

Research Article.

Impact of environmental conditions on the growth of Nile Tilapia

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ABSTRACT

This study contributes to the development and management of aquaculture resources in the Tipaza region by evaluating the impact of stressful environmental conditions on the growth of Nile tilapia (*Oreochromis niloticus*) fry raised under controlled aquarium conditions over a 71-day period. Two groups were observed: a control group of 29 individuals kept in optimal conditions and an experimental group of 46 individuals exposed to stress. The effect of these stressful conditions was assessed based on the weight gain of stressed individuals compared to that of the control group fry, which were kept in freshwater (0 psu salinity) at a stable temperature of 28 °C. Key abiotic variables monitored included salinity and temperature, with averages of 5.233 psu and 20.11 °C, respectively, for the stressed group. Observed temperatures ranged from 17.22 °C to 24.62 °C, while the optimal growth range for this species is reported to be between 26 °C and 30 °C. The recorded average salinity was 5.23 psu, with no significant fluctuations, reaching a maximum of 5.67 psu and a minimum of 4.73 psu. Nile tilapia, known for its salinity tolerance, becomes more resilient to salinity as it matures. The average conductivity for the control group was 9.345±0.164 mS/cm, with maximum and minimum values of 10.07 and 8.51 mS/cm, respectively. The conductivity of the stressed group was lower, at 7.57 mS/cm, due to increased dissolution of ions from food and fish waste. The comparison of weight growth performance between the two groups revealed a significant difference: the final average weight gain was 4.617 g in the stressed group, compared to 16.160 g in the control group, highlighting the negative impact of stress conditions on fry growth.

KEYWORDS

Oreochromis niloticus;
Stressful conditions;
Weight gain;
Rearing.

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1 INTRODUCTION

Aquaculture, as an economic activity, must align with the principles of sustainable development to ensure its continuity, optimization, and significant contribution to food security. This alignment requires preserving aquatic ecosystems, ensuring a fair distribution of income to improve the socio-economic conditions of local communities, and adopting innovative techniques that enhance livestock systems (FAO, 2020).

Algeria's strategy aims to revitalize and diversify its economy beyond hydrocarbons by focusing on other sectors such as agriculture and fisheries. In recent years, the aquaculture sector, both marine and freshwater, has experienced significant growth, driven by new investment projects. Inland aquaculture production in 2020 reached 1,132 tons, a relative increase compared to the 476 tons recorded in 2002 for the entire aquaculture sector. However, this production remains below the sector's ambitions, which aim to reach 40,000 tons by 2030 for the continental segment, given Algeria's considerable water resources (MPPH).

Algeria's freshwater fish fauna includes at least 60 species, half of which have been introduced (Kara, 2012). The pure strain of *Oreochromis niloticus*, the Nile tilapia, the subject of this study, remains an exemplary aquaculture species, ranking third in the world with a production volume exceeding 4,407,000 tons in 2020 (FAO, 2022). Introduced into Algeria in 2002 from Egypt with an initial stock of 4,000 fry and 200 broodstock, this species was intended for farmers to support integrated aquaculture within agriculture (Boutouchent, 2002).

This hardy species, known for its profitability due to its rapid growth, low feed costs and high tolerance, which gives it some resistance to

diseases (Prabu *et al.*, 2019), has promising prospects for increased production. This potential is reinforced by the government's commitment to support the sector through financial incentives (2024 Finance Act) and legal measures.

The availability and supply of fry remain essential factors for effective aquaculture development. Currently, 12 hatcheries (seven public and five private) ensure the local production of approximately 100 million tilapia, Chinese tilapia, and catfish fry. However, these hatcheries are struggling to meet the growing demand due to their limited production capacity (Naji *et al.*, 2023). This study aims to explore the challenges and opportunities in the aquaculture sector, with a focus on the essential role of hatcheries. It highlights the need to encourage and support the creation of additional hatcheries to meet the growing demand for aquaculture products. Developing new hatcheries would ensure a supply of healthy, high-quality juveniles, reduce pressure on wild fish populations, and promote the sustainability of the sector, highlighting the need to encourage and support the creation of additional hatcheries. The principal objective of this study is to evaluate the impact of salinity and temperature fluctuations on the weight gain of Nile tilapia under controlled conditions.

