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ORIGINAL RESEARCH ARTICLE

Comparative Assessment of Growth, Nutrient Utilization and Profitability of *Clarias gariepinus* (Burchell, 1822) Fed Locally Manufactured Feeds and a Foreign Feed

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ABSTRACT

In this study, 240 juvenile *Clarias gariepinus* fish fed three locally manufactured fish feeds (F2, F3, and F4) as well as a foreign feed (F1) were examined for growth performance and nutrient consumption. Three treatments and a control were administered in triplicate during the twelve (12) week investigation, which used a completely randomized design. Water samples and morphometric measurements were collected biweekly. The objectives of this study were to determine the growth performance, nutrient consumption, survival rate, and cost-effectiveness of *C. gariepinus* fed three locally produced fish feeds and a foreign feed. The findings showed that the temperature, dissolved oxygen, and pH of the water were all within the permissible range. From the feeding trials, it was observed that all samples utilized the trial diets effectively. Nonetheless, the fish given F1 gained the most weight (185.73g), followed by F2 (170.24g), F4 (166.46 g), and F3 (149.17 g). There was no discernible difference ($p>0.05$) in the fish's weight growth after consuming various feeds. The SGR showed no significant difference, where F3-fed fish had the lowest specific growth rate (3.27), whereas F4, F2 and F1-fed fish had 3.39g, 3.44g and 3.53g, respectively. Fish fed F3 had the highest survival rate (93.33%), while fish fed F4 had the lowest (88.33%). However, fish fed F1 had the highest feed conversion ratio (1.42), while fish fed F2 had the lowest (1.29). Significant difference was not observed in FCR and survival rate ($p>0.05$) across fish that were fed various feeds. Despite fish fed F1 having the highest SGR (3.53), it had the lowest net profit (₦−87.45), whereas F4 yielded the highest net profit (₦80.41, $p<0.05$) followed by F2 (₦11.6) and F3 (₦4.75). This study revealed that although the foreign feed (F1) had the best growth performance and nutrient utilization, locally manufactured feeds can be more profitable for fish farmers because they are lower in cost than foreign feeds.

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Clarias gariepinus, Feed, FCR, Growth performance, SGR.

INTRODUCTION

There is an increasing need for premium animal protein due to population expansion. Overfishing, pollution, and the degradation of aquatic habitats are all contributing factors to the significant decline in capture fisheries, clearly showing the need for increased aquaculture production to meet this demand (FAO, 2000).

Fish makes up around 37% of Nigeria's total protein needs and is the most affordable and significant animal protein source. Around 16% of the animal nutrients used by people worldwide come from fish. In areas where livestock is relatively limited, it is a crucial source of high-demand protein. (Omeru & Solomon, 2016; Sales & Janssens, 2003). Additionally, fish provide calcium, phosphorus, iron, vitamins, and thiamine. Fish can be used to supplement the high-carb diets common among low-income populations in Nigeria because they are rich in polyunsaturated fatty acids, which help lower blood cholesterol levels (FAO, 2012). In addition to being a staple of the diet, fish is a significant source of income for many people in underdeveloped nations like Nigeria. According to the FAO (2000), almost 35 million Africans (5% of its population) rely solely or in part on fishing for their livelihood.

Reports showed that 40–60% of total recurring production costs are attributable to feed, which serves as a general production input in large, semi-intensive, sustainable aquaculture systems (Falaye, 1993). According to Sogbesan and Ugwumba (2008), fish feed is deemed

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acceptable if it is readily available, easily digestible, affordable, and well-liked by fish. All nutritional components should be included in the proper amounts in high-quality fish feed (Wang *et al*., 2006). The goal of fish nutritionists is to develop a balanced commercial diet that supports optimal growth and well-being for fish. To effectively monitor the fish's feed intake and growth rate, each meal should be evaluated for its commercial feed quality. The two main feed types used by fish farmers in Nigeria are imported and locally manufactured, each with its own benefits and drawbacks. Small-scale farmers can more easily access and purchase local feeds, promoting greater inclusion in the industry. But concerns about their nutritional efficiency and quality often lead to prolonged production cycles and suboptimal growth performance (Idowu and Adepoju, 2021). However, many farmers, especially those with limited financial resources, face significant obstacles due to the high cost and limited availability of foreign feeds, which are highly regarded for their superior nutrient composition and ability to accelerate fish growth (Adedeji *et al*., 2021).

There is little empirical research on the economic effects of using local feed rather than imported feed in Nigeria, despite the fact that feed selection is crucial for aquaculture. Previous research frequently concentrates on fish growth performance or feed efficiency without sufficiently addressing the larger socioeconomic context that influences feed acceptance and utilization patterns (Yusuf *et al*., 2020). This knowledge gap affects policy development because developing interventions that improve aquaculture production and sustainability requires an understanding of the socioeconomic factors and economic trade-offs associated with feed choice.

