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# Lake-Based Nursery Rearing of Nile Tilapia (*Oreochromis niloticus*) Fingerlings in Nylon Hapas: Effects of Stocking Density on Growth, Survival and Profitability

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## Abstract

The inadequate supply of tilapia fingerling is a major limitation to cage culture development in Ghana. Lake-based hapa systems are very efficient in nursing fingerlings although the process can be tricky due to inherent effects of stocking densities and environmental factors. This study aimed at assessing the growth, survival and profitability of Nile tilapia (*Oreochromis niloticus*) fingerlings of the Akosombo strain reared in nine 1 $m^3$ Lake-based hapas at different densities. Each hapa was stocked with 2.12 ± 0.14 g sex-reversed tilapia fingerlings at varying stocking densities of 400 fish/$m^3$, 800 fish/$m^3$ and 1200 fish/$m^3$ serving as treatments T1, T2 and T3 respectively. Each treatment was replicated thrice. Bi-weekly samplings were done and water quality parameters were measured. After the experiment, analysis of variance showed significant differences ($p < 0.05$) in the weight gained, specific growth rate, profit index and feed conversion ratio among treatments. The T1 fingerlings exhibited the highest specific growth rate (3.28 ± 0.10%/day) and FCR (1.42 ± 0.09) than others. Overall, profit index was affected by stocking density and varied significantly between treatments. Treatment T3 was found to be better for commercial fingerling production because survival rate (91.14 ± 3.23%) and profit index (3.96 ± 0.24) were the highest while treatment T1 recorded the least index of 1.31 ± 0.10. Survival rates ranged between 89% and 91% but no statistical differences were observed among treatments. It is concluded that the stocking densities used had significant effects on the specific growth rate, gain in weight and feed conversion ratio of fingerlings reared in Lake-based hapas. However, in fingerling production, not only profit but also rapid growth needs consideration, hence, T2 is highly recommended for nursery rearing of tilapia fingerlings in this system due to the relatively high profit index, growth rate and survival.

**Keywords**

Hapa, Fingerlings, Stocking, Density, Tilapia

## 1. Introduction

With a nearly stabilized global fish production from capture, aquaculture has in recent times increased significantly throughout the world [1] and in most developing countries like Ghana. Aquaculture began in Ghana in 1950 [2] but only over the past two decades has the industry grown significantly, through the establishment of many fish farms across the country. Ghana's fish output from culture has expanded at an average annual growth rate of 50% since 2004, and is gradually making up for the deficit of over 50% between domestic fish demand and supply [3]. Aquaculture, mainly fish farming in Ghana is primarily based on Nile tilapia and 90% of the reported volume is raised in cages on the Volta Lake [3]. The cage system is gradually replacing the traditional fish-growing method of earthen ponds in Ghana due to advantages such as relatively lower investment requirement, easier start up, and so forth that are well catalogued [4]-[6].

However, a major challenge that continually limits the scale up commercialization of tilapia cage culture in Ghana is a lack of reliable quantity and quality fingerlings for stocking in grow-out facilities [7]-[10]. Availability of quality seeds is very important because the lack of it can reduce a farm enterprise to a monumental waste and consequently discourage further financial investments in cage culture [11]. Although the growth in cage farming has stimulated an increase in the establishment of hatcheries along the Volta Lake [6] [10], the current supply of Nile tilapia fingerlings does not meet farm demands and an estimated 50 million seeds are lacking annually [10].

As a practice, Nile tilapia fingerlings are generally stocked as 20 - 40 g fingerlings in Ghana [6] due to the comparatively larger mesh size of production cages. However, due to an inadequate seed supply, competition, and the expensive nature of transporting such fingerlings than smaller fry, farmers are now forced to procure small fry (0.5 - 3 g) and nurse to juvenile sizes (25 - 40 g) in nylon hapa cages although the process can be tricky. Nursing fry in nylon hapas is one of the best options, especially in Lakes and are the most favourable because they are relatively simple to sew, easy to wash and replace, easily available, inexpensive, and enables closer monitoring and grading results in uniform size harvest and better survival [4] [11]. Moreover, fingerlings subjected to pre-grow-out nursery systems in hapas can easily adapt to the Lake environment and show better performance in growth and survival than those stocked directly from ponds into the grow-out cages [12].

