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Reproductive performance and economic analysis of fry production in the Brazilian strain of Oreochromis niloticus in Côte d'Ivoire

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Abstract

This study evaluated the reproductive performance and fingerling production cost of Oreochromis niloticus, Brazilian strain. The trials were conducted in concrete tanks at a stocking density of 1.6 fish/m² for broodstock. Larvae, stocked at 1,000 larvae/m³ in 1 m³ hapas, were reared and fed for 28 days. The total number of larvae produced by 18 females of the Brazilian strain was 5,261 ± 387. The average number of larvae produced per female was 292.33 ± 15.6. The production potential of this strain corresponded to 0.55 ± 0.02 larvae per gram of female body weight. The initial mean larval weight was 0.01 ± 0.001 g. After 28 days of rearing, larvae reached a mean weight of 1.01 ± 0.05 g. The average survival rate obtained was 82.63 ± 3.37%. The average production cost was 13.21 CFA francs per fingerling. These results show that the Brazilian strain of Oreochromis niloticus exhibits promising reproductive performance and a production cost suitable for the Ivorian market and fish farming environment.

Keywords : Nile tilapia; Brazilian strain; reproduction; production cost; Côte d'Ivoire

1. Introduction

The global supply of aquatic products was estimated at 171 million tonnes in 2016, with more than half originating from capture fisheries, contributing 53.18% of total production (Sissao et al., 2019). However, aquaculture is experiencing rapid expansion, with an annual growth rate of around 13%, and has been the main source of fish for human consumption since 2014 (FAO, 2018). This trend occurs in a context of increasing global demand for fishery products, mainly driven by population growth and the need for sustainable management of natural resources (Diana, 2009; FAO, 2018). In this context, improving aquaculture production systems has become a priority at the global level.

In Côte d'Ivoire, fish farming was introduced as early as the 1950s, but its development remains limited despite significant physical, climatic, human, and hydrographic potential favorable to the growth of the sector. Fish nevertheless represents the main source of animal protein in the diet of Ivorian populations, with an average consumption estimated at 15.4 kg per capita per year (Glasser, 2003). In 2000, national production covered only about 30% of annual fish demand, estimated at 250,000 tonnes, forcing the country to import nearly 70% of its consumption, mainly in the form of frozen fish (FAO, 2002).

Nile tilapia (Oreochromis niloticus), particularly the local Bouaké strain, accounts for nearly 90% of the species farmed by Ivorian fish farmers (MIRAH, 2014). However, the relatively low zootechnical performance of this strain has been a major constraint to the development of national aquaculture. To address this limitation, the Government of Côte d'Ivoire introduced an improved strain of Oreochromis niloticus from the Federative Republic of Brazil, with the aim of increasing productivity, enhancing the profitability of fish farming operations, and reducing the country's dependence on fish product imports.

In this context, the present study aims to analyze the reproductive and growth performance of broodstock and fry from this improved strain, as well as to determine the production cost of fry under station conditions. These parameters are essential indicators for assessing the techno-economic viability and the prospects for sustainable dissemination of this strain in Côte d'Ivoire.

2. Materials and Methods

2.1. Description of the Study Site

The study was conducted at the Inland Fisheries and Aquaculture Research Station (SRPAC) of the CNRA. It is located in central Côte d'Ivoire, 6 km from Bouaké, specifically within the Kongodékro classified forest (7°37' N latitude and 5°02' W longitude). The station covers an area of 114 ha. The facility includes ponds, tanks, an aquarium room, a hatchery, a biosecure area, and a quarantine unit. It has 50 concrete tanks of various volumes, 14 raceways, and 20 sorting tanks. The station comprises 80 ponds, covering a total water surface area of 2.5 ha. Individual pond sizes range from 50 m^2 to 1000 m^2. These ponds are arranged in series and are supplied with water by gravity from the Kan dam and by pumping from a borehole.

2.2. Biological Material

The tilapia species used in this study was Oreochromis niloticus (Brazilian strain). This strain is considered improved because its growth performance has been enhanced compared to the local strain through selective breeding and crossbreeding. The broodstock used in this experiment consisted of representatives of the 39th selected generation originating from Brazil. These fish were introduced to the SRPAC in July 2014. A total of 48 broodstock were used, including 12 males and 36 females. These broodstock were used to produce larvae, which were subsequently reared into fry.

