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Comparative growth performance of *Oreochromis niloticus* (Linnaeus, 1758) in cages at different stocking densities

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Abstract
Oreochromis niloticus (23.63 ± 1.25 g) were stocked in triplicate at 50, 100 and 150 fish/m^3 to evaluate their growth performance for a period of 82 days. Fish were fed with commercial floating pellet containing 30% crude protein until harvest. Stocking density affected significantly the survival rate (81.3 to 88.6%) and gross yield. The specific growth rate (2.23 ± 0.08 %/day) and final weight (154.61 ± 12.88 g) of the 50 fish/m^3 group was significantly higher ($p < 0.05$) than 100 fish/m^3 (1.62 ± 0.11 %/day) and 150 fish/m^3 (1.42 ± 0.12 %/day). The high stocking density affected the overall size of fish, but had no negative effect on feed conversion ratio. The least feed conversion ratio (1.76 ± 0.20) was obtained in the 50 fish/m^3 group. Data support the conclusion that high stocking density affect overall size of fish and 100 fish/m^3 shows optimum growth performance.

Keywords: floating net cage; fish farming; growth rate; juveniles; Nile tilapia

Introduction
Ghana's fisheries sector plays a very significant role by providing jobs and excellent food source rich in high-quality protein, vitamins, and minerals. Fish alone accounts for over 60% of per capita animal protein intake and contributes between 3% and 4.5% of national agricultural GDP [1]. Moreover, approximately 10% of the national populations are directly or indirectly dependent on fisheries and related activities for their livelihood [1]. The average annual fish production (420,000 tonnes) is mainly from marine capture fisheries. This output is less than half of Ghana's fish requirement, which is approximately 1000,000 tonnes [2, 3]. Fish imports, valued at over US$200 million, are therefore required to meet the deficit in production [2].

Aquaculture has been promoted as having some future potential for meeting the national fish requirement. Over the years, global aquaculture has grown rapidly and the contribution of fish farming to the Ghana's fish production increased from 1.2% in 2009 to 3% in 2011 [3]. In 2012, the Government of Ghana launched the Ghana National Aquaculture Development Plan (GNADP) with the aim of increasing aquaculture production to 100,000 tonnes by the end of 2016 [2].

Nile tilapia (*O. niloticus*) is an important fish farmed globally due to its fast growth, short food chain, high food conversion ratio, ready acceptance of artificial feeds, and ease of breeding in captivity, disease resistance and high fecundity [4]. Moreover, *O. niloticus* tolerates a wide range of environmental conditions and has a good market price due to its nutritious table food quality. Majority of farmers in Ghana culture the "Akosombo strain" of *O. niloticus*, which is estimated to grow up to 30% faster than non-improved wild fish [5].

The culture of fish in Ghana used to rely mainly on extensive and semi-intensive systems in earthen ponds. However, there have been a gradual shift towards more intensive production systems using floating net cages particularly on the Volta Lake [3,6,7]. In such intensive water-based confinements, individual fish are subjected to different sources of stress due to routine husbandry practices, such as stocking, handling, capture, and sampling. The most common source of stress is inappropriate stocking density [7-9]. Stocking density is the concentration that fish are stocked into a system [10]. It directly influences fish growth, feed utilization, survival and fish health [11-17]. Rearing fish at inappropriate stocking densities may impair growth and reduce immune competence due to factors such as social interactions and deterioration of water quality, that negatively affect the feed conversion efficiency and growth of the fish [12].

In Ghana, cages were mostly stocked with *O. niloticus* fingerlings (10-30g) at densities between 60 and 150 fish/m^3 on the Volta Lake [18, 19]. However, inadequate technical knowledge on optimum stocking densities and its impacts on the success of floating cage farms has led to a diversification of stocking densities among operators [6]. The practice is also partly attributed to the scarcity of investment capital to start and sustain the business [7].