This research is essential for improving the cultivation of Nile tilapia, a key species for food security and sustainable development, both in Algeria and globally. The aim of this study is to evaluate the impact of salinity and temperature fluctuations on the weight gain of Nile tilapia under controlled conditions.

2 MATERIALS AND METHODS

2.1 Presentation of the experimental site

The National Center for Research and Development of Fisheries and Aquaculture (CNRDPA) is a public scientific and technological institution under the supervision of the Ministry of Fisheries and Halieutics Production (MPPH). It is located in Bou Ismail in the Tipaza region. The aquaculture division of the CNRDPA, where this experiment took place, is responsible for implementing a research program that contributes to the sustainable development of both marine and freshwater aquaculture while preserving the environment and resources. Its main missions are the development of water resources, the assessment and management of aquaculture resources, and the reproduction of species of aquaculture interest.

2.2 Biological material

This experiment, which lasted 71 days, involved fry of the species *Oreochromis niloticus*, which were divided into two groups. The first group was a control group consisting of 29 individuals kept under favorable conditions, while the second group was an experimental group of 46 individuals subjected to stress conditions. Both groups were measured for weight and total length.

2.3 Monitoring of Abiotic Variables

The physicochemical parameters of the stressed group included salinity (5 psu) and temperature, which varied according to air temperature (Rodier, 1984). In contrast, the control group had a salinity of 0 psu and a temperature of 28 °C, maintained by a thermostat.

The monitoring of the physicochemical parameters of the environment was conducted

only for the stressed group. Temperature, salinity, and conductivity values were recorded twice a week, with at least three daily measurements. The averages of these measurements were then calculated. Only two pH measurements (8.71 and 8.82) were taken on different days. The aquarium water of the stressed group was renewed twice a week using a siphoning technique with a hose. A decrease in the number of individuals in this group was observed during a weighing session, likely attributed to the siphoning method, given the small size of the fry.

To maintain a stable salinity value (5 psu) throughout the experiment, a volume of filtered seawater was added using a 100 µm sieve. This volume was determined by two methods: (1) dilution law and (2) a multiparameter probe.

Monitoring electrical conductivity in the aquarium provides information about water quality and salinity, as conductivity depends on mineralization. High values of this variable can indicate an accumulation of waste or nutrients in the rearing water, contributing to osmotic stress in fish, which influences their physiology and growth metabolism.

Conductivity values vary from < 100 µS/cm (Rodier *et al.*, 2009), indicating very low mineralization, to > 1000 µS/cm, representing high mineralization.

The relationship between salinity and electrical conductivity for normal water shows a conductivity of 53 mS/cm for water with a salinity of 35 psu and a conductivity of 7.57 mS/cm, or 7570 µS/cm, for slightly brackish water with a salinity of 5 psu.

A summary of the differences between the control and stressed groups is presented in the table below, highlighting variations in environmental parameters and their potential effects on the growth of Nile tilapia. The control

group conditions were carefully stabilized to reflect an optimal environment, while the stressed group was exposed to modified parameters simulating challenging conditions (Table 1).

Table 1. Comparison of Environmental Parameters between the Control and Stressed Groups

Parameter	Control group	Stressed group
Temperature [°C]	28 °C (stable, maintained by a thermostat)	Variable, fluctuation with air temperature (Rodier, 1984)
Salinity [psu]	0 psu (freshwater)	5 psu (maintained by adding filtered seawater at 100 µm)
Physicochemical measurement	Not measured	Temperature, salinity, and conductivity measured twice weekly, with 3 daily reading
pH	Not measured	Two values recorded: 8.71 and 8.82
Water renewal	Not required	Twice a week, using a siphoning technique with a hose.
Number of individuals	Stable	Reduction observed, likely due to the siphoning method.

2.4 Monitoring of biotic variables

Linear and weight measurements were collected monthly throughout the experiment. The total length (Lt) of the fish was measured using an ichthyometer, which records the distance between the fish's snout and the tip of its caudal fin. The total weight was determined using a KERN balance with an accuracy of 0.01 g.

2.5 Feeding

The fry was fed four times daily during this rearing phase. The composition of the commercial feed, which was prepared in the laboratory, is presented in detail in Table 2. According to Jancy and Ross (1982), optimal growth rates of fish require dietary protein levels of 35-40% for fry weighing 0.5-10 g, 30-35% for fish weighing 10-35 g, and 25-30% for broodstock (Table 2).

