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Egg Quality and Morphological, Morphometric, and Behavioral Characteristics of Red Hybrid Tilapia (*Oreochromis* Sp.) Fry Produced in Culture Systems in Cote D'ivoire

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Abstract | **Original Research Article**

The red hybrid tilapia (*Oreochromis* sp.) is a new species introduced into fish farming in sub-Saharan Africa to diversify cultured species and ensure a sustainable supply of fishery products for the population. However, knowledge regarding the quality of the species' eggs and fry, as well as the physicochemical conditions favorable to their development, remains limited. This study aimed to evaluate egg characteristics, hatching and fry survival performance, and water physicochemical parameters. Sixteen broodstock individuals (12 females and 4 males), maintained at a sex ratio of one male to three females, were used. The eggs had a mean diameter of 0.49 ± 0.06 mm, a mean longitudinal axis of 1.60 ± 0.15 mm, and a mean mass of 10.10 ± 0.90 mg. The coefficients of variation are relatively low: 13.3% for diameter, 8.79% for the longitudinal axis, and 8.88% for egg mass. Fertilization and hatching rates were 90% and 95.1%, respectively. After one month of rearing, the produced fry had a mean length of 10.05 ± 3.28 mm, a width of 2.75 ± 0.12 mm, a mean mass of 4.67 ± 1.25 g, a mean daily weight gain of 0.137 ± 0.05 g/day, and a survival rate of 83.33%. Mean values for temperature, oxygen, pH, total dissolved solids, and electrical conductivity were 28.57 ± 1.61°C, 3.25 ± 0.41, 9.31 ± 0.54, 135.75 ± 1.88 mg/L, and 170.16 ± 9.34 µS/cm, respectively. These results demonstrate that the red hybrid tilapia exhibits good reproductive performance and confirm its potential for juvenile production in Ivorian aquaculture.

Keywords: Red hybrid tilapia, reproduction, egg quality, hatching, fry survival, growth performance.

INTRODUCTION

Aquaculture is currently one of the most dynamic sectors of global animal protein production, driven by rising demand for seafood and the progressive decline of capture fishery resources [1]. Over recent decades, the sector has experienced sustained growth and contributes significantly to food security, poverty reduction, and job creation in many countries [2, 1]. According to [1], aquaculture now represents a key means of ensuring a sustainable supply of seafood for human consumption. This development is further supported by advances in farming techniques, feeding practices, and genetic selection programs, which have improved the production performance of numerous aquaculture species [3, 4]. Among the most widely farmed aquatic species worldwide, tilapia hold a significant position due to their hardiness, rapid growth, adaptability to diverse environments, and consumer acceptance [5]. Their ease of reproduction in captivity and favorable production performance also account for their widespread use in extensive, semi-intensive, and intensive farming systems [6, 7].

In Côte d'Ivoire, studies by [8] and [9] have shown that fish farming relies primarily on the culture of three species: Nile tilapia (*Oreochromis niloticus*), catfish (*Heterobranchus longifilis* and *Clarias gariepinus*), and the African sea catfish (*Chrysichthys nigrodigitatus*). However, the introduction of red hybrid tilapia as a new species to diversify fish production is attracting growing interest due to its attractive coloration, growth performance, and commercial potential. Farming this species offers an opportunity to meet the rising demand for high-quality fish. Indeed, this strain represents a promising alternative for diversifying fish

production, particularly in sub-Saharan Africa, where the demand for quality fish continues to increase [10, 1]. Nevertheless, successful farming depends largely on mastering its reproduction and ensuring the availability of high-quality juveniles—factors that rely on egg quality, proper fry development, and the maintenance of optimal rearing conditions.

In fish, egg and fry quality is a crucial indicator of reproductive performance, as it determines hatching success, early-stage survival, and juvenile production. Egg quality directly influences embryonic development, hatching rates, and larval growth and survival during early life stages [11]. Furthermore, larval characteristics allow for the assessment of post-hatching development [12, 13]. Thus, analyzing egg and larval characteristics—including morphometric, physical, biological, and behavioral parameters—makes it possible to evaluate the quality of early developmental stages and better understand the reproductive potential of the red hybrid tilapia (*Oreochromis niloticus*). These parameters are influenced by various factors, such as the age, weight, and physiological condition of the females, as well as their diet and rearing conditions. Among the latter, the physicochemical parameters of the environment—specifically temperature, pH, dissolved oxygen, electrical conductivity, and dissolved solids content—play a decisive role, as their stability directly determines successful egg incubation and larval survival [5].