The issue of sourcing quality fish feed has become a challenge for many aspiring Nigerian fish farmers (Oguguah & Eyo, 2007). The interaction of certain economic barriers underscores the need for a thorough investigation to better understand the combined impact on feed consumption and choice. By evaluating the financial effects of using both locally produced and imported feed in Nigeria, this study seeks to fill this research vacuum.

MATERIALS AND METHODS

Study area

A private compound in Badawa Layout, Nassarawa LGA, Kano State, served as the study site. Latitude 12° 16' 0˝ N and longitude 8° 54' 0˝ E are the compound's coordinates.

Sample size

For this investigation, 240 *Clarias gariepinus* fingerlings in total were utilized. The experimental design was in accordance with the guidelines of earlier research (e.g., De Silva & Anderson, 1995; NRC, 2011), which indicate that in aquaculture nutrition trials, three replicates per treatment and 15–30 fish per replicate are typically sufficient to identify differences in growth performance and nutrient utilization that are both biologically and economically significant. All four dietary treatments were replicated three times, with 20 fish per replicate, for a total of 240 fish, based on these criteria and logistical constraints.

Source of *Clarias gariepinus* juveniles

The juveniles of *Clarias gariepinus* were procured from Gaida commercial farm in Kumbotso LGA, Kano, and transported in a 50-litre plastic container to the study area.

Source of experimental feeds

The experimental feeds (F1, F2, F3 and F4) were purchased from Tarauni market along Sabo Bakinzuwo road, Tarauni LGA, Kano.

Proximate composition of experimental feeds

The proximate composition of the experimental feeds (F1, F2, F3 and F4) was obtained from the nutrition information on the commercial feed's bag.

Experimental tanks

White plastic tanks were used in his experiment as they make it easier to observe fish behaviour and health due to better visibility. Twelve tanks were used, three for each experimental diet, each containing 20 *Clarias gariepinus* juveniles.

Experimental Design

Four treatments were administered in triplicate (three replicates per treatment) within a fully randomized experimental design. Before the trial started, the 240 fish samples, twenty fish samples in all twelve tanks (three replicates for all four treatments), were acquainted with the feeds for two weeks. Prior to the commencement of the study, the samples were starved for 1 day to prepare them for the experimental diet (Eyo & Ekanem, 2011).

Fish in units T1 were fed with feed 1(F1), units T2 with feed 2 (F2), units T3 with feed 3 (F3) and units T4 with feed 4 (F4). In the first two months, 5% of the sample's body weight was fed, and in the third month, 3%. The feeding was divided into 2 to 3 daily sessions. The study lasted for a period of three (3) months.

Data collection

The collection of water samples and measurement of the fish's body weight and standard length in each experimental unit were repeated biweekly for a period of three (3) months.

Water quality was measured using a water quality testing kit, and the weight of randomly selected fish and the feed given to the fish were measured using a digital weighing balance. The standard length of randomly selected fish was measured using a plastic ruler.

Food Utilization and Growth Performance Indices

Mean Weight gain (Adikwu, 2003)

MWG = W2-W1……………………………………..**I**

Where MWG = Mean weight gain, W1 = initial average weight and W2 = final average weight.

Specific growth rate (SGR) (Hepher, 1988)

$$\frac{\log w2 - \log w1}{t} \text{X}100 \ldots\ldots\ldots\ldots\mathbf{II}$$

Condition factor (Wilson, 2002)

$$K = \frac{100xw}{l3} \ldots\ldots\ldots\ldots\mathbf{III}$$

Where, K = Condition factor
L = Length (cm)
w = Body weight of the fish

Survival rate (%) (Akinwole and Faturoti, 2006)

$$SR = \frac{Initial\ number\ of\ fish\ stocked - mortality}{Initial\ number\ of\ fish\ stocked} \text{ x } 100\ldots\mathbf{IV}$$

Feed Conversion Ratio (g) (FCR) (De Silver and Anderson, 1995)

$$FCR = \frac{weight\ of\ feed\ given\ (g)}{Final\ weight\ gain\ (g)} \ldots\ldots\ldots\ldots\mathbf{V}$$

Cost-effectiveness (Akinwole *et al.*, 2006)

$$CE = \frac{Cost\ of\ feed\ (N)}{weight\ gain\ (g)} \ldots\ldots\ldots\ldots\mathbf{VI}$$

Economic weight gain (g) (Fagbenro *et al.*, 2003; Fasakin *et al.*, 2005)

$$EWG = \frac{Weight\ gain\ (g)}{Total\ feed\ cost\ per\ fish\ (₦)} \ldots\ldots\ldots\ldots\mathbf{VII}$$

Statistical Analysis

Fish length and weight data were analyzed using SPSS (version 20). One-way ANOVA was used to evaluate and compare growth performance. Water quality, nutrient utilization, and cost-benefit analysis were also analyzed using one-way ANOVA, all performed in Microsoft Excel (version 16) at the 5% level of significance. Duncan's Multiple Range Test (DMRT) was applied as a post hoc test in SPSS to separate the means when significant differences were observed. The length-weight relationship was determined using regression analysis in Microsoft Excel based on standard models.

