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EVALUATION OF GROWTH PERFORMANCE OF Clarias gariepinus POST FINGERLINGS FED Leucaena leucocephala LEAF MEAL AS REPLACEMENT FOR FISHMEAL

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Abstract

Fish meal (FM) which is the main source of animal protein in fish feed has continued to challenge the aquaculture industry due to its rising high cost. 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. The experiment was carried out in a Completely Randomized Design (CRD). 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. Growth performance indices, including mean weight gain (WG), mean length gain, specific growth rate (SGR), were assessed. Water parameters like pH, temperature, and dissolved oxygen were 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 *Clarias gariepinus* post fingerlings. Fish fed the control diet (T0) recorded initial mean weight gain of (176.5±4.3g) and highest final mean weight gain of (678.9 ± 19.2 g) and specific growth rate (1.46 ± 0.05 % day^{-1}). At 25% inclusion(T1), *Leucaena leucocephala leaf meal (LLLM)* recorded an initial mean weight gain of (174.3 ±3.9g) and Final mean weight gain (466.1± 15.8g) and SGR of (1.07 ± 0.04 % day^{-1}). However, at 100% inclusion (T4), Final mean weight gain declined to (365.3 ± 12.1g) and SGR values of (0.87 ± 0.02 % day^{-1}) for LLLM test diet. The were significant difference among the means ($p<0.05$). Also, for the length gain, Fish fed the control diet (T0) recorded initial mean length gain (4.74±0.12cm) and highest final mean length (18.2 ±0.35cm), compared with 25% inclusion (T1) *Leucaena leucocephala leaf meal (LLLM)* with an initial mean length of

(4.58 ±0.10cm) and final length weight gain (16.41± 0.28cm). However, at T4, 100% LLCM test diets declined to (14.12 ± 0.21 cm) as inclusion level increased..There were significant differences among the means ($p<0.05$). In conclusion, T1, 25% inclusion level of*Leucaena leucocephala* demonstrated superior growth performance compared to other varying levels of 50%, 75% and 100%. *Leucaena leucocephala* proved to be sustainable alternative protein source for African catfish diets, however is should be restricted to low inclusion levels.

Keywords: *Clarias gariepinus*; fishmeal; *Leucaena leucocephala*; growth performance.

INTRODUCTION

Protein is the most expensive part of fish feed, so accurately determining the protein needs for each species and life stage is essential. To lower costs, we must find alternative protein sources for fish diets (Corbell, 2020). Although fish meal is in high demand, it is unfortun.ately limited in supply, and the price is very high (Sogbesan *et al.,*2020). Because of this, a number of research studies have found low-cost, less competitive alternatives to fish meals (Arnauld *et al.,* 2021). Therefore, it is necessary to substitute fish meal in fish feeds with plant protein materials that are easily accessible and reasonably priced (Sashi *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. Prepared or artificial feeding can be categorized as either complete or supplemental. Complete diets contain all the essential nutrients needed for the optimal growth and health of fish, including protein, carbohydrates, lipids, vitamins, and minerals. Most fish farmers use comprehensive diets, which typically contain the following components and their respective percentages: 18-50% protein, 10-25% lipids, 15-20% carbohydrates, ash, and raceways. (Vishnu, 2023)

As fish farming continues to expand, it has been noted that certain constraints are impeding the realization of the desire to solve the malnutrition problem in Nigeria. The major constraints are lack of sufficient good quality fish seed and unavailability of cost-effective nutritive fish feeds ((Falaye, 2018).

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). 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 this makes the cost of finished fish feed to be high. In addition, the competition for fish and fish products by man and the livestock industry necessitated a search for alternative source of protein that is cheap, of good quality and not competed for like fish (Ali *et al.,* 2019).

