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# Influence of stocking size on survival, growth performance and the weight-length relationship of Nile tilapia *Oreochromis niloticus* (Linnaeus, 1758) reared in fish hapas

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**ABSTRACT**

During a development cycle, morpho-anatomical changes influence the growth characteristics of fish. This study evaluated the influence of stocking size on the survival and zootechnical parameters of Nile tilapia (*Oreochromis niloticus*) reared in hapas. Four different initial weights (Size A: 14.81 g; Size B: 30.84 g; Size C: 54.69 g; Size D: 106.57 g) were used to stock fish in hapas. The fish were fed a commercial feed for 56 days. The results showed a higher survival rate in Size A fish, at 90% ($p < 0.05$). Regarding growth, weight gain was highest in size A fish (25.35 g), followed by size D (18.7 g), size B (15.33 g) and C (15.46 g). However, growth rate decreased with increasing stocking size, dropping from 1.77%/day for size A to 0.29%/day for size D. For feed utilization, smaller fish make better use of feed with a feed conversion ratio of 2.8. Regarding the weight-length relationship, three types of allometry were observed for this species as a function of stocking size. The results show that the weight-length correlation decreases with the age of the fish, changing from isometry to positive and negative allometries**.** In conclusion, it can be estimated that smaller fish exhibit better growth, whereas intermediate-sized fish show lower weight gain compared to larger fish. Thus, the choice of the initial stocking size must be carefully managed to ensure better fish production.

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## INTRODUCTION

Seafood products, particularly fish, are playing an increasingly essential role in food security, nutrition, and the well-being of global population. Indeed, global apparent fish consumption per capita has risen from an average of 9.9 kg during the 1960s to 20.7 kg in 2022 (FAO, 2024). In Africa, although aquaculture production is gradually increasing, it remains insufficient to meet population needs. Consumption in Africa is estimated at 10 kg per capita per year, far below the global average (OCDE/FAO, 2025). However, this situation is expected to change due to a rapidly growing population. In some regions, fish already provides more than 50% of the animal protein consumed, compared to only 20% globally (FAO, 2025). In Côte d'Ivoire, fish is among the most consumed foodstuffs, with populations showing a distinct preference for local species.

Despite this high demand, national production from both fisheries and aquaculture remains largely insufficient to meet consumption needs. National production from both fisheries and aquaculture amounts to 83 345 tones, which covers only 12% of the national demand estimated at over 730 000 tones (MIRAH, 2024). Thus, the Ivorian government relies on fish imports, leading to significant outflows of foreign currency (Coulibaly *et al.*, 2021).

To reduce this dependence, the Ivorian government has implemented a National Policy for the Development of Livestock, Fisheries and Aquaculture (PONADEPA, 2022-2026), with the objective of reaching a production of 150 000 tons of farmed fish in 2030 (MIRAH, 2022). In this context, several fish species are being promoted in aquaculture, particularly tilapia, due to their hardiness, easy reproduction characterized by early sexual maturity, dietary flexibility, and ability to adapt to varied environments (Arizi *et al.,* 2014; Mashaii *et al.*, 2016). Among these tilapia species, *Oreochromis niloticus* is the best known and most widely used because of its high market demand, rapid growth, and especially its relatively adaptable diet. This species has been the subject of several research studies (Yeo *et al.*, 2017; Djeke *et al.,* 2024; Adiaffi *et al.,* 2026). These studies have mainly focused on feeding, the impact of stocking density on growth, fish survival rates, and yield. However, knowledge regarding the impact of initial stocking size on growth and the profitability of Nile tilapia (*Oreochromis niloticus*) production remains limited. Identifying the optimal stocking size is crucial for successful fish farming, as it directly influences growth rate, fish survival, health, and consequently, farm profitability (Alebachew *et al.,* 2022). For example, it has been shown that larval size at hatching directly affects growth during the early stages of development (Cahu, 2004).

During a development cycle, morpho-anatomical or morpho-physiological changes considerably influence the growth characteristics of fish. Babiak *et al.* (2004) showed that the average initial weight and initial heterogeneity of fish significantly influence the growth and survival. In order to identify the ideal stocking size for farm profitability, it is important to control certain biological parameters of tilapia during its development cycle. This study determined the evolution of certain zootechnical parameters at different growth stages of Nile tilapia (*Oreochromis niloticus*) reared in hapas.

