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Original Article

Effect of size heterogeneity on the growth and production economics of African Catfish

OPEN ACCESS

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ABSTRACT

This study aimed to evaluate the impact of size heterogeneity on the growth and production economics of African Catfish (*Clarias gariepinus*). The experimental fish were divided into two treatment groups - homogenous and heterogonous - with different feeding time intervals morning hour (08.00am) afternoon hour (1:00pm) and evening hour (6:0pm) respectively. Each treatment had two replicates with 20 fish per replicate. The fish were fed with a commercial feed (coppens) at 5% for 8 weeks and 3% (for 8 weeks) of their body weight to the end of the experiment. The results showed significant differences ($p<0.05$) in the growth rate, and economic aspects of the experimental fish. The heterogeneous group had the highest growth rates in various parameters, while the homogenous group had the highest in most economic indices. The cost implication of feeding the fish varied significantly, with the highest cost at the prevailing market price for the homogenous group. The survival rate remained consistent across the two treatments. The length-weight regression analysis showed that the b-values of 2.112 (Homogenous) and 1.945 (Heterogeneous) exhibited negative allometric growth for the different treatments. The study also revealed a strong positive correlation coefficient for *C. gariepinus*, indicating a strong association between length and weight. The study also found significant differences in the total cost of feed consumed by the fish, indicating that despite differences in the cost of fish and feed used, the profit would still be high and the feeding methods used were also economical.

KEYWORDS: *Interactive effect, Length-weight relationship, Nutrient utilization, Profitability*

INTRODUCTION

African catfish *(Clarias gariepinus* Burchel *1882) is a* species whose global production in aquaculture has markedly expanded in recent years (Baßmann *et al.,* 2023). According to Musa et al. (2020) and Permatasari *et al.* (2023), catfish is one of the freshwater species that can be raised with ease in management in an ample range of simple and advanced aquaculture production systems and also reared in many parts of the world, notably Africa, Europe and Asia. The African catfish exhibits excellent feed conversion ratio (FCR), and remarkable resilience against unfavorable environmental circumstances, such as low oxygen levels or excess nitrogen compounds (Păpuc *et al.*, 2019).

Growth which is simply expressed as an increase or addition of biomass in the entire population, is an

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important factor in aquaculture (Ataguba *et al.,* 2023). Growth in cultivated African catfish (*C. gariepinus)* stock is characterized by large size heterogeneity resulting in poor growth performance and cannibalism (Mwangi *et al.,* 2020). *C. gariepinus* displays allometric growth patterns where larger fish have higher growth potentials than small sized individuals (Davies *et al.,* 2013; Ayo-Olalusi, 2014).

Size heterogeneity is often associated with aggressive behavior since bigger fish dominate smaller ones and eventually end up cannibalizing them **(**Naumowicz *et al.,* 2017) which will depress productivity. Size heterogeneity in African catfish is a major obstacle in successful production of larger quantities of fry in the hatchery and the consequence of heterogenous size stocking is the depletion of the population due to cannibalism. (Ataguba *et al.,* 2022)**.** Musa et al. 2022 observed that individual growth, feed consumption and survival are variables identified to exhibit random pattern in intensive cultivation of African catfish.

When size heterogeneity is modest, cannibalism will be delayed, and the length of this delay depends on the degree of growth heterogeneity (Ataguba *et al.,* 2022). This phenomenon is caused by multiple internal and external factors. The external causes include temperature, food, and stocking density which also exemplify the abiotic and biological variables. Intrinsic factors include genetic influences which are essentially genotypic or phenotypic variation (Sukumaran *et al.,* 2011; Umanah & Nlewadim, 2019). Certain studies presume that variations in initial sizes are the root source of fish heterogeneity. Nonetheless, in cultured fish populations, variability in size or variance among fish of the same age seems to be a natural occurrence (Borrego-Kim *et al.,* 2020).