RESULTS

Experimental Feeds Proximate Composition

Table 1 presents the proximate composition of the experimental feeds. F1, F2, F3, and F4 have 45%, 45%, 40%, and 42% crude protein, respectively. Fat, ash, crude fibre, calcium and phosphorous in F1 were 9%, 6.5%, 3.4%, 1% and 1% respectively, in F2 8%, 8%, 2%, 1% and 1% respectively, in F3 9%, 7%, 3.5%, 1.5% and 1.1% respectively and in F4 6%, 7%, 3%, 1.5% and 0.9% respectively. The crude protein content of all the feeds is within the recommended range for fish feed production (FAO, 2017).

Table 1: Proximate Composition of Experimental Diets

S/N	Nutrients	F1	F2	F3	F4
1	Crude protein (%)	45	44	40	42
2	Fat (%)	9	8	9	6
3	Ash (%)	6.5	8	7	7
4	Crude Fiber (%)	3.4	2	3.5	3
5	Lysine (%)	1.5	-	2.3	-
6	Calcium (%)	1	1	1.5	1.5
7	Phosphorous (%)	1	1.1	1.1	0.9
8	Methionine (%)	0.5	-	1.3	-
9	Moisture (%)	-	10	-	8
10	Sodium (%)	-	0.3	-	0.3
11	Vitamin A (IU/kg)	-	-	7000	-
12	Vitamin D (IU/kg)	-	-	850	-
12	Vitamin E (IU/kg)	-	-	50	-
14	Vitamin C (mg/kg)	-	-	200	-
15	Antioxidant (mg/kg)	-	-	125	-

***Clarias gariepinus*'s Growth Performance on the Experimental Feeds**

Growth in fish is any increase in size (length and weight) after taking feed or food (Dan-kishiya *et al.*, 2018). *Clarias gariepinus*'s growth performance on experimental feeds after 84 days is presented below (Table 2). The fish fed feed 1 (F1) had an average initial weight of 10.08g, whereas the fish fed feeds 2 (F2), 3 (F3), and 4 (F4) had initial weights of 10.05g, 10.21g, and 10.25g, respectively. The fish with the highest mean final weight and weight gain were those fed commercial feed (F1) (195.81g and 185.73g respectively), followed by fish fed the commercial feed F2 with final weight and weight gain (180.29g and 170.24g respectively), then fish fed F4 with final weight and weight gain (176.71g and 166.46g respectively) and the least performing commercial feed F3 with final weight and weight gain (159.38g and 149.17g respectively) after the 84 days of the experiment. Statistical investigation, however, indicates that the growth performance of juvenile *Clarias gariepinus* does not significantly differ ($p>0.05$).

Table 2: *Clarias gariepinus*'s Growth Performance on Experimental Feeds

Parameter	F1	F2	F3	F4
Initial weight (g)	10.08	10.05	10.21	10.25
Final weight (g)	195.81	180.29	159.38	176.71
Weight gain (g)	185.73	170.24	149.17	166.46
% Weight gain	1843	1694	1461	1624
Initial Standard Length (cm)	8.88	8.88	8.70	8.44
Final Standard Length (cm)	17.82	17.8	16.59	17.03
Standard Length Gain (cm)	8.94	8.92	7.89	8.59
% Standard Length Gain	100.68	100.45	90.69	101.78

