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POTENTIALS OF *Leucaena leucocephala* ON THE GROWTH PERFORMANCE AND NUTRIENT UTILIZATION OF AFRICAN CATFISH

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ABSTRACT

The need to substitute the scarce and expensive fishmeal with a cheaper alternative has drawn attention to the use of Leucaena leucocephala in feeds due to their abundance and high nutritional value. Three hundred (300) Clarias garipenius post fingerlings were purchased for this study. Therefore, this study evaluated the potentials of replacement of fishmeal with Leucaena leucocephala leaf meal at varying inclusion levels on the growth performance of Clarias gariepinus post fingerlings. Five (5) experimental diets were formulated comprising of the control diet (T0) which contained 100% fish meal (FM), four (4) Leucaena leucocephala leaf meal (LLLM) experimental diets (T1: 25%; T2: 50%; T3:75%; T4:100%). The feeding trial was conducted across 15 experimental plastic tanks with a 100L water carrying capacity for each tank. Each treatment had three replicates, and the fishes were fed twice a day for 16 weeks (112 days) under controlled conditions. The control diet (T0) contained 100% fish meal (FM), and four (4) Leucaena leucocephala experimental diets (T1: 25% LLLM; T2: 50% LLLM; T3:75% LLLM; and T4:100% LLLM). Growth performance indices, including mean weight gain (WG), mean length gain, specific growth rate (SGR), nutrient utilization and economic indices were evaluated. Other parameters assessed included proximate

composition of the experimental diets using the Association of Official Analytical Chemists, 2019. Water parameters like pH, temperature, and dissolved oxygen were also measured. The mean values recorded were pH: 7.42-7.72, Temperature: 27.1-27.6 (°C), and dissolved oxygen: 6.11-6.52 mg/L, all of which were within acceptable limits for the growth of the African catfish. Data were analyzed using one-way ANOVA, and significant differences among means were separated using Duncan's Multiple Range Test at $p < 0.05$. Fish fed the control diet (T0) recorded initial mean weight gain (176.5±4.3g) and highest final mean weight gain (678.9 ± 19.2 g) and specific growth rate (1.46 ± 0.05 % day^{-1}). At 25% inclusion(T5), Leucaena leucocephala leaf meal (LLLM) recorded an initial mean weight gain of (175.1±3.9g). It produced a final mean weight gain of (480.4±16.5g) and SGR of (1.23± 0.04 % day^{-1}). However, at 100% inclusion (T4), Final mean weight gain declined sharply to 378.2 ± 12.8g for LLLM test diets and with corresponding SGR values of (0.97 ± 0.02) respectively. Significant difference among the means ($p<0.05$) were observed. Also, for the length gain, Fish fed the control diet (T0) recorded initial mean length gain (8.7±0.12cm) and highest final mean length (18.2 ±0.35cm). At 25% inclusion(T1), Leucaena leucocephala leaf meal (LLLM) recorded an initial mean length of (8.6±0.10cm). It produced a final mean length gain of (17.48±0.30cm). However, at 100% inclusion (T4), Final mean length gain reduced to (15.14 ±0.23cm) for ECLM test diets inclusion level increased. There were significant differences among the means ($p<0.05$). In conclusion, T1,25% Leucaena leucocephala leaf meal demonstrated superior growth performance and better profitability among the test diets.

KEYWORDS: Growth performance, *Leucaena leucocephala,* Nutrient utilization, Experimental diets, Water parameters, Feeding trial

INTRODUCTION

Fish meal has been utilized as a main protein component in balanced diet for fish and is the single most expensive fish feed ingredient which makes up over 50% of the total cost of feed (Fasakin *et al.,* 2018). However, the high cost of compounded feeds, especially protein sources like fishmeal, limits profitability. Since feed accounts for 60-70% of production costs (Okeke *et al.,* 2016), there is a pressing need to find cheaper, sustainable, and locally available protein alternatives. As averred by Condrey (2017), to lower costs, we must find alternative protein sources for fish diets.

Fishmeal is especially rich in the essential amino acids (EAAs) and is highly digestible for fish. However, it is mostly imported, its price is exorbitant thus making the cost of finished fish feed high. In addition, the competition for fish and fish products for consumption and the livestock industry necessitated a search for alternative source of protein that is cheaper, of good quality and not competed for like fish (Ali *et al.,* 2019).

The need for plant protein in fish feed is essential because it is more available and affordable. The search for protein-rich plant source is an ongoing process, leaf meal inclusion in aquaculture feed also is fast gaining global attention over the years due to its availability, protein and mineral/vitamin contents and economic feasibility (Ali *et al.,* 2019)

Leucaena leucocephala is a fast-growing shrub high in protein, amino acids, and minerals, making it promising for aquaculture feed. The lead tree is a leguminous tree native to Central America, widely cultivated in tropical and subtropical regions for its various uses. Rich in protein, essential amino acids, minerals like calcium, phosphorus, and potassium, and vitamins A, B12, and K (Haetomi *et al.,* 2022).

Leucaena leucocephala is a local biological resource that has the potential to be used as a source of vegetable protein in fish feed. This is due to the high protein content of about 33.3% - 35.5 %

(Hasan *et al.,* 2020), an amino acid composition that is almost balanced with soybean meal, and is a source of vitamin A with a relatively high content of β-carotene. Although the leaves and seeds contain anti-nutritional factor known as mimosine (Haetomi et al., 2022), which has been reported to inhibit growth in animals (especially non-ruminants), it contains bioactive compounds like tannins, saponins, and flavonoids with antioxidant properties, which are believed to potentially impacting fish health (Agupugo *et al.,* 2022). Furthermore, its processing methods such as soaking, boiling, sun-drying, or ensiling significantly reduce mimosine concentration, making the leaf meal safer for inclusion in fish diets (Hamid *et al.,* 2017).

