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Effects of *Jatropha Tanjorensis* Leaf Meal on the Growth Performance and Physicochemical Parameters of *Clarias Gariepinus*

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ABSTRACT

The Nigerian aquaculture industry, despite its 50-year existence and vast cultivable water resources, still struggles to meet domestic fish demand, largely due to high feed costs. This study investigated the growth performance and physicochemical responses of Clarias gariepinus fingerlings fed graded levels (0%, 5%, 10%, and 20%) of Jatropha tanjorensis leaf meal (JTLM). Standard methodologies were used to assess the physicochemical qualities and growth parameters such as weight, lengths, specific and daily growth rates, protein index, food conversion ratio and condition factor. The results revealed that the proximate composition of JTLM had moderate nutritional values: 25.5% crude protein, 5.0% fibre, 20.3% fat, 9.5% ash, 0.9% moisture, and 38.8% nitrogen-free extract. Water quality parameters remained within optimal ranges, with slight reductions in dissolved oxygen and increases in BOD, TSS, and conductivity at higher inclusion levels. Growth performance was significantly improved in the 5% and 10% JTLM groups, which exhibited superior weight gain, daily growth rate, specific growth rate (SGR), and feed conversion ratio (FCR) compared to the control and 20% treatments. The best FCR was recorded in 5% (3.58) and 10% (3.52), and the Protein Index (PI) was also observed at these levels. Although all groups maintained healthy condition factors (>1.0), the 20% JTLM group had the lowest survival rate. Statistical analysis confirmed significant differences (p≤0.05) across treatments. The findings indicate that JTLM is a viable, cost-effective feed ingredient for African catfish when used at appropriate inclusion levels. It is recommended to limit JTLM inclusion to 5–15%, combine it with high-protein ingredients, and further explore its effects on other cultured fish species.

Keywords: *Physicochemical parameters, Growth performance, Clarias gariepinus, Jatropha tanjorensis and Plant-based protein.*

1.0. Introduction

The Nigerian aquaculture industry is about 50 years old [1], yet the country has not been able to meet domestic production demand for the populace. Regarding her potentials, Ita *et al.* [2] reported that the country has over 13 million hectares of cultivable waters which could be harnessed for aquaculture production. A good number of cultivable fish species, both exotic and indigenous, have also been documented [3].

The major ingredients in aqua feeds are fishmeal, soybeans, and maize. In order to reduce the expenditure involved with fish feed and increase the net profit earned by the fish farmers, alternative cost-effective plant sources are a viable alternative to be incorporated in the formulated feed.

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Plant-based protein appears to be the most suitable substitute for fish meal (FM) in common freshwater diet formulation [4]. Fish by-products, terrestrial animal by-products, and plant protein sources can serve as alternatives to FM. To satisfy the demand of a growing global population, it is anticipated that fish production will increase; this will necessitate the production of more fish feed. Due to its low cost and presence of balanced amino acids, the incorporation of plant-protein components in fish diets has increased [5].

Jatropha species is anticipated to be one of the potential plant species to be a cheap source of foodstuff for fish. In Nigeria, *Jatropha tanjorensis* is commonly called ''Hospital too far, Catholic vegetable, Iyana-ipaja, Lapalapa [6]. Jatropha plant can yield up to four tons of seed per year from one hectare of plantation, which can produce approximately one ton of kernel meal rich in protein [7]. This implies that there is a good possibility of producing enough Jatropha kernel meal to meet the growing demand for fish protein in the aquaculture industry. The processed seed is referred to as Jatropha seed meal. The use of Jatropha seed meal has been impeded so far because of its toxicity, which is mainly ascribed to the presence of phorbol esters (PEs) [8]. The meal also contains antinutritive factors such as trypsin inhibitors, lectin, and phytate [7].

The majority of the poisonous effects of Jatropha spp. are caused by its phytochemical and anti-nutritive ingredients, which include aponins, tannins, proteases, alkaloids, and toxins that restrict its usage for feeding animals [9]. However, it was reported that heat treatment followed by solvent extraction could remove phorbol esters and would result in the elimination of most of the anti-nutrients and toxins from the toxic variety [10].

Research on *Jatropha* species is focused mostly on the distribution areas, cultivation, and nursery development of *Jatropha species.* However, research on its relative species (*J. tanjorensis*) is limited [11]. Studies have confirmed the efficacy of Jatropha seeds as a good protein source for Carp (*Cyprinus carpio*) [12], Rainbow trout (*Oncorhynchus mykiss*) diet [13], Nile tilapia (*Oreochromis niloticus*), and Catfish (*Clarias gariepinus*) [14].

