



Comparative Assessment Studies on Different Feed Formulation Methods with Novel Aquafeed Software in African Catfish, *Clarias gariepinus* (Burchell 1822) Farming in Earthen Ponds

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

This study investigates the impact of a novel Aquafeed software system on the growth, nutrient utilization, and economic feasibility of production African catfish, *Clarias Gariepinus*, in earthen ponds. Being a critical species for aquaculture in many continents, optimizing feed management is essential for enhancing productivity and sustainability. Fifty (50) apparently healthy *Clarias gariepinus* fingerlings weighing (6.50-7.00 g) was allotted into each of the nine hapas and fed for a period of 72 days. During the experimental period, water quality parameters were meticulously monitored to ensure optimal conditions for the growth of *Clarias gariepinus*. The nutrient

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composition of the fish carcasses, including crude protein, lipid, ash, moisture, and nitrogen-free extract, were analyzed in to assess their nutritional status. The results revealed that the implementation of the novel FUTA Aquafeed software significantly enhanced the growth and nutrient utilization of *Clarias gariepinus* fingerlings at ($p < 0.05$) when compared to traditional formulation methods of Pearson square and Winfeed. This software- driven approach provides a more precise and tailored feeding regimen, resulting in improved fish performance. A comprehensive cost analysis underscores the economic advantages of utilizing the Aquafeed software. It demonstrates that the software not only contributes to enhanced fish growth but also reduces production costs, thus improving the overall economic viability of *Clarias gariepinus* aquaculture in earthen ponds. Aquafeed has the highest amount of water molecule of 14.43%, Protein content of 44.01% for aquafeed, Lipid content from the analyzed result state 19.21% for aquafeed, ash recorded, 17.01%, 17.79% and 16.15% for pearson, and aquafeed respectively, while fiber accumulate 0.63%, 0.78%. 1.00% pearson, windfeed and aquafeed respectively. Nitrogen Free Extract dwindle between 7.50 and 5.09%, all these buttress the fact the FUTA Aquafeeds has better performance than two others.

Keywords: Aquafeed; *Clarias gariepinus*; nutrient utilization; aquatic environments.

1. INTRODUCTION

African catfish *Clarias gariepinus* is a freshwater fish species native to Africa, it holds significant importance in the field of aquaculture for several reasons [1]. It versatile farming species is a highly adaptable and versatile species making it suitable for aquaculture in various aquatic environments, including earthen ponds, tanks, and even integrated farming systems. African catfish is known for its rapid growth rate, allowing for efficient production and relatively quick turnover in aquaculture operations [2]. This characteristic makes it a preferred choice for fish farmers looking to maximize their yields. The species has gained popularity due to its economic value, it has a market demand for its white, boneless flesh, which is considered tasty and nutritious, contributing to its profitability in commercial aquaculture. *Clarias gariepinus* exhibits a high degree of tolerance to varying water quality conditions, including low oxygen levels and suboptimal water parameters [3]. This adaptability makes it a hardy species, reducing the risk of losses in aquaculture systems. African catfish is known for its carnivorous feeding habits, readily consuming a wide range of natural and artificial diets. This adaptability in feeding preferences allows farmers to use various feed sources, including formulated feeds, to promote growth and reduce production costs [4]. *C. gariepinus* in African countries plays a crucial role in enhancing food security and providing a source of affordable protein for local communities. Its ability to be farmed in small-scale, backyard ponds also empowers smallholder farmers to participate in aquaculture. Beyond local consumption, African catfish has

export potential, contributing to the economic development of African nations by generating revenue through international trade.