In aquaculture systems, size heterogeneity is a frequent occurrence that affects both ultimate output and economic yield (Dominguez-May *et al.,* 2011). A culture facility with size heterogeneity has been shown to exhibit high levels of cannibalism and conspecific competition (Ataguba *et al.,* 2022). Under-feeding decreases the growth rates through reduction in protein intake and promotes size heterogeneity (Munguti *et al.,* 2012) both of which might result in cannibalism and ultimately low yields. A common practice to reduce size heterogeneity is size-sorting (Policar *et al.,* 2015), which is performed routinely (at least biweekly) in larval and early on-growing stages (Fontaine & Teletchea, 2019).

Production in aquaculture systems depend on a combination of biological, environmental, economic and management factors (Dominguez-May *et al.,* 2011). These factors have a detrimental impact on the final production and economic yield. In order to accomplish both biological productivity and economic optimization in fish cultivation, the implementation of suitable culture management techniques is sacrosanct (Munguti *et al.,* 2021). Pertinent question on how size heterogeneity affects zootechnical performance as well as economic productivity of cultivated African catfish should be further answered in order to assist the business viability of commercial African catfish aquaculture. Therefore, the purpose of this study was to evaluate the effect of size heterogeneity on the growth and production economics of African catfish.

MATERIALS AND METHODS

Study area

The experiment was carried out in the Hatchery Unit of the Department of Fisheries and Aquatic Environmental Management, University of Uyo, Akwa Ibom State, Nigeria for a period of four (4) months spanning from January – May, 2022.

Experimental design

The trial was carried out in a freshwater stagnant-renewal aquaculture system of the Hatchery Unit of the Department of Fisheries and Aquatic Environmental Management, University of Uyo, Nigeria. The production system contains 6 plastic tanks (40-L capacity each) and were supplied with freshwater from a deep well. A total of 120 mixed sex of African catfish (*C. gariepinus*) fingerlings of a mean weight of 2.67 ± 0.0 g obtained from a reputable fish hatchery in Uyo were randomly distributed (20 fish per tank) into the 6 tanks after 1 week of acclimatization. The photoperiod (~12 hr:12 hr, light:dark) and water temperature (30.34 ± 0.15C) were maintained at ambient condition throughout the experimental period.

Two treatment groups were formed on the basis the homogeneity and otherwise, that is heterogeneity, of the individual size of fish stock. Both groups are replicated thrice and stocked with 20 fish per tank. T1 group was made up of individuals with mean weight of 2.03±0.00g while the mean weight of T2 were 2.780±0.05g. The trial lasted 15weeks during which the experimental fish were hand fed with a commercial feed (Coppens®) at a frequency of three times a day and at the rate of feed fish at 5% of the fish body weight for the first eight weeks and later reduced to 3% till the completion of the experiment. Forthnightly, the experimental fish were separately weighed and measured to adjust the quantity of feed. No grading or sorting was done during the trial.

Growth and feed utilization indices

At the end of the trial, growth performance and feed utilization were assessed by:

$IMW\ (g/fish) = Initial\ weight\ of\ fish/$
$Number\ of\ fish\ stocked$ (1)
$FMW (g/fish) = Final\ weight\ of\ fish\ harvested\ (g)/$
$No\ of\ fish\ harvested$ (2)
$Mean\ daily\ weight\ gain\ (g/day) = (FMW\ (g) -$
$IMW\ (g))/\ rearing\ period\ (day)$ (3)
$MWG\ (g) = FMW\ (g) - IMW\ (g)$ (4)
$FCR = \ Total\ weight\ of\ feed\ (g)/\ Total\ biomass (g)$
Oluwalola et al. (2019) (5)
$SGR = ((loge\ W2 - loge\ W1)/t) X\ 100$ Cui & Xie (2000); Alanara *et al.*(2001) (6)
$Survival\ (\%) = No. harvested\ /No. stocked)$ Alatise & Otubusin,(2006) (7)
$Fish\ yield\ (kg/m2) = Total\ biomass/Area\ of\ tank$ Cui & Xie (2000); Alanara *et al.*,(2001) (8)

Where, initial mean weight (IMW), final mean weight (FMW), mean weight gain (MWG), specific growth rate (SGR), survival, metabolic growth rate (MGR), feed conversion ratio (FCR), and protein efficiency ratio (PER).