Fish is one of the healthiest and demanded protein-giving foods around the globe, coupled with the rapid increase in human population that has increased its demand for other purposes. CMFRI and SAARC [15] documented that fish feed is one of the major problems of the aquaculture industry, which is responsible for a significant decline of the agricultural sector. Production of good and quality fish feed has over time, been considered one of the major influences on the success of fish production in aquaculture [16]. This is relative to the scarcity and high cost of some quality protein feedstuffs like Soybean meal and fish meal due to an ever-increasing demand as staple food for man, raw material in industries, and as feed ingredients in farm animals [17]. Daily Trust [18] reported an 80 to 100 percent increase in prices of fish feeds within 8years, causing many fish farmers to leave the business, especially in Lagos State. In fact, Okon *et al.* [19] bought a bag of Bluecrown for about N10,500. Today, that same brand is worth N24,400, which is about 138% increase [20].

The African catfish (*Clarias gariepinus*) is a fast-growing, hardy, and widely cultured fish species in Nigeria. It is highly valued due to its adaptability to diverse environmental conditions, tolerance to low oxygen levels, and ability to thrive in high-density stocking systems [21]. Additionally, its high protein content, palatability, and suitability for various Nigerian culinary styles make it a staple in the diet of many Nigerians. The species plays a critical role in addressing the protein deficiency prevalent in the country, particularly in rural areas [22].

To meet FAO's recommended millennium fish consumption rate of 12.5 kg per head yearly, Nigeria requires about 1.5 metric tonnes of fish annually to satisfy basic protein needs [23]. The demand for fish is still insatiable in the country, until conventional alternative ingredients for fish feeds that are not only for growth, but also for their survival and nutritiveness to man are considered.

This study is designed to provide food scientists, aqua feed manufacturers, public health officers, and even local farmers with a practicable, economical, and affordable alternative in the utilization of eco-friendly ingredients in fish feed production, yet yielding huge profits that will encourage and sustain the farmers, marketers, and all concerned sectors in the industry. This study will form a baseline value of haematological and biochemical parameters of the Catfish based on feed consumption. This analysis could help in understanding the better health condition of this fish fed Jatropha-derived feed in enclosures. Since information on growth performance, haematological and biochemical investigations of *C. gariepinus* fed with *Jatropha tanjorensis* is insufficient, the present work will be carried out to arrive at some baseline values. This study evaluates the growth performance and physiochemical variations of African Catfish (*Clarias gariepinus*) fingerlings fed graded levels of *Jatropha tanjorensis* leaves.

2.0. Materials and Methodology

2.1 Experimental Location.

The experiment was carried out in the Department of Animal and Environmental Biology, Faculty of Biological Science, University of Uyo.

2.2. Obtainment and Identification

Fresh branches of *Jatropha tanjorensis* leaf were obtained from roadside plants in Uyo L.G.A, Akwa Ibom State. The leaves and stems of the plant were taken to the Herbarium of the Department of Botany and Ecological Studies, University of Uyo for proper identification.

2.3. Processing of *Jatropha tanjorensis* Leaf Meal (JTLM)

Jatropha tanjorensis leaves were freshly plucked by hand and thereafter soaked in water for twenty-four (24) hours to reduce ANFs [24]. They were dried directly in an oven for 6hours at 45 °C till they became crispy. The dried leaves were ground into a powdery form using a milling machine. The milled JT leaves were sieved with 2mm mosquito net to separate the fine powder from the remaining fibre to produce the leaf meal.

2.4. Preparation of the *Jatropha tanjorensis* leaf meal

The other feed ingredients (soybean seeds, maize meal, fish meal, cassava flour, vitamins, and mineral premixes) used for the diet formulation were purchased from a feed store in Uyo in Akwa Ibom State. The soybean seeds were toasted according to the method described by Tiamiyu and Solomon [24] and Okomoda *et al.* [25]. The other ingredients were used as purchased (already processed).

2.5. Diet formulation and preparation

The powdered meal produced was mixed directly with the basal diet. It was added to the diets at concentrations of 0%, 5%, 10% and 20% of feed labelled Control, JTLM 1, JTLM 2, and JTLM 3, respectively (Table 1). Compounded feeds were pelletized (2mm) using the pelletizing machine, sundried, allowed to cool in the open air, packed, and stored in an opaque nylon bag.

Four iso-nitrogenous and iso-energetic diets were formulated. The *Jatropha tanjorensis* leaf meal (JTLM) was included in the diet at levels of 0% (Control), 5% (JTLM 1), 10% (JTLM 2), and 20% (JTLM 3). The basal feed ingredients were obtained from a reputable fish feed mill in Uyo, Akwa Ibom State. Equal vitamin premixes were added to all treatments and milled using a milling machine. Warm water was added to the pre-mixed ingredients and homogenized until a dough-like paste was formed. The dough was then passed through a pelleting machine. The moist pellets were sundried to a constant weight and kept in air-tight containers before the experiment. The percentage composition of the experimental diets is given in Table 1.