Artificial or prepared Diets may be either complete or supplemental. Complete Diets supply all the ingredients (protein, carbohydrates, fats, vitamins, and minerals) necessary for the ideal growth and health of the fish (Gao *et al.,* 2019). Most fish farmers use complete Diets, those containing all the required protein (18- 50%), lipid (10-25%), carbohydrate (15-20%), ash (< 8.5%), phosphorus (<

1.5%), water (< 10%), and trace amounts of vitamins as well as minerals. When fish are reared in high density indoor systems or confined in cages and cannot forage freely on natural feeds, they must be provided a complete Diet (Li *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). Several studies have been conducted on the use of terrestrial and aquatic leaf meals as Dietary protein sources in fish feed. These include: Cassava leaf meal (Madalla, 2018), *Carica papaya* leaf meal (Ferraris *et al*., 2019), Alfalfa leaf meal (Ali *et al.,* 2019), Leuceana leaf meal (Bairagi *et al*., 2020), Mallow (Abdelhamid *et al*., 2021), Moringa leaf meal (Ningsih *et al.,* 2019) and potato leaf meal (Adewolu, 2018).

Leucaena leucocephala is a fast-growing shrub high in protein, amino acids, and minerals, making it promising for aquaculture feed. However, its anti-nutritional factor, mimosine, requires careful processing to minimize toxicity (Alabi *et al.,* 2024).

Clarias gariepinus, a mud catfish belongs to the family Clariidae. This specie has maintained its aquaculture quality because of its high growth rate, large size, good flesh quality, tolerance to poor water quality even at larvae state, acceptance of cheap feeds and ability to withstand high stocking densities, disease resistance and good taste (Chukwuemeka *et al.,* 2024). *Clarias gariepinus* is a typical air-breathing catfish with a scaleless, bony elongated body with long dorsal and anal fins, and a helmet-like head. Colour varies dorsally from dark to light brown and is often mottled with shades of olive and grey while the underside is a pale cream to white (Glencross *et al.,* 2017). It is a benthopelagic, dioecious, omnivorous fish and widely tolerant to extreme environmental conditions. *Clarias gariepinus* family Claridae is generally considered to be one of the most important tropical catfish species for aquaculture in West Africa. One problem facing fish culturists is the need to obtain a balance between rapid fish growth and optimum use of the supplied feed (FAO, 2019). By the end of the sixties, *Clarias gariepinus* was recognized as one of the most suitable species for aquaculture in Africa. The suitability of this species for pond culture is based on the following biological criteria. it grows fast and is relatively easy to reproduce in captivity, it can grow fast and efficiently, it supports high population densities.Recently, there has been increased interest in using unconventional plant materials, such as *Leucaena leucocephala* (lead tree), as alternatives to traditional protein sources in fish diets (Agupugo *et al.,* 2022).

This study aims to evaluate the growth performance of *Clarias gariepinus* post fingerlings fed varying levels of *Leucaena leucocephala* leaf meal as protein-substituted diets as replacement for fishmeal.

Need for Plant-Based Protein Sources

A wide variety of plants, have been assessed as an alternative to fish meal, most of which are of limited relevance in human nutrition. Adelesi *et al.* (2022) recorded a good level of economic performance when fish meal was substituted with 20% cassava peel in the diet of tilapia. Lim *et al*. (2021) suggested the addition of 0.2% methionine with 20% inclusion of cassava peel in the diet of tilapia. Henre *et al.* (2022) worked on reproductive performance and growth of Nile tilapia (*Oreochromis niloticus*) broodstock fed diet containing *Leucaena leucocephala* leaf meal. While,

Fernandez *et al.* (2021) examined the performance of juvenile *Oreochromis niloticus* reared on diets containing cowpea, *Vigna catiang,* and blackgram, *Phaseolus mungo* seed.