Considering that environmental conditions and farming practices of *O. niloticus* vary to a great extent from country to country, it is imperative that studies be conducted to study the effects of stocking density on the growth performance of *O. niloticus* juveniles if satisfying yields are expected in Ghana's cage culture industry. This study, therefore aimed at determining the impacts of stocking density on specific growth rate, survival, feed conversion ratio and yield of 'Akosombo strain' Nile tilapia.

2. Materials and Methods

2.1 Study Site and Design

This study was conducted in Ghana's zone of the Volta Lake, specifically in stratum II (N 06^0 16.996, E 000^0 03.562). Nine experimental cages were constructed using galvanized pipes welded into frames that were floated by empty rubber drums. The nylon-net cage units were regularly adjusted to maintain 8 m^3 of water in each compartment.

2.2 Fish stocking and feeding

All-male *O. niloticus* (Akosombo strain) of mean weight 23.63 ± 1.25 g were stocked in net cages at 400, 800 and 1200 fish/cage, which was equivalent to groups A (50 fish/m^3), B (100 fish/m^3) and C (150 fish/m^3) respectively. Each group was replicated thrice. The fish were manually fed four times daily with commercially extruded floating feed containing 30% crude protein, 5% fat, 5% fiber, 8% ash, 1.4% phosphorus and 9.5% moisture.

2.3 Data Collection

Data was collected for a period of 82 days commencing from March to May. Every two weeks, 50, 100 and 150 live fish from cages in groups A, B and C respectively were collected using a hand scoop net, and weighed with a digital scale (Ohaus, 0.01g). The mean weights were used to monitor growth and adjust feeding rates. General inspections were also done on the live specimen to monitor fish welfare. At the end of the study, all survivors in cages were weighed and counted.

Key water quality parameters in the cages (1.5 m deep) were monitored bi-weekly to ensure that they were within recommended limits for Nile tilapia growth. Temperature and dissolved oxygen were measured using an oxygen meter (YSI Model 58). The pH was measured using an electronic pH meter (HACH EC 20 pH/ISE). Samples of water from the cages were taken for laboratory analyses. Ammonia was measured using the direct nesslerization method. Nitrite was measured using the diazotization method and hydrazine reduction method for Nitrate. The Ethylenediaminetetra acetic acid (EDTA) Titrimetric method was used in determining the total hardness and phosphate was determined by Stannous Chloride method.

2.4 Data Analysis

To determine the growth performance of fish, the following parameters were calculated:

1. Specific growth rate (SGR, %/day) = $(\text{In}Wf - \text{In}Wi)\ 100t^{-1}$ where: Wf *and* Wi are the final and initial mean weight respectively and t is the number of days in the experimental period.
2. Feed Conversion Ratio (FCR) = Feed fed /weight gain.
3. Gross yield (kg/m^3) = average final weight x total number of survivors.

All data were analyzed using a one-way ANOVA in order to determine the differences between densities for each group and Tukey test was used to compare differences among individual means. Treatment effects were considered significant at $p \leq 0.05$.

3. Results

After 82 days of culture, fish growth reached a maximum final weight of 154g, 92g and 77g for groups A, B and C respectively. The mean values of initial weight, final body weight, specific growth rate, feed conversion ratio, and survival rate are shown in Table 1. The study revealed that the specific growth rate (SGR) and final weight were significantly higher ($p < 0.05$) for fish stocked at 50 fish/m^3 than the other tested fish groups. The lowest SGR was recorded in group C (1.42 %/day) but did not differ significantly from B (1.62 %/day). Fish growth in all the treatments was gradual and consistent (Figure 1). However, group A fish exhibited superior mean weight after the 8th week of culture.

