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(RESEARCH ARTICLE)

Reproductive performance of Nile tilapia *Oreochromis niloticus*, Linnaeus, 1758 Akosombo strain in a controlled environment in Côte d'Ivoire

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Abstract

The present study aimed to evaluate the reproductive performance of the Akosombo strain of *Oreochromis niloticus* in Côte d'Ivoire, in order to contribute to the improvement of local aquaculture production systems. Thus, 64 breeders were placed in two hapas of 10 m^2, at a density of 3.2 breeders/m^2 with a sex ratio of 1 male to 3 females, and fed at 5% of their biomass. Fry were collected every 14 days. A total of 64,288 larvae with an average weight of 0.011 ± 0.0 g were produced over four (04) collections. The average fry production per gram of female per day was 0.15 ± 0.13 fry during the trial period. The physicochemical parameters regarding temperature, dissolved oxygen, and pH were within the recommended farming values. The Akosombo strain adapted well to the Ivorian environment and exhibited favorable reproductive performance.

Keywords: *Oreochromis niloticus*; Akosombo strain; Zootechnical parameters; Hapas; Côte d'Ivoire

1. Introduction

The growth in the world's population, coupled with the decline in natural fishery resources, is leading to increasing reliance on aquaculture to ensure food and nutritional security for populations. In sub-Saharan Africa, and particularly in Côte d'Ivoire, national fish production is around 116,028 tons/year, which is still too low to meet the consumption needs of the population, estimated at 618,182 tons/year [1]. Fish farming production is around 4,500 tons/year, or approximately 2.4% of annual national production [2]. Given this situation, aquaculture appears to be a sustainable alternative for increasing local production and reducing imports. Among the most popular species in aquaculture, Nile tilapia (*Oreochromis niloticus*) stands out for its rapid growth, hardiness, good adaptation to intensive farming systems, and reproductive performance. It is now one of the most farmed species in the world [3].

Côte d'Ivoire has set up several programs, including the Strategic Program for the Transformation of Aquaculture in Côte d'Ivoire (PSTACI) in conjunction with the National Policy for the Development of Livestock, Fisheries, and Aquaculture (PONADEPA) to achieve self-sufficiency. All these different programs have been initiated to ensure the availability of fry through research and fry production stations. To compensate for this self-sufficiency in fishery products, the Ministry of Animal and Fishery Resources (MIRAH) has introduced several improved strains of *Oreochromis niloticus* tilapia into Côte d'Ivoire, including the Akosombo strain. These strains should help fish farmers to revive national production.

Given the challenges associated with food security and local economic development, it is essential to better understand and control the conditions that influence the reproduction of this strain in a controlled environment.

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It is in this context that the present study aims to evaluate the reproductive performance of the Akosombo strain of Nile tilapia *Oreochromis niloticus* under local conditions in order to validate its potential for the development of aquaculture industries. More specifically, the study sought to determine daily growth, average fry weight, number of fry per gram of female per day, fry weight per gram of female per day, and condition factor.

2. Materials and Methods

2.1. Farming infrastructure and experimental fish

The CNRA's Continental Fisheries and Aquaculture Research Station (SRPAC) is located in central Côte d'Ivoire, 6 km from Bouaké, specifically within the Kongodékro classified forest (7°37' north latitude and 5°02' south longitude) (Figure 1). This station covers an area of 114 hectares. It includes numerous livestock facilities, including a biosecure area comprising 27 concrete tanks, six ponds, and a filtration tank. It has a quarantine area for rigorous biosecurity checks on fish species coming from outside. It has a hatchery, 50 concrete tanks of various sizes, 14 raceways, and 20 sorting tanks. The station also has seven (07) series of ponds arranged in parallel from A to G, for a total of 80 ponds. The station's ponds are supplied with water by gravity from the Kan dam, located 1.7 km upstream, and also by a pumping system from a double borehole. The experimental fish specimens used in this study are broodstock of the tilapia species *Oreochromis niloticus*, Akosombo strain, which arrived from Ghana in 2016 via the Ministry of Animal and Fisheries Resources (MIRAH).

