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Cost-Effectiveness and Growth Performance of *Clarias gariepinus* Fingerlings Fed Formulated Diets Containing Enzyme and Probiotic Additives Compared with a Commercial Feed

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Abstract

Feed cost and growth performance are the two most decisive factors in the profitability of African catfish (Clarias gariepinus) production, given that feed accounts for 60–70% of total operating costs. This study compared the cost of formulating 8.34 kg of three locally compounded 45% crude protein diets one containing a commercial enzyme (Maxigrain®), one containing a commercial probiotic (Biogut® Aqua), and one without either additive against the cost of an equivalent quantity of a commercial feed (Blue Crown®), and evaluated the growth performance and feed utilisation of C. gariepinus fingerlings fed the four diets over sixteen weeks. Formulating the enzyme diet (T1), probiotic diet (T2) and additive-free diet (T4) cost ₦24,275, ₦24,345 and ₦24,175 respectively, roughly 19–24% less than the ₦30,190 cost of an equivalent amount of Blue Crown® (T3). Fish fed the enzyme diet (T1) achieved the highest final weight (35.73 g) and weight gain (32.93 g), followed by the probiotic diet (T2) (31.69 g; 29.46 g); both outperformed the commercial feed (T3), which produced the lowest final weight (14.27 g) and weight gain (11.87 g). The probiotic diet (T2) produced the best specific growth rate (2.61%/day) and the most favourable feed conversion ratio (0.43) and feed conversion efficiency (234.58). These results indicate that locally formulated diets supplemented with enzyme or probiotic additives were both cheaper to produce and more effective in promoting growth than the commercial feed evaluated, supporting their adoption as cost-effective alternatives for small- and medium-scale catfish farmers.

Keywords: *Clarias gariepinus; feed cost; cost-effectiveness; growth performance; feed additives; enzyme; probiotic*

INTRODUCTION

Aquaculture has become one of the fastest-growing food production sectors globally due to the increasing demand for fish and fishery products arising from rapid population growth and heightened awareness of the nutritional and health benefits associated with fish consumption. At the same time, global capture fisheries have declined over the years due to increase in demand for fish, thereby increasing dependence on aquaculture to bridge the widening gap between fish demand and supply (FAO, 2020). Fish remains one of the cheapest and most accessible sources of high-quality animal protein, essential fatty acids, vitamins, and minerals, particularly in developing countries where protein malnutrition remains a major concern (Gbadamosi and Olanipekun, 2020). Among the cultured fish species in Africa, *Clarias gariepinus* (African catfish) remains one of the most economically important freshwater fish species due to its rapid growth rate, high fecundity, hardiness, resistance to disease, and ability to tolerate adverse environmental conditions through accessory air-breathing organs (Geoffrey *et al.*, 2019). In Nigeria, catfish farming contributes substantially to national aquaculture production, accounting for approximately 85% of total aquaculture output (Bolorunduro, 2022). Despite this growth, the expansion of catfish aquaculture continues to face major constraints, among which the high cost of feed remains the most significant.

Feed accounts for approximately 60-70% of the total operational cost in intensive aquaculture systems (Engle *et al.*, 2020). Most commercial aquafeeds used in Nigeria are imported and expensive, thereby reducing the profitability of fish farming, particularly for small-scale farmers (Helfrich and Craig, 2022). Furthermore, the increasing scarcity and cost of conventional feed ingredients such as fishmeal have intensified the search for affordable and sustainable alternatives capable of maintaining optimal fish growth and health. In recent years, probiotics and exogenous enzymes have gained considerable attention as environmentally friendly feed additives capable of improving growth performance, nutrient digestibility, and overall fish health. Probiotics are live beneficial microorganisms that improve intestinal microbial balance, enhance nutrient absorption, stimulate immune responses, suppress pathogenic microorganisms, and improve feed utilization efficiency in cultured fish species (Tsai *et al.*, 2021). Common probiotic organisms used in aquaculture include species of *Bacillus*, *Lactobacillus*, and yeast, which are known to produce extracellular enzymes and antimicrobial compounds that enhance digestion and intestinal health (El-Saadoni *et al.*, 2021). The commercial probiotic used in the present study, Biogut® Aqua, is a consortium of beneficial microorganisms including *Bacillus* species, *Lactobacillus*, and yeast formulated to improve feed conversion efficiency and reduce mortality by limiting the proliferation of pathogenic microorganisms within the fish gut.