According to Fischer et al. [5] importance of aquafeed in catfish farming is paramount as it directly impacts the growth, health, and profitability of catfish production. Additionally, technology plays a crucial role in optimizing feed management in catfish farming. African catfish have specific nutrient requirements for growth, reproduction, and overall health. Aqua feed is formulated to provide these essential nutrients in the right proportions, ensuring that catfish receive a balanced diet. Proper nutrition through aqua feed is vital for maximizing the growth rate of catfish. Jimoh et al. [6] added that well-formulated feeds promote efficient feed conversion, where a minimal amount of feed produces a maximum amount of fish biomass, reducing production costs. Feeding catfish with nutritionally balanced feeds helps bolster their immune systems, making them more resistant to diseases and stress. Proper nutrition can reduce the need for antibiotics and other treatments, contributing to a healthier and more sustainable farming system [7]. Advanced software tools are available for formulating catfish feeds. These tools consider the specific nutritional requirements of catfish and help farmers create customized feed formulations that maximize growth and minimize waste. Technology has given rise to automated feeding systems that can dispense feed at precise intervals and in controlled quantities [8]. This ensures that the African catfish receives their feed consistently, reducing the risk of overfeeding or underfeeding. Precision feeding systems use data and

algorithms to adjust feed delivery based on the actual needs of the catfish population. This reduces wastage and optimizes feed utilization.

The term "Novel Aqua Feed Software" refers to innovative software solutions specifically designed to optimize the management of aquafeeds in aquaculture operations. These software systems are tailored to meet the unique needs and challenges of feeding aquatic species, such as fish and shrimp, in aquaculture settings [9]. Novel aqua feed software includes sophisticated algorithms and databases that help aqua culturists formulate feeds tailored to the specific nutritional requirements of the target species. It considers factors such as the species' growth stage, water temperature, and nutrient composition to create balanced and efficient feed formulas. These software solutions ensure that the feeds provided to aquatic species contain the optimal balance of essential nutrients, including proteins, lipids, vitamins, and minerals. Nutrient optimization is critical for maximizing growth, minimizing feed waste, and reducing production costs [10]. Aqua feed software helps farmers develop and manage feeding regimens that are precise and consistent. It calculates feeding schedules based on factors like fish size, water quality parameters, and environmental conditions, ensuring that fish receive the right amount of feed at the right time. Many novel aqua feed software systems offer real-time monitoring capabilities [11]. Sensors and data collection tools are integrated into aquaculture systems to continuously monitor feeding behavior, water quality, and fish health. This data is then used to adjust feeding practices as needed.

The software assists in cost management by tracking feed consumption, calculating feed conversion ratios, and providing insights into the cost-effectiveness of different feed formulations and feeding strategies [12]. The objective of this research work is to formulate and produce fish feed using a novel aqua-feed software known as FUTA AQUAFEED and compare the biochemical components with conventional feed formulation methods, determining the growth performance and nutrient utilization of African catfish *Clarias gariepinus* reared in earthen ponds.

2. MATERIALS AND METHODS

The experiment was carried out at the Teaching and Research Farm of the Department of Fisheries and Aquaculture Technology, The

Federal University of Technology, Akure, Ondo State, Nigeria. Four hundred and fifty *Clarias Gariepinus* juveniles was obtained and were acclimatized for 7 days and fed with 2 mm on-farm made feed of 40% crude protein twice daily prior to the commencement of experiment. Completely Randomized Design (CRD) was used for the study, nine hapas with a dimension 1x1x1 m³ was used, each was embedded in an earthen pond. Three hapas per experimental diet represented replicate per experimental diet. Fifty (50) apparently healthy *Clarias gariepinus* fingerlings weighing (6.50-7.00 g) was allotted into each of the nine hapas and fed for a period of 72 days.