Figure 1 Satellite view of the research station

2.2. Experimental procedure

Before reproduction, the pond was prepared. This involved cleaning the dikes, draining the pond, and allowing it to dry. After four (04) days, the pond was cleaned and disinfected to eliminate any foreign organisms. The water supply pipe was protected with mosquito netting, and then the water was turned on. The hapas were then installed inside the pond using Chinese bamboo stakes and covered with a 28 mm mesh net to prevent fish from escaping and protect them from predators (Figure 2). Before loading the hapas, the broodstock were kept separately by sex in tanks in the biosecure area. A fishing operation was carried out to select the broodstock. For reproduction, a total of 64 broodstock of the Akosombo strain of Nile tilapia *Oreochromis niloticus* were used. The trial was conducted in two hapas. Each hapa contained 32 broodstock, including 8 males and 24 females, giving a sex ratio of 1 male to 3 females. The average weight of the males was 185.4 ± 22 g and that of the females was 95 ± 27.8 g.

These broodstock were fed a daily ration of 5% of biomass with Koudjis 4 mm floating pellet feed containing 27% protein (Table 1). The broodstock were fed manually twice a day (9:30 a.m. and 3:30 p.m.) on the days when larvae were collected and during control fishing. Daily rations were adjusted as control fishing progressed.

Figure 2 Breeding structure for the test

Table 1 Bromatological composition of Koudijs feed for breeding stock

Components	Contents (%)
Crude protein	27
Crude fat	5.5
Crude fibre	6
Moisture	11
Ash	14
Phosphorus	1.3
Calcium	1.5
Lysine	1.6

After breeding commenced, seven (07) days were allowed for the parent birds to adapt to their new living environment. Then, 14 days later, the first larvae were collected, followed by collections every 14 days until the fourth collection. The collection was carried out by narrowing the breeding hapa in order to gather the larvae at the water surface. The larvae were then captured using a net with a 1 mm mesh size. The broodstock were also captured using a 6 mm mesh net and stored in basins provided for this purpose.

Before returning the hapa to the water, each female's mouth was examined to remove any unexpelled eggs. The larvae collected were weighed, counted per sample and divided between two 10 m^3 hapas. The various male and female broodstock were then weighed and measured (standard length and total length) individually.

2.3. Water quality management

Several physical and chemical parameters of the water, such as hydrogen potential (pH), dissolved oxygen (DO) and temperature (T°), were recorded. To do this, after turning on the oximeter, the probe was immersed in the water of each happa to measure the dissolved oxygen and temperature values. For pH values, the HANNA multi-parameter meter was switched on and the probe immersed in the water of the happa. The various parameters relating to dissolved oxygen and temperature were recorded three days a week and three times a day (6 a.m., 1 p.m. and 5 p.m.). The pH was recorded once a week.

2.4. Calculated zootechnical parameters

The following parameters were calculated. They are daily growth, average weight of fry, number of fry per gram of female per day, fry weight per gram of female per day, and the condition factor.

$$\textbf{Daily growth (g/day)} = \frac{Final\ average\ weight - initial\ average\ weight}{Number\ of\ rearing\ days} \quad (1)$$

$$\textbf{Average weight of fry (g)} = \frac{Sample\ collection\ weight}{Total\ number\ of\ fry\ in\ the\ sample} \quad (2)$$

Number of fry per gram of female per day

$$= \frac{Total\ number\ of\ fry\ produced\ per\ collection}{total\ biomass\ of\ females\ at\ each\ collection} X \frac{1}{number\ of\ days\ between\ two\ collections} \quad (3)$$

Weight of fry per gram of female per day

$$= \frac{Average\ weight\ of\ fry\ produced\ x\ total\ number\ of\ fry\ collected}{total\ biomass\ of\ females\ at\ each\ collection} X \frac{1}{number\ of\ days\ between\ two\ collections} \quad (4)$$

$$\textbf{Condition factor K} = \frac{Final\ averageBody\ weight\ (g)}{(Standard\ length\ of\ fish)3}\ x100 \quad (5)$$