The increasing application of probiotics in aquaculture has been largely driven by concerns regarding the excessive use of antibiotics in fish production. Prolonged use of antibiotics in aquaculture may result in antibiotic resistance, accumulation of residues in fish tissues, and environmental contamination (Nwanna and Tope-Jegede, 2022). Consequently, probiotics have emerged as safer alternatives capable of promoting growth and enhancing disease resistance without adverse environmental effects. Previous studies have demonstrated that probiotic supplementation improves growth performance, feed utilization, survival rate, and immune responses in several cultured fish species including *Oreochromis niloticus* and *Clarias gariepinus* (Haroun *et al.,* 2022). Probiotics also contribute to enhanced digestive efficiency through the production of extracellular enzymes such as proteases, amylases, and lipases, which improve nutrient bioavailability and utilization (Ringo *et al.,* 2020).

Similarly, exogenous enzymes have become important feed additives for improving the utilization of plant-based feed ingredients in aquaculture diets. Plant-derived feed ingredients often contain anti-nutritional factors such as phytates and non-starch polysaccharides that reduce nutrient digestibility and feed efficiency (Burr *et al.*, 2021). Enzymes such as phytase and xylanase help degrade these anti-nutritional compounds, thereby increasing nutrient availability and improving fish growth performance (Maas *et al.,* 2020). Previous studies have shown that enzyme supplementation can improve feed conversion ratio, protein digestibility, and growth performance in aquaculture species by increasing the bioavailability of nutrients that are otherwise poorly utilized (Coelho *et al.*, 2024; Gopalraaj *et al.*, 2023).

Several studies have reported the beneficial effects of probiotics and enzymes in aquaculture nutrition, information comparing the effects of probiotic- and enzyme-supplemented locally formulated diets with commercial fish feeds under tropical culture conditions remains limited, particularly for *Clarias gariepinus* fingerlings. Moreover, there is inadequate comparative information on the relative effectiveness of probiotics and enzymes as feed additives in improving growth performance and feed utilization efficiency in African catfish culture systems. Such information is essential for developing cost-effective and sustainable feeding strategies capable of reducing dependence on expensive commercial feeds while maintaining optimal fish productivity.

Therefore, the present study was conducted to examine the cost-effectiveness and growth performance of *clarias gariepinus* fingerlings fed formulated diets containing enzyme and probiotic additives compared with a commercial feed (blue crown®)

MATERIALS AND METHODS

Study Location

The experiment was conducted at the Hatchery Unit of the Department of Fisheries and Aquaculture, Faculty of Agriculture, Prince Abubakar Audu University. Anyigba is located within the Guinea Savannah Ecological Zone of Nigeria between Latitude 7°48′-7°58′ N and Longitude 7°18′-7°74′ E, with an average altitude of approximately 420 m above sea level. The area experiences a tropical wet-and-dry climate suitable for aquaculture practices (Ogunremi *et al*., 2024).

Experimental Diet Formulation

The feed ingredients used in the formulation included soybean meal, fish meal, groundnut cake, wheat offal, cassava meal, bone meal, blood meal, feather meal, maize, methionine, lysine, vitamin premix, enzyme, and probiotic were procured from Khado fish market Abuja federal capital and Anyigba market, Kogi State, Nigeria.