Table 2. Composition of the feed used to feed the fry of Nile Tilapia

Components	Percentage (%)
Crude proteins	33
Fat	06
crude cellulose	41
Raw ash	71
Phosphorus	1.2
Calcium	0.4
Sodium	0.1

2.5.1 Daily Feeding Ration

The daily feeding ration varies depending on the fish's size, environmental conditions, feed quality, and digestion capacity (Jancy and Ross, 1982).

$$\text{Daily Feed (g/d)} = \text{Average Total Weight} \times \text{Feeding Rate} \times \text{Number of Individuals} \quad (\text{Eq. 1})$$

2.6 Data processing

2.6.1 Growth performance

To estimate this performance, indices were considered:

Weight Gain: It is a key indicator of growth performance influenced by factors such as diet and environmental conditions.

Daily Weight Gain: This metric allows for the daily monitoring of body mass growth.

$$\text{Daily Weight Gain (g)} = \frac{\text{Final Weight} - \text{Initial Weight}}{\text{Rearing Time}} \quad (\text{Eq. 2})$$

Specific Weight Gain Rate (SGR): This parameter is crucial for tracking the growth of cultured fish and making necessary adjustments to optimize rearing conditions. The 'Specific Weight Gain Rate' section features a simplified formula.

$$\text{SGR (\%)} = \frac{\ln(\text{Final Total Weight}) - \ln(\text{Initial Total Weight})}{\text{Rearing Time}} \times 100 \quad (\text{Eq. 3})$$

Survival rate: The calculation of this index provides insight into the individuals' response to farming conditions, which include environmental factors, feeding, and overcrowding.

$$\text{Survival rate} = \frac{\text{Final number of individuals}}{\text{initial number of individuals}} \times 100 \quad (\text{Eq. 4})$$

2.7 Statistical analysis

Statistical analysis was conducted using SPSS to perform t-tests and ANOVA. T-tests were used to

compare the means of weight (P) and length (L) between different groups (Wt1, Wt4, Lot 1, Lot 2), with a significance level set at $p < 0.05$. The comparisons included weight and length differences between groups Wt1 and Wt4 and between Lots; Lot 1 and Lot 2.

3 RESULTS AND DISCUSSION

3.1 Monitoring of environmental parameters

Figure 1 illustrates the variation of three abiotic parameters: temperature (°C), salinity (psu), and conductivity, showing similar patterns of fluctuation. This similarity can be attributed to the strong correlation between water salinity and conductivity.

The maximum and minimum values for the parameters are as follows: Temperature ranged from 17.64 °C to 23.64 °C, conductivity from 8.99 to 9.65 mS/cm, and salinity from 5.03 to 5.42 psu. The three curves in Figure 1 exhibit a similar pattern, with comparable fluctuations observed in all three variables, peaking on the same dates: mid-March, early April, and early May. This can be explained by the close relationship between salinity and conductivity. In terms of dispersion, temperature data showed higher variance compared to conductivity and salinity, with values of 2.22 °C, 0.027 mS/cm, and 0.009 psu, respectively.