## MATERIAL AND METHODS

### Study site, fish and experimental system

The study was conducted in ponds at the experimental aquaculture station of Center for Research of Oceanological. It is located in Dabou, Côte d'Ivoire, at coordinates 5°19'30.69°N, 4°18'45.90°W. This site is situated in a marshy area where the hydroclimate is strongly influenced by the proximity of the lagoon outlet and a forest river, the Agnéby.

The biological material used for this experiment consisted of 240 specimens of Nile tilapia (*Oreochromis niloticus*) with average weights ranging from 14 to 106 g. These fish were collected from the various ponds at the Experimental Aquaculture

Station. Fish were collected in the pond and acclimated to the experimental conditions for two weeks. During the period, fish received a commercial diet (8 am and 4 pm).

The experimental pond was supplied with water from the lagoon through a 32 mm diameter PVC pipe. The pond was 0.80 m deep, 33 m long, and 23 m wide, for a total area of 759 m². Twelve identical hapas were used for this experiment. hapas were constructed from 1.5 mm fine mesh netting, measuring 50 cm in length, 40 cm in width, and 40 cm in depth (net drop), corresponding to a surface area of 0.2 m².

**Experimental rearing conditions**

The fish were stocked at a density of 20 fish per hapa. The different stocking sizes were defined as follows:

Size A: 4.81 ± 1.38 g and 9.31 ± 0.24 cm

Size B: 30.84 ± 1.17 g and 11.73 ± 0.13 cm

Size C: 54.69 ± 0.36 g and 14.21 ± 0.07 cm

Size D: 106.57 ± 3.39 g and 18.18 ± 0.02 cm

After stocking, the fish were fed a commercial diet to apparent satiety. Feeding was carried out twice daily (8:00 am and 4:00 pm), before feeding, environmental physicochemical parameters (temperature: 30.35 °C, pH: 7.28, dissolved oxygen: 7.25 mg/L) were recorded using a multi-parameter analyzer. Sampling was conducted weekly to monitor fish growth. During this operation, 10 fish were randomly selected from each hapa. They were individually weighed and measured using a precision balance and an ichthyometer,

**Zootechnical parameters**

Survival Rate (SR), Daily Weight Gain (DWG), Relative Growth (RG), Specific Growth Rate (SGR), Feed Conversion Ratio (FCR), Voluntary Intake (VI) were calculated as follows:

SR (%) = 100 x (Final number of fish/ Initial number fish);

DWG (g/d) = (Final weight – Initial Weight) / days;

RG (%) = 100 × [(Final weight – Initial weight) / Initial weight];

SGR (%/d) = 100 × (Ln FBW – Ln IBW) / days;

VI (%/d)= 100 × D × [(Final biomass + initial biomass) /2] / days; D (g) is the cumulative amount of feed distributed;

FCR = Dry feed intake (g) / body weight gain (g).

**Weight-length relationship**

The weight-length relationship is a parameter used to monitor fish population growth. It was established using the following formula:

$W = aL^b$,

Where W = weight (g), L = total length (cm), b = the regression coefficient and a = the intercept of the regression curve. The "b" value represents the relative growth constant, b = 3 means isometric growth; b > 3 means positive allometric growth; and b < 3 means negative allometric growth (Levêque and Paugy, 2006).

The coefficient of determination $R^2$, also derived from the regression line, represents the strength of the relationship between the two morphometric parameters considered. It is always between -1 and +1 (Randriaharimino, 2014).

**Statistical analysis**

For statistical analysis, STATISTICA 7.1 software was used. Significant differences between the data were determined using one-way ANOVA. When significant effects were detected, a Duncan's post-hoc test was performed for mean comparisons. Comparisons of the allometric coefficient b to the theoretical value 3, were performed using Student's t-test. Analyses were considered significant at $p < 0.05$.

**RESULTS**

**Survival rate**

Fig. 1 shows the survival rate of juveniles at the end of the experiment. The survival rate ranged from 70% to 90%, with the highest rate observed in Size A fish at the 5% threshold. There was no significant difference between the other sizes ($p > 0.05$).

**Zootechnical parameters**

Weight gains at the end of the experiment according to sizes are presented in Fig. 2. Weight gains ranged

from 15.33 to 25.35 g. Size A fish had the highest values, followed by Size D fish with 25.35 g and 18.7 g ($p < 0.05$). Size B and Size C fish showed the lowest gains, at 15.33 g and 15.46 g, respectively.

