematology and serum enzyme indices) were observed. Therefore, a 4% replacement of maize using goat weed leaf meal (GWLM) in the diet is suitable for the optimum performance of African catfish.

Introduction

Fish farming is considered one of the most prominent sources of protein for all since fish remains one of the cheapest available animal proteins (Hua et al. 2019). Although increased production capacity has been suggested as the most effective way to bridge the ever-growing margin between the demand and supply of fish. However, the drawback has been the cost of production resulting from the high cost and scarcity of feed ingredients such as maize, soyabean, and fish meal. Furthermore, the impact of climate change and the competing interests of livestock and humans for these ingredients also contribute to scarcity and high cost. As the impact of climate change continues to be unfavourable to the production of these essential ingredients, there is a need to consider alternative, sustainable, available and cheaper sources that are not readily competing for by livestock and humans. The use of plant protein sources as an alternative to expensive ingredients in the diets of most cultured fish species, especially African

catfish, has been adopted as an effective and efficient alternative feed ingredient (Nwachi and Irabor 2015; Kari et al. 2020; Irabor et al. 2021a; 2022a).

Recently, several plant sources such as moringa leaves, duckweed, sweet potato, and goat weed have been explored by fish farmers and feed producers based on their benefits to fish both in performance and cost implications (Abdel-Latif et al. 2022; Ekelemu et al. 2023; Irabor et al. 2023). Consequently, these plants have been used as partial or total replacements without compromising the general performance of the fish. Some such as *Moringa oleifera* are also known to contribute significantly to the immunity of the fish because of their antimicrobial, antioxidant and anti-inflammatory potentials (Ekelemu et al. 2023).

Goatweed (*Ageratum conyzoides*) is an invasive plant that grows predominantly in sub-Saharan Africa. This plant is known to grow all year round, although much more in the wet season. The leaves, in addition to being fed to goats, cattle, rabbits, and guinea pigs, are used to tackle various health challenges such as inflammations, headaches, diabetes, and spasm in humans (Ebochonu et al. 2017). This is due to the nutritional and phytochemical properties present in significant proportions. Its nutrient profile includes carbohydrate (36.84%), crude fiber (23.50%) and crude protein (14.73%), which contains ash (12.64%), moisture (10.02%), crude fat (2.27%), vitamins (E, B6, C, and B2) and minerals (Zn, Mg, K, Fe, P, Na, Mn and Ca). The active phytochemicals identified in the leaves are thiamin, saponins, tannins, cardiac glycosides, alkaloids, anthraquinones, niacin, and flavonoids (Gbadamosi and Olanikpekun 2020; Akpodiete et al. 2023).

Considering the nutritional and phytochemical attributes of goat weed leaves, it has been explored in aquaculture as both a probiotic and a feed additive at varying inclusion levels (Gbadamosi and Olanikpekun 2020). Therefore, this study sought to evaluate the growth performance and hematological characteristics of African catfish (*C. gariepinus*) fed diets with varying levels of dietary inclusion of goat weed leaf meal as a partial replacement for maize.

Materials and Methods

Research site and duration of the study

The culture trial was carried out at the Fisheries and Aquaculture Department Research Farm, while measurements and hematologic analysis were conducted at the department laboratory located in the premises of Dennis Osadebay University Anwai, Asaba, Delta State Nigeria.

The research lasted for a period of 56 days from April to June 2023.

Collection of the test ingredient

Fresh goat weed leaves were identified using a chart provided by a plant expert from the Crop science Department and harvested from the reserve vegetation of the Crop Science Department. The harvested leaves were carefully removed and cleaned, then properly dried at room temperature and blended to powder form with the aid of an electric vegetable blender (model BLG 403) (Fig. 1). A proximate and

phytochemical analysis was performed on the leaf (Table 1), before inclusion at varying levels to formulate the test diets. Analysis was carried out using the methods described by Tewelde and Mulubrhan (2019). The relative composition analysis was determined using a mixture of methods namely extraction, Kjeldahl, and near-infrared reflectance spectroscopy (NIR), while the digestibility test was carried out using both the siphoning and stripping methods. Then the formula used to calculate the level of digestibility was;

Digestibility (%) = $100 - (100 \times (\text{marker concentration in food} / \text{marker concentration in faeces}) \times (\text{nutrient concentration in faeces} / \text{nutrient concentration in the test ingredient or diet}))$.