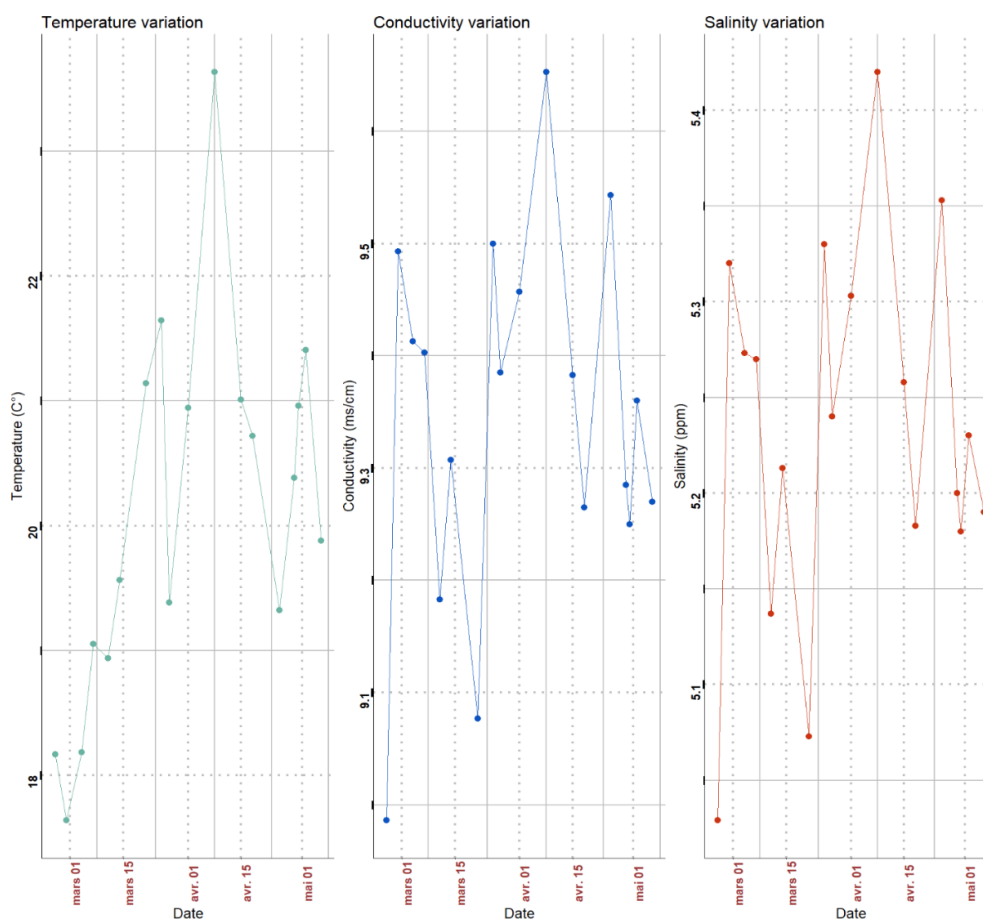


Figure 1. Variation of abiotic factors for the stressed sample

Temperature data were more spread out around the mean of 20.11 °C, while conductivity and salinity data were more tightly clustered around their means of 9.35 mS/cm and 5.23 psu.

The average temperature recorded during the study ranged from 17.22°C to 24.62°C. According to Mélard (1999), the optimal temperature for Nile tilapia growth is between 26 °C and 30 °C.

The average salinity observed during the study was 5.23 psu, with a maximum of 5.67 psu and a minimum of 4.73 psu. Throughout the study period, salinity levels did not fluctuate significantly. Although *Oreochromis niloticus* is known to be sensitive to salinity, its tolerance increases with age. Kraim and Azaza (2007) and Kirk (1972) attributed this tolerance to its marine origins, which support its increased

resilience to salinity variations. On the other hand, Makila *et al.* (2020) found that Nile tilapia can tolerate a range of salinity from 5 to 15 psu.

The mean conductivity value was 9.345 mS/cm $\pm$ 0.1639, with maximum and minimum values of 10.07 mS/cm and 8.51 mS/cm, respectively. In the stressed group, conductivity was measured at 7.57 mS/cm, a result of the dissolution of ions from fish feed and waste, along with evaporation phenomena (Toule *et al.*, 2017). Yada *et al.* (1994) confirmed that salinity levels are influenced by the ionic composition of the surrounding environment (Fig. 1).

A two-way ANOVA was conducted to test the effect of abiotic parameters and sampling duration.

The hypotheses being tested are as follows:

- **H₀:** There is no interaction between abiotic parameters and sampling duration, meaning the relationship between sampling duration and body length is identical for both stressed and control samples (and similarly, the relationship between abiotic parameters and body length).
- **H₁:** There is an interaction between abiotic parameters and sampling duration, meaning the relationship between stressed and control samples and body length varies according to sampling duration (and similarly, the relationship between sampling duration and body length varies according to the abiotic parameters) (Table 3, Fig. 2).

Table 3. Descriptive statistics of abiotic factors used in this study

Parameter	Min	1 st Quartile	Median	Mean	3 rd Quartile	Max
Temperature (°C)	17.64	19.12	20.13	20.11	21.00	23.64
Conductivity (mS/cm)	8.986	9.266	9.371	9.345	9.446	9.653
Salinity (psu)	5.029	5.185	5.235	5.233	5.295	5.420

P-value Threshold: The significance level is indicated as $p < 0.05$. Statistical significance is highlighted where applicable.