The use of *Leucaena leucocephala* leaves has been widely applied as a feed raw material in aquaculture activities, such as tilapia. *Leucaena leucocephala* has been identified to hold the potential to make contributions to fish nutrition, with the possibility of reducing the total dependence of fish farming on fish meal (Okeke *et al.,* 2016). Leaf meal or foliage incorporated into fish diets to improve nutritional value and reduce reliance on expensive conventional feeds (Haetomi *et al*., 2022). Leaves can be used as biofilters in aquaculture ponds, absorbing nutrients and improving water quality (Hlophe-Ginidiza *et al.,* 2022). *Leucaena leucocephala* is available in almost every geographical location in Nigeria and grows fast. Its leaves are a good source of protein and needs to be examined in greater detail on its suitability for the African catfish, *Clarias gariepinus* (Olaniyi *et al*., 2022).

According to (Haetomi *et al*., 2023), the essential amino acids contained in lead plant leaves consist of arginine by 2.20%, histidine by 0.74%, isoleucine by 2.44%, leucine by 3.02%, lysine by 2.37%, methionine by 0.58%, phenylalanine by 1.89%, threonine by 1.94%, tryptophan by 0.31%, and valine by 2.31%.

Today, fish farming has become one of the fastest-growing farming businesses, turning Nigeria into the second biggest aquaculture producer in Africa (Adelesi *et al.,* 2022). Also, Nigeria is the leading country in the production of African catfish (*Clarias gariepinus)* and African bonytongue (*Heterotis niloticus*, (Ajani *et al.,* 2018). The great quantity of land, inland water surface, and coastland, which are suitable for fish farming, has placed Nigeria at a very advantageous position to develop aquaculture further.

The African catfish (*Clarias gariepinus*) dominates freshwater aquaculture due to its fast growth, high survival rate, ability to utilize a wide range of feedstuffs, and tolerance to poor environmental conditions (Djissou *et al.,* 2025). The species is widely preferred by farmers and consumers and significantly contributes to food security and income generation. However, feed cost remains the greatest barrier to expansion, as protein ingredients account for the bulk of feed expenses (Ajani *et al*., 2018).

The ever-increasing demand for fish protein globally is placing immense pressure on wild fish stocks, leading to overfishing and unsustainable practices. Consequently, aquaculture has emerged as a vital sector to meet this demand while safeguarding wild populations. However, traditional aqua-feed formulations rely heavily on fishmeal, a protein source derived from wild-caught fish. This creates a major sustainability concern, perpetuating the pressure on already-depleted fish stocks. (Adewumi *et al.,* 2025)

While Arnould (2021) reported that duckweed, *Lemna paucicostata,* was a suitable protein source for tilapia diet up to 50% inclusion level, Biswas *et al.* (2022) indicated that water hyacinth, *Eichhornia crassipes* was also a suitable protein source for catfish fingerlings. Hua *et al* (2022)

utilized *Leucaena leucophala* seed meal to replace soybean meal in the diet of *Clarias gariepinus* and achieved the best growth performance at 20% inclusion. Olasunkanmi (2019) worked on the utilization and biochemical effects of *Mucuna utilis* meal containing 27.48-29.23% crude protein as a replacement for soya bean meal in the diet of *Clarias gariepinus*. Also, Adesina (2019) used sunflower (*Helianthus annuus*) seed meal to replace soybean meal in *Clarias gariepinus* diet and got positive results at 20% to 40% inclusion.

Therefore, there is a critical need for alternative protein sources in aquaculture, particularly those derived from plants. Utilizing plant-based protein offers several advantages, including replacing fishmeal with plant-based proteins, which reduces dependence on wild fish populations, promotes sustainable aquaculture practices, and contributes to ecosystem conservation. (Haetami *et al*., 2023)

Therefore, this study aims to evaluate the potentials of *Leucaena leucocephala* on the growth performance and nutrient utilization of African catfish. Thus, the specific objectives of the study are to assess the growth performance of *Clarias gariepinus* fed diets supplemented with *Leucaena leucocephala* leaf meals,evaluate the nutrient utilization of *Leucaena leucocephala* leaf meal diets in *Clarias gariepinus*, evaluate the proximate composition of processed *Leucaena leucocephala le*af meals experimental diets, determine the best optimal inclusion level of *Leucaena leucocephala* leaf meal in the diet of *Clarias gariepinus.* assess the effects of *Leucaena leucocephala* leaf meals inclusion on the survival rate of *Clarias gariepinus* and finally estimate the economic analysis of producing experimental diets containing *Leucaena leucocephala* leaf meals.

MATERIALS AND METHODS

Experiment Area and Duration

The experiment was carried out in the research laboratory of the Department of Fisheries and Aquaculture, Nnamdi Azikiwe University, Awka, Anambra State, Nigeria. The experiment lasted for a period of 16 weeks (112 days).