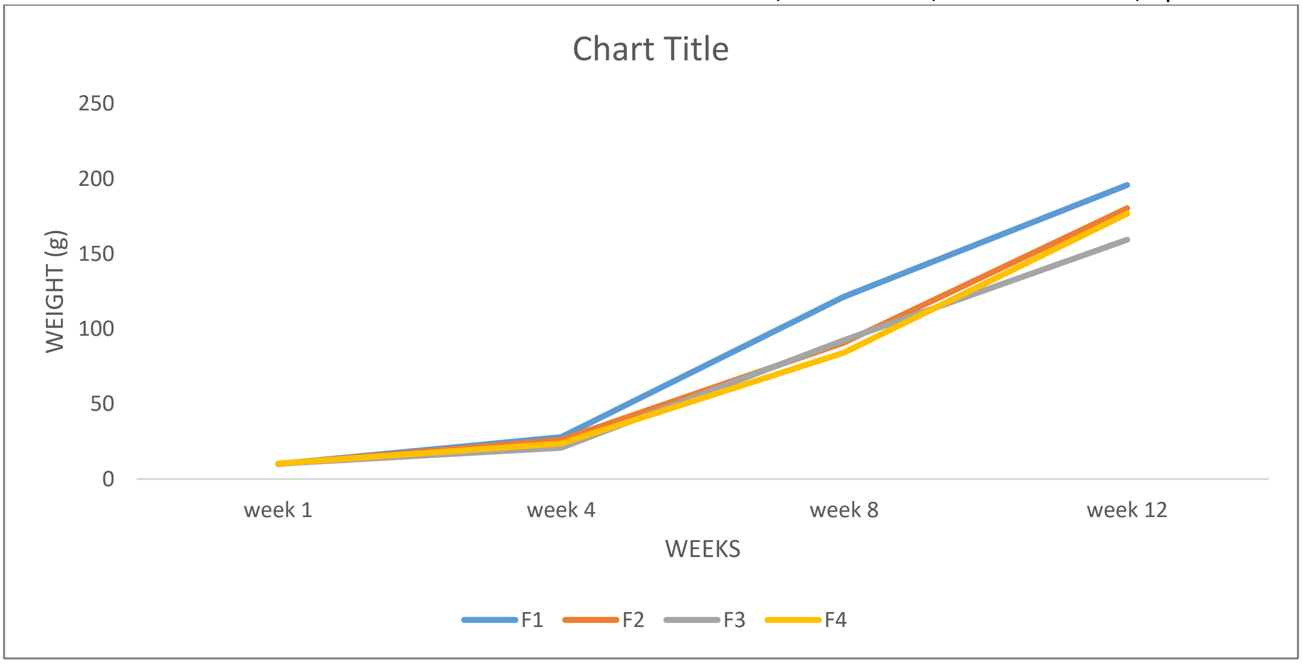

Figure 1: Line chart representing average weight increment of fish administered different feeds over a 12-week feeding trial.

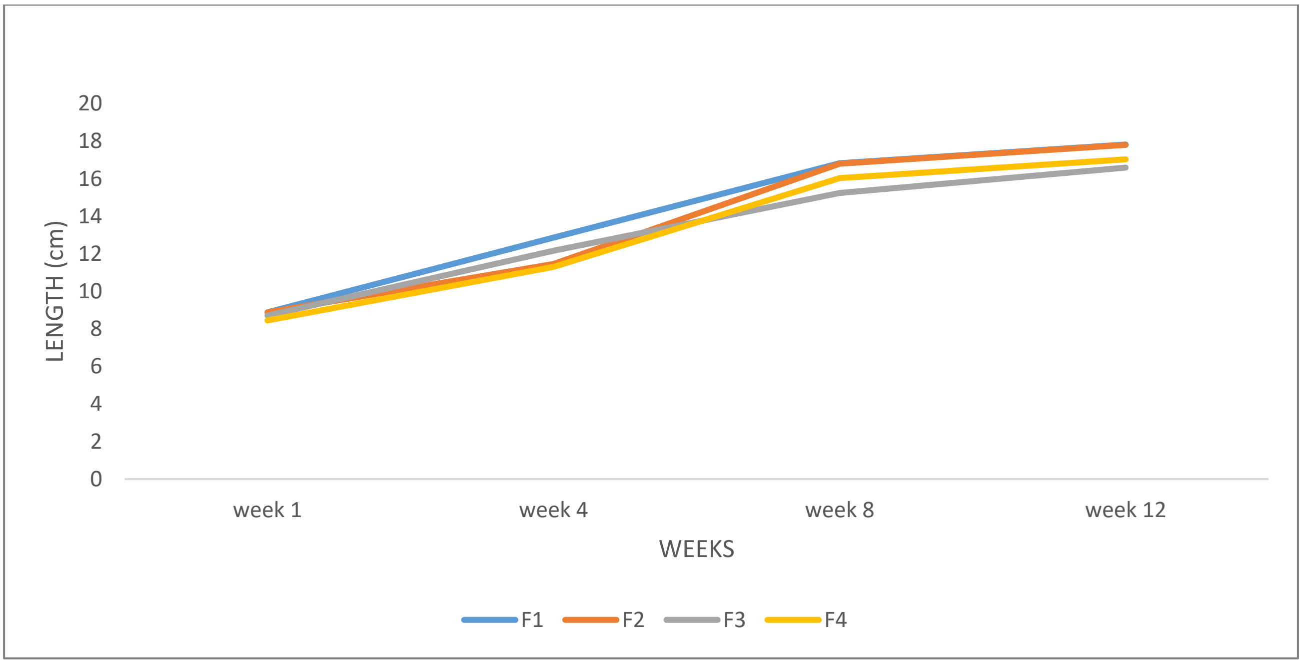

Figure 2: Line chart representing the average standard length increment of fish administered different feeds over a 12-week feeding trial.

Table 3: Condition Factor and Length-Weight Relationship of *C. gariepinus* Fed Four Commercial Diets

		Regression Coefficient				
Feed	**N**	**a**	**b**	**r**	**K**	**Growth Pattern**
F1	20	0.73	0.27	0.93	1.59	-A
F2	20	0.63	0.32	0.95	1.54	-A
F3	20	0.70	0.29	0.95	1.42	-A
F4	20	0.70	0.29	0.96	1.46	-A

b = slope/regression coefficient, a = intercept/regression constant, r = correlation coefficient, K = condition factor, and N = number of samples

Condition Factor and Length-Weight Relationship of *C. gariepinus* Fed with the Four Commercial Diets

A log-log graph of log weight against log total length was constructed, yielding a straight line (Figures 3, 4, 5, and 6).