2.1 Preparation and Formulation of Experimental Diet

Components of feed formulated consist of soybean meal, fish meal, groundnut cake, yellow maize, vegetable oil, starch and vitamin-mineral premix. The feed was formulated using Pearson square, Winfeed software and Aquafeed software. The Winfeed software and Aquafeed software was procured from Aquafeed formulation vendors. Various ingredients to be used were weighed and grinded into fine powder separately. After grinding the ingredients into fine powder they were measured based on the percentage composition of the experimental diets and thoroughly mixed together to form a homogeneous mixture. Physico-chemical parameters like temperature, pH and dissolved oxygen was measured weekly, using HANNA Instruments to measure temperature and pH while dissolved oxygen concentration was also measured using DO meter. Proximate analysis; the proximate composition of whole body of fish and feed was determined using the standard methods of the Association of Official Analytical Chemist (AOAC, 2005). The following parameters were determined, moisture content, crude protein, fiber, lipid, ash, nitrogen free extract.

Moisture content, lipid content and fiber was determined using percentage based analysis equation as expressed below,

$$\text{Percentage of content \%} = ((W2 - W3) / W1) \times 100$$

Where;

W1 = filter paper weight

W2 = one gram (1g) of the sample

W3 = petroleum ether oil residue

Evaluation of growth performance was carried out using the following factors, weight gain WG specific Growth Rate SGR Feed Conversion Ratio FCR Feed Intake FI Protein Intake PI Protein Efficiency Ratio PER Feed Efficiency Ratio FER according to

$$\text{Weight gain (g)} = \text{Final body weight} - \text{Initial body weight}$$

$$\text{Specific Growth Rate (\%/day)} = ((\text{In final body weight} - \text{In initial body weight}) / \text{Duration of feeding}) \times 100$$

$$\text{Feed Intake (g)} = \text{Total amount of feed given (g)} \times \text{number of days}$$

$$\text{Feed Conversion Ratio} = \text{Feed intake} / \text{Weight gain}$$

$$\text{Feed Efficiency Ratio} = \text{Weight gain} / \text{Feed intake}$$

$$\text{Protein Efficiency Ratio} = \text{Weight of fish} / \text{Protein fed}$$

2.2 Statistical Analysis

Data collected were checked for normality using one-way analysis of variance (ANOVA) and homogeneity of variance using Levene's test to test for significant difference in the means using Statistical Package for Social Sciences (SPSS 22.0 for windows). Where there is significant difference, the means was separated using Duncan's multiple range test. Mean difference was considered statistically significant with a 95% confidence level and all data were presented as means \pm standard errors.

3. RESULTS AND DISCUSSION

Basic component of fish feed formulation were composed for this formulation with cognizance on percentage of food nutrient in all the food materials selected. Common feed material in Nigeria were first consider in order to actualize cost reduction in fish production. Pearson square method of fish feed formulation uses arithmetic expression to determine the required feed nutrients for specific fish species, in this case African cat *Clarias gariepinus* fish is the case study [8]. Aquafeed software was design on the principle of algorithms intertwine with deep learning on the basis of artificial intelligence AI. This make it precision more distinct than person square and other arithmetic based method of

formulation. Aquafeed software combined lower percentage of expensive feed and higher percentage of cheap feed to enhance high protein content feed than Pearson square methods.

3.1 Proximate Composition of Feed (%DM)

Proximate analysis revealed composition of moisture content in all the three feeds formulated by Pearson square, winfeed and aquafeed. Aquafeed has the highest amount of water molecule of 14.43% while winfeed has the lowest of 11.80%. Protein content ranges from 39.35% from pearson square to 44.01% of aquafeed, this was in concord with Mansour et al. [13]. Lipid content from the analyzed result state 23.24% for pearson square, 21.45 for winfeed and 19.21% for aquafeed, in the same vain ash and fiber were not left out, ash recorded, 17.01%, 17.79% and 16.15% for pearson, windfeed and aquafeed respectively, while fiber accumulate 0.63%, 0.78%. 1.00% pearson, windfeed and aquafeed respectively. Nitrogen Free Extract dwindle between 7.50 and 5.09%.