Preparation of *Leucaena leucocephala* Leaf meal

The fresh *Leucaena leucocephala* leaves were thoroughly washed with clean water to remove dirt and debris, then dried under room temperature for five days to minimize loss of essential nutrients according to (Okeke *et al*., 2016) and also to help reduce anti-nutritional factors, specifically mimosine according to (Hamid *et al.,* 2017). After drying, the dried leaves were milled into a fine powder separately using a petrol-powered grinding engine Gx200 6.5hp.The milling process was necessary to create a uniform texture and ensure that the powdered leaves could be easily incorporated into the fish feed according to (Sogbesan *et al*. 2015). This powdered form also enhanced the binding capacity of the *Leucaena leucocephala* meal when mixed with other feed ingredients, facilitating the production of pelleted diets suitable for the fish.

Feed Formulation

The feed ingredients used in the experiment, such as fish meal (FM), groundnut cake (GNC), soybean meal (SBM), bone meal (BM), maize meal (MM), vitamin premix, binder (starch), lysine, methionine and salt were pre-grounded and included and then carefully mixed with the grounded *Leucaena leucocephala* leaf meal. Each ingredient was measured as shown in Table 1. These diets

were formulated according to the varying inclusion levels for the different treatments using the Crude Protein percentage(%) inclusion (ingredient contribution) method of feed formulation according to (Vasilaki *et al.,* 2023).The ingredients were then thoroughly hand-mixed to ensure uniform distribution, then water was added to form dough, and the mixture was pelleted using electric pelleting machine.The ingredients were blended, the mixture was processed through a pelletizer to form fish pellets (1.2mm) suitable for *Clarias gariepinus* fingerlings. The control diet(T0) contained fishmeal as the protein source without the grounded *Leucaena leucocephala*. For diets T1,T2,T3 and T4 LLLM were included to mainly replace fishmeal at substitution rates of 25%,50%, 75% and 100%.Also these formulated diets were subsequently dried at 55–60°C using a locally-made drier to remove moisture and enhance their shelf life. It was stored in airtight plastic containers before been used for feeding the fish (Sogbesan *et al*, 2022).

Table 1: Formulated treatment diets with varying rates of fishmeal (FM)substitution with *Leucaena leucocephala* leaf meal (LLLM)

Ingredients/Feed Components	**Treatment Diet 0 (Control) 100% FM**	**Treatment Diet 1(25% LLLM)**	**Treatment Diet 2(50% LLLM)**	**Treatment Diet 3) (75% LLLM)**	**Treatment Diet 4(100% LLLM)**
Fish Meal (g)	30	20	15	10	0
Maize (g)	20	20	20	20	20
Groundnut Cake (g)	16	16	16	16	16
Soybean (g)	25	25	25	25	25
Bone Meal (g)	2.0	2.0	2.0	2.0	2.0
Methionine (g)	2.0	2.0	2.0	2.0	2.0
Lysine (g)	1.5	1.5	1.5	1.5	1.5
Vitamin B Complex(g)	1.5	1.5	1.5	1.5	1.5
Vitamin premix (g)	1.5	1.5	1.5	1.5	1.5
Salt (g)	0.5	0.5	0.5	0.5	0.5
Eichhornia crassipes* leaf meal *(g)	0	10	15	20	30
TOTAL	**100**	**100**	**100**	**100**	**100**

Procurement of Experimental Fish

A total of three hundred (300) *Clarias gariepinus* post fingerlings at four to five weeks old were purchased from a commercial fish farm in Awka, Anambra State for this feeding trial. The post-fingerlings were carefully transported from the farm in two large plastic containers of 50 litres capacity each to the experimental site. Upon arrival at the laboratory, the post fingerlings were transferred into a large holding tank and were allowed a one-week acclimatizing period to adjust

to their new environment. The fish were fed twice daily with a commercial diet at 5% body weight per day before the practical study began.

Experimental Design

The experiment followed a completely randomized design (CRD) consisting of five (5) dietary treatments (T0, T1, T2, T3, and T4) with three (3) replicates each. The *Clarias gariepinus* fingerlings were randomly assigned to 100-liter plastic. Each experimental setup had three (3) replicates each, labeled as R1, R2, and R3, with each replicate containing 20 *Clarias gariepinus* fingerlings. This amounted to a total of 60 fingerlings for each Experimental Setup.

Water Quality Management and Monitoring

The water parameters, including pH, dissolved oxygen, and temperature, were monitored. Water was changed every two days. Water quality was monitored using a digital thermometer (Hanna HI 93510), pH meter (Hanna HI 98107), DO meter (YSI Pro20), and ammonia test kit (API), maintained within optimal ranges for *Clarias gariepinus*. Water quality was maintained within optimal ranges for *Clarias gariepinus*: Fresh, clean water was introduced to the tanks to remove waste, uneaten feed, and any potential toxins that could affect the health and growth of the fish. Regular water changes were essential to maintaining optimal water conditions, ensuring sufficient oxygen levels, and preventing the build-up of harmful substances (Olaniyi *et al.,* 2022). The post fingerlings were monitored for survival by removing the dead fish. The weight and length of the fish were measured and recorded on a weekly basis using sensitive weighing balance and metre rule respectively.

Growth Performance Indices of Fish fed different experimental diets

These growth indices included the following: Weight gain (g/fish), Length gain (cm/fish), specific growth rate (SGR) (%day),), survival rate were recorded as shown in Table 4.