Table 3 displayed the length-weight and condition factor data for *C. gariepinus*. The regression coefficient calculated is presented in Table 3. Figure 7 shows the monthly mean 'K' of *C. gariepinus* fed four commercial diets. Across all treatments, there is a significant positive association between the growth metrics, as the lowest value was 0.93 in F1, and negative allometric growth patterns (-A) were observed from all the treatments (F1, F2, F3 & F4)

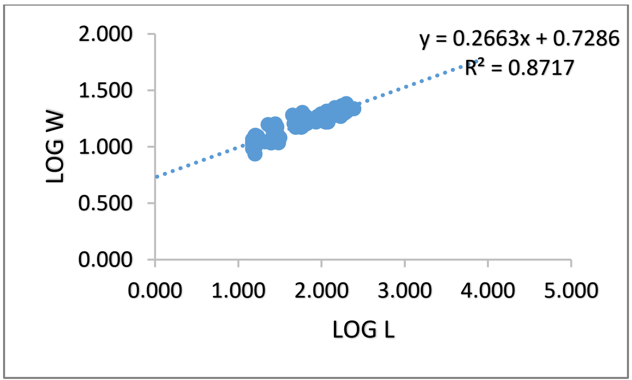

Figure 3: Length-weight relationship of *C. gariepinus* fed F1

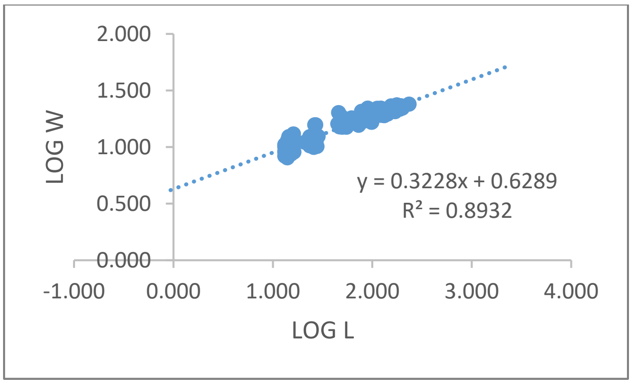

Figure 4: Length-weight relationship of *C. gariepinus* fed F2

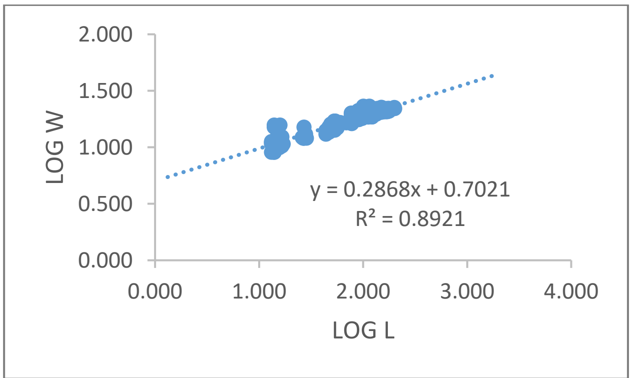

Figure 5: Length-weight relationship of *C. gariepinus* fed F3

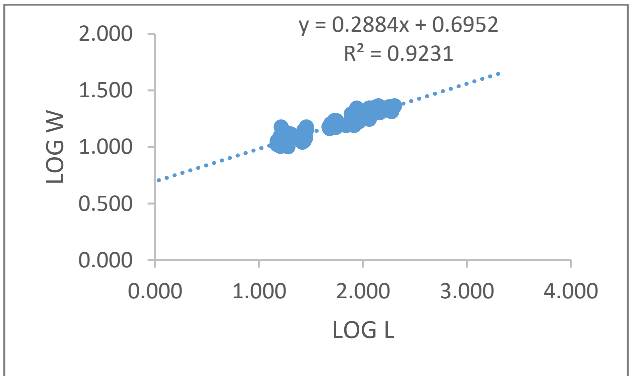

Figure 6: Length-weight relationship of *C. gariepinus* fed F4

Figure 7: Condition Factor of *C. gariepinus* fed four commercial diets

Nutrient Utilization of *Clarias gariepinus* Fed with the Experimental Diets

The outcome revealed no significant difference (p>0.05) in the specific growth rate of Clarias gariepinus across the four treatments, with F3 having the lowest specific growth rate.

The feed conversion ratio (FCR), however, ranged from 1.29 to 1.42. According to Table 4, the fish that was fed F1 had the highest FCR and the fish that was fed F2 had the lowest. The FCR of fish fed each of the experimental meals didn't differ significantly (p>0.05).

According to the survival rate displayed, fish that were fed F3 had the highest survival rate (93.33%), whereas fish that were fed F4 had the least survival rate (88.33%) (Table 4). Significant difference was not observed (p>0.05) in the survival rate of the fish that were fed with all the experimental meals.

Water Quality Parameters

The water analysis results are shown in Table 5. The parameters were within the normal range. The highest DO recorded was 5.02 mg/L in T2, while the lowest was in T1 (4.89 mg/L).

No significant difference was found (P>0.05) across all parameters among the different treatments, except for alkalinity, where T4 was significantly different from T2 and T3.