Despite growing interest in the red hybrid tilapia, scientific knowledge regarding its reproductive performance in sub-Saharan Africa remains fragmentary—particularly data concerning egg quality, larval characteristics, and the physicochemical conditions conducive to their development. It is therefore necessary to characterize these parameters in order to better understand the species' reproductive potential and to provide a scientific basis for improving farming practices.

This study was conducted with the aim of evaluating egg characteristics, hatching and fry survival performance of the red hybrid tilapia (*Oreochromis* sp.), as well as water physicochemical parameters.

1- MATERIALS AND METHODOLOGY

1- Materials

The study was carried out at the Élite Piscicole agro-pastoral enterprise in Bouaké. The biological material consisted of eggs and larvae of hybrid tilapia (*Oreochromis* sp.) obtained from breeding between Brazilian and Thai strain broodstock.

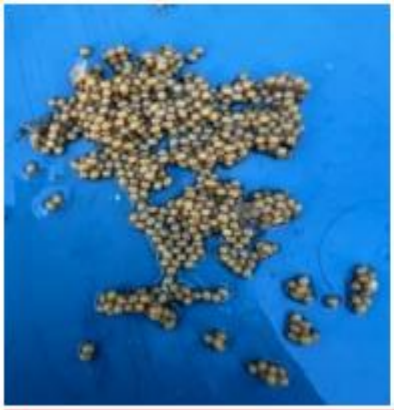

Figure 1: Tilapia eggs.

Figure 2: Tilapia fry.

Figure 3: Tilapia specimen

The technical equipment includes dip nets and buckets for capturing and transferring fish, a precision scale for weighing, a handling table, methylene blue for sex identification, a multiparameter probe for monitoring physicochemical water parameters, and borehole-fed concrete tanks equipped with inlet and drainage systems for tilapia breeding and larval rearing.

2-Methods

The trials were conducted in breeding tanks measuring 5 × 2 × 0.8 m (8 m³ volume), which had been cleaned and sun-dried for 24 hours beforehand. *Oreochromis* sp. broodstock were stocked at a density of 2 fish/m³ (16 fish per tank) with a sex ratio of 1 male to 3 females (4 males and 12 females). The experimental setup was carried out in triplicate. Broodstock were captured using seine nets with 8 mm and 14 mm mesh sizes, then selected based on health status, fin integrity, the condition of the urogenital tract, and—for females—the absence of oral lesions. Sexing was performed by observing the genital papilla. Mean weights were 257 g for females (Brazilian strain) and 550 g for males (Thai strain). Broodstock were fed twice daily with a commercial extruded feed (6 mm pellet size) at a ration of 1.5% of biomass. The feed contained 27% crude protein, 5.5% lipid, and 6% fiber.

Eggs were harvested 12 days after stocking by rinsing the mouths of incubating females (Figure 4), which were identified by their lack of feeding. Egg quality was assessed based on morphological criteria (color, shape, uniformity, and size) as well as fertilization and hatching rates.

Figure 4: Incubation and mouth-washing of hybrid red tilapia females.

The fry were harvested 9 days after egg collection, following yolk sac absorption. Their quality was assessed based on motility, coloration, size uniformity, malformations, feeding behavior, survival rate, and average daily gain (ADG). Eggs and larvae were measured using digital calipers, and their mass was determined using a precision balance. The larvae were then reared in holding tanks and fed seven times daily with a 0.3 mm powdered feed containing 52% crude protein. Physicochemical water parameters (temperature, dissolved oxygen, pH, electrical conductivity, and TDS) were measured daily—morning and evening—using a multiparameter probe to monitor rearing conditions.

3-Statistical analysis

Data were entered and analyzed using Microsoft Excel 2016. Results are presented as mean ± standard deviation for quantitative variables. The coefficient of variation, as well as fertilization, hatching, and survival rates, were calculated as percentages using the corresponding formulas.