2.3. Measurement of Physicochemical Parameters

The monitoring of water physicochemical parameters was carried out twice a week throughout the experimental period. Measurements were taken using a multiparameter device (HANNA). The parameters considered in this study were temperature, pH, and dissolved oxygen.

2.4. Experimental Procedure

Prior to the onset of reproduction, male and female broodstock were kept separately in holding tanks to ensure proper conditioning. Each broodstock individual was then weighed before being introduced into the reproductive units. Two reproduction cycles were conducted in two concrete tanks of 15 m^2 each. The stocking density was set at 1.6 individuals/m^2, with a sex ratio of 1 male to 3 females (El-Sayed, 2020), corresponding to 6 males and 18 females per tank. The average weight of males was 996 ± 87 g, while that of females was 527 ± 58 g. The broodstock were fed a commercial pelleted feed containing

36% crude protein, administered at a daily ration equivalent to 2–3% of biomass (El-Sayed, 2020). Fourteen days after stocking for reproduction, larvae were collected. A total of 200 larvae were individually weighed to determine their initial mean weight. The broodstock were then individually weighed and returned to resting concrete tanks according to sex and weight class. This rotation system helps reduce physiological stress and prepares the fish for subsequent reproductive cycles.

For larval rearing, 3,000 larvae were stocked in three hapas at a density of 1,000 larvae/m³. The larvae were fed a commercial feed containing 55% crude protein. Feeding rates were gradually adjusted according to age (El-Sayed, 2020). Thus, feeding rates of 25%, 20%, 15%, and 10% of biomass were applied during the first, second, third, and fourth weeks, respectively. During each sampling operation, conducted weekly, 50 larvae were randomly collected from each hapa and individually weighed to determine the mean weight, which was used to adjust the feeding ration accordingly. The larval rearing period lasted 28 days.

2.5. Zootechnical and Reproductive Parameters

Zootechnical and reproductive performances were evaluated using the following parameters (Castel and Tiews, 1980; Guillaume et al., 1999):

Daily growth (g/day) = (1)

Survival rate (%) = (2)

Number of fry per female (Fry/female) =

(3)

2.6. Economic Parameters

The economic analysis focused specifically on production costs related to feed, which is considered the main expense in aquaculture. Labor cost for the 42-day rearing period was set at 21000 CFA francs, corresponding to 500 CFA francs per day.

Several economic parameters were calculated:

Cost of broodstock feed (CFA francs) = Quantity of feed used x Cost per kilogram of feed (1450 FCFA / Kg) (4)

Cost of fry feed (CFA francs) = Quantity of feed used x Cost per kilogram of feed (9000 FCFA / Kg) (6) ;

Total expenditure (CFA francs) = Cost of broodstock feed (CFA francs) + Cost of larval feed (CFA francs) + Labor cost (CFA francs) (7) ;

Production cost (CFA francs per fry)= Total expenditure (CFA francs) / Number of fry (8).

2.7. Statistical analysis

The data were recorded in Microsoft Excel (version 2016) and analyzed using Statistica 7 software. Descriptive statistics (means and standard deviations) were calculated for each zootechnical and economic parameter.

3. Results

3.1. Physicochemical characteristics of the rearing environment

During the experiments carried out in the breeding tanks, the mean water temperature was 28.4 ± 2.2 °C. The dissolved oxygen concentration showed an average value of 4.5 ± 0.3 mg/L, while the mean pH recorded was 7.1 ± 0.35 (Table I).

Table I: Physicochemical parameters of the rearing facility

Physicochemical parameters	Mean values
Temperature (°C)	28.4 ± 2.2
Dissolved oxygen (mg/L)	4.5 ± 0.3
pH	7.1 ± 0.35

3.2. Weight growth and survival rate of broodstock

During the reproduction period, broodstock of the «Brazil» strain showed a moderate increase in their mean body weight (Table II). In males, weight increased from 996 ± 87 g to 1,034 ± 79 g, whereas in females it rose from 527 ± 58 g to 572 ± 68 g. The recorded daily growth rate was estimated at 1.2 ± 0.39 g/day for males and 1.4 ± 0.40 g/day for females.