Daily Weight Gain (DWG) and Relative Growth (RG) of tilapia after 56 days of the experiment are presented in Table 1. Daily Weight Gains varied from 0.27 to 0.45 g/d. Size A fish exhibited the highest DWG at 0.45 g/d at the 5% significance level. The lowest DWG were obtained with Size B and Size C fish. In contrast, regarding Relative Growth, Size D fish showed the lowest values at 17.53% ($p < 0.05$). Size A fish had relative growth values exceeding 100%.

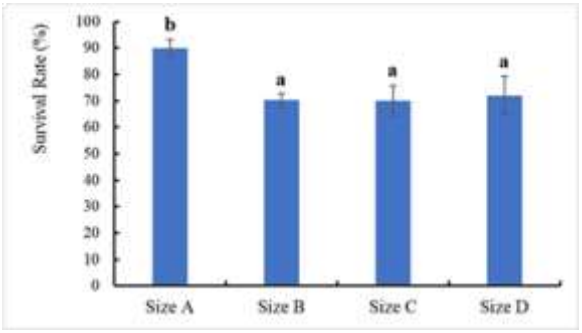



**Fig. 1.** Fish survival rates as a function of stocking size

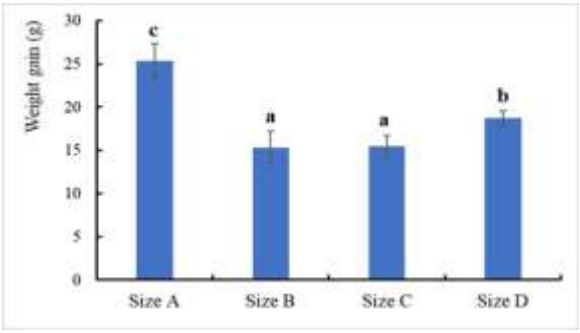



**Fig. 2.** Weight gain at the end of the experiment

**Table 1.** Fish growth parameters at the end of the experiment

| Parameters | Stocking size | | | |
|---|---|---|---|---|
| | Size A | Size B | Size C | Size D |
| Wi (g) | 15.02 ± 1.65 | 30.84 ± 1.17 | 55.01 ± 0.83 | 106.8 ± 3.05 |
| Wf (g) | 40.37 ± 2.92$^{c}$ | 46.17 ± 1.32$^{a}$ | 70.47 ± 1.87$^{a}$ | 125.5 ± 3.07$^{b}$ |
| DWG (g/d) | 0.45 ± 0.04$^{c}$ | 0.27 ± 0.03$^{a}$ | 0.28 ± 0.02$^{a}$ | 0.33 ± 0.03$^{b}$ |
| RG (%) | 168.99 ± 9.84$^{d}$ | 49.83 ± 7.32$^{c}$ | 28.09 ± 2.07$^{b}$ | 17.53 ± 0.93$^{a}$ |

Data are mean values ± SD (n = 3), Means in a row with different superscripts significantly (P<0.05). Wi: Initial Weight; Wf: Final Weight; DWG: Daily Weight Gain; RG: Relative Growth.

**Table 2.** Feed conversion ratio (FCR) and voluntary intake (VI) in different sizes of fish

| Parameters | Stocking size | | | |
|---|---|---|---|---|
| | Size A | Size B | Size C | Size D |
| FCR | 2.8 ± 0.29$^{a}$ | 5.5 ± 0.67$^{b}$ | 6.58 ± 0.39$^{b}$ | 5.72 ± 1.1$^{b}$ |
| VI (%/d) | 3.27 ± 0.08$^{c}$ | 3.3 ± 0$^{c}$ | 2.33 ± 0.14$^{b}$ | 1.94 ± 0.11$^{a}$ |

Data are mean values ± SD (n = 3), Means in a row with different superscripts significantly (P<0.05). FCR: Feed Conversion Ratio; VI: Voluntary Intake.

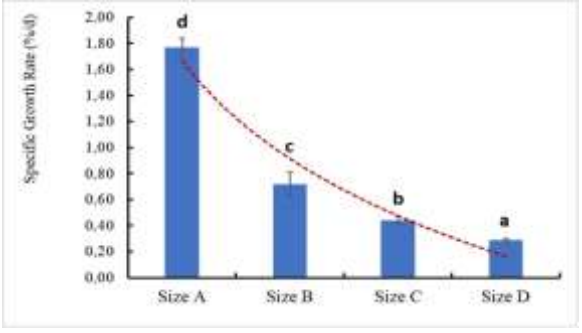



**Fig. 3.** Fish growth rate during the experiment

The growth rate, or specific growth rate, is shown in Fig. 3. This rate varies between 0.29 and 1.77%/day. These specific growth rates (SGR) are significantly different depending on the stocking size of the fish ($p < 0.05$). The growth rate is proportional to the initial weight. Thus, the rate is fastest in Size A fish, followed by Size B, Size C, and finally Size D.