Economic indices

The economic evaluations of the fish were calculated by

$PI = Total\ value\ of\ fish\ (N)/Cost\ of\ feeding$ (9)
$NPV = MWG\ (g)\ X\ Total\ survival\ (n)\ X\ Cost\ per\ kg (N)$ (10)
$ICA = \ Cost\ of\ feeding\ (N) +$
$Cost\ of\ fingerlings\ stocked\ (N)$ (11)
$GP = NPV\ (N)\ -\ ICA\ (N)$ (12)
$IC\ (N/kg) = \ Cost\ feeding\ type (N)/$
$Kg\ weight\ of\ fish\ produced$ (13)
$BCR = NPV/ICA$ (Aderolu & Oyedokun, 2008) (14)

Where: Profit index (PI), Net production value (NPV), Investment cost analysis (ICA), Gross profit (GP), Incidence of cost (IC) and Benefit cost ratio (BCR).

Statistical analyses

One-way analysis of variance was used to analyze the data for significant difference at P < 0.05 using SPSS version 20 on IBM compatible computer. Mean differences were separated with Duncan Multiple Range Test.

RESULTS AND DISCUSSION

Economic performance indices of *C. gariepinus*

Table 1 showed the summary of the results obtained for economic performance indices of *C. gariepinus* reared in plastic tanks under two treatments with replicates. The result showed significant differences (P<0.05) in the Economic Conversion Ratio (ECR) and Investment Cost Analysis (ICA). However, there were no significant differences (P>0.05) in Net Production Value (NPV), Gross Profit (GP), Profit Index (PI) and Benefit Cost Ratio (BCR).

The results from the economic indices of the experimental fish revealed that the cost of feeding was highest in the Heterogeneous group (N6545.00). The highest ECR of 9486.661, NPV (3251.893) and ICA of (6664.300), PI (0.475) and BCR (0.475) were also recorded in the heterogeneous group.

Table 1: Economic performance parameters on the two treatments of *C. gariepinus*

Parameter (All in naira)	HETERO	HOMO
Cost of feed	6545.000± 353.253^{a}	4961.250±329.414^{b}
ECR (Economic cost ratio)	9486.661±780.5717 ^{a}	6719.612±166.384 ^{b}
ICA (Investment Cost Analysis)	6664.300±353.253^{a}	5081.750±329.414^{b}
NPV (Net profit value)	3251.893±163619^{a}	1534.245±222136.2^{a}
GP (Gross profit)	-3412.407±163381.2 ^{a}	-3547.505±221807.5^{a}
PI (Profit index)	0.484±18.2784^{a}	0.308±18.32987^{a}
BCR (Benefit cost ratio)	0.475±16.41214^{a}	0.301±18.94491^{a}

Means in the same row with different superscripts are significantly different at (P<0.05)

Growth performance and Nutrient utilization parameters of *C. gariepinus*

Growth performance and nutrient utilization of *C. gariepinus* reared in plastic tanks under different treatments are presented in Table 2. The result showed no significant differences (P>0.05) in the WG, FCR, PER, SGR, FMW, MWG, RGR, MGR and RWW except for IMW. The highest WG, FCR, IMW, FMW, MWG were observed in the heterogeneous group with their respective values 3629.73±233.74137, 1.45±0.07219, 2.78±0.00, 184.26±11.69, 181.48±11.69, while the homogenous group had the highest values in PER (1.27±0.06), SGR (3.57±213.85), RGR (6.58±784.98), MGR (6.580 ±0.77) respectively.