Prior to formulation, the feed ingredients were thoroughly dried and milled into fine particles using a hammer mill to ensure homogeneity. Diet formulation was carried out using the Pearson square method in combination with trial-and-error adjustments to produce diets containing approximately 45% crude protein. Four experimental diets were prepared and designated as follows: Diet 1 (T1): Locally formulated diet supplemented with enzyme, Diet 2 (T2): Locally formulated diet supplemented with probiotic, Diet 3 (T3): Commercial fish feed (Blue Crown®) and Diet 4 (T4): Locally formulated diet without enzyme or probiotic supplementation (control). The enzyme used for Diet 1 was Maxigrain®, a commercial multi-enzyme preparation containing Xylanase and Phytase. The probiotic used for Diet 2 was Biogut® Aqua, a commercial probiotic consortium containing beneficial microorganisms including Bacillus species, Lactobacillus species, and yeast. Both additives were incorporated at an inclusion level of 0.15%. The probiotic was added after extrusion to avoid possible destruction of viable microorganisms during feed processing due to heat exposure. Feed extrusion was carried out using a double-screw inflating food machine (PE6000) at the Department of Fisheries and Aquaculture Fish Farm, Prince Abubakar Audu University, Anyigba, Nigeria. The resulting pellets were dried using feed dryer and also air-dried at room temperature and stored in airtight containers until commencement of the feeding trial.

Experimental Fish and Culture System

A total of 120 fingerlings of *Clarias gariepinus* with the average weight of 2.43 g were obtained from the Department of Fisheries and Aquaculture Fish Farm, Prince Abubakar Audu University. The fish were acclimatized for two days prior to the commencement of the experiment. During acclimatization, the fish were not fed. Feeding was also suspended 24 h before the commencement of the feeding trial to improve appetite and adaptation to the experimental diets. Twelve circular plastic bowls of 65-L capacity were used as experimental units. Each bowl contained 50 L of clean borehole water. Ten fish with the average of 2.43 g were randomly stocked into each bowl, giving a total of four treatments with three replicates each in a completely randomized design (CRD).

Feeding Trial and Fish Management

The feeding trial lasted for 16 weeks. Fish were fed their respective diets twice daily at a feeding rate equivalent to 5% of body weight. The daily feed ration was adjusted weekly following weight measurements of the fish. Uneaten feed and waste materials were removed regularly, while partial water exchange was carried out twice weekly by siphoning half of the water volume and replacing it with fresh borehole water. Fish were weighed weekly using a digital weighing balance (Model P168) to monitor weight gain. During weekly sampling, all fish from each experimental unit were removed carefully, counted, weighed collectively, and returned to clean bowls containing fresh water. Dead fish, where present, were removed and recorded throughout the experimental period.

Cost Estimation of the Formulated and Commercial Feeds

The quantity, unit price and total cost of every ingredient used in each of the three formulated diets, together with transportation, labour and other associated costs, were recorded and compiled using a simple economic-analysis table (Table 1), and compared with the cost of purchasing an equivalent 8.34 kg quantity of the commercial feed, Blue Crown®.

Growth Performance and Feed Utilization Indices

Growth performance and nutrient utilization parameters were evaluated at the end of the feeding trial according to standard procedures described by Akinwole and Faturoti (2007) as cited Gbadamosi and Adebayo (2023). The following parameters were calculated: weight gain (WG), Absolute weight gain (AWG), Percentage Weight Gain (%WG), Feed Conversion Ratio (FCR), Specific Growth Rate (SGR), Feed Conversion Efficiency (FCE), Protein Intake (P.I) and Protein Efficiency (P.E).

Weight Gain (WG)

$$\mathrm{Wf} - \mathrm{Wi}$$

Where: W_f is the final mean weight and W_i is the initial mean weight.

Percentage Weight Gain (%WG)

$$\%\mathrm{WG} = \frac{Wf - Wi}{Wo} \times 100$$

Absolute Weight Gain (AWG)

$$\mathrm{AWG} = \mathrm{Wf} - \mathrm{Wi}$$

Where D represents the duration of the experiment in days.