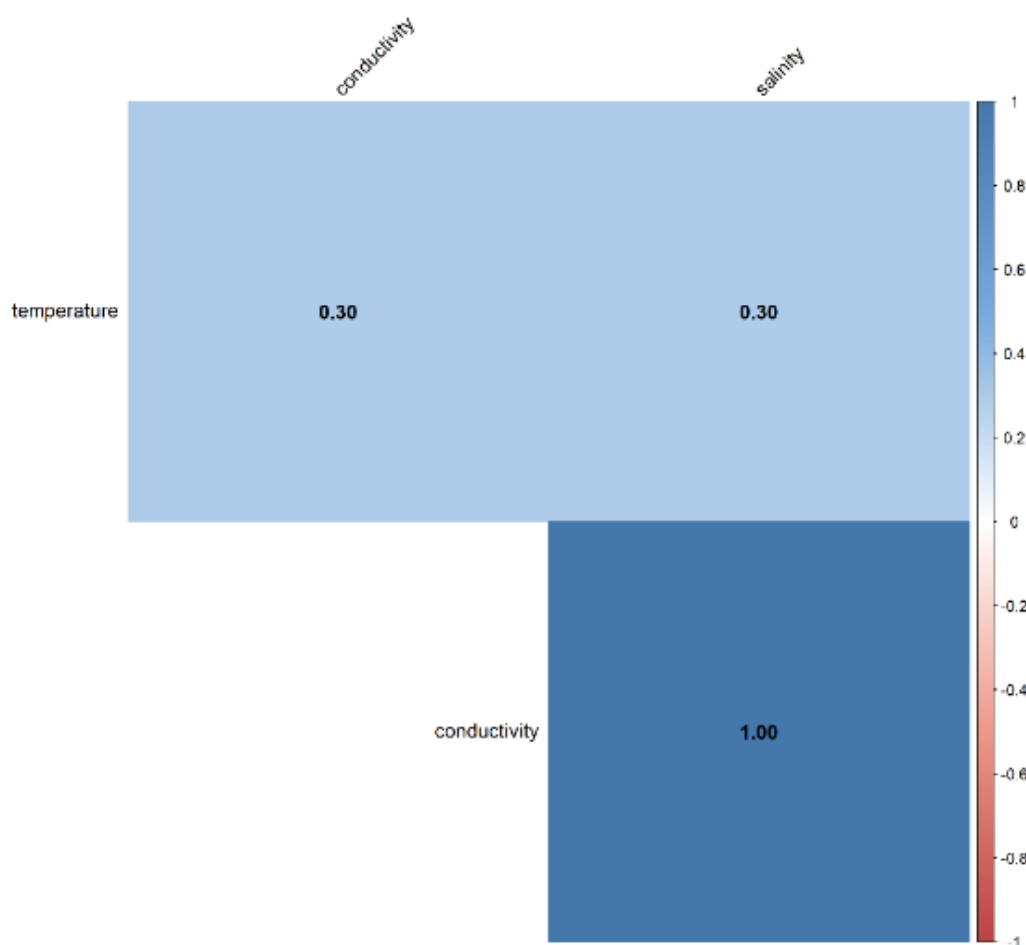


Figure 2. Variation of abiotic factors for the stressed sample

3.2 Monitoring of weight gain in the two batches

The results of the study indicate that the average weight of the stressed group was 7.97 ± 4.62 g, with a maximum weight of 18.15 g and a minimum weight of 1.71 g, and for the control group it was 26.29 ± 7.50 g, with a maximum of 42.84 g and a minimum of 13.61 g. These findings reveal a marked heterogeneity in growth among individuals within the two groups. This variability is consistent with observations by Fontaine and Le Bail (2004) but contrasts with the results of Makila *et al.* (2020), who reported an average weight of 17.25 g. Furthermore, Dagne *et al.* (2013) noted that tilapia growth is typically slow during the initial months but accelerates significantly later, particularly in males (Fig. 3). Further investigation into the role of thermal and osmotic stress in this variability could provide valuable insights, as these factors may differently influence individual metabolic responses in the stressed group.