2.6. Experimental design and feeding

A total of 160 samples of *C. gariepinus* fingerlings were randomly bought from Fish Feed Solution Cooperation, No. 5 Osuk Ntan, off Ikot Akpanobong, Ibiono Ibom, Akwa Ibom State, Nigeria. The fish will be randomly distributed into 12 experimental tanks for four treatments in duplicate. Before distribution of fish into treatment, the fish will be acclimatized for 7 days until they become active, and thereafter will be fed with the locally made feeds. Before feeding commenced, they were weighed. Fingerlings were stocked in 8 tarpaulin tanks (100 X 50 cm) at a density of 15 per tank in duplicate.

Each tank was filled with 15000 mg of unchlorinated water. The fish diet contained graded levels of JTLM for 10 weeks (70 days) and were fed two times daily at the rate of 5% body weight [26] at 07:00h and 18:00h except on sampling days, where they were fed 3 hours after being weighed. During the experimental period, the amounts of feed were adjusted based on the body weight (5%) of the fish for the subsequent weeks. The water in each tank was changed twice weekly. This routine continued for 70 days.

2.7. Analysis of physicochemical parameters

The quality of the physicochemical parameters of the water was monitored during the experimental period for pH, temperature, dissolved oxygen (DO), conductivity, total suspended solids (TSS), and biological oxygen demand (BOD). The pH degree was measured using a pH-meter (Digital Mini-pH Meter, model 55 Fisher Scientific, Denver, CO, USA). The temperatures of the water samples were determined using a mercury-glass thermometer calibrated in °C to 100 °C. The thermometer was dipped into the sample and left for about five minutes for equilibrium before the reading was recorded. DO was measured using an oxygen meter (YSI model 58, Yellow Spring Instrument Co., Yellow Springs, OH, USA). Conductivity was measured using an electrolytic conductivity meter. Total Suspended Solids was determined using the Mohr method as described in APHA [27]. Biological Oxygen Demand (BOD_5) was conducted over five days.

2.8. Fish Growth Performance and Feed Utilization

Growth performance and nutrient utilization parameters were evaluated using standard formulae by Dabrowski [28]; Jauncey [29]; Jamabo and Alfred-Ockya [30]; Pangni *et al.* [31], as stated below:

I. Mean weight gain (MWG) (g): This is calculated by subtracting the initial weight from the Final weight.

MWG = Final weight - Initial weight

ii. Mean Total Length Gain (MTLG) (cm): This is calculated by subtracting the initial length from the final length.

MTLG = Total Length Gain (cm) = Final Length - Initial Length

iii. Mean Standard Length Gain (MSLG) (cm): This is calculated by subtracting the initial length from the final length.

MSLG = Final Standard Length – Initial Standard Length

iv. Specific growth rate (SGR) % day^{-1}: This is the relationship of the difference in the weight of the fish within the experimental period.

$$SGR (\%) = 100 \times \frac{(\ln \text{final weight} - \ln \text{initial weight})\ g}{T}$$

v.Daily growth rate (DGR) g day^{-1}: This is calculated by the difference between the final weight and the initial weight divided by culturing days

$$DGR = \frac{(\text{Final weight} - \text{Initial weight})}{T}$$

Where T is the number of days

vi. Feed conversion ratio (FCR) (g): This is achieved by dividing the quantity of feed consumed by the weight gained.

$$= \frac{\text{Feed consumed (g)}}{(\text{Final weight} + \text{Initial weight})\ (g)}$$

vii. Protein Index (PI): This is calculated by subtracting the number of survivors after the experiment from the number stocked, divided by culturing days.

$$PI = \frac{\text{Survival } (W_1 - W_2)}{\text{Time (days)}}$$

viii. Survival rate (SR) %: This is the percentage of the number of fish stocked divided by the number of surviving fish at the end of the experiment.

$$SR = 100 \times \frac{\text{Final number of fish}}{\text{Initial number of fish}}$$

ix. Condition Factor (K): This is calculated by multiplying the body weight gain of each treatment by 100 and dividing by the length (centimeter) raised to the power 3

$$K = \frac{Wt \times 100}{L^3}$$

Where; K = Condition factor

Wt = Final body weight

L = Final Total length

2.11 Statistical Analysis

The data obtained from the study were subjected to a statistical tool; analysis of variance (ANOVA) to ascertain significant differences in growth rate, haematological variables, and biochemical profile of fish fed different inclusion levels (0%, 5%, 10% and 20%) of JTLM. With the use the IBM-SPSS statistical package of version 22. An acceptable value of $p \leq 0.05$ was considered to be statistically significant.