The protein content is the highest among all the feed formulated with a significant difference showing viability of the feeds in fish growth. aquafeed has the highest percentage of protein while pearson square has the lowest. This is a function of it constituents with low protein content which now affect the resultant protein content, on like aquafeed with cheap components with modratly high protein content. Mansour et al. [13] had similar result in their research to feed female *Clarias gariepinus* for meat development. Fig. 1. showed the gradient of decrease in the percentage of lipid, ash and fiber across the proximate components and between the three formulations.

3.2 Physicochemical Parameters of Cultured *Clarias gariepinus* Fingerlings Water

The physicochemical parameters of water results is presented in Table 3. The pH ranged between 7.58 – 7.6, though winfeed has the lowest pH but does not have any significant impact negatively on the growth of the cultured fish *Clarias gariepinus* since all the pH values are in the sphere of neutral on the pH scale Baek et al. [14] corroborate this in their research in African cat fish. Temperature level ranged between 27.03°C – 27.05°C which is still considered within the

range of normal or room temperature for fish breeding. The dissolved oxygen (DO) concentration ranged from 3.1 – 4.7 mg/L are still very moderate for the growth of the fingerlings.

Table 1. Gross composition of the experimental diets (g/100 g) for Culturing *Clarias gariepinus*

Ingredients	Pearson square	Winfeed	Aquafeed
Fishmeal (68%)	30.65	22.00	16.9
Groundnut cake (45%)	20.65	28.00	34.10
Soybean meal (42%)	18.65	25.00	24.00
Yellow maize (10%)	20.05	15.00	15.00
Oil	6.00	6.00	6.00
Starch	2.00	2.00	2.00
Vitamin/mineral premix	2.00	2.00	2.00
Total	100	100	100

Table 2. Proximate composition of the culturing *Clarias gariepinus*

Composition	Pearson square	Winfeed	Aquafeed
Moisture	12.09	11.80	14.43
Crude protein	39.35	43.09	44.01
Lipid	23.42	21.45	19.21
Ash	17.01	17.79	16.15
Fibre	0.63	0.78	1.00
Nitrogen Free Extract	7.50	5.09	5.20

Premix manufactured by Chemiconsult International Limited, Ikeja, Lagos, Nigeria (2023)