The results of Levene's test for homogeneity of variances showed a significant difference between the two groups ($F = 11.118$, $p = 0.001$), leading to the rejection of the assumption of equal variances. Consequently, the t-test results were interpreted under the assumption of unequal variances. The t-test revealed a significant difference in the means of the two groups ($t = -2.344$, $p = 0.021$), with a mean difference of -0.731. The 95% confidence interval for the mean difference excludes zero, further

confirming this significant difference. These results indicate that the growth of the two groups differs significantly, regardless of whether equal variances are assumed.

This heterogeneity in growth could stem from several factors, including thermal and osmotic stress. A more detailed examination of how these stressors influence individual metabolism and growth is warranted. Genetic and behavioral differences may also contribute to the observed variability, as some individuals may exhibit greater tolerance to or recovery from stress, leading to accelerated growth.

It is also essential to explore the physiological mechanisms underlying this variability. For instance, research into the metabolic responses to stress could help clarify why certain individuals grow more slowly under comparable conditions. Dagne *et al.* (2013) emphasized that tilapia growth accelerates with age, particularly in males, which could interact with the stress factors examined in this study.

In summary, although significant differences were detected between the groups, a deeper discussion of the biological mechanisms driving this variability is necessary. A thorough analysis of the combined effects of thermal and osmotic stress, along with comparative studies, could enhance the understanding of these findings and provide actionable recommendations for optimizing tilapia growth in aquaculture systems.

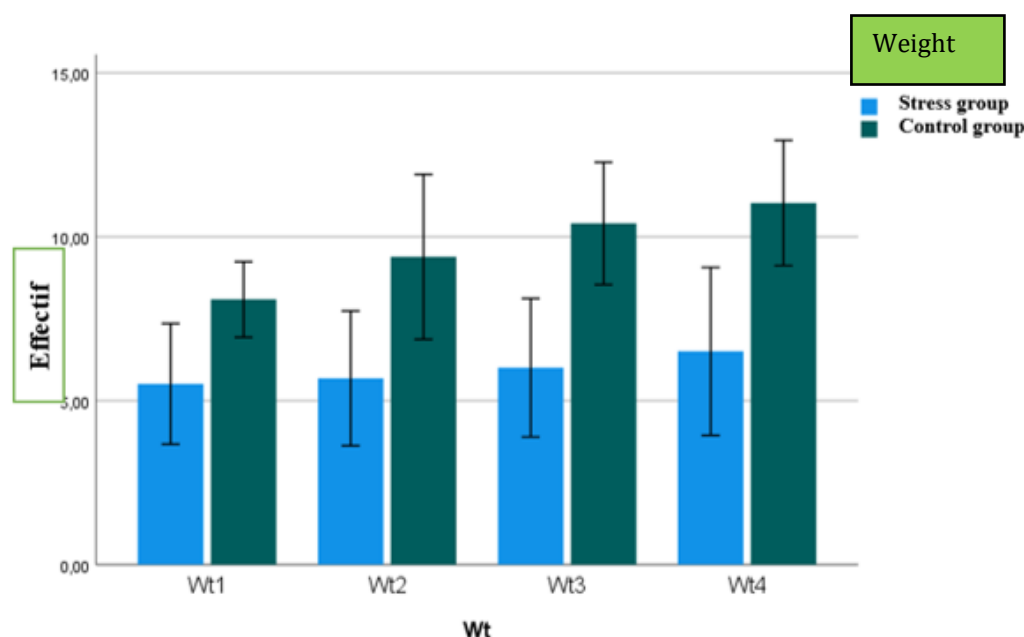


Figure 3. Temporal evolution of the Total weight of the Two Batches (control and stressed)

3.3 Estimation of Growth Performance

After verifying the normality of the distribution of the data. The two-factor ANOVA test, applied to tilapia weight and length data at the 95% confidence level, shows that for the second “batch” factor (controlled, stressed), the variability observed in the lengths and weights of the two samples is globally due to variation in abiotic factors (temperature, salinity, and conductivity). Nevertheless, this same test shows that the sampling duration “date” has a significant impact on the differences observed between the weights and lengths of the two “controlled” and “stressed” samples. Furthermore, the ANOVA models performed show that the interaction between “abiotic factors” and “sampling duration” is significant, and can explain the variability observed between tilapia lengths and weights. In other words, the combined effect of “choice of sampling or measurement time” and abiotic parameters can explain the differences observed between lengths and weights (Fig. 4).