2.12 Ethical Consideration

This study strictly adhered to the principle of Reduction, Refinement, and Replacement (3Rs) to minimize distress and ensure animal welfare. It was followed by internationally accepted ethical principles known as the 3Rs when using animals in research [32].

Reduction: The fewest number of animals necessary to obtain reliable results. The goal is to avoid unnecessary use of animals while still ensuring the research has enough data to be valid.

Refinement: We improved the experimental methods and care to minimize pain, suffering, or stress for the animals. This was done by changing the water twice weekly as the residuals were polluting the water.

Replacement: If live animals must be used, researchers ensure that there are no suitable alternatives available. There were no suitable alternatives.

3.0. Results, Discussion, Conclusion, and Recommendation

3.1 Results

3.1.1. Proximate Composition of the Soaked and Oven-dried *Jatropha tanjorensis* Leaf Meal (JTLM)

Table 2 reveals that the proximate composition of *Jatropha tanjorensis* leaf meal (JTLM) used in this study contained 25.5% crude protein, crude fibre content of 5.0%, crude fat (20.3%), ash content (9.5%), moisture level (0.9%), and the nitrogen-free extract (38.8%).

3.1.2. Physicochemical Parameters of Water

The average values across the 10 weeks are presented in Table 3. pH and temperature did not record significant differences across treatments. All pH values remained stable around neutral, and temperature variations were minimal and within the optimal range for *Clarias gariepinus*.

The DO decreased with increasing JTLM inclusion. DO in the 20% JTLM group (4.8 mg $L^{-1}$was significantly lower than the control (5.3 mg L^{-1}). Conductivity increased significantly from 430 µS cm^{-1} (0%) to 470 µS cm^{-1} (20%). The TSS increased significantly in the 10% and 20% JTLM groups. BOD progressively increased with higher JTLM inclusion. The 20% group (2.6 mg L^{-1}) had significantly higher BOD than the control (1.8 mg L^{-1}). All parameters remained within the optimal range for *Clarias gariepinus* culture throughout the study. No significant adverse variation was observed between treatments.

Table 1. Composition of the experimental diets (g kg^{-1} feed)

Ingredients	Experimental diets			
	Control	**JTLM 1 (5%)**	**JTLM 2 (10%)**	**JTLM 3 (20%)**
JTM	0	5	10	20
Fish meal	25.00	25.00	25.00	25.00
Maize	32.60	27.60	22.60	12.60
Soybeans	20.00	20.00	20.00	20.00
Wheat meal	15.00	15.00	15.00	15.00
Vitamin premix	0.20	0.20	0.20	0.20
Fish oil	7.00	7.00	7.00	7.00
Total	100	100	100	100

Table 2: Proximate Composition of Jatropha tanjorensis Leaf Meal (JTLM)

Nutrient Component	Percentage (%)
Crude Protein	25.5
Crude Fibre	5.0
Crude Fat (Ether Extract)	20.3
Ash	9.5
Moisture	0.9
Nitrogen-Free Extract (NFE)	38.8

***Note:** C (0%) -- 0 % inclusion of JTLM; JTLM 1 - 5%; JTLM 2 - 10%; JTLM 3 - 20%*

Table 3: Water Quality Parameters

Parameter	0% JTLM	5% JTLM	10% JTLM	20% JTLM	Optimal Range (FME, 2006)
pH	6.7 ± 0.10^{a}	6.8 ± 0.11^{a}	6.9 ± 0.12^{a}	7.0 ± 0.09^{a}	6.5–8.5
Temperature (°C)	27.4 ± 0.4^{a}	27.5 ± 0.3^{a}	27.6 ± 0.5^{a}	27.5 ± 0.4^{a}	25–30
DO (mg L^{-1})	5.3 ± 0.2^{a}	5.1 ± 0.2^{b}	5.0 ± 0.2^{b}	4.8 ± 0.2^{c}	≥ 5.0
Conductivity (µS cm^{-1})	430 ± 12^{a}	440 ± 15^{b}	460 ± 14^{b}	470 ± 16^{b}	< 500
Salinity (ppt)	0.01 ± 0.03^{a}	0.01 ± 0.04^{a}	0.02±0.01^{b}	0.02 ± 0.03^{b}	< 0.5
TSS (mg L^{-1})	12.0 ± 2.1^{a}	13.5 ± 2.4^{ab}	14.2 ± 2.5^{b}	15.0 ± 2.6^{b}	< 50
BOD (mg L^{-1})	1.8 ± 0.3^{a}	2.0 ± 0.2^{a}	2.3 ± 0.3^{b}	2.6 ± 0.4^{c}	< 10

***Note:** Values with different superscripts across rows are significantly different at $p \leq 0.05$ using Duncan's Multiple Range Test. JTLM = Jatropha tanjorensis Leaf Meal; DO = Dissolved Oxygen; TSS = Total Suspended Solids; BOD = Biological Oxygen Demand*