Specific Growth Rate (SGR)

$$\mathrm{SGR}\ \% = \frac{LnWf - LnWi}{D} \times 100$$

Feed Conversion Ratio (FCR)

$$\mathrm{FCR} = \frac{Total\ Feed\ Intake}{Total\ weight\ Gain}$$

Feed Conversion Efficiency (FCE)

$$\text{FCE} = \frac{1}{FCR} \times 100$$

Feed Efficiency (FE)

$$\text{FE} = \frac{\text{Weight gain}}{\text{Feed fed}}$$

Protein Intake (PI)

$$\text{Protein Intake (g)} = \text{Total Feed Intake (g)}\ X \frac{\%\ Crude\ Protein}{100}$$

Protein Efficiency Ratio (PER)

$$\text{Protein efficiency ratio (PER)} = \frac{\text{Weight gain (g)}}{\text{Protein intake (g)}}$$

Statistical Analysis

Data on cost were recorded and compiled using a simple economic-analysis table, data obtained from growth performance and feed utilization analyses were subjected to one-way analysis of variance (ANOVA) using SPSS statistical software package (version 2019). Where significant differences occurred among treatment means, Duncan's Multiple Range Test (DMRT) was used to separate means. Statistical significance was accepted at $P < 0.05$.

RESULTS AND DISCUSSION

Cost Estimate of the Three Formulated Feeds and the Commercial Feed (Blue Crown®)

The cost analysis showed that the formulated diets (T1, T2 and T4) were considerably cheaper than the commercial feed (T3). The formulated diets cost ₦24,275, ₦24,345 and ₦24,175 respectively, compared with ₦30,190 for the same quantity (8.34 kg) of Blue Crown®, indicating that locally formulated feeds were approximately 20–25% cheaper than the commercial diet and that on-farm feed formulation can meaningfully reduce production costs.

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This cost advantage is attributable largely to the use of locally available ingredients such as soybean meal, groundnut cake, cassava, maize, wheat offal and blood meal, which minimise transportation and procurement costs; sourcing feed ingredients locally is one of the most effective strategies for reducing feed cost in aquaculture, particularly in developing countries where imported feeds are expensive (Hua *et al*., 2019). Fish meal was the single largest contributor to feed material cost (₦11,440), consistent with reports that fish meal typically accounts for 40–60% of total feed cost in aquaculture diets because of its high protein content and limited global supply (Naylor *et al*., 2021), and that its high price continues to drive interest in alternative protein sources and locally formulated feeds (FAO, 2022).

The modest cost difference between the enzyme diet (T1) and the probiotic diet (T2) reflected the higher unit cost of the probiotic supplement (₦170) relative to the enzyme (₦100); the overall difference between the two diets remained small, indicating that functional additives can be incorporated into formulated feeds without materially increasing total feed cost (Dawood *et al*., 2018). The higher cost of the commercial feed (₦30,190) likely reflects industrial processing, packaging, branding, distribution and profit margin, all of which add to the retail price of commercial aquafeeds relative to farm-formulated feeds (FAO, 2020). Even after accounting for transportation, labour, extruder servicing, diesel and other operational expenses in the formulated diets, local feed formulation remained economically advantageous, in line with reports that small-scale fish farmers can reduce feed expenditure substantially through on-farm formulation using locally sourced ingredients (Hua *et al*., 2019).

Because feed accounts for approximately 60–70% of total operational cost in aquaculture production (FAO, 2022), the cost reduction demonstrated here has direct implications for farm profitability. Overall, the cost analysis supports the conclusion that locally formulated diets particularly those supplemented with enzyme or probiotic additives can serve as cost-effective alternatives to commercial feed without a corresponding sacrifice in nutritional quality.

