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Effect of goat weed leaf meal (*Ageratum conyzoides*) as a partial dietary replacement for maize in the diet of African catfish (*Clarias gariepinus*)

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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*. A 56-day feeding trial was conducted with a total of 500 juveniles with an average weight of 13.7 g. After sterilizing the fish in a mixture of potassium permanganate and water to reduce stress, a one-week acclimatisation period was ensured using commercial feed (2 mm). Subsequently, the juveniles were randomly stocked in quadruplets of 25 fish per culture tank measuring 1.2 m × 1.2 m × 0.9 m each (labelled Ai-iv, Bi-iv, Ci-iv, Di-iv, and Ei-iv) based on the number of repetition and the diet to be fed. A total of five (5) different diets with varying levels of dietary inclusion (A: 0 %, B: 2 %, C: 4 %, D: 6 %, and E: 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 behaviour. 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 (36.52 g), 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 an optimum performance of African catfish.

Keywords: conventional feed, feed formulation, fish nutrition, serum enzyme

1 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,

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

Recently, several plant sources such as moringa (*Moringa oleifera*) leaves, duckweed (*Lemna minor*), and sweet potato (*Ipomoea batatas*) leaves 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; Ekokotu *et al*., 2018; 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 inflammation, headaches, diabetes, and spasms 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 (Gbadamosi & Olanikpekun, 2020). The active phytochemicals identified in the leaves are thiamin, saponins, tannins, cardiac glycosides, alkaloids, anthraquinones, niacin, and flavonoids (Gbadamosi & 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 of 2 % and below in the diets of catfish, and a positive impact on the growth was achieved (Gbadamosi & Olanikpekun, 2020). Therefore, this study sought to evaluate the growth performance and haematological characteristics of African catfish (*C. gariepinus*) fed diets with higher varying dietary inclusion levels of goat weed leaf meal as a partial replacement for maize.

2 Materials and methods

2.1 Research site and duration of the study

The culture trial was carried out at the Fisheries and Aquaculture Department Research Farm located on the premises of Dennis Osadebay University Anwai, Asaba, Delta State Nigeria, while measurements and haematological analysis were conducted at the department's laboratory. The research lasted for a period of 56 days from January to February 2024.

2.2 Collection of the test ingredient

Fresh goat weed leaves (Fig. 1) were identified using a plant identification 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 (estimated at 23 °C) and blended to powder with the aid of an electric vegetable blender (model BLG 403).

Fig. 1: *Goat weed leaves (*Ageratum conyzoides*).*

A proximate and phytochemical analysis was performed on the leaves (Table 1), before inclusion at varying levels to formulate the test diets. Analysis was carried out using the methods described by Reda & Atsbha (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. The formula used to calculate the digestibility level was as described by Gbadamosi & Olanikpekun (2020).

Digestibility (%) = 100 − (100 × (marker concentration in food/marker concentration in faeces) × (nutrient concentration in faeces/nutrient concentration in the test ingredient or diet)).

Table 1: *Proximate composition and phytochemical constituents of goat weed leaf meal (GWLM).*

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 (mg kg^{-1})	
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

Table 2: *Composition of the five experimental diets in percentage.*

	GWLM				
Ingredients	*0 %*	*2 %*	*4 %*	*6 %*	*8 %*
Maize	25.80	25.28	24.77	24.25	23.74
Fish meal	29.50	29.50	29.50	29.50	29.50
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	2.50	2.50	2.50
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

GWLM = goat weed leaf meal.

2.3 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 test 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.

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 + 0.02). After sterilizing the juveniles 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 × 1.2 m × 0.9 m each (labelled Ai-iv, Bi-iv, Ci-iv, Di-iv, and Ei-iv) based on the diet fed (Figure 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 behaviour.

2.4 Growth performance and feed utilisation

The growth parameters and feed utilisation 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. This was done by sampling 15 fish out of the total population of each culture tank. 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).

$$\text{Body weight gain (g)} = \text{final weight} - \text{initial weight}$$

The specific growth rate was calculated with:

$$\frac{\text{Lin (final weight)} - \text{Lin (initial weight)}}{\text{Number of culture days}} \times 100$$

Daily feed intake was determined by:

$$\text{daily feed given (g)} - \text{total daily waste collected (g)}$$

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

$$\text{FCR} = \frac{\text{Total feed consumed}}{\text{Total weight gained}}$$

Survival rate (SR) was expressed as the difference between total fish stock and quantity harvested at the end of the experimental period:

$$\text{SR} = \frac{\text{Number of fish harvested}}{\text{Number of fish stocked}} \times 100$$

2.5 *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. These water quality parameters were conducted on a twice-weekly basis.

2.6 *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 & Olanikpekun (2020). Using sterile needles and syringes (1 ml), 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 utilised 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 × RBC divided by 29.8.

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

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

MCH concentration (MCHC %) = Hb (g/dL) × 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 Rpm 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).

2.7 *Ethical consent*

Prior to the commencement of the research, ethical approval for this research was obtained from the Animal Welfare Committee, Research Quality Assurance Unit, Faculty of Sciences (Zoology Department) Dennis Osadebay University, Asaba (Protocol number DOU-14-2024-321).

2.8 *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.