Table 1
Proximate compositions and phytochemical constituents of goat weed leaf

Parameters (%)	GWLM
Moisture	7.82 ± 0.97
Crude protein	14.64 ± 0.64
Crude fibre	11.87 ± 0.45
Ether extract	5.80 ± 0.08
Ash content	8.98 ± 1.13
Nitrogen free extract	49.72 ± 0.51
Anti-nutritional factors (g)	
Alkaloids	26.98 ± 0.27
Tannins	7.36 ± 0.19
Saponins	62.03 ± 0.28
Flavonoids	20.74 ± 0.51
Phenol	6.26 ± 0.72
Ascorbic acids	12.35 ± 0.21
Anthraquinones	10.42 ± 0.13
Anthocyanin	15.58 ± 0.49
Cardiac glycosides	-
Trypsin inhibitor	4.23 ± 0.04
Oxalate	5.12 ± 0.09
Phytate	2.61 ± 0.05

Diet formulation and feeding trial

A total of five (5) different diets with varying levels of dietary inclusion (0%, 2%, 4%, 6% and 8%) of goat weed leaf meal (GWLM) as a partial replacement for maize were formulated to contain a minimum of 40% crude protein level (Table 2). The conventional ingredients (maize, soya bean, fishmeal, starch as binder and salt) were sourced from a notable market (Abraka market) in Asaba, Delta State, while vitamin premix, lysine and methionine were purchased from an approved seller. The feed ingredients were mixed with the text ingredient (at varying levels of dietary inclusion) and used to produce 2-mm pellet diets using a locally fabricated pelletizer with a 2-mm die. The various 2 mm feeds produced were further separated in different well-labelled containers (Fig. 2).

Table 2
Percentage composition of diets

Ingredients	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%
Maize	25.80	25.28	24.77	24.25	23.74
Fish meal	26.50	26.50	26.50	26.50	26.50
Soya beans	34.20	34.20	34.20	34.20	34.20
GWLM	0.00	0.52	1.03	1.55	2.06
Vitamin premix	2.50	2.50	2.00	2.00	2.00
Lysine	2.00	2.00	2.00	2.00	2.00
Methionine	2.00	2.00	2.00	2.00	2.00
Salt	1.50	1.50	1.50	1.50	1.50
Binder	2.50	2.50	2.50	2.50	2.50

A total of 500 African catfish (*C. gariepinus*) juveniles collected from Fisheries and Aquaculture Research Farm were used for the feeding trial. Prior to the beginning of the feeding trial, the healthy juveniles were individually weighed to ensure the weight difference was minimal (average 13.7 g). After sterilizing in a mixture of potassium permanganate and water to reduce stress, a one-week acclimatization period was ensured using commercial feed (2 mm). Subsequently, they were randomly stocked in quadruplets of 25 fish per culture tank measuring 1.2 m x 1.2 m x 0.9 m each (labelled Ai-iv, Bi-iv, Ci-iv, Di-iv, and Ei-iv) based on the diet fed (Fig. 3). The test diets were administered twice daily (7:00 hrs. and 18:00 hrs.) and the sampled fish were adequately fed (5% body weight) with proper follow-up to monitor feeding behavior.

Growth Performance and Feed Utilization

The growth parameters and feed utilization indices (body weight gain, final weight, initial weight, specific growth rate, survival rate, feed intake, and feed conversion ratio) of the sampled fish were measured

biweekly using an Anid® weighing balance (product of A&D Technology Trading (Shanghai) Co., Ltd. (Shanghai, China)) to measure body weight (BWT), meter rule, and calliper for standard length (SL) and total length (TL) of the fish. Survival rates (SR) and feed conversion rate (FCR) were evaluated using the methods described by Irabor et al. (2022a). The changes in weight and length observed as recorded were calculated using the modified methods of Garca-Ortega et al. (2016) and Irabor et al. (2016).

Body weight gained (g) = final weight - initial weight

The specific growth rate was calculated with $\frac{\text{Lin}(\text{finalweight}) - \text{Lin}(\text{initialweight})}{\text{Numberofculturedays}} \times 100$

Daily feed intake was determined by = weight of leftover feed - weight of the total feed given.

The feed conversion ratio (FCR) is expressed as the quotient of food intake and weight gained:

$$\frac{\text{Totalfeedconsumed}}{\text{Totalweightgained}}$$

Survival rate was expressed as the difference between total fish stock and quantity harvested:

$$\frac{\text{Numberoffishharvested}}{\text{Numberoffishstocked}} \times 100$$

Water Quality Analysis

Basic water quality parameters as inferred by Boyd (2001); dissolved oxygen, hydrogen, and hydroxyl ion concentration (pH) and temperature were monitored with the aid of the YSI (556 mps) meter model, while the APHA (1998) method was used to measure ammonia concentration in the holding receptacle.

Haematological and serological analysis

The blood profile of the sampled fish was evaluated at the end of the feeding trial (56 days) to determine the effect of the test ingredient. This was done by collecting blood samples from ten (10) randomly selected fish each from the various culture tanks using the procedure described by Gbadamosi and Olanikpekun (2020). Using sterile needles and syringes (1ml), blood was drawn from each of the fish through the lateral line close to the tail region and placed in sterile vials containing ethylenediaminetetraacetic acid (EDTA). The technique outlined by Amenyogbe et al. (2022) and Witeska et al. (2022) was used to calculate white blood cell (WBC), red blood cell (RBC), packed cell volume (PCV), haemoglobin concentration (Hb), total leukocyte counts, and erythrocyte counts. The following methods were also used to calculate the mean corpuscular volume (MCV) of the blood constants, the mean corpuscular haemoglobin (MCH), and the mean corpuscular haemoglobin concentration (MCHC):

White blood cell (WBC) counting area: The 4 huge squares at the edges of Neubauer's compartment are utilized to count white blood cells.