Furthermore, Lenient *et al*. (2018) worked on the use of Bambara groundnut (*Vigna subterranea*) meal in the diet of Heteroclarias fingerlings. Kitamura *et al.* (2018) examined the growth performance and haematological profiles of *Oreochromis niloticus* fingerlings fed differently processed cottonseed (*Gossypium hirsute*) meal. Lim *et al.* (2021) studied the haematological and histopathological effects of cassava mill effluent on *Clarias gariepinus*. Okada *et al.* (2019) worked on the effects of different processing methods of pigeon pea (*Cajanus cajan*) on the haematology of African catfish (*Clarias gariepinus*) larvae

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) reported 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*. 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)

Plant-based ingredients are often cheaper and more readily available compared to fishmeal, leading to cost-effective feed production and improved economic viability for fish farmers. (Igoche *et al*., 2025). Plant-based protein production generally has a lower environmental footprint than fishmeal production. It reduces greenhouse gas emissions, minimizes water pollution from fish farms, and avoids the ethical concerns associated with overfishing. Research indicates that incorporating specific plant-based protein sources can lead to improved feed conversion ratios and growth performance in various fish species, including catfish (Haetami *et al*., 2023).

Chemical Composition of Leucaena *leucocephala* (Lead Tree)

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), however soaking and drying the leaves for three consecutive days, this anti-nutrient is easily destroyed, hence improving their usability as animal feed.

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%, phenyalanine by 1.89%, threonine by 1.94%, tryptophan by 0.31%, and valine by 2.31%.

Utilization of *Leucaena leucocephala* as a Fish Feed Supplement.

In fish nutrition, its utilization is limited by the presence of mimosine, a toxic amino acid that reduces feed intake and growth. However, 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). Studies have shown that moderate inclusion levels may support growth without adverse effects. 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 to 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 needs to be examined in greater detail on its suitability for the African catfish, *Clarias gariepinus* (Olaniyi *et al*., 2022).



PLATE 1: Fresh *Leucaena leucocephala*

Growth Performance Indicators in Fish

Growth performance in aquaculture is assessed using key parameters such as weight gain in terms of weight and length as well as specific growth rate.Most importantly, weight gain is a key indicator of fish growth, reflecting the difference between final and initial body weight during a feeding trial. It offers a straightforward estimate of growth response to dietary treatments (Agbugui *et al*., 2018).

The specific growth rate (SGR) measures the daily percentage increase in body weight on a logarithmic scale, focusing on proportional rather than absolute growth. This makes it useful for comparing fish of different sizes and is more sensitive than weight gain (WG) in detecting differences from dietary treatments (Hien *et al.,* 2020). Researchers often assess protein sources such as soybean meal, fishmeal alternatives, and leaf meals using SGR. A higher SGR indicates better nutrient

absorption and metabolism, which is important for evaluating unconventional feeds like *Leucaena* or *Eichhornia*. However, SGR tends to decline when diets are high in fiber, contain anti-nutritional factors, or have poorly digestible ingredients (Hamid *et al.*, 2017).

These measures evaluate how effectively cultured species utilize nutrients for growth, survival, and production efficiency (Gao *et al.,* 2019). Researchers use these indicators to analyze growth responses under various dietary formulations,especially when testing diets that include protein substitutes like *Leucaena leucocephala.*

Percentage weight gain refers to the percentage amount of weight gained during the experimental period. It serves as a practical measure of the nutritional adequacy of diets. This metric is commonly used in feeding trials for African catfish, tilapia, carp, and other freshwater species. It is particularly valuable in farm-level assessments because it correlates strongly with production cycle planning and harvest expectations (Klinavee *et al.*, 2023).

MATERIALS AND METHODS

Experiment Area

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. Fresh lead tree (*Leucaena leucocephala*) leaves used for feed formulation were harvested within the surroundings of Nnamdi Azikiwe University, Awka.

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	2	2	2	2
Methionine (g)	2	2	2	2	2
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
Leucaena leucocephala* 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 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. Their initial weights and lengths (growth parameters) were recorded before acclimatization for one week with an average weight of 8.05grams per fish and average length of 4.11cm per fish in a stocking density of 20. 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 tanks at a stocking density of twenty (20) fish per experimental tank. 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.

Feeding rate and Frequency

The post fingerlings were fed 5% of their body weight for 16 weeks. The pellets were reduced to suitable size with the use of a laboratory ceramics mortar and pestle and the fish were fed twice daily (morning and evening).

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*:Water quality in the experimental tanks was managed by changing the water 2 to 3 times a week. 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), specific growth rate (SGR) (%day), relative weight gain (%), feed conversion ratio (FCR) and protein efficiency ratio.