Nursing fry in hapas is nevertheless subjected to the effects of stocking densities and ecological problems inherent in the system. The effect of stocking density on growth and fingerling production in Nile tilapia, has been studied by several authors [13]-[23] with varied results. It is generally accepted that growth performance and survival rate of fish tend to be inversely related to stocking densities and is mainly attributed to social interactions [20] [21]. However, in some cases, such an advantage of lower stocking densities is either non-existent [24] or temporary and wanes after sometime so that generally no differences occur across different stocking densities.

Increasing stocking density results in stress which leads to enhanced energy requirements causing reduced growth and food utilization [25] [26]. However, increasing it to a certain level may enhance total fish yield and lead to higher gross and net return at a lower cost of production [20] [21] [27]. Moreover, where land, water, manpower and other facilities are limiting it may be more profitable to adopt higher stocking densities [28]. On the contrary, reducing stocking densities ensures better fish growth [13]-[16] but may not always be favorable for commercial culture [11]. Proper management of stocking densities can therefore improve the growth, profitability, sustainability, health as well as reduce competition among fingerlings for food, space and other essentials of survival [29]. Therefore identifying and recommending the ideal fingerlings stocking densities in time is important to minimize cage production deficiencies in Ghana, where limited efforts have been devoted and performance data is even scarcer. The specific objectives of this study were:

To compare the growth (daily weight gain (DWG), specific growth rate (SGR) and growth homogeneity) and survival of fish cultured different stocking densities.

To investigate the effects of stocking density on feed conversion ratios (FCR) and profitability of Nile tilapia fingerlings stocked in hapas.

## 2. Materials and Methods

### 2.1. Study Site

The hapa cages were constructed and mounted in stratum II of the Volta Lake near the premises of Aquaculture Research and Development Center of the Water Research Institute in Akosombo, Ghana (N 06˚ 16.996, E 000˚ 03.562). The Lake has a mean depth of 19m, a surface area of about 8500 km$^2$ and a volume of 149 km$^3$ at maximum level [30]. There are two rainy seasons in this portion of the Lake extending from May to October, followed by a prolonged dry season. This study was conducted between December 2012 and March 2013.

### 2.2. Research and Experimental Design

The study involved stocking Nile tilapia fry at different stocking densities and maintaining uniform management practices for a period of 84 days. Data was collected bi-weekly to assess impact of stocking density on survival, growth and profitability of fingerlings.

### 2.3. Stocking and Feeding

The Sex reversed Nile tilapia fry (2.12 ± 0.14 g) were manually selected from earthen ponds, and randomly stocked in 1 $m^3$ hapa cages at three stocking densities of 400 fish/hapa (T1), 800 fish/hapa (T2) and 1200 fish/hapa (T3). Each stocking were made in triplicate. The hapas were rectangular of synthetic netting of mesh size 1.5 mm and closed from all sides except the top. After stocking, fish were fed with a 38% crude protein commercial feed (Raanan) five times a day at an initial rate of 12% of their body weight for the first 2 weeks, then 10% from weeks 4 to 9 and finally adjusted to 7% from week 10 to the end of the trial period, following the standard of [31].

### 2.4. Sampling and Growth Parameters

Sampling was done bi-weekly to assess the growth performance of the fingerlings. Random samples of 50 fish from each hapa were weighed individually. Moreover, the final weight (g), specific growth rate (SGR), feed conversion ratio (FCR), coefficient of variation (CV) and survival rate of fingerlings were calculated at the end of trial period.