Red blood cells (RBCs) are counted in the 5 squares of the central square (which is separated into 25 squares, each one is then split further into 16 squares).

Haemoglobin (Hb) = MCV x RBC divided by 29.8.

Mean corpuscular volume (MCV %) = $\frac{PCV}{RBC} \times 10$

Mean corpuscular haemoglobin (MCH %) = $\frac{Hb}{RBC} \times 10$

Mean corpuscular haemoglobin concentration (MCHC %) = $Hb \text{ (g/dL)} \times 100/Hct$.

Serum was extracted from the blood samples collected by centrifuging some volume of the blood samples separated into well-labelled red top tubes for 5 minutes at 5000 g and 4 ° C in fresh sterile microtubes. After being thoroughly separated, the supernatant was stored at -20 ° C for additional examination using methods described by Rashidian et al. (2021).

Data Analysis

The data collected from the research were subjected to a One-way Analysis of variance (ANOVA) using the SPSS version 23 analysis package. Furthermore, a Duncan multiple range test was employed to separate the means.

Results

Proximate composition of diets

The results on the approximate composition of diets are presented in Table 3. All diets contained the required crude protein level (40%). However, there were variations in the values obtained for the other nutrients as the inclusion levels increased between treatments. Additionally, the level of antinutritional factors contained in the diets showed variations as the dietary inclusion of GWLM increased between treatments. However, all were within the acceptable standard for the fish species sampled.

Table 3
Proximate composition of diets

Parameters (%)	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%
Crude protein	40.7 ^b	40.6 ^{bc}	40.7 ^a	40.4 ^c	40.4 ^d
Lipids	9.42 ^e	7.31 ^d	8.98 ^b	7.69 ^a	8.87 ^c
Crude fibre	2.68 ^e	3.19 ^d	3.98 ^c	4.82 ^b	6.72 ^a
Moisture	8.41 ^d	7.52 ^c	6.98 ^a	5.99 ^b	5.36 ^e
Total ash	9.74 ^e	9.77 ^d	10.51 ^c	8.90 ^b	9.50 ^a
NFE ^{**}	27.8 ^a	30.5 ^b	34.9 ^c	32.8 ^d	34.3 ^e
Anti-nutritional Factors (g)					
Alkaloids	2.20 ^e	2.24 ^d	2.58 ^c	2.71 ^b	2.93 ^a
Tannins	0.30 ^d	0.31 ^c	0.30 ^d	0.34 ^b	0.39 ^a
Saponins	1.13 ^d	1.15 ^c	1.94 ^a	1.62 ^b	1.11 ^e
Flavonoids	3.54 ^d	3.55 ^d	3.62 ^c	3.87 ^b	4.22 ^a
Phenol	0.06 ^e	0.08 ^d	0.10 ^c	0.13 ^b	0.17 ^a
Ascorbic Acids	4.35 ^c	4.41 ^b	5.17 ^a	4.22 ^d	3.59 ^e
Anthraquinones	0.32 ^e	0.34 ^d	0.37 ^c	0.39 ^b	0.42 ^a
Anthocyanin	0.02 ^e	0.04 ^d	0.07 ^c	0.09 ^b	0.12 ^a
Cardiac glycosides	-	-	-	-	-
Trypsin inhibitor	0.002 ^e	0.005 ^d	0.008 ^c	0.014 ^b	0.019 ^a
Oxalate	0.03 ^e	0.06 ^d	0.11 ^c	0.031 ^b	0.057 ^a
Phytate	1.35 ^d	1.37 ^c	1.55 ^a	1.48 ^b	1.22 ^e

Digestibility test on test ingredients (GWLM) and formulated diets

The results of the digestibility test of the test ingredient and diets are presented in Table 4. The nutrients contained in the test ingredient were easily digestible as all the recorded values for dry matter (DM), organic matter (OM), crude protein (CP) and gross energy (GE) were within acceptable limits, therefore

adequate nutrients contained in the formulated diets were easily digested by the sampled fish. However, there were variations in the values obtained as dietary inclusion levels increased in diets.

Table 4

The digestibility (D,%) of dry matter (DM), organic matter (OM), crude protein (CP), and gross energy (GE) in the reference ingredient (GWLM) and test diets in *C. gariepinus* juveniles were measured using faeces collected by siphoning or stripping.