Table 2: Growth performance and nutrient utilization parameters on the two treatments of *C. gariepinus*

PARAMETERS	HETERO	HOMO
WG (Weight gain)	3629.73±233.74137[a]	2941.8±317.33749[a]
FCR (Food Conversion Ratio)	1.45±0.07219[a]	1.36±0.06438 [a]
PER (Protein efficiency ratio)	1.19±0.06[a]	1.27±0.06[a]
SGR (Specific Growth Ratio-FINAL- % day $^{-1}$)	3.49±450.52[a]	3.57±213.85[a]
IMW (Initial mean weight-g fish $^{-1}$)	2.78±0.00[a]	2.03±0.01[b]
FMW (Final mean weight -g fish $^{-1}$)	184.27±11.69[a]	149.12±15.87[a]
MWG (Mean weight gain)	181.487±11.69[a]	147.09 ±15.87[a]
RELATIVE GROWTH RATE	6.52±400.99[a]	7.24±784.98[a]
METABOLIC GROWTH RATE -g kg $^{-0.8}$ day^{-1}	5.98±0.73[a]	6.58 ±0.77a

Means in the same row with different superscripts are significantly different at (P<0.05

Length – Weight relationship and Condition Factor for *C. gariepinus*

Total length, total weight, Correlation coefficient, regression coefficient and Condition factor K of the experimental fish under different treatments are presented in Table 3. The result showed that only correlation coefficient (r) among the treatment was significantly different (P<0.05) from others. The heterogeneous group had the highest value for condition factor K (1.16±0.06), TW (184.26±15.87), TL (26.42±0.36), and r (0.58±0.07); while the homogenous group recorded the highest value in b (2.11±0.03), and r^2(2.45±2.38) respectively.

A pool of the economic indices, nutrient utilization indices, growth performance, condition factor and length-weight relationship of *C. gariepinus* reared in plastic tanks under different treatments are presented in Table 4. The result showed no significant differences (P>0.05) in most of the parameters measured. Higher values were recorded in the heterogenous group for PI, BCR, FCR, WG, TW and TL.

Figure 1 showed a graph indicating the interacting effect of economic indices, nutrient utilization, growth parameters, length weight relationship and condition factor. ECR had the highest value for Heterogenous group while GP had the least value for the Homogenous group.

Table 3: Length – weight relationship parameters and condition factor of the experimental fish

PARAMATERS	HETERO	HOMOGENOUS
R (Correlation coefficient)	0.58±0.07[a]	0.18±0.10[b]
r^2 (regression)	0.35±0.08[a]	2.45±2.38[a]
b (Slope)	1.94±0.18[a]	2.11±0.03[a]
Condition factor K	1.16±0.06[a]	1.08±0.05[a]
TW (Total weight)	184.26±15.87[a]	149.12±11.69[a]
TL (Total length)	26.42±0.36[a]	25.14± 0.68[a]

Means in the same row with different superscripts are significantly different at (P<0.05)

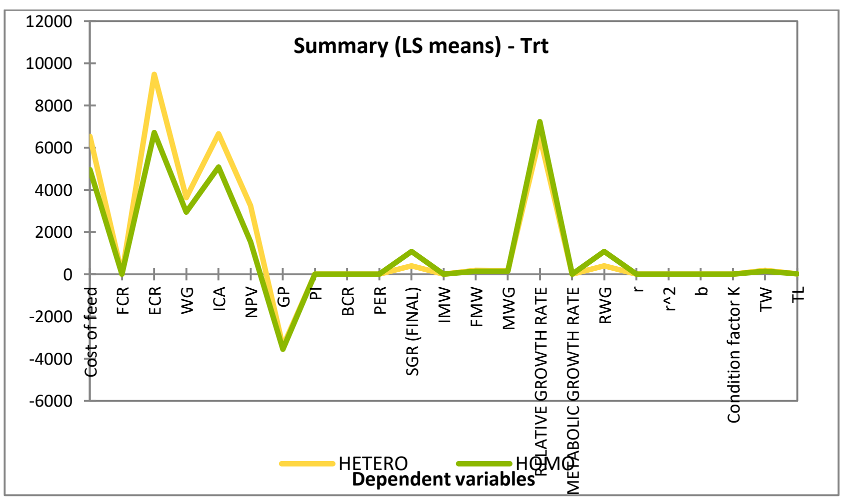

Figure 1. Interacting effect of the growth performance, nutrient utilization indices, economic performance parameter, length – weight relationship, and condition factors on the two treatments (Heterogeneous and Homogeneous) of *C. gariepinus*