The following parameters were used to evaluate the growth performance of fry:

$$\text{Weight gain}\ (\text{g}) = \text{Mean final weight} - \text{Mean initial weight} \tag{1}$$

$$\text{SGR}\ (\%/\text{day}) = (\text{In final weight} - \text{In initial weight})\,100\text{t}^{-1} \tag{2}$$

$$\text{FCR} = \text{dry weight of feed consumed}\ (\text{g}) / \text{wet weight gain}\ (\text{g}) \tag{3}$$

$$\text{Survival}\ (\%) = \text{No. of fish harvested} / \text{No. of fish stocked} \times 100 \tag{4}$$

The biomass was calculated as the product of the average final weight and the total number of survivors. A simple economic analysis was used to estimate the profitability in each treatment. The cost of feed, fingerlings and total revenue generated from harvest were estimated.

$$\text{Profit index} = \text{value of fish crop} / \text{total cost of feed}\ \ [32]. \tag{5}$$

### 2.5. Water Quality Measurement

Water quality parameters such as temperature, pH and dissolved oxygen were monitored. Ammonia was measured using the direct nesslerization method, Nitrite 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. Temperature was recorded using Celsius thermometer; pH and dissolved oxygen (DO) were measured by a portable digital pH and DO meters respectively.

### 2.6. Statistical Analysis

Data was subjected to one-way analysis of variance (ANOVA) and when ANOVA indicated that there was a statistical difference between the stockings densities means, Tukeys tests were used to compare these means to determine whether significant difference existed between the different treatments and the parameters tested at 5% level of significance.

## 3. Results

The growth curves showed a gradual growth of fingerlings from the start to the end of experiment (Figure 1). The growth performance indicators and survival rate of fingerlings cultured at the three treatments are shown in Table 1. From the analysis, significant differences ($p \le 0.05$) were observed among the different treatment groups and T1 showed the best performance in growth parameters studied, namely; final weight gain (33.54 ± 0.66 g) and specific growth rate (3.28 ± 0.10%/day). The SGR was significant ($p < 0.05$) between the treatment groups although, rates for treatment T2 (3.13 ± 0.05) and T3 (2.86 ± 0.15) were similar.

The values of feed conversion ratio (FCR) increased with increasing stocking density. FCR were significantly ($p < 0.05$) different for fingerling stocked in all treatments except for T2 and T3. The best FCR was observed in T1 (1.42 ± 0.09) whereas the highest was recorded in T3 (2.07 ± 0.14). Survival and recovery was generally high in all treatments with rates ranging from 89% to 91%. Although among T1, T2 and T3, there were no observed significant differences at $p > 0.05$, the highest survival rate was recorded in the T3 (91.14 ± 3.23) while the lowest was observed in T2 (89.29 ± 0.64). The different stocking densities did not significantly affect the CV of fish in all treatments (Table 1).

A summary of the mean values of water quality parameters recorded during stocking and throughout the culture period is presented in Table 2. All the parameters measured