Cost Benefit Analyses of Juvenile Production using four commercial diets.

Table 6 presents the cost-benefit analysis for the production of *C. gariepinus* using the various treatments. While commercial feed (F4) had the lowest feed cost per kilogram, feeding cost, and total cost, Feed (F1) had the highest cost per kilogram, feeding cost, and total cost (₦ 1,750, ₦577.03, and ₦487.03). Table 6 below also revealed that the fish fed F4 had the highest net profit (₦80.41), followed by F2, F3, and F1 (₦11.6, ₦4.75, and ₦-87.45, respectively), in order of decreasing net profit. Statistical analysis showed net profit significantly differed (p<0.05) across all feeds.

Table 4: Nutrient Utilization of *Clarias gariepinus* Fed Experimental Diets

Parameter	F1	F2	F3	F4
Specific growth rate (g)	3.53[a]	3.44[a]	3.27[a]	3.39[a]
Feed conversion ratio	1.42[a]	1.29[a]	1.41[a]	1.34[a]
Survival rate (%)	90.00[a]	91.67[a]	93.33[a]	88.33[a]
Feed Intake (g)	278.30	232.70	225.00	236.00

Table 5: Mean Water Quality Parameters

Parameters	T1	T2	T3	T4
DO (mg/L)	4.89±0.07[a]	5.02±0.03[a]	4.97±0.10[a]	4.94±0.04[a]
pH	7.03±0.04[a]	7.11±0.01[a]	7.10±0.02[a]	4.11±0.04[a]
Ammonia (mg/L)	0.16±0.01[a]	0.14±0.01[a]	0.11±0.02[a]	0.17±0.01[a]
Temperature (ºC)	25.61±0.16[a]	25.82±0.02[a]	25.97±0.03[a]	25.81±0.01[a]
Alkalinity (mg/L)	25.32±0.17[ab]	25.74±0.05[b]	25.38±0.02[b]	27.18±.02[a]

Key: the same superscript in a row signifies no significant difference

Table 6: Cost and Benefit Analyses of Experimental Diets

Parameter	F1	F2	F3	F4
Cost of Juvenile (₦)	90	90	90	90
Cost of Feed/Kg (₦)	1,750.00	1,500.00	1,350.00	1,150.00
Feed Intake (g)	278.3	232.7	225	236
Feeding cost (₦)	487.03	349.05	303.75	271.4
Total cost (₦)	577.03	439.05	393.75	361.4
Cost of fish/kg (₦)	2,500.00	2,500.00	2,500.00	2,500.00
Average weight (g)	195.81	180.29	159.38	176.71
Economic Weight Gain (g)	2.49±0.00[a]	1.93±0.01[b]	1.90±0.00[b]	1.52±0.02[c]
Total sales (₦)	489.5±0.02[a]	450.7±0.16[b]	398.5±0.03[d]	441.8±0.17[c]
Net Profit (₦)	-87.45±0.07[a]	11.60±0.11[c]	4.75±0.07[d]	80.41±0.04[b]
Benefit Cost Ratio	0.84±0.00[c]	1.04±0.01[b]	1.03±0.02[b]	1.23±0.02[a]
Cost-effectiveness	0.84±0.00[c]	1.04±0.01[b]	1.03±0.02[b]	1.23±0.02[a]

The economic weight gain was lowest in fish fed F4 (1.52g), while F1 had the highest economic weight gain (2.49g), followed by F2 (1.93g) and then F3 (1.90g). Statistical analysis showed that F2 and F3 do not differ significantly ($p>0.05$) but differ significantly from F1 and F4 ($p<0.05$).

The highest benefit-cost ratio (BCR) was observed in fish feed F4 (1.23). The least benefit-cost ratio was observed in F1 (0.84). All treatments had significantly different benefit-cost ratios ($p<0.05$), except F3, which did not differ significantly from F2 ($p>0.05$).

DISCUSSION

Nutrient Composition of the Experimental Diets

Table 1 shows the crude protein content of the diets for each feed, which was within the recommended range (40-45%) for optimal growth of *Clarias gariepinus* juveniles (Yusuf *et al.*, 2022). It was reported that *Clarias gariepinus* and *Heterobranchus bidorsalis* require crude protein of at least 40% for normal growth (Jimoh *et al.*, 2014; Umanah *et al.*, 2019). The diets' nutritional content met the acceptable requirements for most tropical fish. For fish to grow quickly, dietary crude protein is essential in their diets (Jauncey, 1982; Oluyinka *et al.*, 2015). One of the reasons for the rapid growth observed in this study may be the amount and quality of protein in the experimental diets.