Table 4: A Pool of Growth and nutrient utilization indices, economic performance indices, length – weight relationship and condition factor for *C. gariepinus* under different treatments

PARAMETERS	HETERO	HOMO
Cost of feed	6545.00±353.25^{a}	4961.25± 329.41^{b}
FCR (Food Conversion Ratio)	1.4467±0.07219^{a}	1.3633±0.06438 ^{a}
ECR (Economic Cost Ratio)	9486.6633±780.57215^{a}	6719.6133±166.38521^{b}
WG (Weight gain)	3629.7333±233.74137^{a}	2941.8±317.33749^{a}
ICA (Investment Cost Analysis)	6664.300± 353.25^{a}	5081.750±329.41^{b}
NPV (Net Profit Value)	3251.893±163618.96 ^{a}	1534.245±222136.24385^{a}
GP (Gross profit)	-3412.407±163381.16^{a}	-3547.505±221807.49^{a}
PI (Profit Index)	0.48±18.28^{a}	0.30±18.33^{a}
BCR (Benefit cost Ratio)	0.47±16.41^{a}	0.30±18.94^{a}
PER (Protein Efficiency Ratio)	1.19±0.06^{a}	1.27±0.06^{a}
SGR (Specific Growth Ratio -% day^{-1})	3.49±450.52^{a}	3.57±213.85^{a}
IMW (Initial mean weight -g fish^{-1})	2.78±0.00^{a}	2.03±0.01^{b}
FMW (Final mean weight -g fish^{-1})	184.27±11.69^{a}	149.12±15.87^{a}
MWG (Mean weight gain -g fish^{-1})	181.49±11.69^{a}	147.09 ±15.87^{a}
RELATIVE GROWTH RATE	6.52±400.99^{a}	7.24±784.98^{a}
METABOLIC GROWTH RATE-g kg$^{-0.8}$ day^{-1}	5.98±0.73^{a}	6.58 ±0.77a
r (Correlation coefficient)	0.58±0.07^{a}	0.18±0.10^{b}
^{r2} (Regression)	0.35±0.08^{a}	2.45±2.38^{a}
b (slope)	1.94±0.18^{a}	2.11±0.03^{a}
Condition factor K	1.16±0.06^{a}	1.08±0.05^{a}
TW (Total weight)	184.26±15.87^{a}	149.12±11.69^{a}
TL (Total length)	26.42±0.36^{a}	25.14± 0.68^{a}

Means in the same row with different superscripts are significantly different at (P<0.05

Figure 2 showed the graph for length-weight relationship of *C. gariepinus* which was log transformed for the heterogenous group. The y value was 0.2823x + 1.7743 while R^2 value was 0.0782

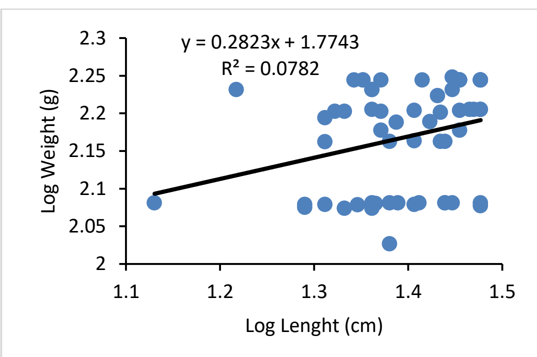

Figure 2: Log transformed graph for Length-weight relationship of *C. gariepinus* for the homogenous group

Figure 3 showed the graph for length-weight relationship of *C. gariepinus* which was log transformed for the heterogenous group. The y value was 0.2808x + 1.865 while R^2 value was 0.1653