- **Weight gain (g/fish)**

Weight gain is a key performance indicator (KPI) that measures the increase in fish body mass, either in weight or length. It is calculated as the difference between final and initial weight or length. This Measures the total body weight or length increase over the experimental period (Giovanni *et al.,* 2025)

$$\text{Weight gain} = (W_f - W_i)$$

Where W_f =final weight at the end of the experiment, W_i =initial weight at the start of the experiment

$$\text{Length gain} = (L_f - L_i)$$

L_f= final length at the end of the experiment, L_i= initial length at the start of the experiment

- **Specific growth ratio (SGR)**

This is a metric used to quantify the growth of fish over a specific period of time. This refers to the percentage of weight gain in days, weeks or months. This measures the growth efficiency expressed as percentage per day. (Folorunso *et al.,* 2021)

$$SGR = \frac{1nW_2 - InW_1}{T_2 - T_1} \times 100$$

Where In = natural logarithm

W_2 and W_1= final and initial weight of fish, respectively in grams, T_2 and T_1-end of growth period and beginning and same respectively.

- **Percentage survival**

This measures the Percentage of fish that survived during an experimental study. It is used in evaluating survival rates in feeding trials comparing different feeds or stocking densities (Ogunji *et al.,* 2020)

$$\% \text{ Survival} = \frac{\text{Number of fish survival}}{\text{Number of fish stocked}} \times 100$$

Feed Utilization Indices

The following indices of feed utilization were studied using the data collected.

- **Feed conversion ratio (FCR)**

This measures the efficiency of converting feed into body mass. A lower FCR indicates higher efficiency and a higher FCR indicates lower efficiency of the feed consumed by the fish. This refers to the weight gain in fish due to an increase in body weight. (Boyd *et al.* 2022)

$$FCR = \frac{\text{Feed intake (g)}}{\text{Fish weight gain (g)}}$$

- **Feed Efficiency Ratio (FER)**

This is a metric used to determine how effectively a fish converts the food it consumes into body mass. It is the biological inverse of the Feed conversion Ratio, meaning that the higher the FCR, the lower the FER and the Lower the FCR, the higher the FER (Boyd, 2021). It is calculated by dividing the weight gain by the total feed intake using the method of Emil Von Wolff (1864).

$$FER = \frac{\text{Fish weight gain (g)}}{\text{Feed intake (g)}}$$

- **Crude Protein Intake (CPI)**

This measures the actual weight of protein consumed by the fish over the entire experimental period or a specific time frame. It is calculated as the total feed intake and the crude protein

concentration in the feed (Gopika *et al.,* 2020). It is calculated using the method of Delong, Haver and Yasutake (1958) It is expressed as:

CPI= Total Feed Intake Per Diet (g) x Dietary Crude Protein Content of the Feed (%) x 100.

- **Protein efficiency ratio (PER)**

This measures the nutritional quality of a diet by calculating the grams of wet weight gain per gram of crude protein consumed. It is used to evaluate feed efficiency and the ability of a protein source to promote growth. (Oboh, 2022)

$$PER = \frac{\text{Weight gain (g wet fish)}}{\text{Weight of protein fed (g crude protein fed)}}$$

Proximate Analysis of Treatment Diets

The treatment diets as shown in Table 2 were analyzed for moisture, crude protein, crude fiber, ash, crude lipid, ether extract, and dry matter using standard methods from the Association of Official Analytical Chemists (AOAC, 2019).

Production Cost of the Experimental Diets and the economic evaluation of the feeding trials

The economic benefit of rearing the *Clarias gariepinus* post fingerlings to post juveniles stage within the period of 16 weeks (112 days) was assessed using the following economic analysis indices such as: Economic Conversion Ratio (ECR), Net production value (NPV), Profit Index (PI) and Benefit: Cost ratio (BCR) as shown in Table 6.

Statistical Analysis

The data was subjected to One-way Analysis of variance (Anova) using the statistical software for the social sciences (SPSS) to determine the significant difference between the experimental diets and the control. Significant means were separated using Duncan Multiple Range Test at $P < 0.05$

RESULTS

The proximate composition of the experimental diets showed clear variations across treatments as presented in Table 2. Crude protein was highest in the control diet (63.0%) and progressively declined across inclusion levels, reaching the lowest value in T4 (13.2%). Moisture was highest in the T4 (11.3) and increased across inclusion levels, reaching the lowest value in the Control diet (7.8).

Table 2: Proximate Composition of Experimental Diets

Experimental Diets	Moisture	Ash	Crude Protein	Crude Fiber	Fats/Oil	Carbohydrate
T0 (Control)	7.8	5.8	63.0	3.5	12.0	20.1
T1(25% LLLM)	10.2	7.5	36.4	5.1	10.1	28.6
T2 (50% LLLM)	10.8	7.8	31.5	5.3	10.0	30.7
T3 (75% LLLM)	11.1	8.2	30.1	6.2	8.1	37.2
T4 (100% LLLM)	11.3	8.2	13.2	6.6	8.0	40.3

Water Quality Parameters

Water quality variables monitored throughout the 112 days feeding trial remained within acceptable limits for freshwater fish culture. The water quality parameters of the experiment varied as follows: temperature ranged from 27.1 -27.6°C, pH 6.45-6.72, and dissolved oxygen 6.11-6.50mg/l and Biological Oxygen Demand(mg/L) 3.51-4.87 .The acceptable optimal range accepted in feeding trials for Temperature: 26–30°C, pH: 6.5–9.0, DO: >5 mg/L, and BOD: <6.0mg/L according to (Boyd, 2018).