The condition factor or condition coefficient is used to assess the body condition of a fish species in its habitat. It was calculated using the formula developed by [4]

2.5. Statistical analysis

The results are presented as means ± standard deviation. The physicochemical parameters, zootechnical parameters and condition factor were subjected to one-way analysis of variance (ANOVA 1). This test was followed by Tukey's multiple comparisons of means for parameters showing a significant difference (p-value < 0.05) in order to identify specific differences between the different collections. These analyses were performed using STATISTICA 7.1 software.

3. Results

3.1. Water quality in livestock facilities

The relevant parameters were analysed according to the hours of the day between 6 a.m. and 5 p.m. and are recorded in Table 2. The average temperature values range from 28.47 ± 1.01 to 29.38 ± 1.23 on the 14th and 42nd days of rearing, respectively. As for average oxygen levels, they fluctuate between 8.79 ± 3.03 mg/l (56th day of rearing) and 12.54 ± 6.11 mg/l (14th day of rearing). The pH values ranged from 7.4 ± 0.1 on the 42nd day to 8.2 ± 0.6 on the 14th day of rearing.

Table 2 Summary of the physical and chemical parameters of the rearing structure

	Rearing days			
Physicochemical parameters	14	28	42	56
Temperature (°C)	28.47 ± 1.01	28.66 ± 0.77	29.38 ± 1.23	29.04 ± 1.08
Dissolved oxygen (mg/l)	12.54 ± 6.11	10.38 ± 4.44	10.06 ± 4.83	8.79 ± 3.03
pH	7.6 ± 0.3	8.2 ± 0.6	7.4 ± 0.1	7.9 ± 0,4

3.2. Change in the average weight of broodstock during the trial

This trend has been analysed by gender.

The change in the average weight of females is shown in Figure 3. It showed a gradual increase from the start of feeding (95 ± 27.8 g) to the 56th day of rearing (192.9 ± 37.6 g). Daily growth over the entire duration of the experiment was

1.7 g/day. The one-factor analysis of variance performed showed no significant difference (p-value > 0.05) between the average weights at the time of collection.

For males, the change in their average weight is shown in Figure 4. The curve showing the change in average weight for males showed a gradual increase over the entire duration of the trial. The average weight, which was 185.4 ± 22.7 g at the start of the trial, increased to 373 ± 58.8 g at the end of the experiment. Daily growth was 3.3 g/day. One-way analysis of variance shows no significant difference (ANOVA, p-value > 0.05) between the average weight of male broodstock during control catches 1 and 2, but differences are observed in the average weight recorded at loading with catches 3 and 4 (ANOVA, p-value < 0.05).