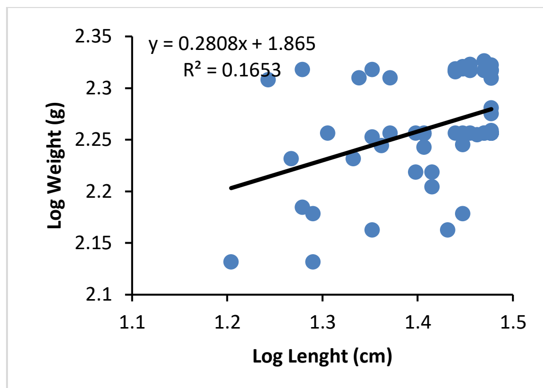

Figure 3: Log transformed graph for Length-weight relationship of *C. gariepinus* for the heterogeneous group

Data on the growth performance, nutrient utilization, economic performance indices, length weight relationship and condition factor of African catfish *C. gariepinus* reared in a plastic tank with two treatments and fed at different time intervals are presented in Tables 1 - 4. Significant differences (P < 0.05) were noticed in the feed intake, ECR, IMW and weight gain amongst other parameters of the fish in the various treatments.

Profitability from fish production is determined by the ultimate weight increase and the fish survival rate, both of which are dependent on the farmer's/investor's knowledge of fish production and the implementation of technical management methods developed over time (Oluwalola *et al.*, 2019).

The determination of growth rates in aquaculture relies on the specific growth rate (SGR) (Ataguba *et al.*, 2023). In this study, the growth rates were significantly affected by size differences (Table 2). *Clarias gariepinus* reared under different size cohort had better ECR than those that were of the same sizes. Highest WG, FCR, IMW, FMW, MWG were observed in the heterogeneous group while PER (1.27±0.06), SGR (3.57±213.85), RGR (7.240±784.98) and MGR (6.580 ±0.77) were highest in the homogenous group. This shows that the feed fed to the fish impacted the fish positively at the various time intervals of feeding. This current study showed that there were no significant differences ($P > 0.05$) in the feed conversion ratio across the two treatments. This result corroborates the findings of Oboh (2022) who also had similar observations while working on the same species.

Data on the quantitative aspects of aquatic species, such as length-weight relationships and condition parameters, are useful for research (Sadauki *et al.*, 2023). Fish's physiological information and variations reflect the condition factor designated (K) (Manikandaraja & Ananth, 2024). The condition factor (K) is a measure that reflects the interactions of biotic and abiotic elements in fish physiological conditions (Ukagwu *et al.*, 2021). Fish health and growth trends can be predicted using length-weight connections (Manikandaraja and Ananth, 2024). The length-weight relationship of fish, often known as the growth index, is a valuable fishery management tool and thus provides information about a fish's health, growth, and habitat suitability (Dos Santos *et al.*, 2022). Results for these are shown in figures 1 – 3 above.

According to Abowei *et al.* (2010), it is critical to estimate the average weight in a certain length category. Regression coefficients derived from length-weight correlations (L-W) that indicate isometric or allometric growths vary not only between species, but also within stocks of the same species (Ndome *et al.*, 2012). Generally, the exponent value ranges from 2.5 to 4.0. Growth of fishes could be negative allometric, positive allometric or isometric (Arame *et al.*, 2020). Growth is isometric when the length exponent (b-value) is equal to 3 and allometric when length exponent (b-value) is less than or greater than 3. It is negative allometry when b-value is less than 3 and positive allometry when b- value is greater than 3 (Mortuza & Misned, 2013).

In this current study, the length exponent "b" = 2.11 (Homogenous) and 1.94 (Heterogeneous) for *C. gariepinus* showed that growth was negatively allometric (Table 3). The observed negative growth pattern in this current study implied that the weight of the fish increases at a lesser rate than the cube of the body lengths. This result agrees with the studies of Sadauki *et al.* (2024), whose length-weight regression analysis revealed 'b' values of 2.81, 2.93, and 2.85, indicating a negative allometric growth for *C. gariepinus* from Ajiwa reservoir, Katsina State, Nigeria and Dan-kishiya *et al.* (2023), who reported similar negative allometric growth for silver catfish (*Bagrus bayad forskal*) in Zobe Reservoir, Katsina State. However, the negative allometry observed in this current study contradict the reports of Oluwale (2024) who reported positive allometry on *C. gariepinus* in Epe Lagoon Lagos State, Nigeria and Arame *et al.* (2020) who also detailed positive allometric growth trends in Niger River for Mochokidae. The reason for the discrepancies could be more likely due to the fact that growths differ not only between species but sometimes also between stocks of same species. Francis & Elewuo (2012) attributed negative allometric growth pattern to climatic change and temporal effects.