2- RESULTS AND DISCUSSION

2-1- Results

2.1.1. Zootechnical, morphometric, and morphological parameters of hybrid tilapia eggs and larvae

Tables I and II present the morphometric characteristics of red hybrid tilapia (*Oreochromis* sp.) eggs. Table I summarizes the descriptive statistics for the measured variables (egg diameter, longitudinal axis, and mass), while Table II shows the distribution of eggs according to diameter classes. The results show that the eggs have a mean diameter of 0.49 ± 0.06 mm, a mean longitudinal axis of 1.60 ± 0.15 mm, and a mean mass of 0.0101 ± 0.0009 g. The coefficients of variation are relatively low: 13.3% for diameter, 8.79% for the longitudinal axis, and 8.88% for egg mass. Furthermore, the diameter distribution reveals a predominance of the 0.50 mm class, which accounts for 56.7% of the total sample (17 out of 30 eggs). The 0.40 mm class comprises 26.7% of the eggs, while the 0.60 mm class is the least represented, with 16.7% of observations. Egg mass is approximately 0.0101 ± 0.0009 g.

Table 1: Parameters of red hybrid tilapia eggs

Parameter	Effective	Coefficient of variation (%)	Minimum	Maximum	Moyenne
Diameter of eggs (mm)	30	13,3	0,40	0,60	0,49 ± 0,06
Longitudinal axis of the eggs (mm)	30	8,79	1,40	1,80	1,60 ± 0,14
Egg mass (g)	30	8,88	0,0078	0,0118	0,0101 ± 0,0009

Table 2: Distribution of eggs according to diameter classes

Diameter class (mm)	Effective	Percentage %
0,40	8	26,7
0,50	17	56,7
0,60	5	16,7
Total	30	100,0

Morphological observations of hybrid tilapia eggs are presented in Table III. The eggs observed were predominantly spherical, with some slightly oval shapes. Their coloration ranged from pale yellow to orange-yellow. The texture was slightly firm, and no adhesion was observed between the eggs found in the buccal cavity of the brooding females. No eggs exhibited visible deformity, whitish coloration, or apparent alteration of the external structure.

Table 3: Morphological criteria and dimensions of *Oreochromis* sp. hybrid eggs

Criteria	Observations
Shape	Spherical, sometimes slightly oval
Color	Pale yellow to orange-yellow
Texture	Slightly firm, non-sticky, eggs separate in the mouth of the brooding female.
Uniformity	Good uniformity (shape, color, and size)

2.1.2. Fertilization, hatching, and fry survival parameters for hybrid tilapia

The fertilization, egg hatching, and fry survival rates for hybrid tilapia are recorded in Table IV. A total of 701 eggs were collected, of which 631 were identified as fertilized, representing a fertilization rate of 90%. Following embryonic development of the fertilized eggs, 600 larvae were obtained, corresponding to a hatching rate of 95.1%. A check-count performed one month into the fry rearing period yielded a total of 500 individuals. The survival rate calculated for this period was 83.33%. The majority of the fry were normal (98.8%). The malformation rate was 1.2%.

Table 4: Reproductive performance and larval characteristics of hybrid tilapia

Parameters	Number	Rate (%)
Œufs récoltés	701	
Œufs fécondés	631	90
Œufs éclos	600	95,1
Survie alevins	500	83,33
Alevins malformés	6	1,2
Alevins normaux	494	98,8

Table V presents the morphological, morphometric, and behavioral characteristics of the fry. Low mobility was observed after hatching, but this increased progressively during development. In total, 70% of the fry were red, followed by 25% that were red-spotted, and 5% that were grayish. Larger larvae reacted more quickly to the distribution of feed and dominated access to the food. The population was heterogeneous, consisting of small, medium, and large individuals.

Table 5: **Description of morphological and behavioral parameters of *Oreochromis* sp. fry.**

Parameters	Description of observations / Values
Mobility	Initially low at hatching
	Mobility increases during development Predominantly at the surface at hatching
Coloration	70 % red; 25 % stained red; 5 % greyish
Feeding behavior	Faster response of large larvae to distributed feed
Size uniformity	Heterogeneous population composed of small, medium, and large individuals.

2.1.3. Zootechnical parameters of the fry

Results regarding weight and length growth, as well as the growth rate, are presented in Table VI. The initial mean mass was 0.05 ± 0.02 g, while the final mean mass reached 4.67 ± 1.25 g. The recorded mean daily gain was 0.137 ± 0.05 g/day. After one month of rearing, the mean length of the fry was 10.05 ± 3.28 mm, and the mean width was 2.75 ± 0.12 mm.

Table 6: Growth parameters of hybrid red tilapia larvae

Paramètres	Valeur
Masse moyenne initiale	0,05± 0,02g
Masse moyenne finale	4,67 ± 1,25g
Gain moyen quotidien (GMQ)	0,137 ± 0,05g/jour
Longueur moyenne finale	10,05 ± 3,28 mm
Largueur moyenne finale	2,75 ± 0,12 mm

2-1-4-Physicochemical parameters of the fish rearing environment

Table 7 presents the variations in the physicochemical parameters of the water in the rearing environment. Temperature ranged from 27 to 31.13°C, while pH remained alkaline, with values between 8.54 and 10.08. TDS and electrical conductivity values showed moderate variations during the observation period, reflecting the relative stability of conditions in the rearing environment.