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Table 1: Cost Estimate of the Three Formulated Feeds and the Commercial Feed (Blue Crown®)

Ingredients	T1			T2			T3			T4		
	Qty (kg)	Unit price (₦)	Amount (₦)	Qty (kg)	Unit price (₦)	Amount (₦)	Qty (kg)	Unit price (₦)	Amount (₦)	Qty (kg)	Unit price (₦)	Amount (₦)
Blue Crown (commercial)	-	-	-	-	-	-	8.34	3,500	29,190	-	-	-
Fish meal	2.08	5,500	11,440	2.08	5,500	11,440	-	-	-	2.08	5,500	11,440
Soybean meal	2.08	1,050	2,185	2.08	1,050	2,185	-	-	-	2.08	1,050	2,185
Groundnut cake	1.67	950	1,590	1.67	950	1,590	-	-	-	1.67	950	1,590
Blood meal	0.50	850	425	0.50	850	425	-	-	-	0.50	850	425
Wheat offal	0.42	650	275	0.42	650	275	-	-	-	0.42	650	275
Bone meal	0.25	1,800	450	0.25	1,800	450	-	-	-	0.25	1,800	450
Feather meal	0.42	5,500	2,310	0.42	5,500	2,310	-	-	-	0.42	5,500	2,310
Cassava	0.30	350	105	0.30	350	105	-	-	-	0.30	350	105
Maize	0.48	440	215	0.48	440	215	-	-	-	0.48	440	215
Probiotic (Biogut® Aqua)	-	-	-	0.0125	13,500	170	-	-	-	-	-	-
Enzyme (Maxigrain®)	0.0125	8,000	100	-	-	-	-	-	-	-	-	-
Methionine	0.042	6,000	255	0.042	6,000	255	-	-	-	0.042	6,000	255

Lysine	0.042	6,000	255	0.042	6,000	255	-	-	-	0.042	6,000	255
Vitamin premix	0.042	4,000	1,670	0.042	4,000	1,670	-	-	-	0.042	4,000	1,670
Transport			1,000			1,000			1,000			1,000
Labour			1,000			1,000			-			1,000
Other expenses			1,000			1,000			-			1,000
Total	**₦24,275**			**₦24,345**			**₦30,190**			**₦24,175**		

Key: Qty = Quantity

Growth Performance and Feed Utilization of *Clarias gariepinus* Fingerlings Fed Experimental Diets

The growth performance and feed utilization of *Clarias gariepinus* fingerlings fed diets containing enzyme (T1), probiotic (T2), commercial fish feed (Blue Crown®) (T3), and control diet without enzyme or probiotic supplementation (T4) are presented in Table 2. Significant differences ($p < 0.05$) were observed among treatments for most growth and feed utilization parameters. Fish fed the enzyme-supplemented diet (T1) recorded the highest final weight (35.73 ± 0.58 g) as shown in figure 1 and weight gain (33.30g), followed closely by fish fed the probiotic diet (T2) with final weight and weight gain values of 31.69 ± 0.54 g and 229.46 ± 0.52 g, respectively. The control diet (T4) produced intermediate growth performance, while fish fed the commercial diet (T3) recorded the lowest final weight (14.27 ± 0.33 g) as also emphasized in Figure 1 and weight gain (11.87 ± 0.29 g). Similarly, specific growth rate (SGR) was significantly higher in fish fed the probiotic diet (2.61 ± 0.07 % day^{-1}), followed by the enzyme diet (2.27 ± 0.08 % day^{-1}), whereas the commercial diet produced the lowest SGR (1.57 ± 0.05 % day^{-1}). These findings indicate that both enzyme and probiotic supplementation enhanced growth performance compared to the commercial and un-supplemented diets.

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Table 2: Growth performance and feed utilization of *Clarias gariepinus* fingerlings fed enzyme-supplemented, probiotic-supplemented, commercial, and control diets for sixteen weeks.