Digestibility test (%)	DM	OM	CP	GE	SEM	P
Siphoning						
GWLW	29.57 ^c	38.73 ^c	14.58 ^f	37.31 ^f	1.03	0.15
GWLM 0%	26.18 ^f	37.28 ^f	40.53 ^b	43.69 ^d	1.72	0.08
GWLM 2%	28.18 ^e	37.94 ^e	40.40 ^c	45.20 ^c	0.39	0.24
GWLM 4%	29.53 ^d	39.21 ^b	40.59 ^a	47.11 ^a	1.11	0.09
GWLM 6%	31.19 ^a	41.08 ^a	40.06 ^d	46.32 ^b	2.20	0.21
GWLM 8%	29.66 ^b	38.09 ^d	40.02 ^e	42.44 ^e	3.52	0.11
Stripping						
GWLW	30.17 ^b	39.03 ^d	15.82 ^f	-	2.15	1.51
GWLM 0%	27.62 ^f	38.31 ^e	40.37 ^b	-	0.86	1.18
GWLM 2%	28.87 ^e	38.11 ^f	40.33 ^c	-	0.27	0.53
GWLM 4%	29.92 ^c	39.84 ^b	40.57 ^a	-	0.25	1.59
GWLM 6%	30.75 ^a	40.38 ^a	40.14 ^d	-	1.02	0.92
GWLM 8%	29.73 ^d	39.14 ^c	40.03 ^e	-	0.67	1.21

Growth performance and diet utilization indices

The growth indices of the fish sampled across treatments revealed that at a 4% level of dietary inclusion of GWLM, optimal weight gain values, Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), and Survival Rate (SR) were achieved (36.52 g, 2.31 g, 2.15 and 95%, respectively) (Table 5). However, beyond the 4% inclusion level, a steady decline in these growth indices was observed as the inclusion level of the test ingredient increased between treatments (Fig. 4).

Table 5
Growth performance of *C. gariepinus juveniles* fed dietary GWLM for 56 days

Parameters (%)	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%	SEM	P
Initial weight (g)	13.7	13.6	13.7	13.7	13.6	0.00	0.05
Final weight (g)	48.28 ^b	47.03 ^c	50.22 ^a	43.19 ^c	36.71 ^d	2.37	0.48
Weight gain (g)	34.58 ^b	33.43 ^c	36.52 ^a	29.49 ^c	23.11 ^d	0.19	0.35
SGR	2.25 ^b	2.22 ^c	2.31 ^a	2.05 ^d	1.77 ^e	1.04	0.19
Feed given (g)	82.88 ^a	81.	78.4 ^c	73.36 ^d	68.32 ^e	2.32	0.22
FCR	2.40 ^d	2.45 ^c	2.15 ^e	2.49 ^b	2.96 ^a	0.02	0.51
SR (%)	90 ^b	92 ^b	95 ^a	84 ^c	75 ^d	0.36	0.43

Haematological parameters

The results of the haematological analysis presented in Table 6 showed a variation in blood indices as the inclusion levels of the test ingredient increased between treatments. The blood profile of the sampled fish was influenced by the test ingredient, especially the packed cell volume (PCV), white blood cell (WBC), and lymphocyte (LYMPH). As the level of inclusion of the test ingredient increased, all blood indices increased however, as the level of inclusion level of the test ingredient increased above 4% a steady decline was observed for mean corpuscular volume (MCV), mean corpuscular haemoglobin (MCH) and WBC.

Table 6
Haematological indices of juveniles of *C. gariepinus* fed dietary GWLM for 56 days

Parameters (%)	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%	SEM	<i>P</i>
RBC (10mm ⁻³)	2.64	2.81	2.97	3.35	3.82	0.04	0.03
MCV (fl)	91.2	91.43	91.84	89.77	88.26	0.17	0.04
MCH (pg)	30.3	30.6	30.9	30.1	29.7	0.39	0.46
WBC (10mm ⁻³)	4478	7267	8167	6942	5193	33.24	0.002
PCV (%)	22.1	26.4	29.8	33.6	37.9	0.34	0.028
MCHC (%)	33.7	33.9	33.3	33.8	34.1	0.25	0.037
Hb (g/mol)	10.2	8.37	9.56	9.22	11.7	0.39	0.03
LYMPH (%)	53.08	55.21	60.72	62.95	68.33	1.06	0.61

RBC, red blood cell; MCV, mean corpuscular volume; MCH, mean corpuscular haemoglobin; WBC, white blood cell; PCV, packed cell volume; MCHC, mean corpuscular hemoglobin concentration; Hb, haemoglobin; LYMPH, lymphocyte.

Serum analysis

The serum enzyme indicators of the sampled fish were examined (Table 7). Significant ($p < 0.05$) variations ($p < 0.05$) were recorded between diets, with an increase in serum parameters that matched an increase in GWLM dietary inclusion levels. At GWLM 8%, aspartate aminotransferase (AST), alkaline phosphatase (ALP), and Alanine aminotransferase (ALT) had the highest levels (23.11, 55.41 and 12.95), while GWLM 0% had the lowest mean values (19.52, 45.81 and 10.68), in that order.