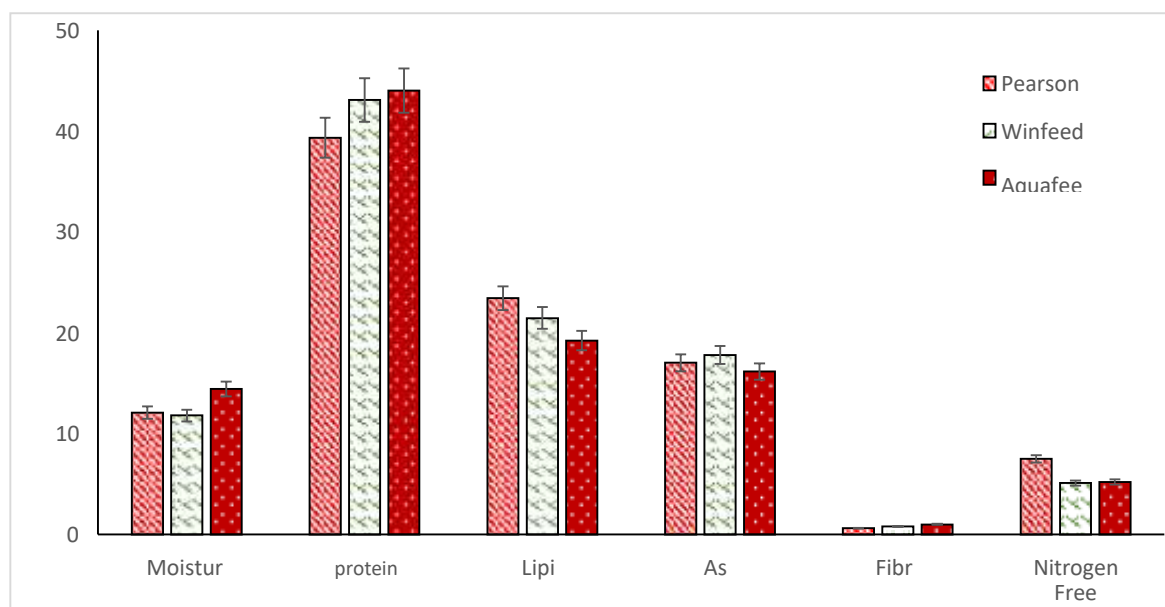


Fig. 1. Graphical representation of proximate composition result of feeds

Table 3. Physicochemical parameters of cultured *Clarias gariepinus* fingerlings in the earthen pond

Parameters	Pearson square	Aquafeed	Winfeed
Temperature (°C)	27.05±0.03	27.00±0.01	27.03±0.01
pH	7.59±0.02	7.63±0.04	7.58±0.01
Dissolved Oxygen (mg/L)	5.95±0.05	6.10±0.10	6.20±0.00

Mean ± SE, n=3. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05)

3.3 Carcass (Dry Matter) Composition of African Catfish (*Clarias gariepinus*) Fed Experimental Diets

Table 4 shows the results of carcass composition for *Clarias gariepinus* fingerlings that were fed various experimental diets. The analysis revealed that there were no significant differences in the crude protein content, ash content, and nitrogen-free extract of the fish carcasses among the groups ($P>0.05$). Among the diets, the highest crude protein content was observed in the AQUAFEED diet 32.18 ± 0.29 , while the pearson square diet had the lowest crude protein content 28.84 ± 0.29 . Notably, the initial fish had a significantly lower crude protein content compared to the fish that were subjected to the experimental diets over the course of the study. In terms of nitrogen-free extract, the WINFEED group exhibited the highest value 25.94 ± 0.78 , whereas the AQUAFEED group had the lowest value 22.83 ± 0.78 Zhang et al. [15]. Similar to crude protein, the nitrogen-free extract in the initial fish was significantly higher than that in the experimental fish that were fed the various diets. There were significant differences in the lipid content and moisture content of the fish among the experimental diet groups, this is in consonance with Zulfahmi et al. [16]. The AQUAFEED group had the highest lipid content 18.57 ± 0.49 , while the WINFEED group had the lowest lipid content 12.15 ± 0.49 . Regarding moisture content, the WINFEED group had the highest value 15.41 ± 0.51 , while the pearson square group had the lowest moisture content 10.72 ± 0.51 .

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

In Table 5, we present the growth and nutrient utilization indices observed in this study. The initial mean weight IMW did not show any significant differences ($P>0.05$) among the groups. The highest IMW was noted in the AQUAFEED group 7.15 ± 0.08 , while the lowest was observed in the pearson square group 6.31 ± 0.02 . However, the final mean weight FMW, mean weight gain MWG, and specific growth rate SGR exhibited significant differences ($P<0.05$) among the groups. The AQUAFEED group showed the highest values for FMW 34.49 ± 1.73 , MWG 27.34 ± 1.66 , and SGR 2.18 ± 0.05 , while the WINFEED group displayed the lowest values FMW: 22.22 ± 2.05 , MWG: 15.58 ± 2.03 , SGR: 1.67 ± 0.12 Fawole et al. [4]

corroborate the outcome of this study. The feed conversion ratio (FCR) varied significantly ($P<0.05$) across the groups, with the highest FCR found in the WINFEED group 2.29 ± 0.21 and the lowest in the AQUAFEED group 1.67 ± 0.09 . Furthermore, the feed efficiency ratio FER and protein efficiency ratio PER also exhibited significant differences ($P<0.05$) among the groups. The AQUAFEED group had the highest values for both FER 0.60 ± 0.01 and PER 0.80 ± 0.07 , whereas the WINFEED group had the lowest values FER: 0.44 ± 0.06 , PER: 0.50 ± 0.08 .