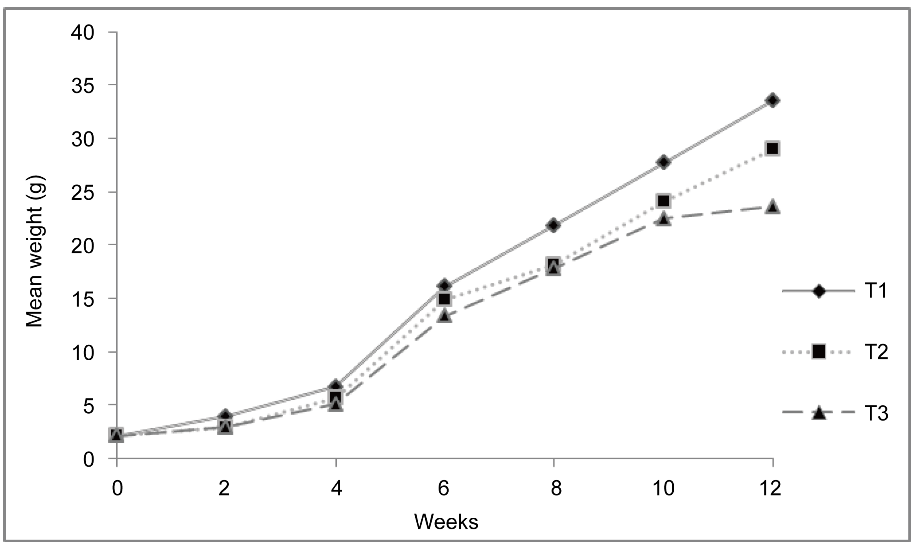


Figure 1. Growth of *O. niloticus* fingerlings cultured for 12 weeks at three stocking densities.

Table 1. Growth of *O. niloticus* fingerlings cultured for 12 weeks at three stocking densities.

| Treatments | Av. initial wt (g) | Av. final wt (g) | Av. weight gain (g) | SGR (%/day) | FCR | CV (%) | Survival (%) |
|---|---|---|---|---|---|---|---|
| T1 (400/hapa) | 2.13 ± 0.14$^a$ | 33.54 ± 0.66$^a$ | 31.41 ± 0.80$^a$ | 3.28 ± 0.10$^a$ | 1.42 ± 0.09$^a$ | 41.15 ± 2.11$^a$ | 91.08 ± 0.84$^a$ |
| T2 (800/hapa) | 2.09 ± 0.06$^a$ | 29.03 ± 1.01$^{ab}$ | 26.95 ± 0.99$^{ab}$ | 3.13 ± 0.05$^{bc}$ | 1.72 ± 0.09$^{bc}$ | 37.08 ± 1.28$^a$ | 89.29 ± 0.64$^a$ |
| T3 (1200/hapa) | 2.15 ± 0.23$^a$ | 23.63 ± 2.14$^c$ | 21.49 ± 2.09$^c$ | 2.86 ± 0.15$^c$ | 2.07 ± 0.14$^c$ | 41.33 ± 1.73$^a$ | 91.14 ± 3.23$^a$ |

Mean values in the column with different superscripts are significantly different.

Table 2. Mean (±SE) values of water quality parameters in the hapa cages during culture.

| Parameters | Temperature (˚C) | pH | Concentration (mg/l) | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | Total Alkalinity | Total Hardness | Morning DO | $NH_4$-N | Nitrite ($NO_2$-N) | $NO_3$-N | $PO_4$-P |
| Initial | 28.1 ± 0.01 | 6.80 ± 0.01 | 27.91 ± 0.03 | 25.01 ± 0.02 | 4.90 ± 0.11 | 0.02 ± 0.00 | 0.002 ± 0.01 | 0.03 ± 0.00 | 0.01 ± 0.00 |
| Culture | 27.3 ± 0.19 | 6.70 ± 0.04 | 28.53 ± 0.09 | 24.00 ± 0.23 | 4.11 ± 0.18 | 0.04 ± 0.00 | 0.004 ± 0.000 | 0.05 ± 0.01 | 0.03 ± 0.01 |

reflect the environmental conditions under which the fish were cultured and were within the optimal range for tilapia growth.

As shown in Table 3, fish biomass as well as the value of fish crop increased with increasing stocking densities. The highest value of juvenile fish crop was found in T3 (GH¢ 295.29 ± 10.47) while the lowest value was recorded in T1 (GH¢ 98.37 ± 0.91). Significant differences ($p < 0.05$) were found in the calculated profit index among the treatment groups. Treatment T3 attained the highest value of (3.96 ± 0.24) followed by T2 and T1 with values of 2.46 ± 0.07 and 1.31 ± 0.10 respectively.