Table 7: **Physicochemical parameters of the rearing environment**

Parameters	Minimum	Maximum	Moyenne
Temperature (°C)	26	31,13	28,57±1,61
Dissolved oxygen (mg/L)	3,04	5,10	3,25± 0,41
pH	8,54	10,08	9,31±0,54
TDS (mg/L)	132,67	138,83	135,75±1,88
Electrical conductivity (µS/cm)	155,67	184,65	170,16±9

2.2. Discussion

The eggs of the hybrid red tilapia (*Oreochromis* sp.) have a mean diameter of 0.49 ± 0.06 mm with a coefficient of variation of 13.3%, reflecting moderate morphometric variability within the studied sample. This relatively low dispersion indicates that the eggs are generally uniform, while still exhibiting individual differences commonly observed in tilapia under natural breeding or culture conditions [12]. This biometric uniformity may be attributed to the use of a uniform batch of broodstock kept under similar conditions. However, the mean egg diameter obtained in this study appears lower than values generally reported in the literature for tilapia eggs. This difference could be linked to the characteristics of the broodstock used—specifically the mean female weight (257 g)—as well as to rearing conditions and traits specific to the hybrid strain studied. Indeed, egg size varies according to populations and breeding conditions, with larger females generally tending to produce larger eggs [12, 5].

The morphological characteristics observed in the eggs (spherical shape, pale yellow to orange coloration, slightly firm and non-adhesive texture, and dimensional uniformity) align with the quality criteria described by [14] and [15]. This uniformity suggests good synchronization of embryonic development and enhanced viability of the fertilized oocytes [16].

The fertilization (90%) and hatching (95.1%) rates obtained in this study indicate favorable reproductive conditions for *Oreochromis* sp. hybrids. These results are comparable to those reported in controlled rearing systems, where broodstock diet quality and proper environmental management contribute to improved reproductive performance [16, 17]. Indeed, the nutritional status of broodstock directly influences oocyte maturation and yolk quality. A balanced diet rich in proteins, essential fatty acids, vitamins, and minerals promotes gonad development, improves gamete quality, and enhances embryo viability [18, 5]. Furthermore, optimal environmental conditions—specifically stable temperature, good oxygenation, and adequate physicochemical parameters—reduce broodstock stress and foster embryonic development [19, 6]. In tilapia, egg quality also depends on the physiological state, age, and body condition of the broodstock [12]. Finally, the observed performance may also be attributed to good compatibility between parental strains; compatible *Oreochromis* crosses are associated with high fertilization and hatching rates when rearing conditions are well-controlled [20].

The fry survival rate of 83.33% at 30 days post-hatching indicates satisfactory rearing conditions. According to [21], good water quality and appropriate sanitary practices promote larval survival by reducing the risk of infection. The larvae had an average length of 10.05 mm and an average width of 2.75 mm, with few malformations. Furthermore, the eggs showed low diameter heterogeneity—reflected by a coefficient of variation of 13.3%—indicating normal development. The size heterogeneity among larvae observed in this study is a common phenomenon in tilapia. It manifests as the coexistence of small, medium, and large individuals and results primarily from individual growth differences, access to feed, and the social hierarchy established during the early stages of development [12, 5]. The largest larvae, being more responsive during feeding, enjoy a competitive advantage that progressively widens growth disparities within the population. These observations align with those reported by [22], who also highlighted size heterogeneity in tilapia larvae during early development stages. Measures such as size grading and appropriate feeding can help further reduce these disparities [23]. This satisfactory survival rate is attributable to effective rearing management, specifically appropriate feeding and regular monitoring of water quality. The larvae benefited from a favorable environment that minimized stress and mortality, allowing a large number of individuals to survive until the end of the rearing period.

Morphological and behavioral observations of the larvae indicate a developmental pattern consistent with that described for species of the genus *Oreochromis*. The low mobility observed immediately after hatching is linked to the early post-embryonic developmental stage, during which larvae still rely on yolk reserves and exhibit limited locomotor activity. As the yolk sac is absorbed, mobility gradually increases, facilitating active foraging [6, 5]. The predominance of red larvae (70%) and the low incidence of malformations suggest normal embryonic development, resulting from favorable incubation and rearing conditions. According to [19], water quality, temperature, and adequate oxygenation are essential factors in minimizing morphological abnormalities in fish larvae.