These findings collectively demonstrate variations in growth and nutrient utilization indices among the different diet groups in the study. The growth indices in this study revealed significant differences ($P<0.05$) in the mean weight gain and specific growth rate of fish fed experimental diets. The highest mean weight gain and specific growth rate were observed in the AQUAFEED group, followed by the WINFEED group, while the pearson square group exhibited the least growth. This difference in growth can be attributed to the superior composition of AQUAFEED, which contains a high crude protein content of 44.01%. Previous research of Mansour et al. [13] reported that some commercial feeds emit stronger odors and possess different palatability factors that enhance their acceptability to fish. This, in turn, increases the fish's feed intake, leading to improved growth. The findings of this study align with the research conducted by Shadyeva et al. [11] who observed high growth performance in *Clarias gariepinus* when fed commercial-based feeds compared to fish fed locally formulated feeds using the pearson square method of formulation. These results emphasize the importance of feed composition and quality in influencing the growth and performance of fish in aquaculture, with commercial feeds like AQUAFEED and WINFEED showing notable advantages in this study.

Table 5 within this study provides a comprehensive breakdown of the ingredient costs for each treatment. Yellow maize, serving as the energy source, was procured from Farm Support Feed Mill in Akure. Vegetable oil was sourced from Oja Oba in Akure, Ondo State. The protein sources, which include fish meal, soya bean meal, and groundnut cake, were acquired from Farm Support Feed Mill in Akure, Ondo State. Cassava starch was obtained from Isinkan Market in Akure, Ondo State, while the vitamin/mineral premix was sourced from Farm

Table 4. Carcass (dry matter) composition of fed experimental diets on African catfish (*Clarias gariepinus*)

Parameters	Initial	Pearson Square	Aquafeed	Winfeed
Moisture	14.87±1.21 ^b	10.72±0.51 ^a	11.52±0.51 ^a	15.41±0.51 ^b
Crude protein	23.98±0.29 ^a	28.84±0.29 ^b	32.18±0.29 ^b	29.62±0.29 ^b
Crude lipid	6.16±1.32 ^a	16.57±0.49 ^c	18.57±0.49 ^c	12.15±0.49 ^b
Ash	16.20±2.55 ^a	19.40±0.47 ^a	15.45±0.47 ^a	17.41±0.47 ^a
NFE	38.78±0.84 ^b	25.01±0.78 ^a	22.83±0.78 ^a	25.94±0.78 ^a

Mean ± SE, n=2. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05)

Table 5. Growth performance and nutrient utilization of *Clarias gariepinus* fingerlings fed experimental diets

Parameters	Pearson square	Aquafeed	Winfeed
Initial Mean Weight	6.31±0.02	7.15±0.08	6.64±0.02
Final Mean Weight	24.02±1.46 ^a	34.49±1.73 ^b	22.22±2.05 ^a
Mean Weight Gain	17.71±1.44 ^a	27.34±1.66 ^b	15.58±2.03 ^a
Specific Growth Rate	1.85±0.08 ^a	2.18±0.05 ^b	1.67±0.12 ^a
Feed Conversion Ratio	2.11±0.15 ^{ab}	1.67±0.09 ^a	2.29±0.21 ^b
Feed Efficiency Ratio	0.48±0.05 ^a	0.60±0.01 ^b	0.44±0.06 ^a
Protein Efficiency Ratio	0.61±0.06 ^a	0.80±0.07 ^b	0.50±0.08 ^a

Mean ± SE, n=50. Values with same superscripts letter(s) in the same row are not significantly different (P>0.05)