Table 4: Growth Performance and Feed Utilization of Clarias gariepinus Fed Different Levels of Jatropha tanjorensis Leaf Meal (JTLM)

Parameter	0% JTLM	5% JTLM	10% JTLM	20% JTLM
Initial Mean Weight (g)	4.62 ± 0.34	4.85 ± 0.51	4.58 ± 0.49	4.12 ± 0.52
Final Mean Weight (g)	12.00 ± 0.48^{a}	14.00 ± 0.42^{b}	13.70 ± 0.46^{b}	10.00 ± 0.39^{c}
Weight Gain (g)	7.39 ± 0.28^{a}	9.22 ± 0.31^{b}	9.13 ± 0.33^{b}	5.95 ± 0.26^{c}
Initial Total Length (cm)	6.17 ± 0.51	7.77 ± 0.39	7.85 ± 0.41	6.64 ± 0.31
Final Total Length (cm)	8.90 ± 0.42^{a}	10.50 ± 0.39^{b}	10.77 ± 0.43^{b}	9.10 ± 0.37^{a}
Initial Standard Length (cm)	4.71 ± 0.36	4.91 ± 0.45	6.43 ± 0.31	4.21 ± 0.26
Final Standard Length (cm)	6.55 ± 0.35^{a}	7.12 ± 0.34^{b}	8.20 ± 0.38^{c}	6.12 ± 0.32^{a}
Daily Growth Rate (g day^{-1})	0.106 ± 0.01^{a}	0.132 ± 0.01^{b}	0.130 ± 0.01^{b}	0.085 ± 0.01^{c}
Specific Growth Rate (% g day^{-1})	1.36 ± 0.04^{a}	1.52 ± 0.03^{b}	1.56 ± 0.03^{b}	1.28 ± 0.04^{c}
Feed Conversion Ratio (FCR)	3.94 ± 0.02^{b}	3.58 ± 0.05^{a}	3.52 ± 0.06^{a}	4.18 ± 0.07^{c}
Protein Index (g protein g day^{-1})	0.092 ± 0.01^{b}	0.109 ± 0.01^{a}	0.121 ± 0.01^{a}	0.064 ± 0.01^{c}
Condition Factor (K)	1.70 ± 0.04^{a}	1.22 ± 0.03^{c}	1.10 ± 0.03^{c}	1.33 ± 0.03^{b}
Initial Number of Fish	40	40	40	40
Final Number of Fish	35	33	37	30
Survival Rate (%)	87.5	82.5	92.5	75.0

***Note:** Superscripts (a, b, c) within rows indicate statistically significant differences ($p \leq 0.05$). Values with the same letter are not significantly different, while those with different letters are significantly different*

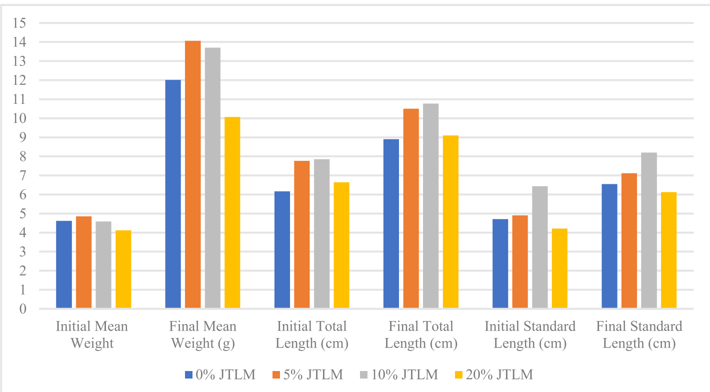

Figure 1: Showing a fraction of Growth parameters

3.1.3. Growth Performance and Feed Utilization of *Clarias gariepinus* Fingerlings

The growth indices of *Clarias gariepinus* fingerlings fed diets containing 0%, 5%, 10%, and 20% JTLM for 10 weeks are shown in Table 4. Each group started with distinct average initial weights and length parameters.

Fish fed 5% and 10% JTLM diets exhibited significantly higher final weights and weight gains ($p \leq 0.05$) compared to the control (0%) and 20% groups. These groups were statistically similar, which showed maximum performance. The daily growth rate recorded was in highest in the 5% (0.132 ± 0.01 % g day^{-1}) JTLM group, followed closely by 10% (0.130 ± 0.01) JTLM group. While the SGR was recorded highest in 10% (1.56 ± 0.03 % g day^{-1}) JTLM group, followed closely by 5% (1.52 ± 0.03% g day^{-1}).