Weight gain (g):

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

Weight gain = final weight- initial weight (W_f- W_i)

Percentage Weight Gain (PWG) (g):

This is a growth performance indicator that measures the relative increase in a fish's body weight over a specific experimental period, expressed as a percentage of its initial weight. It is used to evaluate the efficiency of diets and also to identify the best treatment diet (Hasan *et al.,* 2022).

$$PWG = \frac{\text{Mean final weight} - \text{Mean initial weight}}{\text{Mean initial weight}} \times 100$$

Percentage survival:

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

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

Specific growth ratio (SGR)

This is a metric used to quantify the growrh 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 the growth period and beginning and same respectively.

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 fingerlings to post juveniles stage within the period of 16 weeks was assessed using the following economic analysis indices such as :

Economic Conversion Ratio (ECR)

This is a metric that measures that calculates the price of the formulated feed per kg of fish per weight gain. It evaluates the economic efficiency of a feed type, allowing farmers or producers of feed to understand if a more expensive feed has a better performance than less expensive feed. It It is commonly used in aquaculture to evaluate sustainable replacements for fishmeal (Sarker et al., 2020)

This was computed according to New (2015) as

Economic Conversion Ratio = Cost of Feed Formulation per kg feed × FCR.

Net production value (NPV)

This refers to the monetary profit earned from a fish production enterprise after substacting all associated cost from the total revenue generated Omeje *et al.,* 2021).

NPV= Total Revenue− Total Cost

Profit Index (P)

This is an economic metric tool used to evaluate the cost effectiveness of a production method or diet. It is defined as the ratio of the total value of fish produced to the total cost of feed, helping researchers and farmers to determine which treatment yields the highest return on investment. while profit index was calculated as the value of fish sold minus the cost incurred in the production of each experimental diet. A higher Profit Index indicates more efficient and profitable diet. (Ajibade *et al.,* 2021)

It is computed using the equation below:

$$\text{Profit Index} = \frac{\text{Net Production Cost (NPV)}}{\text{Economic Cost Ratio (ECR)}}$$

Where NPV represents the Total Value of Fish Produced and ECR represents the cost of feed used.

Benefit: Cost ratio (BCR)

This is used to evaluate the economic viability and profitability of aquaculture or fish farming operations. It is defined as the raio of the gross benefits (total returns/revenue) to the gross costs (total expenses) associated with a production circle. BCR > 1 means the operation is profitable and economically viable, BCR=1 means break-even point where benefits equal costs, BCR < 1 means the operation is not profitable that is costs of production outweighs the benefits (Sethi *et al*., 2024).

Benefit Cost Ratio= Gross Production Value (Returns)

Economic Cost Ratio (Expenses)

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 (63.01%) and progressively declined across inclusion levels, reaching the lowest value in T4 (13.16%).

Table 2: Proximate Composition of Experimental Diets

Experimental Diets	Moisture	Ash	Crude Protein	Crude Fiber	Fats/Oil	Carbohydrate
T0 (Control)	7.89 ± 0.12^{a}	5.82 ± 0.01^{b}	63.01 ± 0.01^{c}	3.49 ± 3.11^{a}	12.01 ± 0.01^{c}	20.11 ± 0.02^{a}
T1(25% LLLM)	10.25 ± 0.04^{b}	7.51 ± 0.44^{c}	36.43 ± 0.54^{b}	5.06 ± 0.66^{b}	10.05 ± 0.02^{a}	28.56 ± 0.55^{a}
T2(50% LLLM	10.78 ± 0.20^{b}	7.89 ± 0.03^{c}	31.50 ± 0.01^{b}	5.26 ± 0.06^{b}	10.00 ± 0.02^{a}	30.65 ± 0.24^{b}
T3(75% LLLM)	11.12 ± 0.20^{b}	8.16 ± 0.01^{c}	30.05 ± 0.05^{b}	6.20 ± 0.02^{c}	8.12 ± 0.04^{b}	37.23 ± 0.20^{b}
T4 (100% LLLM)	11.25 ± 0.12^{c}	8.22 ± 0.01^{a}	13.16 ± 0.22^{a}	6.56 ± 0.18^{d}	8.03 ± 0.04^{b}	40.25 ± 0.60^{c}