Growth Performance and Nutrient Utilization of *Clarias gariepinus* Fed Four Commercial Diets

According to Dankishiya *et al.* (2018), fish, like any other animal, take in feed and increase in size (length and weight). In this study, the Juvenile *C. gariepinus* were fed varying commercial feeds (F1-F4), and they exhibited a positive growth response in varying degrees. F1 had the highest weight gain (185.75g) and F3 the lowest (149.17g). According to the study's findings, the MWG was significantly impacted by higher dietary quantities of crude protein (Sogbesan *et al.*, 2005). The effects of dietary protein and fat levels on Arctic charr (*Salvelinus alpinus*) development, body composition, and utilization efficiency were investigated by Tabachek (1986), who reported results comparable to those reported by Tabachek (1986).

Both the specific growth rate and the feed conversion ratio were higher for the fish fed F1. This contradicts the conclusion that feed quality improves with higher SGR and lower FCR (Omeru & Solomon, 2016). Conversely, F2, F3, and F4 are consistent with the results. While F3 had the lowest SGR and second-highest FCR, F2 had the second-best SGR and the lowest FCR. (Umanah *et al.*, 2019) It has been reported that the fish use feed more effectively when the FCR is lower.

Treatment T3 had the highest survival rate, whereas treatment T4 had the lowest (88.33%). The variation in the survival rate had no apparent cause, but since most of it occurred after biweekly sampling, it might have been due to handling stress. The experimental tanks' comparatively good water quality and perhaps the fish's well-processed and maintained diet may have contributed to the treatment's high survival rate (80% and above) (Abdelhamid *et al.*, 2010).

Length-Weight Relationship of Juvenile *C. gariepinus*

The estimated regression exponent for the combined sexes showed a negative allometric growth pattern in juvenile catfish fed various types of commercial feeds. That is, both the weight and length of the fish are not increasing in equal proportion. This may be due to the fish's early age. In many research findings, *C. gariepinus* was found to exhibit allometric growth, particularly in younger individuals, due to length or weight effects, as reported by several workers (Nwazuebe and Garba, 2015; Odo *et al.,* 2009). However, there is a strong positive correlation (r), indicating that the fish growth pattern will continue to balance with increasing age. It has been noted that the length-weight relationships of various fish species show a comparable trend (Neimat, 2003; Odo *et al.,* 2009; Ibrahim *et al.,* 2012; Dan-kishiya *et al.*, 2013).

Condition factor (K)

The mean condition factor (K) recorded indicated that *C. gariepinus* was in good condition during the study period. This was attributed to the influx of nutrients from the commercial feeds tested, which, in turn, increases the potential for the species' well-being. Hence, the availability of good feed has improved the well-being of the species during the study period. Different studies (Nababa *et al.*, 2022; Frose, 2006) reported several findings on fish well-being and growth patterns. Though the mean K-value of the fish studied was greater than 1 in this study, it was also noted that F1 and F2 had the highest K-values compared with F3 and F4 (Table 3). It can be deduced from the results of this work that the age, length, and weight of fish, among other factors, can impact fish health (Nababa *et al.*, 2022; Dan-kishiya *et al.*, 2023). Ibrahim *et al.* (2012) and Dankishiya *et al.* (2023) have also identified differences in condition factor between males and females in some open waters (reservoirs). However, the condition factor of aquatic organisms is an important predictor in fisheries biology.

Physicochemical Parameters

For the fish culture of *Clarias gariepinus*, the physicochemical characteristics of the culture water in experimental tanks during this study period were ideal (APHA, 2007). Catfish need a pH of 6–9, dissolved oxygen of ≥5 mg/L, ammonia of < 8.8 mg/L, and an ideal temperature of 23–32 °C for both development and reproduction (FAO, 2000; Momoh & Solomon, 2017). The physicochemical parameters were similar in range (not significantly different) across the treatments except alkalinity. In all the treatments, the survival percentage and growth rate might have been influenced by the ideal physicochemical characteristics of water. Furthermore, the recorded values for these parameters were within normal ranges for experimental fish and for African catfish, *C. gariepinus*, culture (FAO, 2018; Ajiboye *et al.*, 2015; Loiselle, 1994; Oluyinka *et al.*, 2015).

Cost and Benefit Analysis of the Experimental Diets

Cost-benefit analysis (CBA) is a practical approach to evaluate the strengths and weaknesses of ways to achieve freedom of choice, which gives the ideal focus on successfully bringing a profit at the same time preserving savings; for instance, in transactions, activities, and functional business necessity (Umaru *et al.,* 2016).

The present study showed that the cost of feed/Kg, total cost, and feeding cost were highest in feed F1, while F4 had the lowest cost of feed/kg (also rich in nutrients) and feeding cost. This indicated that the foreign feed is the most costly and F4 is the least expensive of the experimental feeds. F1 had the highest total sales among the four treatments, as the fish with the highest WG did, while F3, with the lowest WG, had the lowest total sales. F2 had the second-best total sales value and the second-highest weight rise, right behind F1. From a different angle, F4 had the highest net profit (₦80.41) among all treatments, while F1 had the lowest (₦-87.45).