3.3. Reproductive performance

Reproduction of broodstock from the «Brazil» strain yielded an average of 5,261 ± 387 larvae per cycle. The mean individual weight of larvae at collection was 0.01 ± 0.001 g. Each female produced an average of 292.33 ± 15.6 larvae, corresponding to a specific productivity of 0.55 ± 0.02 larvae per gram of female (Table II).

3.4. Larval growth and survival

After 28 days of rearing in happas, the larvae reached the fingerling stage, with a mean weight of 1.01 ± 0.05 g. The daily growth rate during this phase was estimated at 0.033 ± 0.0094 g/day. The average survival rate obtained was 82.63 ± 3.37% (Table II).

Table II: Zootechnical and reproductive parameters of the «Brazil» strain of Nile tilapia (Oreochromis niloticus)

Phases	Parameters	Mean values
Broodstock	Initial male weight (g)	996 ± 87
	Final male weight (g)	1,034 ± 79
	Initial female weight (g)	

527 ± 58

Final female weight (g)

572 ± 68

Daily growth rate – males (g/day)

1.2 ± 0.39

Daily growth rate – females (g/day)

1.4 ± 0.40

Survival rate (%)

100 ± 0

Larval phase

Number of larvae produced per cycle

5,261 ± 387

Mean larval weight (g)

0.01 ± 0.001

Number of larvae per female

292.33 ± 15.6

Number of larvae per g of female

0.55 ± 0.02

Fingerling phase

Final mean weight of fingerlings (g)

1.01 ± 0.05

Daily growth rate (g/day)

0.033 ± 0.0094

Survival rate (%)

82.63 ± 3.37

3.5. Economic parameter

The economic parameters related to larval production are presented in Table III. The cost of feed for broodstock amounted to 7845 FCFA, while that used for larvae reached 28800 FCFA. The total number of fingerlings produced during the trial was 4,363 individuals. In addition, the total expenditure was estimated at 57645 FCFA, corresponding to a unit cost of 13.21 FCFA per 1 g fingerling produced.

Table III: Selected economic parameters of larval production

Parameters	Mean values
Broodstock feed quantity (g)	5412
Broodstock feed cost (FCFA)	7845
Larval feed quantity (g)	3209
Larval feed cost (FCFA)	28800
Labor cost (FCFA)	42000
Total expenditure (FCFA)	57645
Number of fingerlings	4363
Production cost per fingerling (FCFA)	13.21

4. Discussion

During this study, the physicochemical parameters of the water remained within the ranges considered optimal for the reproduction and growth of Nile tilapia (Oreochromis niloticus), namely a temperature between 26 and 30 °C, a dissolved oxygen concentration above 4 mg/L, and a pH ranging from 6.5 to 8.0 (El-Sayed, 2006; FAO, 2019).

The weight evolution of Oreochromis niloticus broodstock of the «Brazil» strain showed a clear increasing trend in both sexes, rising from 996 ± 87 g to 1,034 ± 79 g for males and from 527 ± 58 g to 572 ± 68 g for females. This progression reflects the good adaptation of the broodstock to the experimental conditions, characterized by favorable water quality and a protein-rich diet. The differences observed between sexes can be explained by distinct physiological strategies: males allocate a significant portion of energy from feed to somatic growth, whereas females invest more in vitellogenesis and egg production (Toguyeni et al., 2016; Sifa et al., 2019). This differential energy allocation justifies the slightly higher growth observed in females. Furthermore, the daily growth rate of broodstock, estimated at 1.2 ± 0.39 g/day for males and 1.4 ± 0.40 g/day for females, appears higher than values reported in earlier studies conducted in Côte d'Ivoire (Lazard, 1980), but is consistent with results obtained in genetic improvement programs in West Africa, where rates between 1.0 and 1.5 g/day have been reported (Bentsen et al., 2017). The 100% survival rate confirms the robustness of the rearing protocol and the good control of experimental conditions, largely exceeding the minimum threshold of 90% generally accepted in tilapia aquaculture (Mabroke et al., 2018).