Additionally, a one-way ANOVA was performed to compare means across experimental groups, revealing a significant difference ($F = 5.43$, $p = 0.002$), indicating that experimental conditions significantly influenced tilapia growth.

3.4 Comparison of daily weight gain

The statistical significance of differences between groups was assessed using independent samples t-tests in SPSS, with the p-value denoted as Sig. The results are as follows. For the comparison of weight (P) between Groups Wt1 and Wt4, Sig. = 0.000, indicating a highly significant difference ($p < 0.05$), confirming a substantial difference in weight between these two groups. For the comparison of length (L) between Groups Wt1 and Wt4, Sig. = 0.000, revealing a highly significant difference ($p < 0.05$), showing a statistically significant variation in length between the two groups. Regarding the comparison of weight (P) between Groups Lot 1 and Lot 2, Sig. = 0.006, indicating a statistically significant difference in weight between the two lots ($p < 0.05$). For the comparison of length (L)

between Groups Lot 1 and Lot 2, Sig. = 0.000, which demonstrates a highly significant difference ($p < 0.05$), showing substantial variation in length between the two lots. Figure 3 shows a significant difference in growth between the two groups, with the weight gain of the unstressed individuals (16.16 g) being more than three times higher than that of the stressed individuals (4.61 g). The weight growth rate is 1.51% per day for the control group and 1.22% per day for the stressed group, confirming that stressful culture conditions negatively affect the growth of Nile tilapia. Avit *et al.* (2014) estimated a specific weight growth rate of 0.73% per day, while Chab and Dis (2023) estimated it at 1.20% per day for the control group and 1.44% per day overall. The daily weight gain is recorded at 0.06 g/day for the stressed group and 0.25 g/day for the control group, with results similar to those reported by Santi *et al.* (2023) and Avit *et al.* (2014) (Fig. 5).

4 CONCLUSIONS

This study assessed the impact of abiotic stressors, particularly temperature and salinity, which are recognized as the most influential factors in aquaculture. These variables directly affect critical metabolic processes, including growth and reproduction (Azaza and Kraïem, 2005; Kikuchi and Furuta, 2007). Our results indicated an average salinity of 5 psu and a temperature fluctuating around 20 °C, which corresponds to particularly slow growth rates in individuals exposed to these stressful conditions.

It is important to note that during the entire duration of our experiment, we did not observe any apparent disease, confirming the robustness of Nile tilapia.

Understanding the effects of salinity is essential for controlling the reproductive cycles of this species, especially under marginal conditions, which could enable land-based aquaculture practices.

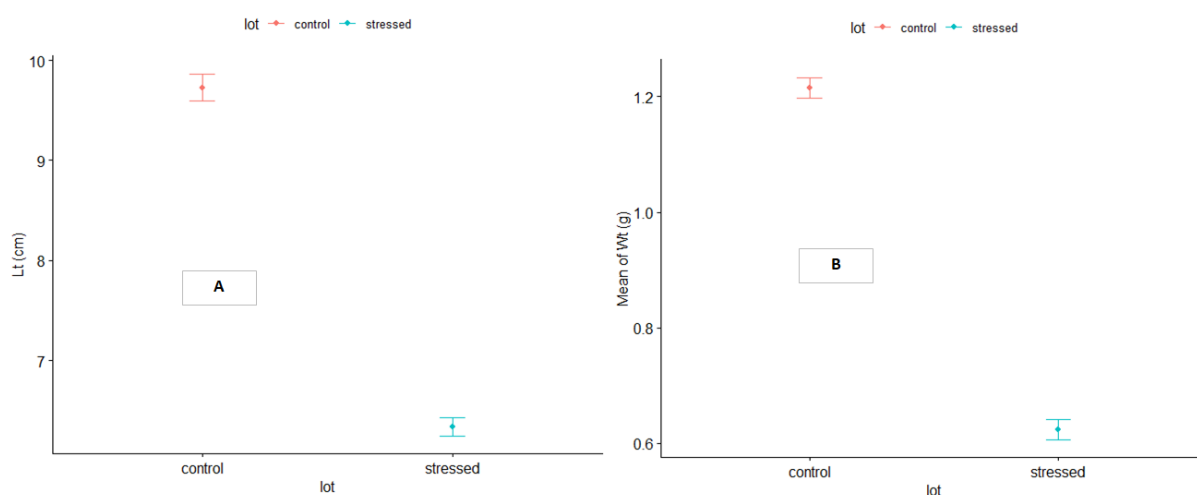


Figure 4. Visualization of the results of the ANOVA test, 2 factors performed for the length/weight data of Nile Tilapia