Table 7
Serum enzyme indicators of *C. gariepinus* juveniles fed different levels of GWLM diets at 56 days

Parameters	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%	SEM	<i>P</i>
AST (UL ⁻¹)	19.52 ^{cd}	20.33 ^c	21.91	22.66 ^a	23.11 ^a	0.43	0.16
ALP (UL ⁻¹)	45.81 ^d	46.29 ^d	47.97 ^c	51.82 ^b	55.41 ^a	0.52	0.22
ALT (UL ⁻¹)	10.68 ^c	11.13 ^{bc}	11.43 ^b	12.24 ^a	12.95 ^a	0.93	0.19

AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase.

Water Quality Indices

The water quality indices recorded from the culture media were all within the acceptable range, which indicated that the test ingredients did not have a negative impact on water quality. However, a variation was observed between water parameters between treatments (Table 8).

Table 8
Summary of Physicochemical Parameters

Parameters	GWLM 0%	GWLM 2%	GWLM 4%	GWLM 6%	GWLM 8%
pH	6.85	6.84	6.81	6.88	6.82
DO (mg/L)	6.20	6.22	6.27	6.24	6.23
Temperature (°C)	28.4	27.9	28.2	28.5	28.3
Ammonia (mg/L ⁻¹)	0.06	0.07	0.07	0.06	0.08
TOM (%)	1.68	1.69	1.64	1.66	1.67
BOD (mg/L ⁻¹)	3.56	3.58	3.61	3.64	3.62
DO: dissolved oxygen; TOM: total organic matter; BOD: biological oxygen demand					

DISCUSSION

Appropriate nutritional levels were contained and easily digestible in the test ingredient and formulated diets (goat weed leaf meal) determined by proximate analysis and nutrient digestibility test, supporting the findings of Irabor et al. (2022a). This demonstrated the nutrient and health potential of the test ingredient, thereby confirming it is a good energy source (partial replacement for maize) (Jones et al. 2020). According to Elesho et al. (2021) and Ojewole et al. (2022), the crude protein required for African catfish at the juvenile stage fell between 40% and above, which is the necessary range for optimum growth performance. However, when the levels of dietary inclusion of the test ingredient increased, $p < 0.05$ was observed in all diets. This result is consistent with that of Gbadamosi and Olanikpekin (2020), who noted changes in the amounts of crude protein in the diets of African catfish, as the inclusion levels of goat weed leaf meal increased between treatments.

A gradual reduction was observed when the inclusion levels of the test components increased above 4% and beyond. Growth indices and feed consumption demonstrated $p < 0.05$ in all treatments. However, a significant increase in weight gain was observed at the 4% dietary inclusion level. It was revealed that the test ingredient's (Goat weed leaf) high nutritional content and low fiber content led to a higher weight gain. This is consistent with the findings of Hutabarat et al. (2019), who observed that *O. niloticus* gained in weight as the amount of duckweed included rose. Furthermore, Gbadamosi and Olanikpekin (2020) reported the same result in African catfish as the dietary inclusion of the goat weed leaf increased in all treatments. Additionally, the under-use of nutrients in diets may be related to the loss of growth performance shown when the level of inclusion of the test ingredient increased to 6% and beyond. This

supported the findings of Tavares et al. (2008), who observed that *O. niloticus* growth was reduced as the dietary inclusion of duckweed increased across treatments. Flores-Miranda et al. (2015) also found the same result: when the test component (fermented duckweed) was added to the diets in amounts of more than 50% across treatments. In the same vein, the growth performance of *L. vannamei* abruptly decreased as the levels of duckweed dietary inclusion increased between treatments.

The feed intake as indicated by the result demonstrated a consistent decrease in feed consumption as the levels of dietary inclusion of goat weed leaf meal increased above 4%. This may be explained by some characteristics of the test diet, such as decreased nutritional content, poor digestibility, and increased palatability when the test ingredient rose above the level of dietary inclusion of 4%. The results of Olaniyi and Oladunjoye (2012) and Wanderi and Olendi (2020), who observed that *O. niloticus* fed diets with elevated levels (over 50%) of duckweed meal had low feed intake, agree with the findings of this study. Furthermore, Gbadamosi and Olanikpekun (2020) reported the same finding in a study in which more goat weed leaf meal was fed to African catfish juveniles.

The antimicrobial characteristics of GWLM were indicated by the considerable changes ($p < 0.05$) changes in blood parameters observed as the inclusion levels of GWLM increased between treatments. Significant ($p < 0.05$) impacts of the antioxidant content of the test ingredient were observed in some blood indices, especially PCV and LYMPH, with increasing values correlating with increased levels of inclusion of the test ingredient. This study contradicts the findings of Kakwi and Olusegun (2020), who found that the feeding of *Cyprinus carpio* with different ingredients from *Mucuna pruriens* decreased PCV levels. However, this result is in line with the report of Gbadamosi and Olanikpekun (2020), where increased PCV was observed in African catfish as GWLM inclusion levels of GWLM increased between treatments. Additionally, in this study, GWLM also improved WBC levels (immune stimulating capacity), although there was a significant decrease as inclusion levels increased above 4%. The same was observed in a study carried out on *C. Carpio* fed sesbania leaf meal (Anand et al. 2020). Similar trends were also observed in MCH and MCV, all of which may be related to physiological stress.