Table 3: Physiochemical Parameters measured during the 16 weeks of Study

Parameter	Treatments	Mean±SE	Recommended Range
Ph	T0	7.64 ± 0.33[a]	6.5 – 9.0
	T1	7.59 ± 0.22[a]	
	T2	7.72 ± 0.38[a]	
	T3	7.45 ± 0.55[a]	
	T4	7.52 ± 0.55[a]	
Temperature (°C)	T0	27.6 ± 0.03[a]	26–30°C
	T1	27.5 ± 2.89 [a]	
	T2	27.4 ± 0.77 [a]	
	T3	27.1 ± 1.87 [a]	
	T4	27.3 ± 1.87 [a]	
Dissolved Oxygen (mg/L)	T0	6.41 ± 0.33[a]	>5 mg/L
	T1	6.11 ± 0.66[a]	
	T2	6.50 ± 0.33[a]	
	T3	6.42 ± 0.88[a]	
	T4	6.42 ± 0.88[a]	
Biological OxygenDemand(mg/L)	T0	3.51 ± 0.14[a]	<6.0mg/L
	T1	4.20±0.20[a]	

	T2	4.33±0.25[a]	
	T3	4.39±0.26[a]	
	T4	4.52±0.3[a]	

a: Means within the same column with the same superscripts are not significantly different (P>0.05)

Growth Performance of the Experimental diets

The growth performance of *Clarias gariepinus* post fingerlings during the feeding trial are presented in Table 3. The highest growth performance was observed in fish fed the control diet T0 (678.9grams), This result indicates that 25% LLLM, T1 diet recorded 466.1grams, the highest mean weight gain among the tested diets. while the lowest growth was recorded in fish fed the 100% LLLM T4 diet (365.3 grams). There was significant difference between the control diet and the LLLM experimental diets($p<0.05$)

Analysis of Growth Performance Indices of *Clarias gariepinus* fed Experimental Diets.

At the end of 16 weeks feeding trial, the results of the growth performance, specific growth rate, survival rate and biomass for the different treatment diets were obtained, recorded and statistically analysed as follows as shown in Table 3

Parameters	**Treatment Diet 0 (Control) 100% FM**	**Treatment Diet 1(25% LLLM)**	**Treatment Diet 2(50% LLLM)**	**Treatment Diet 3) (75% LLLM)**	**Treatment Diet 4(100% LLLM)**
Initial Mean weight (g/fish)	174.5 ± 0.33[a]	174.3 ± 0.31[a]	174.1 ± 0.30[a]	174.7 ± 0.29[a]	174.2 ± 0.28[a]
Final Mean Weight (g/fish)	678.9 ± 0.94[a]	466.1 ± 0.57[b]	443.4± 0.54[c]	410.5 ± 0.45[d]	365.3 ± 0.40[e]
Initial Mean length (g/fish)	8.7± 0.12[a]	8.6± 0.10[a]	8.5 ± 0.09[a]	8.4 ± 0.09[a]	8.3 ± 0.08[a]
Final Mean lenght (g/fish)	18.2± 0.35[a]	16.4± 0.28[b]	15.5± 0.26[c]	14.4± 0.23[d]	14.1± 0.21[e]
Initial Stocking Density	60	60	60	60	60
Final Stocking Density	51	50	49	48	47

Specific	1.46 ± 0.05[a]	1.07 ± 0.04[b]	1.05 ± 0.03[bc]	0.99 ± 0.03[c]	0.87 ± 0.02[d]
Growth Rate					
Survival (%)	85	83	82	80	78

[a,b,c,d,e:] Data within the same column with **different superscripts (a–e)** are **significantly different (p < 0.05)**

Table 5: Nutrient Utilization of *Clarias gariepinus* **fed Control and** ***Leucaena leucocephala*** **leaf meal (LLLM) experimental diets.**

Nutrient Utilization Parameters	Treatment Diet 0 (Control) 100% FM	Treatment Diet 1(25% LLLM)	Treatment Diet 2(50% LLLM)	Treatment Diet 3) (75% LLLM)	Treatment Diet 4(100% LLLM)
Feed Conversion Ratio	1.07[e]	1.65[d]	1.73[c]	1.91[b]	2.25[a]
Feed Efficiency Ratio	0.93[a]	0.61[b]	0.57[c]	0.52[c]	0.44[d]
Crude Protein/Diet	41.6	38.3	36.6	35.0	31.7
Crude Protein Intake	222.7[a]	184.0[b]	171.2[c]	159.3[d]	138.5[e]
Protein Efficiency Ratio	2.26[a]	1.58[b]	1.57[b]	1.49[c]	1.40[d]

[a,b,c,d,e:] Data within the same column with **different superscripts** are **significantly different (p < 0.05)**

Table 6: Economic indices of *Clarias gariepinus* **fed Control and** ***Leucaena leucocephala*** **leaf meal (LLLM) experimental diets.**

Economic Indices	Treatment Diet 0 (Control) 100% FM	Treatment Diet 1(25% LLLM)	Treatment Diet 2(50% LLLM)	Treatment Diet 3) (75% LLLM)	Treatment Diet 4(100% LLLM)
ECR (₦/kg fish	1,360.00[d]	1,998.19[c]	2,047.50[c]	2,208.02[b]	2,477.32[a]
NPV (₦/kg fish)	2,640.00[a]	2,001.80[b]	1,952.50[c]	1,791.98[d]	1,522.68[e]
BCR	2.94[a]	2.00[b]	1.95[c]	1.81[d]	1.61[e]
PI	1.94[a]	1.00[b]	0.93[c]	0.81[d]	0.61[e]