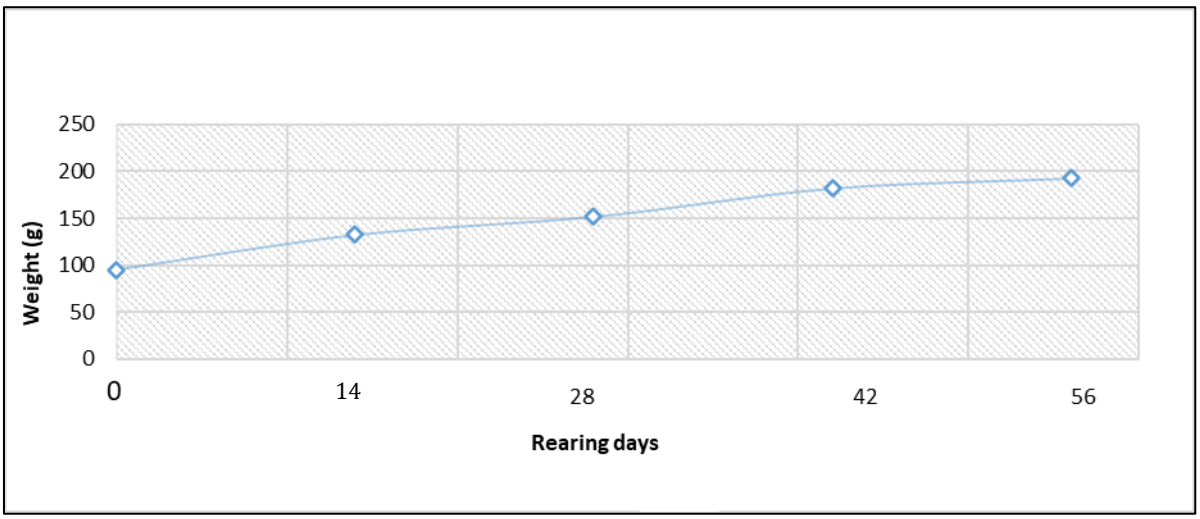

Figure 3 Change in the average weight of female broodstock during the trial

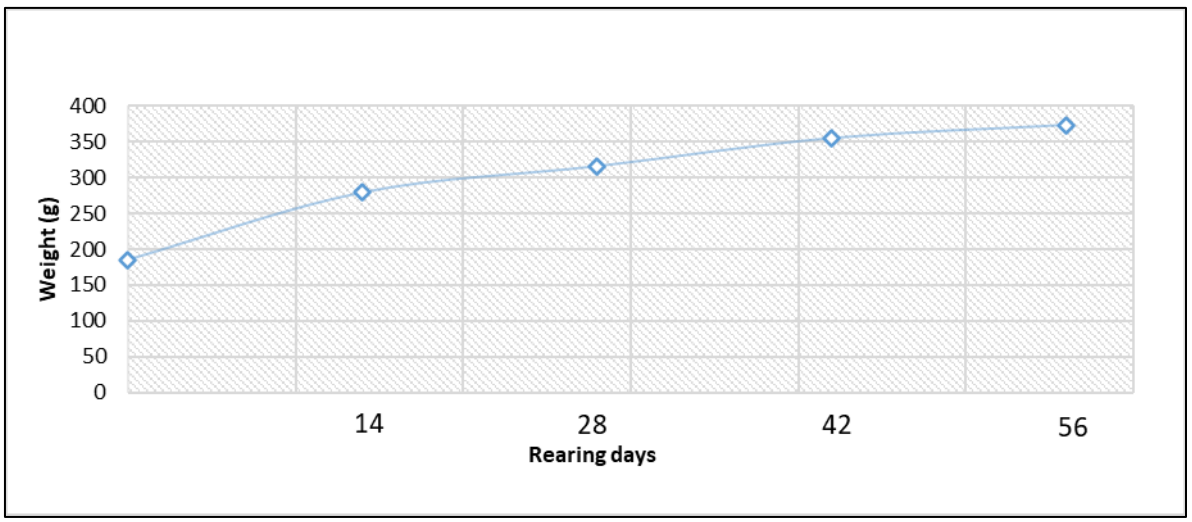

Figure 4 Change in average weight of male broodstock during the trial

3.3. Condition factor of broodstock

Table 3 shows the evolution of the condition factor of male and female broodstock of *Oreochromis niloticus* Akosombo strain during the trial.

The condition factor for male broodstock gave an average value of 4.4 ± 0.2 over the trial period. It showed a steady increase from the day of loading (3.7 ± 0.2) to the last day of the trial, with an average value of 4.6 ± 0.7. However, in females, the condition factor did not really change and stabilised around its initial value, with an average of 4 ±0.3 over the entire period.