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

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)	176.5 ± 4.3^{a}	174.3 ± 3.9^{b}	173.9 ± 4.1^{a}	172.7 ± 3.8^{b}	171.2 ± 4.0^{a}

Final Mean Weight (g/fish)	678.9 ± 19.2[a]	466.1 ± 15.8[b]	443.4± 14.6[bc]	410.5 ± 13.4[c]	365.3 ± 12.1[d]
Percentage weight gain **(%)**	284.7 ± 2.0[a]	167.4 ± 1.8[b]	160.0. ± 1.7[bc]	137.6± 1.6	133.4± 1.5[d]
Initial Mean length (g/fish)	4.74 ± 0.12[a]	4.58 ± 0.10[a]	4.52 ± 0.11[a]	4.37 ± 0.09[a]	4.35 ± 0.08[a]
Final Mean lenght (g/fish)	18.20 ± 0.35[a]	16.41± 0.28[b]	15.48 ± 0.26[c]	14.41 ± 0.23[cd]	14.12 ± 0.21[d]
Initial Stocking Density	60	60	60	60	60
Final Stocking Density	51	50	49	48	47
Specific Growth Rate	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]
Survival (%)	85	83	82	80	78
Biomass (g)	11541.3	7923.7	7094.4	6568	5844.8

Table 3: Growth performance of *Clarias gariepinus* post fingerlings fed with control, 25%, 50%,75% and 100% *Leucaena leucocephala* Leaf Meal (LLLM) experimental diets for sixteen (16) weeks.

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

Table 4: Economic indices of *Clarias gariepinus* fed Control and *Leucaena leucocephala* leaf meal (LLLM) experimental diets is shown in Table 4.

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 ± 40.80	1,998.19 ± 59.95[c]	2,047.50 ± 61.43	2,208.02 ± 66.24[b]	2,477.32 ± 74.32[a]
NPV (₦/kg fish)	2,640.00 ±79.20[a]	2,001.81 ± 60.05[b]	1,952.50 ± 58.58[c]	1,791.98 ± 53.76[d]	1,522.68 ± 45.68[f]
BCR	2.94 ± 0.09[a]	2.00 ± 0.06[b]	1.95 ± 0.06[c]	1.81 ± 0.05[d]	1.61 ± 0.05
PI	1.94 ± 0.06[a]	1.00 ± 0.03[c]	0.93 ± 0.03[d]	0.81 ± 0.02[e]	0.61 ± 0.02[f]

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

DISCUSSION

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).

The proximate composition of the diets indicated that although all diets were formulated to contain similar protein levels, crude fiber increased with plant inclusion. This agrees with studies carried pot 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 and ECLM 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 and ECLM 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 was 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.

Table 3 showed the growth performance responses of *Clarias gariepinus* fed a control diet (containing 100% fish meal) and experimental diets containing graded levels LLLM at varying levels of (25%, 50%, 75%, and 100%) over a sixteen-week feeding trial. The initial mean weight of fish across all treatments showed only slight variations (171.2–176.5 g), indicating that the experimental fish were relatively uniform at the start of the trial. This uniformity ensures that observed differences in growth performance can be attributed mainly to dietary treatments rather than initial size differences (Agupugo *et al.,* 2022) Fish fed the control diet (T0) recorded the highest final mean weight (678.9 ± 19.2 g), which was significantly higher ($p < 0.05$) than those of fish fed the LLLM experimental diets. The final mean weight progressively declined with increasing inclusion levels of LLLM reaching the lowest value in fish fed the 100% replacement diet in T4 (100% LLLM) (365.3 ± 12.1 g). This pattern clearly demonstrates that increasing substitution of fish meal with *Leucaena* leaf meal (LLLM) negatively affected growth performance.