Table 6. Cost of ingredients per treatment

Ingredients	Pearson Square(₦/kg)	Winfeed(₦/kg)	Aquafeed(₦/kg)
Fishmeal	827.55±135.51 ^b	594.00±65.40 ^a	456.30±65.40 ^a
Soybean meal	92.93±15.60 ^a	112.00±22.10 ^b	136.40±21.32 ^{ab}
Groundnut cake	74.60±11.40 ^b	112.50±14.49 ^a	108.00±15.33 ^a
Yellow maize	60.15±1.08 ^b	45.00±0.22 ^c	45.00±0.22 ^c
Veg. Oil	96.00±0.00 ^a	96.00±0.00 ^a	96.00±0.00 ^a
Vit/Min Premix	50.00±0.00 ^a	50.00±0.00 ^a	50.00±0.00 ^a
Starch	20.00±0.00 ^a	20.00±0.00 ^a	20.00±0.00 ^a
TOTAL (TFI)	1221.23±23.94 ^b	1029.50±14.74 ^a	911.70±14.75 ^a

Values with same superscripts letter(s) in the same row are not significantly different (P>0.05)

TFI: Total Cost of Feed Ingredients

Table 7. Cost of feed preparation

Preparation	Locations	Cost (₦)
Transportation	Farm support, Road block	300
	Oja oba	150
	Isinkan market	250
Grinding	Isinkan market	1000
Workmanship	Farm support, Road block	1700
TOTAL (TFP)		3400

TFP= Total cost of feed preparation

Support in Road Block, Akure. Significant differences (P>0.05) were noted in the cost of fish meal across all treatment groups. The highest cost was observed in the pearson square treatment 827.55±135.51, while the lowest cost was found in the AQUAFEED treatment 456.30±65.40 across the treatments.

The highest cost was associated with the AQUAFEED treatment, while the Control group had the lowest cost. Groundnut cake costs displayed significant variability (P>0.05) among the treatments, with the highest price recorded in the WINFEED treatment and the lowest in the pearson square treatment. Furthermore, there

Table 8. Cost of feed

Ingredients	Pearson Square(₦)	Winfeed(₦)	Aquafeed(₦)
Fish meal	827.55	594.00	456.30
Soybean meal	92.93	112.00	136.40
Groundnut cake	74.60	112.50	108.00
Yellow maize	60.15	45.00	45.00
Vegetable Oil	96.00	96.00	96.00
Vit/Min Premix	50.00	50.00	50.00
Starch	20.00	20.00	20.00
TFP	3400.00	3400.00	3400.00
TOTAL (CF)	4621.23	4429.50	4311.70

TFP= Total cost of feed preparation

were significant differences in the prices of yellow maize across the treatments, with the WINFEED and AQUAFEED treatments having the lowest prices and the Pearson Square treatment having the highest cost. Conversely, the costs of vegetable oil, vitamin-mineral premix, and starch did not exhibit significant differences across the treatments. The mean total cost of feed ingredients (TFI) per treatment also displayed significant differences ($P > 0.05$), with the highest total cost observed in the Pearson Square treatment 1221.23 ± 23.94 and the lowest total cost in the AQUAFEED treatment 911.70 ± 14.75 , Nankinga et al. [7] made a similar observation in their research on tilapia feeding.

4. CONCLUSION

The study found that water quality parameters remained within recommended ranges and did not adversely affect the growth of *Clarias gariepinus* juveniles. The nutrient composition of the experimental fish carcasses (crude protein, lipid, ash, moisture, and nitrogen-free extract) fell within acceptable levels for this species. Furthermore, utilizing AQUAFEED for feeding *Clarias gariepinus* fingerlings improved their growth and nutrient utilization compared to other feeding methods. Cost analysis revealed that using AQUAFEED was a cost-effective choice compared to Pearson Square and WINFEED methods, reducing expenses while still meeting the nutritional needs of *Clarias gariepinus* fingerlings. These findings suggest that employing AQUAFEED software can help reduce the reliance on imported fish feed tailored for tropical fishes like the African mud catfish (*Clarias gariepinus*). This, in turn, could enhance productivity and profitability in Nigeria's aquaculture industry by optimizing costs and nutrient requirements without compromising feed quality.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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