Parameter	**T1**	**T2**	**T3**	**T4**	**LOS**
Initial Weight (g)	2.43 ± 0.03^{a}	2.23 ± 0.02^{b}	2.40 ± 0.02^{a}	2.30 ± 0.03^{b}	*
Final Weight (g)	35.73 ± 0.58^{a}	31.69 ± 0.54^{b}	14.27 ± 0.33^{d}	20.14 ± 0.41^{c}	*
Weight Gain (g)	33.30 ± 0.56^{a}	29.46 ± 0.52^{b}	11.87 ± 0.29^{d}	17.84 ± 0.38^{c}	*
Percentage Weight Gain (%)	1370.37 ± 24.62^{a}	1321.97 ± 22.84^{b}	494.58 ± 14.53^{d}	775.65 ± 18.72^{c}	*
Absolute Weight Gain (g)	33.30 ± 0.56^{a}	29.46 ± 0.52^{b}	11.87 ± 0.29^{d}	17.84 ± 0.38^{c}	*
Specific Growth Rate (% day^{-1})	2.27 ± 0.08^{b}	2.61 ± 0.07^{a}	1.57 ± 0.05^{d}	1.93 ± 0.06^{c}	*
Feed Conversion Ratio	0.45 ± 0.03	0.43 ± 0.02	0.51 ± 0.03	0.48 ± 0.03	NS
Feed Conversion Efficiency (%)	222.29 ± 5.26^{b}	234.58 ± 4.81^{a}	196.53 ± 3.92^{d}	208.33 ± 4.15^{c}	*
Feed Efficiency	2.21 ± 0.05^{b}	2.37 ± 0.04^{a}	1.96 ± 0.04^{d}	2.08 ± 0.05^{c}	*
Protein Intake (g)	6.71 ± 0.22^{a}	5.63 ± 0.18^{b}	2.09 ± 0.11^{d}	3.85 ± 0.14^{c}	*
Protein Efficiency Ratio	4.96 ± 0.18	5.23 ± 0.21	5.68 ± 0.26	4.63 ± 0.17	NS
Mortality (No.)	2.67 ± 0.33^{a}	1.67 ± 0.21^{c}	1.33 ± 0.19^{d}	2.33 ± 0.28^{b}	*

The means along the rows with different letter superscript is significantly different ($p<0.05$)

Key: SEM = Standard error of mean, LOS = Level of significant, NS = Not significant, T = Treatment, T1 = Fish Fed with formulated feed containing enzyme, T2 = Fish fed with formulated feed containing probiotic, T3 = Commercial fish feed (Blue Crown), T4 = (Control) fish fed with formulated feed with no enzyme and no probiotic.

Progressive Weekly Growth Pattern of *Clarias gariepinus* fingerlings fed enzyme-supplemented, probiotic-supplemented, commercial, and control diets for sixteen weeks is shown in Figure 1

The superior growth performance observed in fish fed enzyme-supplemented diets may be attributed to improved nutrient digestibility and enhanced nutrient availability resulting from the activity of phytase and xylanase contained in Maxigrain®. Exogenous enzymes have been reported to improve the utilization of plant-based feed ingredients by degrading anti-nutritional factors such as phytate and non-starch polysaccharides, thereby increasing nutrient digestibility and promoting better growth performance in fish (Maas *et al.*, 2021; Ghodrati *et al.*, 2021). Similar improvements in weight gain and feed utilization following enzyme supplementation have been reported in catfish and tilapia fed diets rich in plant protein ingredients (Maas *et al.*, 2018). The enhanced final weight and weight gain observed in T1 therefore suggest that the enzyme supplementation improved nutrient release and feed utilization efficiency.
Fish fed the probiotic-supplemented diet (T2) also demonstrated significantly improved growth performance, particularly in terms of specific growth rate. This may be linked to the beneficial effects of Biogut® Aqua, which contains *Bacillus spp.*, *Lactobacillus spp.*, and yeast. Probiotics are known to improve intestinal microbial balance, stimulate digestive enzyme secretion, enhance nutrient absorption, and suppress pathogenic microorganisms within the gastrointestinal tract (Abdel-Latif *et al.*, 2023; Choi *et al.*, 2025). The significantly higher SGR recorded in T2 suggests improved metabolic activity and nutrient assimilation in probiotic-fed fish. Similar findings have been reported in *Clarias gariepinus* and other aquaculture species where probiotic supplementation enhanced growth performance, feed utilization, and digestive efficiency (Sathishkumar *et al.*, 2025)