Regarding reproductive performance, the average number of larvae produced per cycle was 5,261 ± 387, corresponding to a mean fecundity of 292.33 ± 15.6 larvae per female and 0.55 ± 0.02 larvae per gram of female. These results are comparable to those obtained with other improved strains in Ghana and Nigeria, where fecundity levels ranging between 200 and 300 larvae per female have been reported (Ayinla et al., 2019; Attipoe et al., 2021). However, some studies conducted using diets enriched with essential fatty acids and vitamins report higher performances, reaching up to 350 larvae per female (Yakubu et al., 2020). The difference observed in the present study may be related to the feed composition used for broodstock. Although the diet had a high protein content (48% crude protein), suitable for tilapia requirements, it did not include specific supplementation with micronutrients essential for reproduction, such as long-chain polyunsaturated fatty acids (HUFA) or fat-soluble vitamins.

At the larval stage, the individual weight of collected larvae (0.01 ± 0.001 g) is consistent with standards reported for Oreochromis niloticus (Ridha & Cruz, 2018). However, after 28 days of rearing in happas, the average survival rate recorded (82.63 ± 3.37%) remains below international benchmarks, which generally range between 85 and 95% under controlled conditions (Azevedo et al., 2015; Abdel-Tawwab et al., 2020). Several factors may explain this reduced survival rate. On one hand, the larval stocking density applied (1,000 individuals/m²) likely increased feeding competition and promoted cannibalism, a well-documented phenomenon in tilapia (Melard & Philippart, 2018). On the other hand, the nature of the feed provided, consisting of a powdered diet with 67% protein, although energy-rich, may have presented limitations in terms of digestibility and availability of polyunsaturated fatty acids, which are essential for larval development (El-Sayed et al., 2019). Finally, the manual “broadcast feeding” method used under field conditions results in heterogeneous feed distribution, which may increase growth disparities and mortality.

These findings raise several avenues for improvement. The incorporation of live feeds such as rotifers or natural zooplankton during the first days post-hatching could enhance larval survival, as demonstrated by recent studies conducted in Côte d’Ivoire and Cameroon (Konan et al., 2022; Ngueguim et al., 2023). Moreover, reducing initial stocking densities or transferring larvae earlier into ponds could limit the intensity of cannibalism and improve survival rates. Finally, more rigorous monitoring of physicochemical parameters, particularly ammonia and nitrites, would help better identify the causes of the observed mortalities.

From an economic perspective, although the quantity of feed distributed to broodstock was higher than that provided to larvae, larval feed was more expensive due to its higher protein content (55% compared to 36% for broodstock feed). According to Thabet (2017), the production cost of a 2 g fingerling in geothermal water, including all fixed and variable costs, is estimated at 13.83 FCFA. In the present study, the production cost of a 1.06 ± 0.6

g fingerling was slightly lower, at 13.21 FCFA. This relatively small difference can be explained mainly by two factors. First, the infrastructure used in the experimental setup has already been depreciated, thereby reducing fixed costs (equipment depreciation and initial investments). Second, some operational costs were not fully integrated into the estimation, particularly certain indirect and variable expenses (full maintenance, indirect labor, energy, or secondary inputs, depending on the case). Thus, the observed cost reflects more an experimental or partially consolidated production cost rather than a complete economic cost. Nevertheless, these results indicate that fingerling production in hatchery conditions can achieve a relatively competitive cost level, which represents a potential advantage for the aquaculture sector by facilitating farmers’ access to quality fingerlings at lower cost.

5. Conclusion

The study showed that a stocking density of 1.6 ind/m² and feed quality significantly influence the zootechnical performance of Nile tilapia (Oreochromis niloticus) broodstock of the “Brazil” strain. The broodstock exhibited excellent survival (100%) and satisfactory growth, while larval survival reached 82.63%. The production cost of a 1.06 g fingerling was estimated at 13.21 FCFA, providing useful information for the economic planning of production. These results highlight the need to optimize both stocking density and feeding strategies in order to improve fingerling production and the profitability of hatchery systems.

Conflict of Interest

The authors declare that they have no conflict of interest.

Authors’ Contributions

All authors contributed to this article according to their respective roles.

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