Table 3 Evolution of the condition factor of broodstock

	Rearing days				
K factor	0	14	28	42	56
Female	3.8 ± 0,9	4 ± 0.6	4 ± 0.3	4.2 ± 0.3	4.1 ± 0.8
Male	3.7 ± 0.2	4.5 ± 0.3	4.5 ± 0.3	4.6 ± 0.4	4.6 ± 0.7

3.4. Reproductive potential of Tilapia *Oreochromis niloticus* Akosombo strain

3.4.1. Total number of fry produced

The change in the number of fry produced during the trial is shown in Figure 5.
The total production of fry during the trial was 64288 for the four fry collections. In this figure, fry production during the second collection (34100 fry) is significantly higher than the number of fry from the first collection (12954 fry), the third collection (5967 fry) and the fourth collection (11267 fry). The one-factor analysis of variance shows a significant difference (p-value < 0.05) between the number of fry in collection 2 and those in collections 1, 3 and 4.

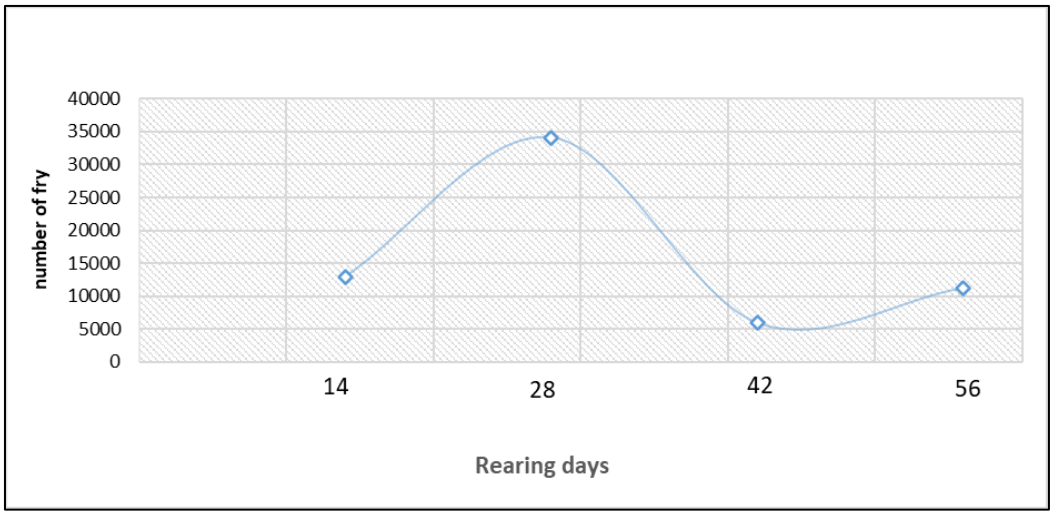

Figure 5 Change in the number of fry produced during the trial

3.4.2. Average weight of fry produced

The change in the average weight of the fry during the trial is shown in Figure 6. In this representation, the average weight of the fry produced is 0.011± 0.0g. The maximum average weight of the fry was recorded on the 56th day of rearing (0.013g). The average weight on the 14th day of rearing (0.011 g) is identical to that on the 42nd day of rearing, with a slight decrease between the two (0.010 g) on the 28th day of rearing. However, one-way analysis of variance shows no significant difference (ANOVA, p-value > 0.05) between the average weight of the different collections.