[a,b,c,d,e:] Data within the same column with **different superscripts (a–e)** are **significantly different (p < 0.05)**

DISCUSSION

Proximate Composition of Experimental Diets

Table 1 shows clear and significant differences ($p < 0.05$) in the proximate composition of the experimental diets as the level of *Leucaena leucocephala* leaf meal increased. Crude protein showed a marked decline with increasing LLLM inclusion. High priority is given to protein requirement in any nutritional study mainly because it is the single nutrient that is required in the largest quantity for growth, development and the most expensive ingredient in formulation of Diet (Ozorio *et al*., 2022). In the present feeding trial, a greater value of crude protein was found in the control diet(T0) 63.01% however the crude protein content of the experimental feeds analysed in other dietary treatments (T4, 13.6%) were lower than the control diet. Nevertheless, the crude protein fell within the permissible range suggested for fish used for commercial purposes (Ezeuoke ,2018).

Crude fiber increased with plant inclusion, this agrees with studies conducted by Obih *et al*., 2019 showing that leaf meals generally increase dietary fiber content, which may affect digestibility and carcass fat deposition. In this study, the proximate composition of the experimental feeds showed that T0 (Control diet) had the higher crude protein, while T4(100% LLLM*)* had the higher crude fibre. This probably affected the feed utilization by *Clarais gariepinus* fishes. Obih *et al.* (2019) also highlighted that high fibre affects feed utilization of fish and consequently affects its growth. Moreover, the highest moisture content of LLLM in this study was found to be 11.25 % obtained in T4 (100% LLLM*)*. This agrees with Olanipekun *et al*., 2022 who reported that plants generally contain a lot of moisture.

Dietary lipids function as a ready source of energy for fish and also provide essential fatty acids which are needed for fish growth and survival. Fish generally require omega-3 fatty acids rather than omega-6 fatty acids in contrast to terrestrial animals which require omega- 6 fatty acids as reported by Wang *et al.,* (2017). The measured lipid concentrations in this study in *LLLM experimental* diets were lower than the control diet (12.01%), T1(10.05) and T8(8.13%). This is consistent with the findings of Enyidi *et al.,* (2017) who found that, most freshwater fish diets should contain 6–15% lipid to promote ideal development rates without creating an overly fatty carcass. Additionally, the ash content of experimental diets were within the same range in this study and were also within the range for fish diets (Agbugui *et al.,* 2018). Moreover, the values of carbohydrates obtained in the present feeding trial T4 (100%) were higher (44.55%) in all dietary treatments than the control diet(T0) which had 20.11%. Research studies carried out by Okeke *et al.* (2016) reported that plant meals also contain high carbohydrates content.

Growth Performance of *Clarias gariepinus* fed Control and *Leucaena leucocephala* Leaf Meal (LLLM) experimental diets.

Weight gain and Specific growth rate are direct reflections of how well fish can convert feed into body mass Sogbesan *et al.,* (2022). Table 4 showed the growth performance responses of *Clarias gariepinus* fed a control diet (containing 100% fish meal) and experimental diets containing graded levels of LLLM at varying levels of (25%, 50%, 75%, and 100%) over a sixteen-week feeding trial.. Fish fed the control diet (T0) recorded the highest final mean weight (678.9g), which was significantly higher ($p < 0.05$) than those of fish fed the LLLM experimental diets. The final mean weight progressively declined with fish fed the 100% replacement diet in T4 (100% LLLM) (365.3g) The results of this experimental study also demonstrated that dietary treatments of *Leucaena leucocephala* leaf meal LLLM significantly influenced the linear growth of *Clarias gariepinus as presented in Table 4*. Fish fed the control diet (T0) recorded the highest final length(18.2cm), this indicated superior nutrient availability and utilization in the control diet. However, compared to fish fed the LLLM diets, T5(25% LLLM) had final length of (17.5cm), and the lowest length gain was recorded for T4(100% LLLM) with final length of 15.1cm.

Specific growth rate (SGR), which expresses growth as a percentage increase in body weight per day, showed a similar declining trend. Fish fed the control diet (T0) exhibited the highest SGR (1.46%/day), while fish fed T1,25% LLLM inclusion diets showed moderate SGR values (1.07%/day). The lowest SGR was recorded in T4, fish fed 100% LLLM inclusion diet (0.87%/day). Since SGR integrates both initial and final weights, it is a reliable indicator of overall growth performance (Adeyemi *et al.,* 2023).

The superior growth performance recorded in the control (T0) and 25% LLLM (T1) inclusion diets suggests better nutrient digestibility and amino acid availability, leading to enhanced muscle development and improved carcass quality (Dawood *et al.,* 2024). The results showed that partial replacement of fish meal with *Leucaena leucocephala* leaf meal LLLM, specifically T5 (up to 25%) can support acceptable growth performance in *Clarias gariepinus* post fingerlings. However, higher inclusion levels T3 and T4(75–100%) significantly compromise growth efficiency These findings suggest that *Leucaena leucocephala* leaf meal is better suited as a partial rather than total replacement for fish meal in African catfish diets.