## 4. Discussions

With an increasing need of Nile tilapia seeds by cage operators in Ghana, various strategies are being practiced with the aim of obtaining profits. Lake-based nursing of fry in hapa cages is one of them. However, stocking density affects this technique in terms of fry growth performance, survival and economic profitability. In the present study, significant differences are found among the growth parameters of the three treatments. This complies with [11] [23] [28] [29] and [33], who also found similar effects of stocking density.

Treatment 1 with a stocking density of 400 fish per hapa was most favorable and found all the growth parameters like final weight, FCR and SGR best. Reference [15] confirmed that increasing the number of fish (density) will adversely affect fish growth. Additionally, [34] also proved that the least stocking rate attained the highest final weight, weight gain, SGR, feed conversion, and protein efficiency ratio for *Oreochromis niloticus*. The lower growth performance of tilapia at higher stocking density could have been caused by voluntary appetite suppression, more expenditure of energy because of antagonistic behavioral interaction, competition for food and living space [35] and increased stress [36].

In commercial production of Nile tilapia, an increase in stocking density will also increase net profit with the same unit area and resources. But in small scale farming, not only profit but investment capability also needs to be taken into consideration [11]. In the present study, although growth rate is found best in lowest stocking density (T1), it is not commercially feasible because of low profit index which was affected significantly by stocking density. This agrees with [24] who found significant differences ($p < 0.05$) in the profit index for Nile tilapia, reared at different densities. Treatment T3 with a stocking rate of 1200/hapa was most profitable with an index of 3.96 ± 0.24.

A major drawback for fish production during the nursery phase is differential

**Table 3.** A simple economic analysis for profitability among the treatment groups.

| Treatments | Fingerlings cost (GH¢) | Feed applied (kg) | Feed cost (GH¢) | Biomass (kg) | Value of fish cropped (GH¢) | Profit index |
|---|---|---|---|---|---|---|
| T1 (400/hapa) | 48.00 | 44.00 | 75.82 | 12.22 ± 0.32 | 98.37 ± 0.91 | 1.31 ± 0.10[a] |
| T2 (800/hapa) | 96.00 | 46.00 | 78.43 | 20.75 ± 0.86 | 192.87 ± 1.37 | 2.46 ± 0.07[b] |
| T3 (1200/hapa) | 144.00 | 44.00 | 74.80 | 25.75 ± 2.01 | 295.29 ± 10.47 | 3.96 ± 0.24[c] |

Mean values in the column with different superscripts are significantly different.

growth. Economically, harvest and sales of uniformly sized fingerlings is preferred to differential sizes. The tested stocking densities in this study did not significantly ($p > 0.05$) affect the weight variations of the fish unlike [37] who found some significant effect on final CV in their trial with Florida red tilapia in marine cages.

Feed conversion ratio, FCR in this study was significantly affected by stocking density as was the case of [29] and [24] although differences in the 800/hapa and 1200/hapa treatments were similar. The best FCR was realized in T1 (1.42) and could be attributed to effective feed utilization which was reflected in the growth rate. The realized increase in FCR with higher stocking densities is in conformity with results obtained by [38] and [29]. Although feed intake and utilization by fish in treatment T3 was observed to be very low (44 kg), it still recorded the worst FCR of 2.07. This can be explained by the fact that efficient utilization of diets can vary even within a single species because of the highly densed interactions and inherent environmental factors [39].

All the physical-chemical parameters of the water in the cages were within the acceptable optimal range for fish culture. The water quality parameters recorded were within the acceptable ranges as recommended for tropical aquaculture [40] [41] and therefore did not affect the culture of fish.

## 5. Conclusion

Optimum utilization of space for maximum production in intensive fish culture practices is known to improve the profitability of fish farms. In this study, it is revealed that increasing the stocking density of Nile tilapia fingerlings significantly affects growth, feed conversion, profitability and yield of tilapia fingerlings reared in Lake-based hapas.

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