Percentage weight gain differed significantly ($p < 0.05$) among treatments, with the highest value recorded in the enzyme-based diet (T1) (1370.37 ± 24.62%), and followed by the probiotic-based diet (T2) (1321.97 ± 22.84%). However, the high percentage weight gain observed in T1 may be attributed to the relatively high body weight gain of fish stocked in that treatment, since percentage growth calculations are highly influenced by weights gain. Consequently, specific growth rate and absolute growth indices may provide more reliable indicators of treatment effects in the present study. Absolute weight gain (AWG) did not differ significantly ($p > 0.05$) among treatments, although fish fed T1 and T2 numerically recorded higher daily growth rates than fish fed T3 and T4.

Feed utilization indices further demonstrated the beneficial effects of enzyme and probiotic supplementation. Although feed conversion ratio (FCR) did not differ significantly ($p > 0.05$), fish fed T2 (0.43 ± 0.02) and T1 (0.45 ± 0.03) recorded numerically lower FCR values compared to T4 (0.48 ± 0.03) and T3 (0.51 ± 0.03), indicating better feed utilization efficiency in the supplemented groups. Similarly, feed conversion efficiency (FCE) and feed efficiency (FE) were significantly higher in T1 and T2 than in T3 and T4. These findings agree with previous studies which reported improved feed efficiency and nutrient utilization following enzyme and probiotic supplementation in aquaculture diets (Sathishkumar *et al.*, 2025). Improved feed efficiency in enzyme-fed fish may result from enhanced breakdown of indigestible feed components, while probiotics improve digestive processes through microbial enzyme production and stabilization of intestinal microbiota.

Protein intake (PI) was significantly higher in fish fed T1 than in the other treatments, which corresponded with the higher feed consumption and superior growth performance observed in the enzyme-fed fish. However, protein efficiency ratio (PER) did not differ significantly among treatments, indicating that despite higher protein consumption, the efficiency of converting dietary protein into body tissue remained relatively similar across treatments. Similar observations have been reported in studies where increased feed intake and digestibility did not necessarily result in proportional increases in PER due to metabolic or physiological limitations (Shekarabi *et al.*, 2022; Adeoye *et al.*, 2016).

Mortality values were generally low across treatments, although fish fed T1 recorded slightly higher mortality ($2.67 \pm 0.33\%$) compared to other groups. Nevertheless, survival remained high overall, indicating that all experimental diets adequately supported fish health throughout the feeding period. Previous studies have shown that probiotics may contribute to reduced mortality and enhanced disease resistance through immune stimulation and competitive exclusion of harmful microorganisms (Abdel-Latif *et al.*, 2023). The relatively low mortality observed across all treatments suggests that the experimental diets were nutritionally adequate and well accepted by the fish.