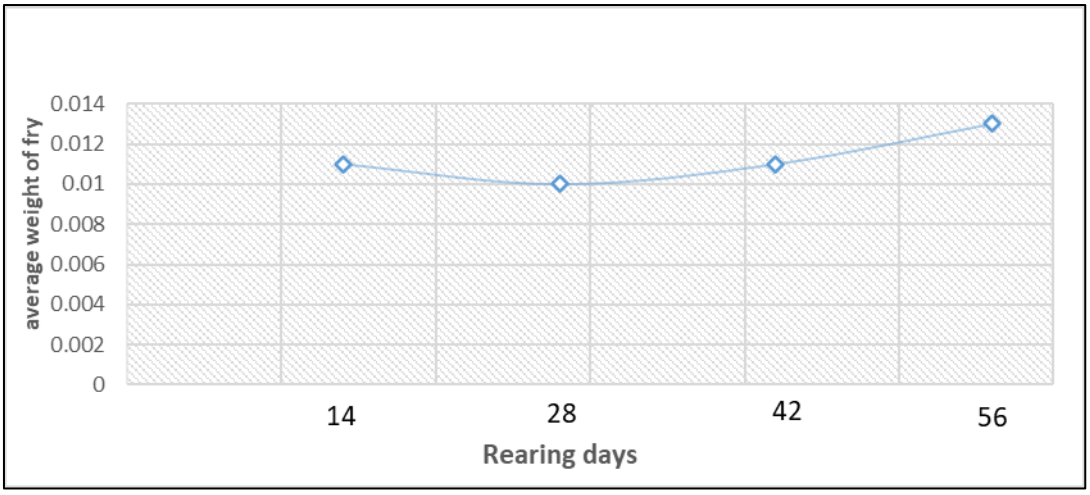

Figure 6 Change in average weight of fry

3.4.3. Number of fry per gram of female per day

The change in the number of fry produced per gram of female per day during the trial is shown in Figure 7.

The average production during the trial period was 0.15 ± 0.13 fry per gram of female per day. 0.17, 0.34, 0.05 and 0.09 fry per gram of female per day were recorded on the 14th, 28th, 42nd and 56th days of rearing, respectively.

In the figure, fry production per gram of female per day at collection point 2 increased significantly compared to other collection points during the trial period. It increased from the first harvest (0.17 fry per gram of female per day on the 14th day of rearing) to reach its maximum (0.34 fry per gram of female per day) on the 28th day of rearing, before falling to (0.05 fry per gram of female) on the 42nd day of rearing, and at the end of the trial a slight increase (0.09 fry per gram of female per day). The one-factor analysis of variance showed a significant difference (p-value < 0.05) between the number of fry in collection 2 and those in collections 1, 3 and 4.

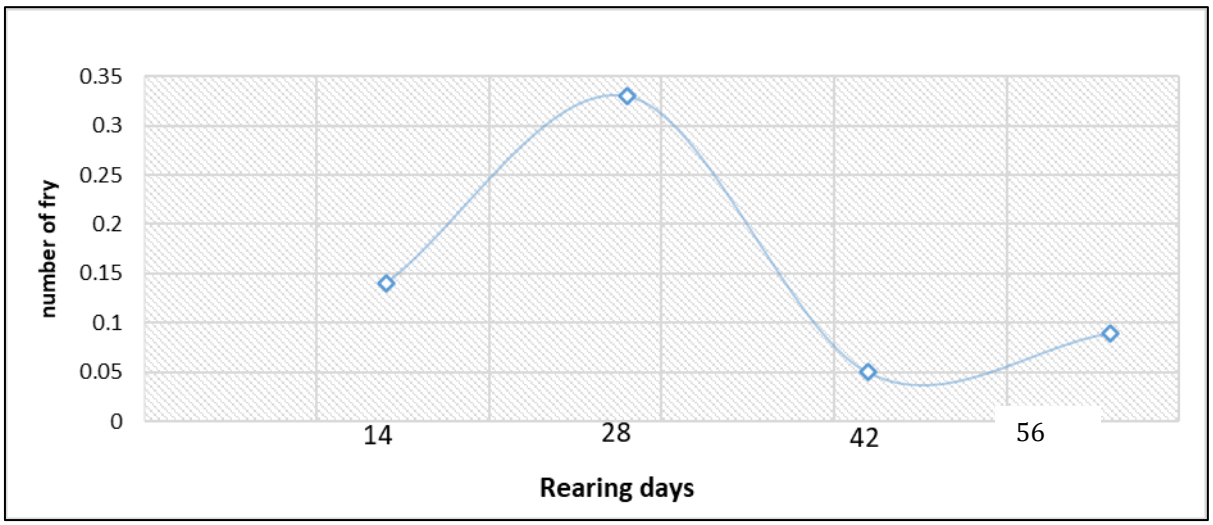

Figure 7 Change in the number of fry produced per gram of female per day

3.4.4. Weight of fry produced per gram of female per day

The change in the weight of fry produced per gram of female per day during the trial is shown in Figure 8.