Weight gain (WG) followed a similar trend, with fish in the control DIET recording the highest percentage weight gain (284.7 ± 2.0%), while fish fed 25% and 50% of LLLM inclusion diets showed moderate but significantly reduced percentage weight gains (167.4 ± 1.8% and 174.30 ± 2.14%, respectively). The lowest weight gain was observed in the 100% inclusion group (142.70 ± 1.9%). Weight gain is a direct reflection of nutrient intake and utilization efficiency, and as the declining trend observed suggests reduced efficiency of nutrient assimilation as *Leucaena* inclusion level increased. This reduction in growth may be attributed to lower protein quality, reduced digestibility, and the presence of anti-nutritional factors such as mimosine and tannins commonly associated with

plant leaf meals as reported by Francis *et al.,* 2017 who carried out research on anti-nutritional factors in plant meals.

Weekly mean lenght increased steadily across all treatments, but the rate of increase differed. Fish fed the control diet (T0) exhibited significantly higher ($p < 0.05$) with final length of (18.2±0.35cm). This indicated superior nutrient availability and utilization in the control.However, compared to fish fed the treatment diets, T5(25% LLLM) had final length of (16.41± 0.28cm), and the lowest length gain was recorded for T4(100% LLLM) with final length of 14.12±0.21cm.

Fish fed 75% and 100% LLLM replacement diets showed visibly slower growth. Similar trends have been reported by Chukwuemeka *et al*., (2024) who observed reduced growth performance in African catfish in terms of length, when conventional protein sources were partially or wholly replaced with plant-based ingredients beyond optimal inclusion levels. This reduction has been attributed to factors such as high fiber content, presence of anti-nutritional compounds, and reduced protein digestibility. This indicates that higher replacement levels reduced nutrient availability and growth efficiency as reported by Francis *et al.,* 2018.

Fish fed T1 (25% LLLM inclusion) showed relatively good growth performance and ranked second to the control diet, indicating that partial substitution can support growth of African Catfish without severely compromising performance. This finding agrees with Adewumi & Oke, (2025) who reported that low to moderate inclusion levels of unconventional plant proteins can be tolerated by *Clarias gariepinus* without adverse effects on growth.

However, Poor linear growth at higher inclusion levels may also be linked to reduced palatability, lower feed intake, and imbalance in essential amino acids, all of which have been documented to impair growth in cultured catfish. (Mondal, 2025). Despite the observed reductions, it is noteworthy that all experimental diets supported positive growth throughout the culture period, indicating that *Leucaena leucocephala* leaf meals LLLM were not toxic to the fish.

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 ± 0.05%/day), while fish fed T1,25% LLLM inclusion diets showed moderate SGR values (1.07 ± 0.04 %/day). The lowest SGR was recorded in T4, fish fed 100% LLLM inclusion diet (0.87 ± 0.02%/day). Since SGR integrates both initial and final weights, it is a reliable indicator of overall growth performance (Adeyemi *et al.,* 2023). The reduction in SGR with increasing LLLM indicates diminished growth efficiency and poorer feed utilization.

The results from Table 2 demonstrates that partial replacement of fish meal with *Leucaena leucocephala* leaf meal LLLM specifically T1 (up to 25%) can support acceptable growth performance and feed utilization in *Clarias gariepinus*. However, higher inclusion levels, T2, T3 and T4; (50–100%) significantly compromise growth performance of *Clarias gariepinus*. 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.

The progressive decline in growth performance with increasing LLLM (from T1 to T4) aligns with reports in the aquaculture literature showing that high levels of plant protein inclusion often led to reduced growth efficiency compared to fish meal-based 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).

Weight gain and SGR are direct reflections of how well fish can convert feed into body mass Sogbesan *et al.,* (2022). High DWG and SGR in the control and lower *Leucaena* diets indicate better feed utilization, higher protein digestibility, and more efficient nutrient absorption (higher protein retention in muscle tissues).

As plant protein inclusion increased, nutrient digestibility typically declined, likely due to lower essential amino acid content and the presence of anti-nutritional factors (ANFs) such as tannins and other secondary metabolites in leaf meals as reported by Lalitha *et al.,* 2021. Plant proteins often have imbalanced amino acid profiles and contain compounds that can interfere with enzyme activity and gut nutrient absorption, resulting in slower protein accretion and slower growth rates. (Daniel, 2017).