Both were significantly better than 0% and 20%. Best (lowest) FCR was recorded in the 5% and 10% groups (3.58 ± 0.05 and 3.52 ± 0.06), which were statistically superior to both the 0% (3.94) and 20% (4.18) inclusion levels. For protein index, 5% JTLM group had the highest protein utilization (0.109 ± 0.01g protein g day^{-1}), followed closely by the 10% group.

The highest K was observed in the control group (1.70). However, fish in all groups maintained a healthy range (>1.0). The survival rate was high across treatments (75.0% to 92.5%), but 20% JTLM (75%) had a significantly lower survival rate than the others. Statistical analysis (ANOVA) revaled significant differences ($p \leq 0.05$) in weight gain, DGR, SGR, FCR, PI, and K among treatments. Post hoc Duncan's test showed that 5% and 10% JTLM groups were significantly better than the 0% and 20% for growth indices.

Figure 1 is a graphical representation of some growth parameters in this study.

3.2. Discussion

The nutritional composition of a feed ingredient is crucial in determining its suitability for fish diets. The proximate analysis of *Jatropha tanjorensis* leaf meal (JTLM) used in this study showed the crude protein (25.5%), crude fibre (5.0%), Crude Fat (20.3%), ash (9.5%), moisture (0.9%), and nitrogen-free extract (38.8%). These values are similar to those reported by Obikaonu *et al.* [33]. But disagrees with other results [13], with a higher CP level. However, our result was lower than the 35-45% protein requirement of *Clarias gariepinus* fingerlings [23]. The protein content of JTLM is moderate and suitable for partial inclusion in fish diets, if other components are efficiently composited. However, *Clarias gariepinus* fingerlings generally require diets with crude protein ranging from 35-45% for optimal growth [23]. While JTLM cannot be used as the sole protein source, its 25.5% protein content is significant for a plant-based supplement and complements higher-protein ingredients like fishmeal and soybean meal. This makes JTLM a promising alternative or supplemental protein source for cost-effective aqua feeds [34]. They also reported a similar CP value. However, Kumar *et al.* [12] reported 35.3% and 35.6% crude protein for prepared and raw JTLM. Ugbogu *et al.* [35] reported similar crude protein of 29.4% for raw *Jatropha curcas* seeds. It is a well-established fact that protein is given priority in fish feed and production. This is because, among other nutritional requirements, protein is the most required in large amounts and currently expensive amongst all [36], so replacement with a low-cost product without compromising the health of culture organisms or general production output has been a thing of great concern to aquaculturists.

The improved growth performance observed in fish fed diets containing 5% and 10% JTLM aligns with the nutritional adequacy of the protein level. It suggests that at moderate inclusion levels, JTLM can enhance the protein matrix of the feed without causing a nutritional deficiency.

Crude fibre levels in JTLM are relatively high compared to conventional fish feed ingredients. High fibre content can be detrimental to nutrient digestibility and feed conversion, especially in carnivorous fish like *C. gariepinus* that are not well-equipped to digest large amounts of cellulose and lignin [37]. The decreased growth and increased feed conversion ratio (FCR) observed at the 20% inclusion level in this study may be linked to the high fibre content of JTLM. However, fibre also plays a functional role in gut motility and detoxification. At lower inclusion levels (e.g., 5-10%), the fibre may aid digestion without negatively affecting performance, which supports the higher specific growth rate (SGR) and better FCR observed in these treatments. Excessive fibre, as present in the 20% JTLM diet, likely exceeded the digestive threshold for *C. gariepinus*, leading to reduced feed utilization efficiency and growth. High fibre can reduce nutrient digestibility and increase FCR, especially in carnivorous fish like *C. gariepinus*[37].

According to NRC [38], the Crude Fat content of JTLM is modest, indicating the presence of beneficial lipids such as unsaturated fatty acids. Lipids are essential for energy supply, membrane structure, and hormone production in fish [38]. This level is considered modest, providing sufficient energy without risking fat accumulation in tissues. The moderate fat level could explain why diets with JTLM supported reasonable growth without leading to lipid accumulation, especially at 5% and 10% inclusion. Additionally, *Jatropha tanjorensis* is known to contain phytochemicals such as flavonoids and saponins, which may offer antimicrobial and antioxidative benefits, potentially improving overall fish health [39].

The ash content represents its total mineral composition. The observed value (9.5%) is acceptable and suggests the presence of essential minerals such as calcium, potassium, magnesium, and phosphorus. Although, thorough screening was not done to that effect, several studies have presented ash content to comprise such minerals [38].

The moisture content was within safe limits for storage and feed formulation. Moisture above 12% can promote microbial growth and reduce shelf life [40]. The 9.8% moisture observed suggests that the drying and storage conditions were adequate to maintain feed quality. This supports the high survival rates recorded in all treatment groups and suggests that spoilage or feed contamination was not a factor influencing growth outcomes.