A 2022 study carried out by Haetami *et al.,*2022 on *Clarias gariepinus* showed that diets formulated with complete replacement of fishmeal by alternative protein mixtures (including plant and animal sources) resulted in significantly different growth performance relative to a fishmeal control diet, emphasizing that essential amino acids and ingredient digestibility are key determinants of growth outcomes in catfish nutrition which also agrees with Li *et al*., 2019). Similarly, a 2024 feeding trial evaluating *the use of* leaf meals as a partial fish meal substitute in *Clarias gariepinus* fingerling diets reported that moderate inclusion levels (around 20%) supported comparable growth and survival, whereas higher inclusion levels tended to reduce growth performance(Alabi *et al.,* 2024).

As presented in Table 2, Survival rate decreased slightly with increasing levels of LLLM plant protein substitution; however, values remained within acceptable limits for African catfish culture (Ronald *et al.,* 2021). T0 (Control diet) recorded 85%, T1 (83%), T2(83%), T3(80%) and T4(78%)

survival rate. However, **a**ll treatments recorded survival rates above 75%**,** indicating that the experimental diets were generally safe. The results demonstrate that partial replacement (25–50% LLLM) are biologically acceptable (Zhou *et al*., 2021)

Nutrient Utilization of *Clarias gariepinus* fed Control and *Leucaena leucocephala* Leaf Meal (LLLM) experimental diets.

As presented in Table 5, the FCRs observed in this feeding trial showed that the control diet T0 recorded the best FCR (1.07) followed by T5 (25% LLLM) with a value of 1.65. The least FCR was recorded in T4 (100% LLLM) with a high FCR value of 2.25. This is similar to the research study carried out by Adeyemi *et al*., (2023), who reported a range of 1.00-1.80 FCRs for *Clarias gariepinus* fed unconventional plant ingredients. However, the FCR values obtained for experimental diets are higher than 1.80; this could be a result of anti-nutritional factors from high inclusion levels of *Leucaena leucocephala* Leaf Meal (LLLM) at 100% inclusion level. It is important to note that the lower the values of FCR, the higher the ability for the fish to easily convert the fish feed faster and easily into a higher body mass and higher weight gain and length gain as reflected in the Control diet (T0). Plant ingredients often contain higher fibre and anti-nutritional factors that impair digestibility and amino-acid availability; fish thus require more feed to deposit the same amount of tissue (Haetami *et al.*, 2023).

The result of the feed efficiency ratio (FER) showed that the control diet (T0) recorded the highest FER value of (0.93) followed by T5 (25% LLLM) with a value of (0.61), However, the lowest FER was recorded by T4(100% LLLM) with the lowest FER value of (0.44). The higher the value of FER, the better the feed efficiency and the reverse the case. However, this feeding trial showed that a high food conversion ratio and low FER were attributed to poor feed intake of fish feed, mainly due to the poor palatability of the feed, especially diets T4 diet (contained 100% of *Leucaena leucocephala* Leaf Meal (LLLM) (Ronald *et al.,* 2021)..

The results of this study revealed a clear variation in crude protein intake (CPI) of *Clarias gariepinus* across the experimental diets, with the control diet (T0) recording the highest value (222.7 g). This superior CPI observed in the control diet can be attributed to its higher crude protein content (41.6%) and better palatability, which likely enhanced feed consumption and nutrient utilization. This finding is consistent with earlier reports that fish-fed conventional fishmeal-based diets exhibit higher feed intake and protein utilization due to their balanced amino acid profile and absence of anti-nutritional factors (Nwanna, 2019).

A progressive decline in CPI was observed with increasing inclusion levels of *Leucaena leucocephala* leaf meal (LLLM) from T1 to T4. The lowest CPI was recorded in T4 (138.5 g), indicating reduced protein intake at 100% replacement. This trend may be linked to the presence of anti-nutritional factors such as mimosine in plant meals which is known to impair feed intake, protein digestibility, and overall nutrient utilization in fish (Haetami *et al.,* 2023; Francis *et al.,*

2017). Additionally, the reduction in crude protein percentage of the diets with increasing LLLM inclusion further contributed to the observed decline in CPI.

In contrast, diets containing 25% *Leucaena leucocephala* leaf meal (LLLM**)** demonstrated relatively higher CPI values (184.0 g) This observation showed that *Leucaena leucocephala* may be more acceptable to *Clarias gariepinus* at low inclusion levels Akinpelu *et al.,* (2022). The significant differences ($p < 0.05$) observed among treatments further indicate that dietary composition had a pronounced effect on protein intake.

Protein Efficiency Ratio (PER) is a measure of the capacity of dietary protein to be converted into fish body mass. Higher PER values indicate that fish are utilizing the protein in the diet more effectively for growth, whereas lower values suggest inefficiencies in protein utilization.The Protein Efficiency Ratio (PER) obtained in this study, as presented in Table 5, clearly demonstrated that dietary protein quality and source significantly influenced protein utilization efficiency in *Clarias gariepinus*. The significantly higher PER observed in the control diet (T0) with a PER value of 2.26, which confirms that conventional fishmeal-based diets still provide superior protein bioavailability, digestibility, and amino acid balance required for optimal growth. Recent studies such as Konyeme *et al. (*2022) and Sogbesan *et al.* (2022) showed that animal-derived proteins remain the benchmark for efficient nutrient conversion due to their high digestibility and optimal essential amino acid profiles, particularly lysine and methionine, which are often limiting in plant-based diets.