Generally, goat weed leaf meal (GWLM) had a positive influence on fish health status, since there was an observed difference between treatments as the dietary inclusion levels of the test ingredient increased. This result confirms that of Gbadamosi and Olanikpekun (2020), who reported an improvement in health status in African catfish fed goat weed leaf meal at varying inclusion levels. This also confirms the probiotic potentials of most of these plant leaves used such as *Moringa oleifera* (Irabor et al. 2021a), duckweed (Irabor et al. 2022a; b), and sweet potato (Irabor et al. 2023).

Conclusion and Recommendation

The study found that juvenile *C. gariepinus* performed optimally in terms of growth and immunity at a 4% level of dietary inclusion of GWLM. Additionally, the added GWLM had an antioxidant quality that, in turn, positively affected the white blood cells (WBC), thereby enhancing the overall health of the sampled fish.

Therefore, it is suggested that 4% of maize can be replaced with GWLM to improve the performance and general well-being of African catfish.

Declarations

Acknowledgement

We express our gratitude to the whole Department of Fisheries and Aquaculture team for their invaluable assistance during this project. The authors also sincerely appreciate the laboratory technician for her help with the lab work.

Ethical approval

All aspects of the research that needed ethical approval were duly approved by the Senate Council for Research and Development, through the subcommittee on Aquatic Animal Research, Dennis Osadebay University, Anwai, Asaba, Delta State, Nigeria. The approval number is RDAAD-12.

Consent to participate

All authors worked together to establish the idea and design of the study. Material preparation, data collection, and analysis were handled by Irabor Arnold Ebuka, Onwuka Maureen, and Olele Nkeonyeasua Florence. Irabor Arnold Ebuka and Pierre Hardin Aaron wrote the first draft of the manuscript, which was subsequently evaluated and improved with contributions from Jovita Oghenenyehovwo Sanubi, Augustine Onyemaechi Ozor, and Muhammad Faisal Khalil. The final manuscript was collectively reviewed, approved, and approved by all authors.

Consent to publish

All authors have consented to publish this article as they have no relevant financial or nonfinancial conflict of interest to disclose.

Funding

The authors declare that this research was completely self-funded and that no external funds, grants, or other support were received.

Data Availability Statements

The data for this investigation will be made available by the corresponding author upon reasonable request.

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Figures



Figure 1

a: Goat weed plant; **b:** Goat weed leaves; **c:** Goat Weed Leaf Meal (GWLM)