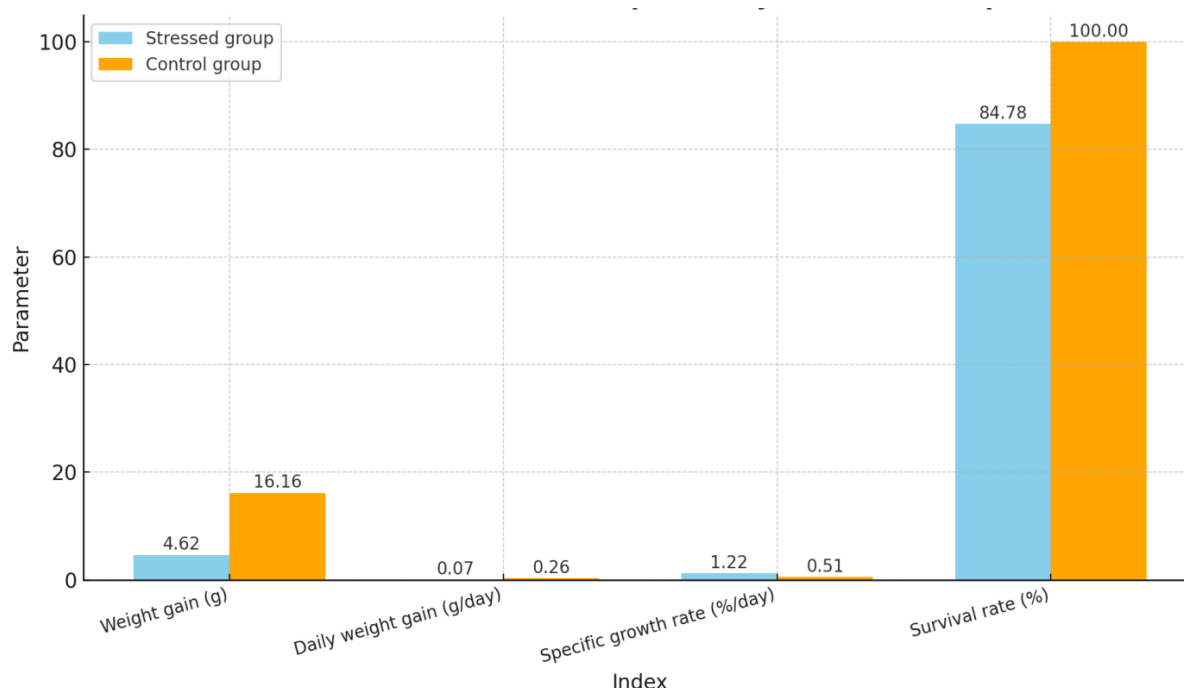


Figure 5. Comparison of index for estimating growth performance

To improve fry growth, it is recommended that fish farmers maintain a stable temperature between 26 °C and 30 °C and minimize salinity fluctuations. These measures will help improve fry growth and ensure more consistent results across farms.

Furthermore, our research highlights the need to select more productive strains of Nile tilapia to support the sustainable development of this relatively new activity in various regions of the country. Genetic erosion, which results in decreased growth performance over generations, is one of the major challenges in farming economically important species. Therefore, the constant search for more profitable strains is essential (Nihoreye *et al.*, 2011). Future research could explore other abiotic factors such as pH and dissolved oxygen, as well as the potential of selective breeding programs that prioritize genetic diversity and resilience of farmed populations.

Finally, these results highlight the importance of optimizing aquaculture practices by considering environmental parameters to ensure the viability and sustainability of Nile tilapia farming in the region.

All the significance values obtained are below the 0.05 threshold, demonstrating that the observed differences in weight and length between the groups and lots are statistically significant. These findings suggest that the variations are unlikely to be due to random chance and reflect genuine differences between the groups.

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