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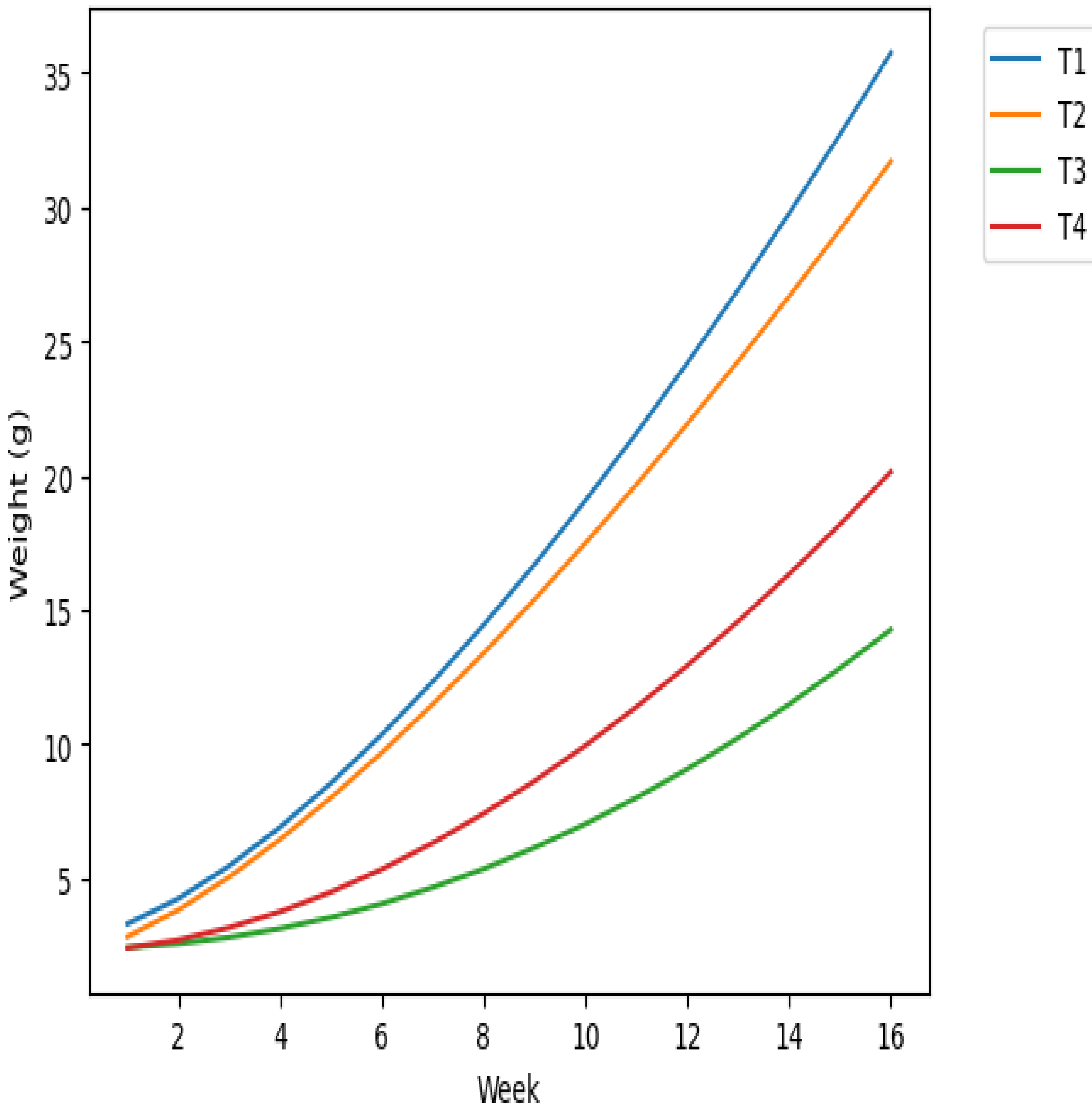
Figure 1: Progressive Weekly Growth Pattern of *Clarias gariepinus* fingerlings fed enzyme-



supplemented, probiotic-supplemented, commercial, and control diets for sixteen weeks is shown

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CONCLUSION AND RECOMMENDATION

Locally formulated 45% crude protein diets were both cheaper to produce and more effective in promoting growth of *Clarias gariepinus* fingerlings than the commercial feed evaluated in this study. Formulating 8.34 kg of the enzyme, probiotic and additive-free diets cost approximately 19–25% less than purchasing an equivalent quantity of Blue Crown®, while fish fed the enzyme- and probiotic-supplemented diets achieved markedly higher final weight, weight gain, specific growth rate and feed conversion efficiency than fish fed the commercial feed. These findings indicate that dietary supplementation with enzymes or probiotics, combined with the use of locally sourced ingredients, can deliver both an economic and a biological advantage over the commercial feed tested, supporting their use as cost-effective feeding strategies in commercial catfish production.

The study recommended that locally formulated diets supplemented with Maxigrain® enzyme and Biogut® Aqua probiotic can effectively improve the growth performance and feed utilization efficiency of *Clarias gariepinus* fingerlings, also the use of functional feed additives in locally formulated aquafeeds could serve as a sustainable and cost-effective feeding strategy capable of reducing dependence on expensive commercial feeds while enhancing catfish production efficiency.

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