**Feed utilization parameters**

Feed conversion ratio and voluntary intake according to stocking size are shown in Table 2. The feed conversion ratio ranged from 2.5 to 5.58. The lowest ratio was obtained with Size A fish, and the others showed no significant difference at the 5%

significance level. Voluntary intake ranged from 1.94 to 3.33%/d. Sizes A and B showed no significant difference ($p > 0.05$), with values of 3.27% and 3.33%/day, respectively.

**Weight-length relationship**

Fig. 4 illustrates the correlation curve, the allometric coefficient b and the coefficient of determination $R^2$ during the experiment. The coefficient of determination $R^2$ decreases with increasing fish size. The highest $R^2$ was observed with size A (0.99) and the lowest with size D (0.86). Regarding the allometric coefficients b, size A fish have a b of 2.96, similar to 3 ($p > 0.05$) after a student's t-test, considered isometric. Conversely, size B and D fish have allometric coefficients $b < 3$, therefore negative allometric. However, size C fish have an allometric coefficient b of 3.52, which is positive allometric.

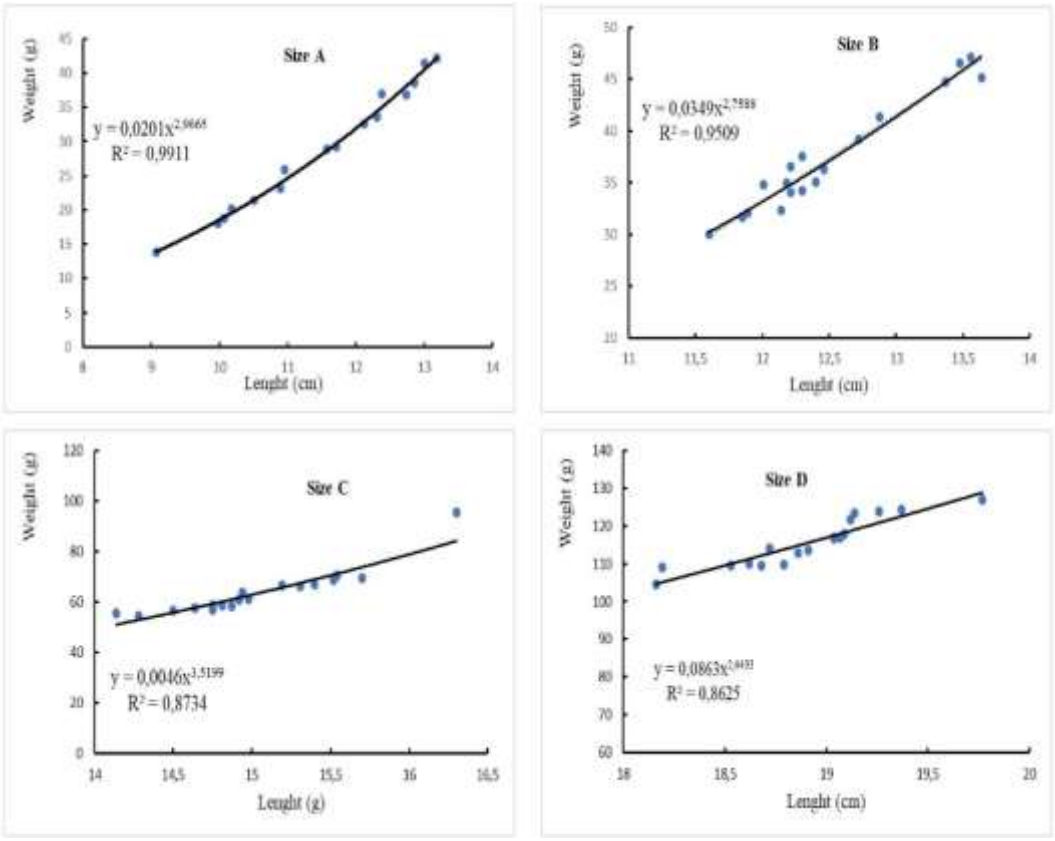



**Fig. 4.** Weight-length relationship of different fish sizes during growth

**DISCUSSION**

During the experiment, the physicochemical parameters of the water varied from 30.17 to 30.35 °C for temperature, 7.09 to 7.10 for pH, and 5.35 to 7.25 for dissolved oxygen. These values fall within the optimal range for tilapia farming (Abdel-Tawwab and Monier, 2018; FAO, 2022). The fish were subjected to the same experimental conditions; in other words, the differences observed in zootechnical performance could not be attributed to an effect of the rearing environment.