Table 1: Growth performance of *O. niloticus* juveniles cultured for 82 days at different stocking densities (mean ± SE)

Treatments	Mean initial wt (g)	Mean final wt (g)	Mean wt gain (g)	SGR (%/day)	FCR	Gross Yield (kg/cage)	Survival (%)
A (50 fish/m^3)	23.54 ± 0.57^a	154.61 ± 12.88^a	131.07 ±12.51^a	2.23 ± 0.08^a	1.76 ± 0.20^a	50.20 ± 3.69^a	81.33 ± 1.72^a
B (100 fish/m^3)	23.70 ± 0.81^a	92.74 ± 7.56^b	69.04 ± 7.58^b	1.62 ± 0.11^b	1.99 ± 0.30^a	65.82 ± 5.77^b	88.63 ± 0.78^b
C (150 fish/m^3)	23.64 ± 1.85^a	77.50 ± 1.80^{bc}	53.86 ± 3.44^{bc}	1.42 ± 0.12^{bc}	2.31 ± 0.17^a	78.60 ± 2.12^c	84.50 ± 0.59^{abc}

The same letter in the same column is not significantly different at $P<0.05$.

The results also showed that fish specimen under group C were least efficient at converting feed into flesh (FCR=2.31) when compared with groups A (FCR=1.92) and B (FCR=2.18) although the differences were insignificant ($p > 0.05$). With regards to measurements related to production efficiencies, the gross yield increased significantly with increasing stocking density. However, fish in group A were significantly bigger than those in B and C (Table 1). Survival rates ranged between 81.3% and 88.6%. Fish in group B had the highest rate of 88.6% whiles fish in A had the lowest survival rate (81.3%). The results however, show no clear relationship between survival rate and stocking density.

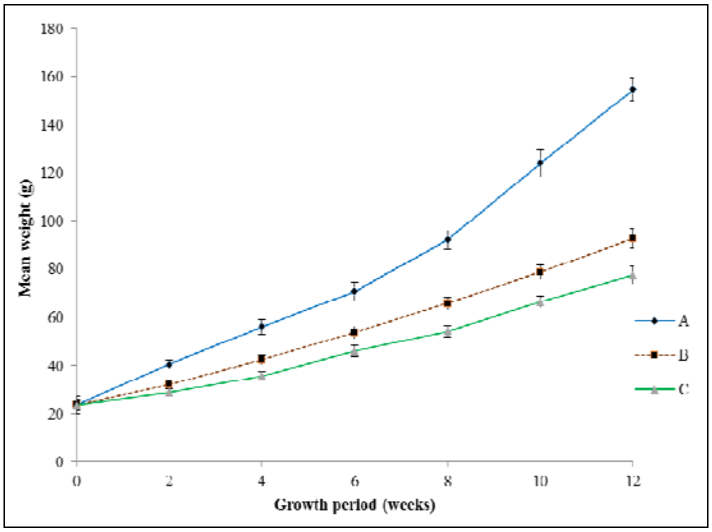

Fig 1: Growth pattern of *O. niloticus* juveniles cultured for 12 weeks at three densities

Mean water temperature and pH in all treatments were 28.46 ± 0.10°C and 6.67 ± 0.06 respectively, throughout the experimental period. From Table 2, all the water quality parameters measured were in the suitable levels for rearing *O. niloticus* and no signs of disease were observed on all fish specimens throughout the whole period of the experiment.

Table 2: Mean (± SE) values of water parameters during the culture trial.

Temperature (°C)	pH	Concentration (mg/l)					
		Total Alkalinity	Total Hardness	Morning DO	NH4-N	NO3-N	PO4-P
28.46 ± 0.10	6.67 ± 0.06	28.43 ± 0.23	26.14 ± 1.20	3.71 ± 0.31	0.05 ± 0.01	0.04 ± 0.00	0.07 ± 0.01