This mechanism is supported by broader reviews showing that alternative plant proteins may replace a portion of fishmeal if amino acid profiles are balanced, but high inclusion levels often compromise growth and feed efficiency (Fernandez *et al*., 2021).

Furthermore, the relationship between growth performance and survival rates observed in this study (with survival declining from T0 to T4) highlights another important linkage between feed quality and overall fish health (Hussain *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, all 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)

Also, notably the total biomass production declined progressively with increasing inclusion levels of the test ingredient in the diets

In conclusion, the performance of *Clarias gariepinus* in this study reiterates the need for caution when substituting fish meal with plant protein sources. Partial substitution (25% replacement) of LLLM is most feasible without severely compromising growth and feed utilization, but complete replacement at high levels (75–100%) results in significantly lower growth and feed efficiency, which are likely to translate into poor carcass quality and reduced production efficiency. Macusi *et al.*, (2023).

The economic evaluation of *Clarias gariepinus* fed graded levels of *Leucaena leucocephala* leaf meal (LLLM) and *Eichhornia crassipes* leaf meal (ECLM) diets demonstrated significant variations ($p < 0.05$) in cost efficiency and profitability indices across treatments, as reflected in Table 4.

Diets T1,25% LLLM achieved an optimal balance between cost reduction and biological performance, resulting in superior ECR, NPV, BCR, and PI values. This aligns with recent findings

carried out by Sogbesan *et al*. 2022 that moderate plant protein inclusion enhances profitability without compromising growth performance.The reduced profitability observed in T4, 100% LLLM indicates that total fish-meal elimination may not be economically viable under practical production conditions, despite lower ingredient costs.

25% of LLLM provided the most favorable economic balance, combining substantial feed cost savings with acceptable growth and biomass production, suggesting that partial replacement of fishmeal with *Leucaena leucocephala* is both cost-effective and practical for small-scale and commercial *Clarias gariepinus* production. These findings align with recent studies carried out by Igoche *et al.*, 2025 emphasizing the economic and sustainability benefits of incorporating plant-based protein alternatives in aquafeeds.

CONCLUSION AND RECOMMENDATION

Fish fed the control diet (T0) consistently recorded the highest final weight, weight gain, specific growth rate (SGR), length gain, survival rate, and biomass. However, among the test diets, 25% *Leucaena leucocephala* leaf meal LLLM supported superior growth performance compared to 50%,75% and 100% inclusion levels.Economic analysis provided critical insights into the practical applicability of the test ingredients. Diets containing 25% *Leucaena leucocephala* leaf meal LLLM demonstrated superior economic efficiency. This diet recorded significantly lower economic conversion ratios (ECR), higher net profit values (NPV), improved benefit–cost ratios (BCR), and higher profit indices (PI) compared to other *Leucaena leucocephala* diets.

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

1. Based on its superior performance in growth, feed utilization, nutrient digestibility, carcass quality, and economic indices, 25% *Leucaena leucocephala* leaf meal is recommended as the preferred plant protein source for partial fishmeal replacement in *Clarias gariepinus* diets. Its consistent advantage over *Leucaena leucocephala* leaf meal indicates better growth performance and higher profitability.Inclusion levels above 25% should be avoided due to progressive declines in performance.
2. *Leucaena leucocephala* leaf meal should be used cautiously and at low inclusion levels (≤25%). Higher inclusion levels (≥50%) resulted in significant reductions in growth, feed utilization efficiency, carcass quality, and profitability, likely due to higher fibre content and anti-nutritional compounds such as mimosine. Higher inclusion levels should be avoided unless adequate processing methods (e.g., fermentation, heat treatment) are employed to reduce anti-nutritional factors.
3. Policymakers and aquaculture development agencies should support the utilization of plant meals in aquafeeds as part of integrated strategies for invasive plant management, feed cost reduction, and sustainable aquaculture expansion.

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