The fish given F4 had the lowest economic weight gain and the highest benefit-cost ratio. The feed is economically good if the benefit-cost ratio is higher and the economic weight gain is lower. According to Iyabo *et al.* (2007), a project is generally considered profitable, break-even, or a loss if its benefit-cost ratio is greater than, equal to, or less than 1. The fact that three out of the four experimental meals had BCRs higher than one suggests that while all of the experimental feeds are fine, some are superior. Economically speaking, F4 is good, but because it produced the second-least weight gain throughout the same period of the trial, the farmer will have to wait longer for the fish to reach table size. The revenue from fish production is estimated using gross and net yields for growth (Umaru *et al.*, 2016).

Qualitative feed, feed acceptance by the fish, and appropriate water quality are all factors that contribute to the high net profit and low economic weight gain (EWG) in fish fed F4, which, in turn, leads to improved growth performance and a high survival rate. Because the fish in this group have the highest feed utilization efficiency and the best economic value, F4 is the best feed in this study. This outcome is consistent with a study that found some inexpensive feeds to be more cost-effective than more expensive feeds that comprise conventional feed ingredients (Agbabiaka & Ezeafulukwe, 2013).

The highest benefit-cost ratio (BCR) was observed in fish feed F4 (1.23) with the net profit also highest in F4 (₦80.41). The lowest benefit-cost ratio and net profit were observed in F1 (0.84 and ₦-87.45, respectively). With the exception of F3 and F2, which are not significantly different, the benefit-cost ratio varied significantly ($p<0.05$) across all treatments.

The foreign commercial feed (F1) in this study yielded the highest Specific Growth Rate (SGR = 3.53), indicating that *Clarias gariepinus* grew more effectively. Nevertheless, it also led to a significant financial loss (-₦87.45/kg), suggesting that the high cost of the imported feed exceeded the biological benefits. Conversely, locally produced feeds (F2, F3, and F4) had positive net profits but somewhat lower SGRs (3.44, 3.27, and 3.39, respectively); F4 produced the largest profit (₦80.41/kg). These results highlight that, especially when feed prices are high, biological growth performance does not necessarily translate into economic efficiency. Aquaculture systems' profitability is frequently more affected by input costs, particularly feed, than by small variations in growth rates, as Tacon and Metian (2008) noted. Thus, choosing an economical diet that balances affordability and growth is more important in commercial catfish farming than focusing solely on maximum growth potential.

Protein Content and Feed Cost Structure: Implications for Profitability

Despite producing the highest Specific Growth Rate (SGR = 3.53) and the highest crude protein content (45%), Feed F1 (the foreign commercial feed) resulted in a large financial loss (-₦87.45/kg). This result highlights a significant economic trade-off: whereas higher protein levels generally improve growth performance, they also increase feed costs, which, if not economically justified, may outweigh the biological benefits (NRC, 2011; Hardy, 2010). The locally prepared diets (F2, F3, and F4), which had protein values between 40% and 44%, produced significantly lower SGRs (3.27–3.44) but positive net profits; the largest profit (₦80.41/kg) was recorded with F4.

This suggests that achieving a balance between feed affordability and protein incorporation is just as important for economic sustainability as maximizing growth. In addition to raising feed costs, excessive protein in the diet can lead to inefficiencies because fish excrete excess nitrogen from their food, resulting in waste and environmental issues (Tacon & Metian, 2008). In terms of profitability and cost-benefit efficiency, F4's performance demonstrates that a moderately protein-rich feed with a lower cost structure can outperform a high-protein, expensive feed.

CONCLUSION

According to the current investigation, the fish fed foreign feed F1 exhibited the best nutrient utilization and growth performance. Despite the negative allometric growth across the four treatments, which was attributed to the age of the fish, there is evidence of good well-being, as the K value for all samples was greater than 1. Additionally, juvenile catfish fed F1 feed had the poor feed conversion ratio.

All measured physicochemical properties were within the normal range for fish production. The survival rate in this research is high, as all treatments have survival rates above 80%. This could be due to the high quality of the water and the qualitative feeds used in the research. Economically, this study revealed that locally manufactured feeds are more effective than foreign feeds, as F4 yielded a profit of ₦80.41, which is better than F1, the foreign feed, with a loss of ₦-87.45. This is due to the lower feed cost and a good FCR, which made it more cost-effective.

This study's short duration and limited reproducibility may have limited the extent to which the findings can be applied. To confirm these results, lengthier trials with more replicates should be used in future studies.

RECOMMENDATIONS

The present study led to the following suggestions.

1. There is a need to extend the study period to a complete culture cycle (4-6 months).
2. These feeds need to be tested on other species to confirm the FCR observed in this study.
3. There is a need to invest more in research on fish feed technology to enhance local fish production at low cost and with higher profits.

AUTHOR CONTRIBUTION

Each author made a contribution to the research: Dr Auta Timothy and Abdulsalam Nababa were involved in the design of the manuscript, the choice of methodology, and laboratory work. Dr Auta Timothy participated in the statistical analysis. The paper has been read and approved by all authors.

CONFLICT OF INTEREST

The authors have no conflicts of interest. The contents of the work have been examined and approved by all co-authors, and no financial interest has to be declared. The submission is original, and no other publisher is considering it, we attest.

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