The weight of fry per gram of female per day averaged 0.0017 ± 0.0012g over the trial period. We recorded 0.0026 g/g female/day and 0.0033 g/g female/day for the 14th day of rearing and 28th day of rearing, respectively. For the 42nd and 56th days of rearing, values of 0.0005 and 0.0012 g/g/female/day were recorded, respectively.

The graph shows an upward trend from the 14th day of rearing (0.0026 g/g female/day) to the 28th day of rearing, when the maximum was reached (0.0033 g/g female/day), followed by a gradual decline until the 42nd day of rearing (0.0005 g/g female/day), then gradually increasing until the 56th day of rearing with 0.0012 g/g female/day.

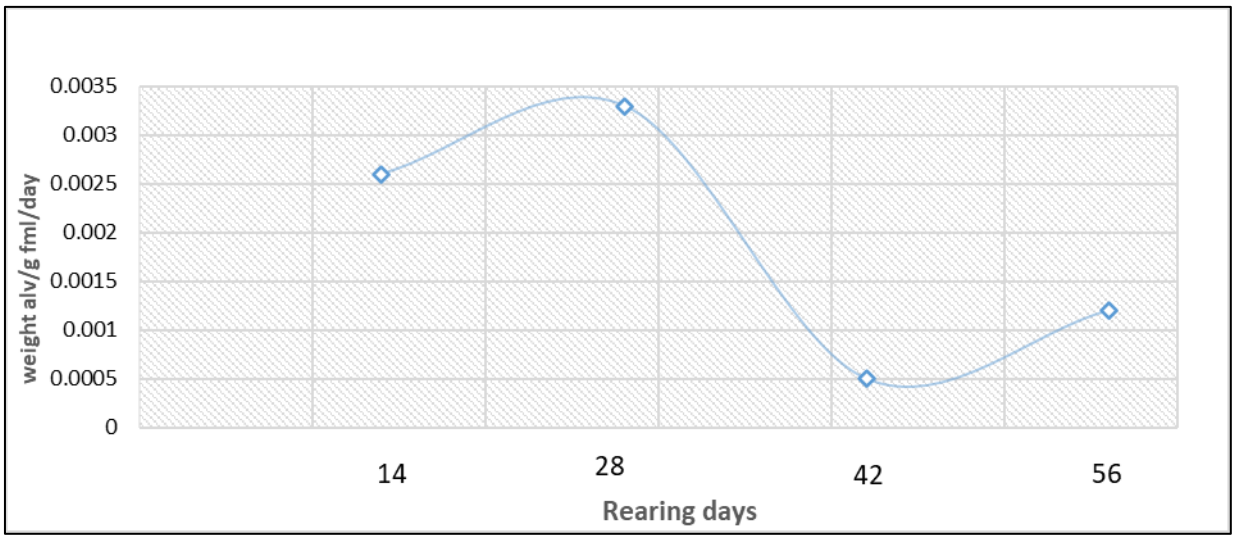

Figure 8 Evolution of the weight of fry produced per gram of female per day

4. Discussion

The average temperature values (28.47 ± 1.01 to 29.38 ± 1.23) recorded in this study are similar to those reported in previous studies by several authors [5,6,7,8]. According to [9], for good reproduction and optimal development of secondary sexual characteristics in *Oreochromis niloticus* tilapia, the average water temperature must be between 21°C and 30°C. Similarly, as the major constraint in tilapia aquaculture is temperature, the minimum rearing temperature is 16°C and the maximum is 38°C, with an optimum range of between 28 and 32°C for Nile tilapia [10]. The temperatures obtained were therefore within the specified ranges. With regard to dissolved oxygen, the average values fluctuated between 8.79 ± 3.03 mg/l and 12.54 ± 6.11 mg/l. According to [11], the ideal concentrations of dissolved oxygen for reproduction start at 2 mg/l. The dissolved oxygen level obtained is therefore very favourable for reproduction. As for pH, it ranged from 7.4 ± 0.1 on day 42 to 8.2 ± 0.6 on day 14 of rearing. These values easily fall within the recommended range for rearing, which is a pH between 7 and 8.5 [11].