The result of this present study evinced strong positive correlation coefficient for *C. gariepinus* indicating a strong association between length and weight for the fish. Similar findings have been reported by authors including Mortuza & Misnad (2013), Obasohan *at al.* (2012) (*O. niloticus*), and Ayo-Olalusi (2014) (*C. gariepinus*) for different water bodies in Nigeria. According to Ndome *et al.* (2012), condition factor value greater than 1 (K >1) is an indication of good condition in fishes. In this study, the mean condition factor for, the two treatments 1.16 (Hetero) and 1.08 (homogeneous) were all greater than 1, indicating a good condition of the fish. Similar results were observed by Dan-kishiya *et al*. (2023), Mortuza & Misnad (2013), Sadauki *et al.* (2024) and Zaliha *et al.* (2023) with a mean K-value greater than 1 for catfish. The condition factor of the two treatments for *C. gariepinus* in this present study falls within the range suggested for developed fresh water fish species in the tropics.

Feed in aquaculture accounts for the largest unit cost incurred during the production phase (Hussein 2012; Sharma & Dhaker, 2017). At the end of any production system, the growth and economic viability should be evaluated to ensure acceptable performance (Oluwalola *et al.*, 2019). It will be evident whether such a production method is lucrative or not. The following economic indices are significant in fisheries science: cost of fish and feed, gross profit (GP), profit index (PI), economic conversion ratio (ECR), investment cost analysis (ICA), and benefit cost ratio (BCR. In this current study, the two treatments had an independent and interactive significant effect ($P<0.05$) on the economic indices.

Gross profits were negative across all the treatments resulting in the least economic feeding strategy (Table 1). Gross profit and profit index in this study revealed that the most economical feeding strategy would be to feed the *C. gariepinus* at 5% body weight. These findings corroborate with that of Sharma and Dhaker (2017) where the highest economic growth was obtained at the lower feeding level (8%) away from 12% feeding level. It however, contradicts with the findings of Hussein (2012) where feeding regime did not have any significant effect on economic parameters measured. There was also a significant difference ($P < 0.05$) among treatments in total cost of feed consumed by the fish in the course of the experiment The observed significant differences ($P < 0.05$) in the total cost of feed consumed were as a result of the different body weight gain of the fish in accordance to their different feed of the fish. This means that though there were significant differences ($P < 0.05$) in the cost of the fish and feed used, the profit would still be high and that the feeding methods used were also economical.

CONCLUSIONS AND RECOMMENDATIONS

The African catfish exhibits alterations in behavioral patterns in constrained environments such as ponds, aquaria, and concrete tanks when there are size differences in the stock, resulting in lower feed intake, aggression, cannibalism and death. It is widely established that when fish of different sizes are reared together, intraspecific competition and agonistic interaction increase, resulting in size heterogeneity and cannibalism. According to the current data, individual of *C. gariepinus* grow better when raised in uniformly sized grading groups. The statistics demonstrate that fish thrive better in homogenous groupings. In confined spaces. From an economic standpoint, heterogeneous group was more economical as it recorded the highest Profit index, BCR, NPV, ICA, ECR. Finally, farmers are strongly advised to stock homogeneous species since variability during seeding has a detrimental impact on system performance by lowering biomass and diminishing the quasi-profits of variable costs.

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Authors' Contributions

Author OEA had the conceptual idea, BOM was involved in the experimental layout and analysis while EU was involved in collecting data. All authors read and approved the final manuscript.

Ethical Approval: Not Applicable

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