4. Discussion

The need for knowledge to advance cage fish culture in Ghana's declining capture fisheries cannot be overemphasized. From this study, fish stocked at 50 fish/m^3 significantly showed higher mean final weight and specific growth rate while those stocked at 100 fish/m^3 and 150 fish/m^3 were statistically similar (Table 1). This finding agrees with Gibtan *et al.* (2008) [9] who conducted a similar study in Lake Kuriftu and found the highest mean weight (219.71 g) at 50 fish/m^3. Similar to present findings, Yi and Lin (2001) [20] reported a decrease in final body weights of *O niloticus* as densities increased. The possible reasons for this trend include; social stress or chronic stress response, voluntary appetite suppression, more expenditure of energy because of intense antagonistic behavioral interaction and competition for food and living space in higher densities [21, 22]. Moreover, some aggressive behaviour, were observed in the 100 fish/m^3 and 150 fish/m^3 cage units during feeding. Such behaviour is suspected to be a density-dependent social interaction and might have negatively affected the growth and general performance of fish stocked at the higher density treatments [23].

The range of specific growth rates, 1.42 - 2.23 %/day in the present study are higher than rates (1.14 to 1.55 %/day) reported by Osofero *et al.* (2009) [24] using 29.5 g *O. niloticus* in bamboo-net cages. The difference could be due to differences in environmental conditions and strain of fish. Feed conversion ratios in this study (1.76, 1.99 and 2.31 for groups A, B and C respectively) were not significantly affected ($p > 0.05$) by stocking density as was the case of Gibtan *et al.* (2008) [9] and Osofero *et al.* (2009) [24]. The better FCR for fish in group A than those in B and C could be due to an observed fish-induced water turbulence at feeding time for the higher density groups, which possibly increased feed loss potential [23]. Moreover, pheromone secretions by dominant fish could also have resulted in repressed feeding activity among most sub-dominant individuals in higher densities. Regardless, the FCR values recorded were within the typical range (1.4 to 2.5) for *O. niloticus* cage systems in Africa [25, 26].

The highest survival rate (88.63%) was recorded in group B followed by C (84.5%) and finally, 81.33% for A. The differences among groups were significant ($p < 0.05$). This observation contrasts a report by Daungsawasdi *et al.* (1986) [27] that mortality in *O. niloticus* raised in cages is not dependent on stocking density. The survival rates in the present study are however higher than the typical survival rate (70%-80%) in small-scale tilapia cage culture in Africa [28, 29]. The differences could be attributed partially to favourable levels of physicochemical parameters in the cages [30] and adequacy of handling and food supplied throughout the period of culture. Nonetheless, rates greater than 90% have been associated with stocking densities in excess of 100 fish/m^3 [9, 21, 24].

Gross yield increased with increasing stocking density although fish in group A were significantly bigger than those in B and C. The maximum yield occurred at 150 fish/m^3 but at the expense of individual weight gain. The highest mean weight of fish in group A (154 g) was less than desirable market sizes (>250 g). This is due to the shorter grow-out period and size at stocking. Supplemental feeding of *O. niloticus* starting at 100 -150 g size is probably the most effective stocking density to produce large-sized tilapia [31].

Water quality plays a significant role in the biology and physiology of fish and may impact on the health and productivity of the culture system [32]. Generally, an increment of stocking density is suspected to cause deterioration of water quality and in poor conditions, fish grow less and die more at high stocking densities. However, the parameters measured in this experiment (Table 2) remained within the optimal range for growth of *O. niloticus* [33]. Therefore, the variation in fish growth rates in this study cannot be strictly attributed to the characteristics of water quality parameters since all treatments were growing in the same system.

5. Conclusion

Results from this experiment showed that it is biologically feasible to culture tilapia juveniles at all the tested stocking densities in cages. It also showed that stocking density affects the growth performance of *O. niloticus* under floating cage culture conditions. We conclude that fish stocked at 50 fish/m^3 had better individual growth performance than the others. However, stocking density had no significant effect on the FCR of all fish. In addition, the water quality parameters recorded in this study did not affect the growth of *O. niloticus*. The results explained that stocking *O. niloticus* juveniles at 100 fish/m^3 using an initial weight of 24 g/fish in cages with protein diet at 30% is preferable to achieve optimum growth and profits.

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