PER dropped significantly to 1.40 in T4(100% LLLM), indicating reduced protein utilization efficiency. This reduction can be linked to plant-derived proteins known to contain anti-nutritional compounds such as mimosine, tannins, and phytates, which impair digestive enzyme activity and reduce nutrient absorption. (Hamid *et al.*, 2017). However, diets containing 25% *Leucaena leucocephala* leaf meal (LLLM) exhibited relatively better PER values at low inclusion levels T1 with a PER value of 1.58. This shows that LLLM possess a more favorable nutritional or structural composition that supports protein utilization when included at low levels. Similar findings have been reported in recent nutritional trials, where low inclusion of alternative plant proteins maintained acceptable growth and nutrient utilization, but excessive inclusion resulted in reduced efficiency due to increased fiber content and reduced digestibility (Olaniyi *et al*., 2022)

Economic indices of ***Clarias gariepinus*** **fed Control and** ***Leucaena leucocephala*** **leaf meal (LLLM) experimental diets.**

The Economic Conversion Ratio (ECR) provides a direct measure of the cost required to produce 1 kg of fish. Among the diets tested**,** T1(25% LLLM) was the most cost-efficient, with an ECR of ₦1,998.19/kg per fish, lower than T2(50% LLLM) with ECR value of ₦2,047.50/kg per fish while the highest ECR was recorded in T4(100% LLLM) with a value of ₦2,477.32/kg per fish. Although feed cost per kilogram decreased progressively from T0 to T4, higher inclusion levels led to poorer feed conversion and consequently higher ECRs for T4. The 100% *Leucaena leucocephala* diet (T4) required ₦2,477.32 to produce 1 kg of fish. These results indicate that partial replacement of fish meal (25% LLLM) optimizes both feed cost and growth efficiency**,**

striking the best balance between affordability and economic productivity in *Clarias gariepinus* culture Djissou *et al.,* 2025).

Among the treatment diets as shown in Table 6, the control diet T0 recorded a the highest NPV of ₦2,640.00/kg per fish, followed by T1 (25% LLLM) which achieved the highest NPV of ₦2,001.80/kg per fish, among the test diets indicating the greatest profit per kilogram of fish produced. In contrast, complete fish meal replacement (T4, 100% LLLM) resulted in the lowest NPV of ₦1,522.68, reflecting higher ECR despite the lowest feed cost per kg. These results suggest that partial replacement of fishmeal with ECLM (25%) optimizes economic returns, providing both cost savings and high profitability for small-scale and commercial *Clarias gariepinus* farmers (Wardono *et al.,* 2018).

The Benefit–Cost Ratio (BCR) provides a clear indicator of investment efficiency by showing the return per ₦1 spent. A BCR greater than 1 indicates profitability, 1 represents break-even, and less than 1 indicates a loss. Among the treatment diets as shown in Table 6, T1 (25% LLLM**)** achieved the highest BCR of 2.00**,** indicating that every ₦1 invested returned ₦2.00, making it the most economically advantageous option. The control diet (T0) had a BCR of 2.94, while complete fishmeal replacement (T4, 100% LLLM) showed the lowest BCR of 1.61, reflecting reduced growth efficiency and higher feed conversion costs. These results confirm that partial replacement of fishmeal with (25%) of LLLM maximizes profitability**,** making it the best investment strategy for small-scale and commercial *Clarias gariepinus* farming (Igoche *et al*., 2025).

The Profit Index (PI) provides an integrated measure of economic efficiency, accounting for both profit and feed conversion cost. Among the test diets, T1 (LLLM) recorded the highest PI of 1.00**,** indicating the most profitable and efficient feed formulation. The control diet (T0) had a PI of 1.94, while (T4. 100% LLLM) had the lowest PI of 0.61, reflecting reduced growth performance despite lower feed cost per kilogram. These results reinforce that partial replacement of fishmeal (25% of LLLM) achieved the best balance between feed cost savings, growth efficiency, and profitability**,** making it the most viable economic strategy for small-scale and commercial *Clarias gariepinus* farming.

As a cost savings strategy, T1, 25% LLLM diets demonstrated better cost efficiency and profitability. Lower economic conversion ratio, alongside higher benefit–cost ratio and profit index, shows that offers greater economic returns to farmers most especially at 25% ECLM inclusion.

Based on the results and conclusions of this study, the following recommendations are made:

1. *Leucaena leucocephala* leaf meal be included at 25% fishmeal replacement levels, as these inclusion rates produced the best balance between growth performance (WG and SGR), feed efficiency (low FCR and high PER),and economic returns (lowest economic conversion ratio and highest net profit, benefit–cost ratio, and profit index) Inclusion levels above 25% should be avoided due to progressive declines in performance
2. To enhance the nutritional value of *Leucaena leucocephala* leaf meal, appropriate processing methods such as fermentation, soaking, or heat treatment are recommended to

reduce anti-nutritional factors and improve digestibility before incorporation into aquafeeds.

3. Feed manufacturers should consider incorporating *Leucaena leucocephala* leaf meal as a sustainable plant protein ingredient in commercial African catfish feeds, particularly in regions where fishmeal is expensive or scarce. This will enhance feed affordability and support sustainable aquaculture development.
4. Policymakers and aquaculture development agencies should support the utilization of *Leucaena leucocephala* in aquafeeds as part of integrated strategies for invasive plant management, feed cost reduction, and sustainable aquaculture expansion

Consent for Publication

All the authors gave their approval and consent that this research work should be published.

Availability of Data and Material

The data provided and inserted in this manuscript are the exact results and outcomes that were obtained during and at the end of this feeding trial.

Conflicting Interest

The authors declared that there is no conflict of interest.

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