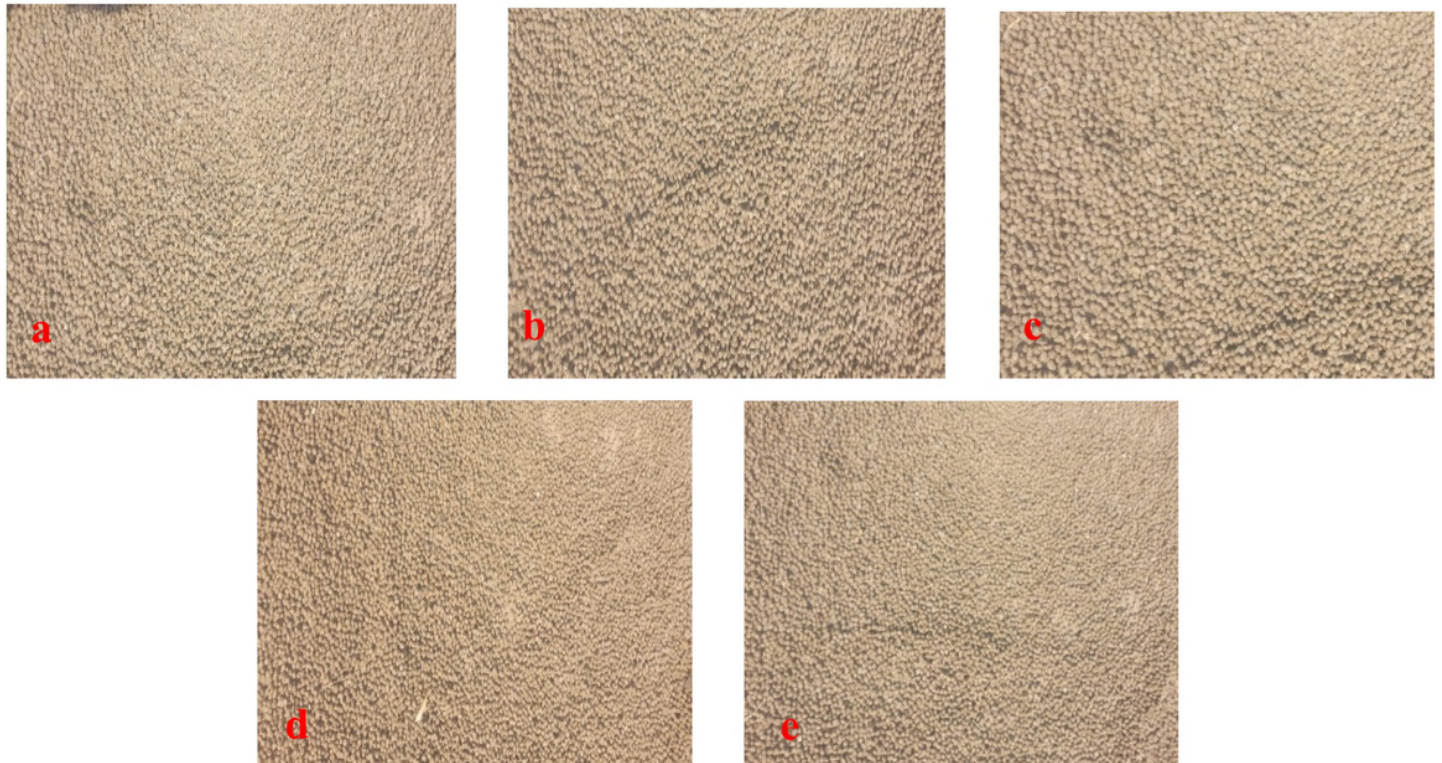


Figure 2

Formulated diet; **a:** Test diet one (0% replacement level); **b:** Test diet two (2% replacement level); **c:** Test diet three (4% replacement level); **d:** Test diet four (6% replacement level); **e:** Test diet five (8% replacement level)