Table 3: *Proximate composition of the experimental diets.*

	GWLM				
Parameters (%)	*0 %*	*2 %*	*4 %*	*6 %*	*8 %*
Crude protein	40.7^{b}	40.6^{bc}	40.7^{a}	40.4^{c}	40.4^{b}
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}	3.62c	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 glyc.	–	–	–	–	–
Trypsin inh.	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}

GWLM = goat weed leaf meal: *NFE: Nitrogen free extract;
$^{a-e}$ = means in the same row without common superscript differ at $p < 0.05$.

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* Clarias gariepinus *juveniles were measured using faeces collected by siphoning or stripping.*

	Digestibility test (%)					
diet	*DM*	*OM*	*CP*	*GE*	SEM	P
Siphoning						
GWLM	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						
GWLM	30.17^{b}	39.03^{d}	15.82f	-	2.15	1.51
GWLM 0 %	27.62f	38.31^{e}	40.37^{b}	-	0.86	1.18
GWLM 2 %	28.87^{e}	38.11f	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

GWLM = goat weed leaf meal; $^{a-e}$ = means in the same row without common superscript differ at $p < 0.05$.

3 Results

3.1 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.

3.2 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. However, there were variations in the values obtained as dietary inclusion levels increased in diets.

3.3 Growth performance and diet utilisation 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.

3.4 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.

3.5 Serum analysis

The serum enzyme indicators of the sampled fish were examined (Table 7). As the inclusion level of the test ingredient (GWLM) increased in the test diets, increased mean values for serum enzyme indicators were recorded. 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), respectively.

3.6 Water quality indices

The water quality indices recorded from the culture media were all within the acceptable range, which indicated

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

	GWLM						
Parameters	*0 %*	*2 %*	*4 %*	*6 %*	*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}	81.00	78.40^{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

GWLM = goat weed leaf meal; SGR = specific growth rate; FCR = feed conversion ratio;
SR = survival rate; $^{a-e}$ = means in the same row without common superscript differ at $p < 0.05$.

Table 6: *Haematological indices of juveniles of* Clarias gariepinus *fed dietary GWLM for 56 days*

	GWLM						
Parameters	*0 %*	*2 %*	*4 %*	*6 %*	*8 %*	*SEM*	*P*
RBC ($10\,mm^{-3}$)	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 ($10\,mm^{-3}$)	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

GWLM = goat weed leaf meal; 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. GWLM = goat weed leaf meal.

that the test ingredients did not have a negative impact on water quality. However, a variation (p>0.05) was observed between water parameters between treatments (Table 8).

4 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 Gbadamosi & Olanikpekun (2020). This demonstrated the nutrient and health potential of the test ingredient, thereby confirming it is a good energy source to partially replace for maize (Jones *et al*., 2020). According to Elesho *et al*. (2021) and Ojewole *et al*. (2022), the crude protein required for optimal growth performance of African catfish in the juvenile stage is around 40 %. However, when the levels of dietary inclusion of the test ingredient increased above 40 %, a decrease in the crude protein was observed in diets. This result is consistent with that of Gbadamosi & Olanikpekun (2020), who noted changes in the amounts of crude protein in the diets

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

	GWLM						
Parameters	*0 %*	*2 %*	*4 %*	*6 %*	*8 %*	*SEM*	*P*
AST (UL^{-1})	19.52^{cd}	20.33^{c}	21.91^{b}	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

GWLM = goat weed leaf meal; AST: Aspartate aminotransferase; ALT: Alanine aminotransferase; ALP: Alkaline phosphatase. SEM = standard error margin;
$^{a-d}$ = means in the same row without common superscript differ at $p < 0.05$.

Table 8: *Summary of physicochemical parameters.*

	GWLM				
Parameters (%)	*0 %*	*2 %*	*4 %*	*6 %*	*8 %*
DO (mg L^{-1})	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

GWLM = goat weed leaf meal; DO: dissolved oxygen; TOM: total organic matter; BOD: biological oxygen demand.

of African catfish, as the inclusion levels of goat weed leaf meal increased between treatments.

A gradual reduction in weight gain of the sampled fish was observed when the inclusion levels of the test components increased above 4 %. 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 fibre 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 & Olanikpekun (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 above 50 %. In the same vein, the growth performance of *L. vannamei* abruptly decreased as the levels of duckweed dietary inclusion increased over 50 %.

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 poor digestibility, and increased palatability when the test ingredient rose above the level of dietary inclusion of 6 %. The results of Olaniyi & Oladunjoye (2012) and Wanderi & Olendi (2020), who observed that O. niloticus fed diets with increased dietary levels (over 50 %) of duckweed meal had low feed intake, agree with the findings of this study. In the same vein, Gbadamosi & Olanikpekun (2020) reported the same finding in a study where increased dietary inclusion of goat weed leaf meal (over 5 %) was fed to African catfish juveniles.

The antimicrobial characteristics of GWLM were indicated by the considerable changes ($p < 0.05$) in blood parameters observed as the inclusion levels of GWLM increased between treatments. Significant 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 & 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 & 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 mean values of serum enzyme indicators between treatments as the dietary inclusion levels of the test ingredient increased. This result confirms that of Gbadamosi & Olanikpekun (2020), who reported an improvement in health status expressed in the mean values for the haematological profile and serum enzyme indicators of 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 *M. oleifera* (Irabor *et al*., 2021a), duckweed (Irabor *et al*., 2022a; 2022b), and sweet potato (Irabor *et al*., 2023).

5 Conclusion

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.

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Conflict of interest

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

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