The NFE reflects the carbohydrate fraction of the leaf meal. While carbohydrates are not essential nutrients for fish, they can provide an inexpensive source of energy, sparing proteins for growth and tissue synthesis. However, *Clarias gariepinus* has a limited capacity to digest complex plant polysaccharides, so excessive NFE could reduce feed efficiency [40].

The high NFE in JTLM suggests that at higher inclusion levels (20%), excessive carbohydrates may have diluted the energy-protein balance, contributing to reduced performance. In contrast, at 5–10% inclusion, the carbohydrate contribution likely complemented protein energy metabolism effectively, which may explain the better growth indices in those groups [41].

Water quality remained stable and within optimal ranges throughout the trial, as recommended by APHA [27]. Mean temperature in all plastics was ~27–28 °C (optimal 23–32 °C for *C. gariepinus* and no treatment differences were observed ($p>0.05$). Similarly, pH was maintained at a neutral level (6.7-7.0) in all groups (permissible 6.0–9.0), with no significant difference ($p>0.05$). DO remained ≥4.8 mg L^{-1} in every plastic, which was above the minimal requirement (3 mg L^{-1}). Other parameters, such as conductivity, total suspended solids, and BOD, showed slight increases with higher Jatropha inclusion. This was likely attributed to organic load from undissolved materials. However, conductivity <500 µS cm^{-1}, TSS <50 mg L^{-1}, and BOD <10 mg L^{-1} were all below critical limits. These results were similar to studies of formulated feed utilization on *Clarias gariepinus* Fingerlings [42]. The recorded values for temperature, DO, and pH fell within the optimal requirements for freshwater fish production [43, 19].

Parameters like temperature, pH, DO, and BOD remained within acceptable limits [28]. Slight increases in BOD and TSS in the 20% JTLM group were likely due to undigested plant material and organic load, as also observed by Silas *et al.* [44], Fagbenro [45], and Al-Thobaiti [46].

The present study on the growth status of *Clarias gariepinus* fingerlings fed different inclusion levels of *Jatropha tanjorensis* leaf powder meal (JTLM) revealed significant differences ($p<0.05$) among treatments. Fish fed 10% JLM was considered the best in the culture of *C. gariepinus.* Studies have recorded the highest in 30% inclusion level [47]. This agrees with a previous study, which showed significantly higher growth response to plant meal when compared with commercial fish meal [46].

All groups started with similar initial weights and lengths. After 70 days, fingerlings fed 5% and 10% JTLM showed the greatest growth. Correspondingly, specific growth rate (SGR) and daily growth were highest in the 10% and 5% treatments respectively and lowest in the 20% group. These trends mirror literature showing improved growth at moderate leaf-meal inclusion as seen in Asuquo and Ifon [47]. They reported specific growth rate (SGR) increased with the increase levels of *J. tanjorensis* inclusion (5.5% g day^{-1} at 30% inclusion over 4.78% in control); by analogy, our study found that the optimal inclusion range was 10%.

Feed conversion ratios (FCR) were best (lowest) in the 5%–10% groups and worst in the 20% group, indicating more efficient feed use at moderate inclusion. This agrees with Fagbenro *et al.* [45] and Al-Thobaiti *et al.* [46], who support plant-based protein inclusion for cost-effectiveness when properly processed. By contrast, the control and 20%. Protein indices followed the same pattern; highest in 10% diets (0.121 g protein g day^{-1}) and lowest at 20%. This was also a similar trend in the results from Asuquo and Ifon [47].

These patterns are consistent with other studies showing moderate inclusion of Jatropha leaf meal of similar plant supplements; same genus [48]. They submitted that Jatropha can improve catfish growth. He added that 10% *Jatropha curcas* meal yielded the highest weight gain and lowest FCR in *C. gariepinus,* and Adesina *et al.* [49] reported maximal SGR (1.56% g day^{-1}) and best FCR for a 20% Jatropha diet, with declines at higher levels.

Condition factor K remained within normal range (>1.0) for all groups; fish in the 0% (1.70) and 20% (1.33) groups had slightly higher than the 5% and 10% groups, which reflected their lower length-weight ratios.

Survival was high across treatments, with a slight reduction at 20% (75.0%), likely due to higher anti-nutritional effects at high leaf levels. These growth patterns are consistent with reports on *C. gariepinus* fed levels of melon (*Citrillus lanatus*) seed peel meal that ranged between 82-86%. Jimoh *et al.* [50] also reported similar survival percentages of 82- 91% of Nile tilapia fed toasted *Jatropha curcas* seed meal. On the contrary, Musa *et al.* [14] reported 62-79% survival percentages of *C. gariepinus* fed processed *Jatropha curcas* kernel.