With regard to the reproduction of *Oreochromis niloticus* from the Akosombo strain, the average weight of males increased. From 185.4 ± 22.7g at stocking, it rose to 375 ± 58.8g at the last control harvest, with a daily growth of 3.3g/day. As for the females, their average weight changed slightly. It rose from 95 ± 27.8g at the start of the experiment to 192.9 ± 37.6g at the last control catch, with a daily growth rate of 1.7g/day. However, according to [10], depending on the strain used, feeding and breeding conditions, tilapia can grow between 2 and 4 g per day. The increase in weight in males is due to the fact that the energy derived from food is devoted to growth in males, whereas females devote their energy to reproduction (egg production, mouthbrooding, caring for young larvae). The survival rate of broodstock was 100% at the end of the trial.

The number of larvae produced was 64,288 over the four (04) collections in two months, with an average weight of 0.011 ± 0.01g over the trial period. However, the average weight of the larvae decreased during the second collection (0.010 g), which yielded the highest production during the trial (34,100 larvae), compared to the other collections. However, during the last collection, we obtained a better average weight (0.013g) than in other collections, with a production of 11,267 fry. These results confirm the conclusions of [12] who, at the end of his work, found that the average weight of the larvae decreased as the number of larvae increased. This is related to the increase in weight of females over time. These values, obtained over two months, are broadly in line with the statistics of [13], who produced between 60,000 and 80,000 larvae in three (03) to four (04) months with 200 females weighing between 150 and 300g on average. The production of fry from the Akosombo strain was 24 fry per female per day over the trial period.

Regarding the number of fry produced per gram of female per day, our trials yielded an average of 0.15 ± 0.13 fry per gram of female per day over the experimental period. We also observed a decrease in production after the 28th day of

rearing (0.34 fry/g of female). This decrease was from 0.29 to 0.25 fry/g of female. According to [14], a decrease from 0.27 to 0.23 in the number of fry/g of female/day is observed for females weighing between 50 and 130 g.

In terms of fry weight per gram of female per day, we obtained an average of 0.0017 ± 0.0012g over the experimental period. We noticed that when females produce a large number of fry, the weight of the fry is low, whereas the weight of the fry produced is high for a small number of fry. There is therefore a trade-off between the number of fry produced and the weight of these fry [15].

The condition factor determines the physiological state of a species, including its reproductive capacity and the influence of the environment on the species [16]. The condition factor (K) obtained in this study for males is on average 4.4 ± 0.2 and that for females is also 4 ± 0.3. According to [17], in farming, the optimal condition coefficient for O. niloticus is 4.07 for both sexes. The K values obtained in our study therefore favoured good reproduction of the Akosombo strain.

5. Conclusion

The first study on Nile tilapia *Oreochromis niloticus* Akosombo strain in the Ivorian environment aimed to evaluate reproductive performance. With regard to the breeding environment, the physico-chemical parameters measured, such as temperature (28.9 ± 0.2 °C), dissolved oxygen (10.4 ± 1.9 mg/l) and pH (7.8 ± 0.4), were favourable for the reproduction of the Akosombo strain. During reproduction, 64,288 fry were produced over four (04) collections in two months, with an average weight of 0.011 ± 0.0g. The average number of fry per gram of female per day was 0.15 ± 0.13 fry. Average condition coefficients of broodstocks were of 4.4 ± 0.2 and 4 ± 0.3 for males and females, respectively. They were therefore in better breeding conditions, which favoured the production of a good quantity of fry.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

The authors declare no conflicts of interest regarding the publication of this paper

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