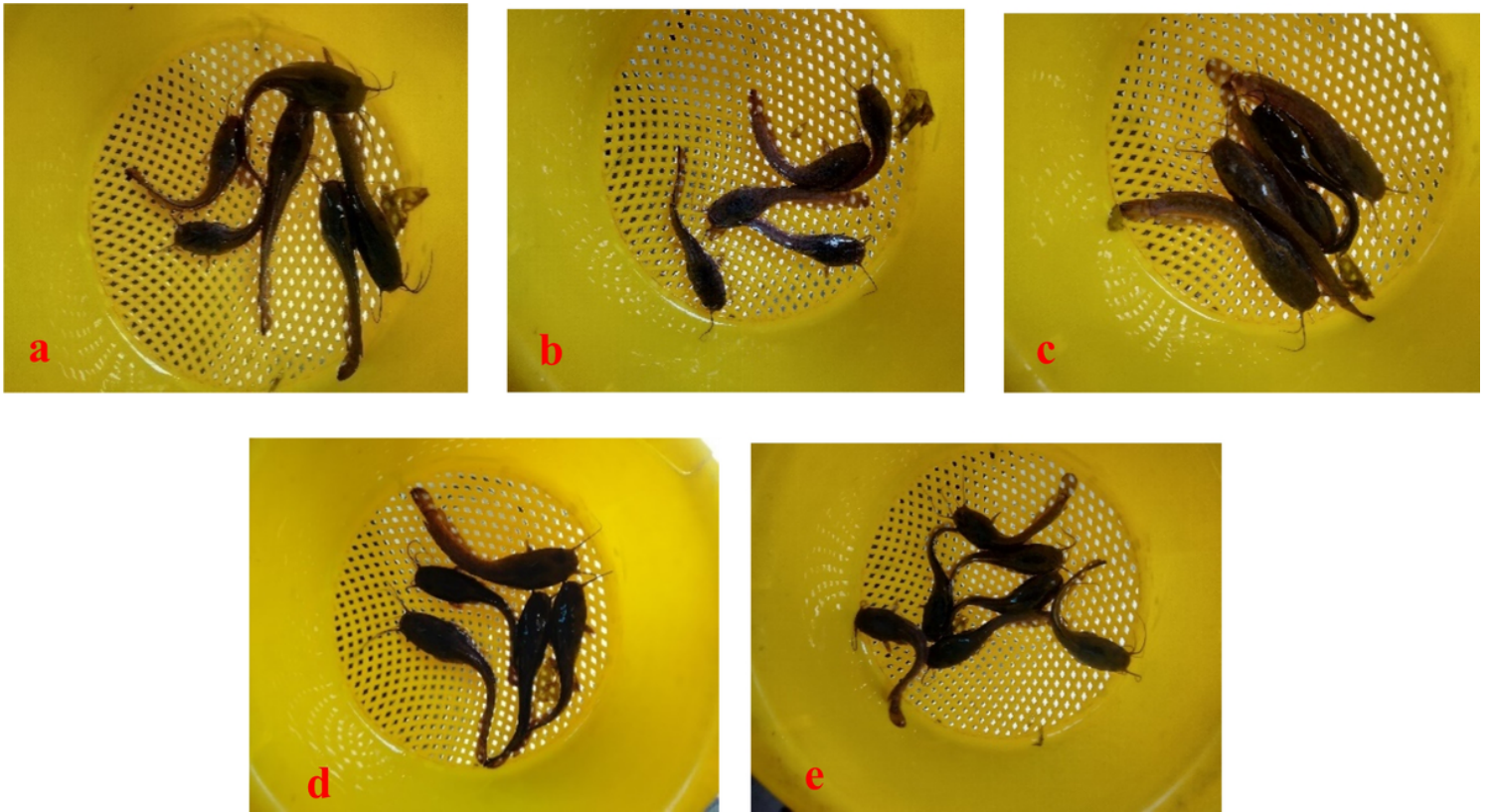


Figure 3

Fish samples; **a:** Tank one (to be fed the diet with 0% replacement level); **b:** Tank two (to be fed the diet with 2% replacement level); **c:** Tank three (to be fed the diet with 4% replacement level); **d:** Tank four (to be fed the diet with 6% replacement level); **e:** Tank five (to be fed the diet with a 8% replacement level).

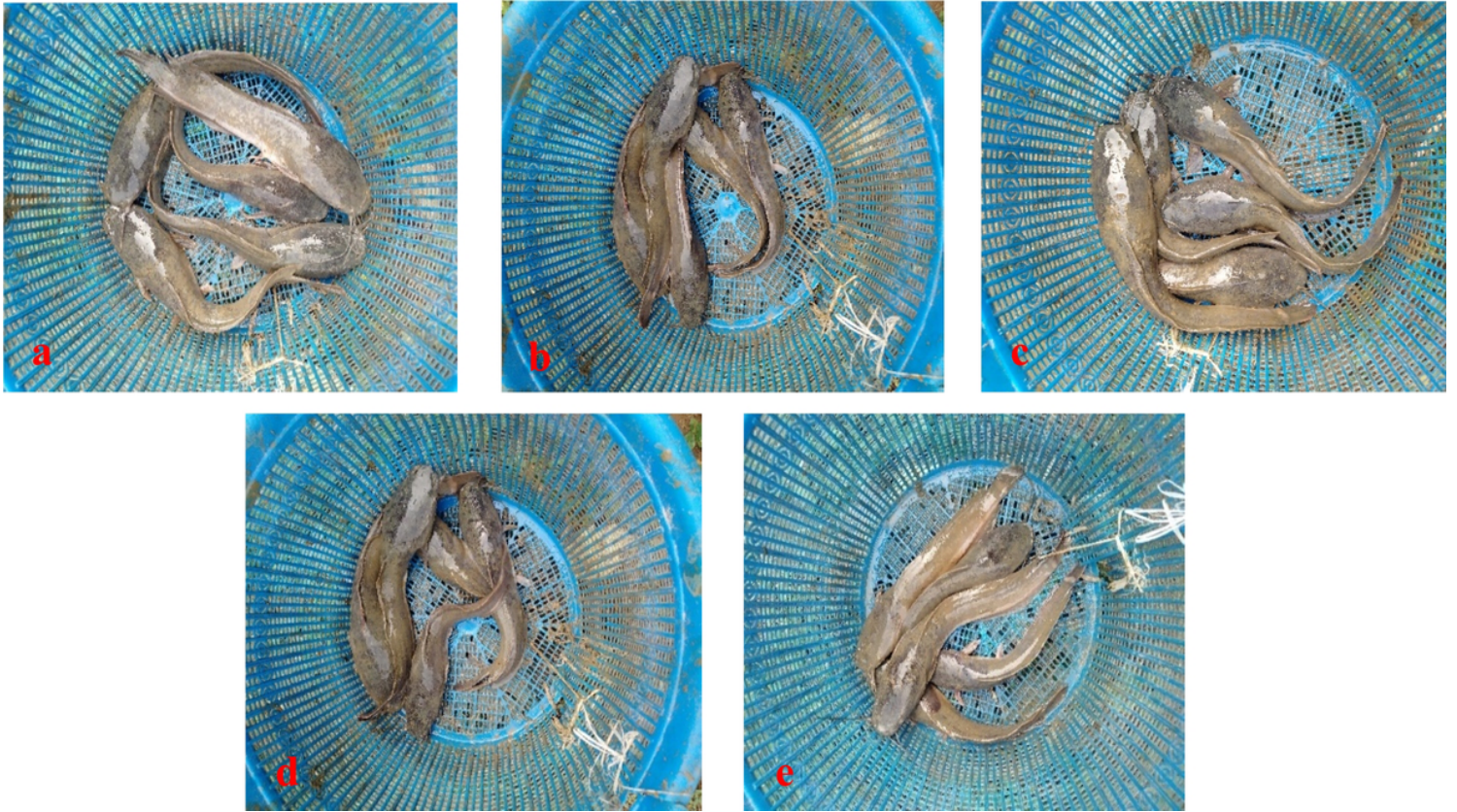


Figure 4

a: Sampled fish from tank one (0% replacement level of test ingredient); **b:** Sampled fish from tank two (2% replacement level of the test ingredient); **c:** Sampled fish from tank three (4% replacement level of test ingredient); **d:** Sampled fish from tank four (6% replacement level of test ingredient); **e:** Sampled fish from tank five (8% replacement level of test ingredient)