The increase in mean weight from 0.05 g to 4.67 g—representing an average daily gain of 0.137 g/day—reflects satisfactory larval growth and confirms that the

rearing conditions supported normal development, consistent with findings from several studies on tilapia raised under controlled conditions [20, 5]. This growth may be attributed to a diet that meets the nutritional requirements of the young fish, particularly regarding protein and essential amino acids [22].

In any aquaculture operation, water quality is a key determinant of successful fish production. Consequently, monitoring physical, chemical, and biological water parameters is crucial. However, the red tilapia is a hardy variety capable of tolerating a wide range of environmental fluctuations [24]. In our experiment, the mean temperature of 28.57°C fell within the optimal range for reproduction, larval development, and rearing; tilapia growth, feeding, and metabolism are optimized in warm water [15].

These results align with those of [25], who report that temperatures between 26 and 31°C ensure favorable conditions for tilapia development. They also corroborate the observations of [26], according to which maintaining the temperature within this range promotes zootechnical performance and optimal physiological function in the fish.

Water pH fluctuated between 8.54 and 10.08, with a mean of 9.31. These values indicate an alkaline environment, with pH levels slightly above the generally recommended range for red tilapia farming (6 to 9) [24]. These results differ from those of [5] and [25], who report pH values generally falling within the optimal range for tilapia. However, despite this relatively high alkalinity, mortality remained low, indicating that no major disruption to the rearing environment occurred during the study period. These hybrids possess a broad capacity to adapt to alkaline environmental conditions.

Red tilapia can tolerate and be reared in oxygen conditions ranging from 3 to 5 mg/L [24]. This species can survive for several hours at very low dissolved oxygen levels, in the order of 0.1 mg/L [27].

TDS values recorded during this study ranged from 132.67 to 138.83 mg/L, with a mean of 135.75 mg/L. These results reflect a low concentration of dissolved solids in the rearing water, indicating a relatively stable environment favorable to the development of *Oreochromis* sp. fry. TDS serves as an indicator of the total quantity of dissolved mineral and organic substances; moderate concentrations contribute to maintaining good water quality. These results are consistent with the observations of [25], who report that moderate TDS values characterize good-quality water in tilapia farming systems. They also corroborate the work of [26], according to which maintaining TDS at moderate levels promotes the stability of the culture environment and good fish growth performance.

Electrical conductivity fluctuated between 155.67 and 184.65 µS/cm, with a mean of 170.16 ± 8.54 µS/cm. These values indicate low to moderate water mineralization, reflecting an ionic concentration compatible with tilapia requirements. Electrical conductivity is a key parameter, as it reflects the quantity of dissolved ions in the water and allows for an assessment of its physicochemical balance [28, 29].

These results align with those of [30], who highlights that moderate electrical conductivity values indicate good water quality in fish farming operations. They also concur with the findings of [26], which state that monitoring conductivity is essential to ensure an environment that is stable and conducive to the growth of *Oreochromis* sp., with the values observed in this study remaining compatible with favorable rearing conditions.

CONCLUSION

This study evaluated egg quality and larval characteristics of the red hybrid tilapia (*Oreochromis* sp.) reared in Bouaké (central Côte d'Ivoire). The eggs exhibited good morphometric uniformity, with a mean diameter of 0.49 ± 0.06 mm, a mean longitudinal axis of 1.60 ± 0.15 mm, and low coefficients of variation (12.27% and 9.44%). The predominance of the 0.50 mm diameter class (60%), combined with normal morphology, indicates good egg quality. Fertilization (90%) and hatching (95.1%) rates demonstrate good reproductive performance. The larvae showed normal development, characterized by a low incidence of malformations, a mean length of 10.05 mm, a mean width of 2.75 mm, a survival rate of 83.33%, and a mean daily gain of 0.137 g/day. Physicochemical water parameters remained generally favorable for fish development throughout the study. These results provide baseline data on egg quality and larval development for the red hybrid tilapia in Côte d'Ivoire. They confirm the reproductive potential of this strain and its suitability for producing juveniles for fish farming. Further studies investigating the influence of broodstock nutrition, rearing density, and genetic factors on egg and larval quality will help to further optimize reproductive performance and strengthen the development of this aquaculture sector.

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