Fish survival rates during this experiment ranged from 70% to 90%, with a significantly higher rate observed in Size A fish. According to the FAO (2022), tilapia survival rates are around 70% under optimal conditions. Konan *et al.* (2017) showed that rearing conditions and social interactions can affect tilapia survival rates. The better survival observed in smaller fish could be explained by better adaptation to rearing conditions and lower competition for territory. A phenomenon of food competition among larger fish can induce hierarchical stress and increase mortality due to aggression or cannibalism (Limbu *et al.*, 2017).

The best growth was observed in the small fish (Size A), with a weight gain of 25.35 g and a daily weight gain of

0.45 g/d. This reveals that fish with a smaller initial size possess a greater growth potential than larger fish. It can be explained by more intense metabolic activity, allowing them to utilize feed more efficiently for tissue growth. Similar observations were reported by Hamed *et al.* (2024), who emphasize that juvenile tilapia exhibit superior growth performance compared to adults when dietary and environmental conditions are favorable. Indeed, the slower growth of Size B, C, and D fish could be due to the fact that their ingested energy is directed more towards other uses than tissue growth. According to Skeeles and Clark (2023), the energy of larger fish is redirected towards body maintenance and reproduction at the expense of growth.

Abdel-Tawwab *et al.* (2021) also showed that tilapia growth performance decreases as fish reach larger sizes, due to increased energy requirements for maintaining vital functions. However, the results of our study indicate that larger fish (Size D) exhibited better growth than intermediate-sized fish (Sizes B and C). Regarding the growth rate, the values are proportional to the stocking size. This rate decreases with increasing size, from 1.77% to 0.29%/day. This observation is consistent with the finding of Dikel and Tellioğlu (2020), who indicate that smaller fish exhibit higher growth rates due to a more active metabolism. Similarly, according to the FAO (2022), tilapia growth is faster in the juvenile stage, before slowing down with increasing size and age.

Feed utilization parameters indicate a better feed conversion ratio in smaller fish. This lower value reflects better feed intake, indicating that smaller fish efficiently utilize the provided feed to produce biomass. Thus, smaller initial sizes appear to allow for greater feed efficiency. These results corroborate those of Poot-López *et al.* (2014), who revealed that optimizing rearing parameters reduces feed losses, maximizes available resources, and therefore promotes better fish productivity. Voluntary intake in the results shows significant differences between groups. High Voluntary intake in Size A and B fish indicates that they consumed more of the distributed feed, promoting good growth. Xie *et al.* (1997) demonstrated that the voluntary feed intake of larger fish decreases, which explains their low growth rate.

The correlation coefficient $R^2$ decreases with increasing fish size, from 0.86 to 0.99. This result reflects a reduction in the weight-length relationship as the fish growth progresses. Thus, isometry was observed in Size A fish, while allometry was noted in Size B, Size C, and Size D fish. According to Diop *et al.* (2019), the length-weight relationship varies between fish species and even within the same species from one specimen to another. Size B and D fish exhibit negative allometries with coefficients below 3. Negative allometries have also been observed in this species in Lake Lôkpôhô at Ferssedougou in Côte d'Ivoire (Koné *et al.*, 2025). In contrast, Size C fish showed positive allometry during the experiment. Olurin and Aderibigbe (2006) reported positive allometry in tilapia *Oreochromis niloticus* in fish farms in Ogun State, Nigeria.

## CONCLUSION

The objective of this study was to determine the influence of stocking size on specific growth performance indicators of the tilapia *Oreochromis niloticus*. The results show a higher survival rate in smaller fish. In terms of weight gain, the smallest fish showed the best gains, followed by the largest fish. However, growth rate decreased with increasing fish size. The weight-length relationship exhibited all three types of allometry for this species during its development, with a decrease in the weight-length correlation during growth.

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