Overall, the moderate inclusion (5–10%) yielded the highest growth indices and best FCR (lowest values), whereas 20% inclusion gave significantly poorer growth. These findings agree with related studies where low to moderate leaf-meal levels enhance growth, while excessive levels can depress it [48].

The water quality values observed here are typical of healthy catfish culture [14]. The growth trends of best performance at moderate inclusion are supported by earlier reports on *J. tanjorensis* and other leaf meals [45].

Fagbenro *et al*. [45], Al-Thobaiti *et al.* [46], Asuquo and Ifon [47], and other authors showed the need to adopt plant-based protein diets in the culture of fish and other aquatic organisms. Although toxic and other anti-nutritive substances in plant-based feed can affect feed intake with attendant poor growth, drying and conversion to powder has over time, been agreed to be one of the commonest methods adopted to remove anti-nutritional factors in *Jatropha* leaf meal. This resulted in improvement of the quality of feed, reduction in the cost of production, and growth of fish. Decreased growth, higher FCR, and lower survival in a 20% inclusion level may have resulted from high fibre and anti-nutritional factors such as saponins and tannins, which become problematic at higher levels and reduce palatability and feed intake, as documented by Musa *et al.* [14] and Jimoh *et al.* [50] in related *Jatropha curcas* studies. The findings support the consensus that excessive inclusion of leaf meal suppresses performance.

3.3. Conclusion

The results revealed that diets containing 5% and 10% JTLM significantly improved growth parameters, including weight gain, specific growth rate (SGR), feed conversion ratio (FCR), and protein index, compared to the control (0%) and the 20% JTLM group. The 10% JTLM group recorded the best overall performance, indicating an optimal balance of protein supplementation and digestibility. Water quality parameters such as pH, temperature, and dissolved oxygen remained within acceptable ranges across treatments, although BOD, TSS, and conductivity showed a slight increase at 20% inclusion. This suggests a threshold above which increased plant material may begin to compromise water quality and fish health. Furthermore, fish survival and condition factor remained high across all treatments, but a notable decline in survival rate at the 20% inclusion level indicates the possible impact of anti-nutritional factors and high fiber content at excessive JTLM incorporation. The proximate composition of JTLM, especially its moderate protein (22.5%), fat (4.3%), and carbohydrate level, supports JTLM as a potential cost-effective, plant-based ingredient in sustainable aquaculture feed formulation when properly included.

3.4. Recommendations

Based on this and similar studies, it is recommended that *Jatropha tanjorensis* leaf meal be included at 5% to 10% of total feed composition for *Clarias gariepinus* fingerlings to achieve optimal growth and feed efficiency without compromising water quality or fish health. Also,

- JTLM should be well-dried, crushed, or fermented to reduce anti-nutritional factors such as tannins, saponins, and phytic acid, thereby improving nutrient availability and palatability. To enhance JTLM-based diets, it is recommended to supplement with higher-protein sources like fishmeal, soybean meal, or amino acid concentrates to meet the nutritional requirements of catfish, especially during early growth stages.
- Further studies should be conducted to examine the long-term effects of JTLM inclusion on their proximate analysis, biochemical, and haematological profiles.
- JTLM should be used in other aquaculture species, such as tilapia or *Heterobranchus spp*., for broader application.

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Conflict of Interest: The authors declare that there is ''No conflict of interest'' regarding the publication and outcomes of this research. All procedures and analyses were conducted solely in pursuit of scientific knowledge and transparency.

Ethical Approval: The authors declare that the study was conducted in accordance with all applicable international, national, and/or institutional guidelines for the care and use of animals. The research did not involve the killing of any of the fish samples. Also, the number of fish used (160 samples) did not exceed the threshold requiring ethical approval (200 samples and above) as per the local regulations. The study was performed on a private fish farm licensed by the Akwa Ibom State Government, which lies outside the jurisdiction of the Ethical Approval Research Committee in Nigeria. For these reasons, no formal ethical approval number was issued for this study.

Artificial Intelligence (AI): No AI tools were used during manuscript preparation, image creation, data collection, or analysis. Authors bear full responsibility for all content in their manuscript, including sections generated with AI tools (if any), and we are accountable for ensuring compliance with publication ethics.

Author's Contribution

EEA: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Resources, Software, Validation, Writing - original draft, Writing - review & editing

OAO: Conceptualization, Data curation, Investigation, Methodology, Resources, Supervision, Validation, Writing – review & editing

UEP: Conceptualization, Resources, Supervision, Validation, Writing - review & editing

LHD: Methodology, Resources, Funding acquisition, Validation, Writing – editing

OOF: Methodology, Resources, Validation, Funding acquisition, Writing – editing.

MSO: Conceptualization, Resources, Validation, Writing - review & editing.

All authors read and approved the final manuscript.

Data Availability

The data that support the findings of this study are available from the corresponding author on request.

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