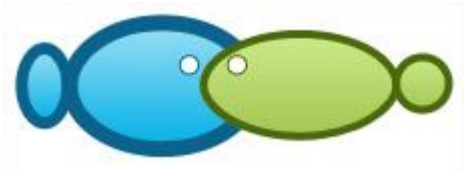

Comparison of a formulated diet and a commercial feed on the growth performance of *Oreochromis niloticus* under controlled farming conditions in Algeria

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Abstract. In a context of growing demand for animal protein and depletion of traditional fishery resources, aquaculture offers a sustainable alternative for improving food security. This study evaluated the biometric indices and growth performance of Nile tilapia (*Oreochromis niloticus*) reared under controlled conditions at the Cherchell School of Fisheries and Aquaculture (Algeria). The main objective was to compare the effects of two diets, a commercial feed (diet A) and a feed formulated with 41% *Azolla* and 35% wheat flour (diet B), on fish growth during a 75 day trial, conducted in four aquaria (two aquaria per feeding group). Environmental parameters (temperature, salinity and pH) were maintained at optimal conditions throughout the experiment. Results showed significantly higher growth in fish fed diet B, with a daily weight gain of 0.86 g day^{-1}, a percentage weight gain of 39.76% and a specific growth rate of 0.45% day^{-1}, compared with 0.75 g day^{-1}, 35.42% and 0.40% day^{-1}, respectively, for fish fed diet A (Tukey's HSD test, $p < 0.05$). These results highlight the nutritional potential of *Azolla* as a sustainable and cost-effective feed ingredient for tilapia farming. Its incorporation may enhance growth performance, reduce feed costs, and promote more sustainable tilapia aquaculture practices.
Key Words: alternative feed, *Azolla* meal, feed formulation, growth parameters, Nile tilapia.

Introduction. Rapid global population growth, combined with increasing urbanization and declining natural resources, is putting increasing pressure on animal protein supplies. In many countries, traditional fisheries can no longer meet demand due to overexploitation and declining fish stocks. Nearly 35% of the world's most productive fisheries are experiencing significant resource depletion (Fao 1997b; Xinhua 2025). In this context, aquaculture is emerging as a strategic and sustainable alternative, capable of meeting growing food demand while contributing to food security, job creation, and economic development, particularly in rural and coastal areas (FAO 1997a).

In Algeria, aquaculture represents a promising opportunity to optimize the use of available water resources, particularly in coastal areas and southern regions rich in ponds, lakes, and hillside reservoirs. It provides an additional source of high-quality animal protein and supports the development of sustainable local value chains. To meet growing market demand, high-value species such as mullet (*Mugil cephalus*) and, more specifically, Nile tilapia (*Oreochromis niloticus*) have been introduced. Global tilapia

production already exceeded 970,000 tonnes in 1998, highlighting its growing importance in international aquaculture markets (Josupeit 2005).

Among the various cultured species, Nile tilapia stands out for its biological and economic advantages, including rapid growth, high adaptability, and tolerance to fluctuating environmental conditions (Lazard 1984; Rodríguez-Hernández et al 2025). These characteristics make it a prime candidate for intensive and semi-intensive aquaculture systems, particularly in developing countries.

Nutrition plays a critical role in successful fish farming. The quality of feed intake directly influences growth performance, feed conversion ratio, health status, and overall production profitability. Given the high cost of commercial feed, the development and evaluation of alternative, sustainable, and locally available feed ingredients is a priority. *Azolla*, a fast-growing aquatic fern rich in protein, has shown promising results in previous aquaculture studies. However, most of these studies have been conducted outside of Algeria and under varying environmental conditions (Rahmah et al 2022; Refaey et al 2023; Sallam et al 2024).

The objective of the present study is to identify a cost-effective and sustainable feed solution tailored to Algerian aquaculture systems. The findings aim to support the development of environmentally friendly and economically viable feeding practices to enhance aquaculture productivity in the country.

Material and Method. This study was conducted over a total duration of 75 days, from February 2, 2025, to April 17, 2025, at the Technical School of Fisheries and Aquaculture (EFTPA) in Cherchell, Algeria, a coastal institution specialized in aquaculture training and research.

The objective was to evaluate the growth performance of Nile tilapia juveniles fed two different diets: Diet A (commercial feed) and Diet B (locally formulated feed containing 41% *Azolla* and wheat flour).

A total of 40 juvenile Nile tilapia were randomly distributed across four glass aquaria (60 × 36 × 45 cm), with 10 fish per tank. Two aquaria were assigned to each dietary treatment (two replicates per diet). All tanks were equipped with a 300-watt submersible heater, continuous aeration, and mechanical filtration to maintain stable water quality. Two-thirds of the water volume was renewed daily, and complete water changes were performed every five days. In addition to regularly monitoring water quality parameters (temperature, salinity, and pH), the fish were fed twice daily at 5% of their total biomass, with diet amounts adjusted weekly based on growth.

The trials took place in an aquaculture farm supervised by the School of Fisheries and Aquaculture of Bou Ismaïl (Tipaza). The aquariums were filled with freshwater (0‰ salinity) and were kept at a constant temperature of 28°C via a thermostat, ensuring optimum tilapia growing conditions. As it was surfaced water, the air temperature will often be a determining factor in the temperature of water (Rodier 1984).

Biometric measurements (weight and total length) were taken every 15 days using standardized procedures. During each sampling, fish were gently captured with a clean, soft mesh net. Weight was measured using a precision digital scale, and total length was recorded using an ichthyometer. Fish were positioned with the mouth closed and the caudal fin touching the measuring stop to ensure accuracy and repeatability.

Diet composition. Diet A (commercial) consisted of: 41% soybean meal, 14% fish meal, 35% corn, 8% vegetable oil, 2% multivitamin premix. Diet B (formulated) consisted of 41% *Azolla*, 14% fish meal, 35% wheat flour, 8% vegetable oil, 2% multivitamin premix. Diet B was prepared from local ingredients. The *Azolla* used in Diet B was collected from local freshwater ponds in the Tipaza region. The plant was thoroughly washed before being incorporated into the diet mixture. This approach follows standard practices reported in previous aquaculture studies (El-Sayed 2006).

Data collection and analysis. Fish were individually weighed using a precision digital scale and measured using an ichthyometer at regular intervals throughout the trial. Initial and final mean weights (IMW and FMW) were used as intermediate variables to calculate

growth performance parameters, including weight gain (WG), specific growth rate (SGR), daily weight gain (DWG), and daily growth rate (DGR). Total length measurements were used to assess linear growth and to analyze the evolution of fish length during the experimental period. The formulae for the above mentioned parameters as as follows:

$$IMW\ (g) = \frac{\text{Initial biomass (g)}}{\text{Initial number of fish}}$$

$$FMW\ (g) = \frac{\text{Final biomass (g)}}{\text{Final number of fish}}$$

$$WG\ (\%) = \frac{FMW - IMW}{IMW} \times 100$$

$$SGR\ (\%\ day^{-1}) = \frac{\ln(FMW) - \ln(IMW)}{t} \times 100$$

$$DWG\ (g\ day^{-1}) = \frac{FMW - IMW}{t}$$

$$DGR\ (\%\ day^{-1}) = \frac{FMW - IMW}{IMW \times t} \times 100$$

where: t = duration of the experimental period (days).

Statistical analysis. All data were statistically analyzed to evaluate the effect of the experimental diets on the growth performance of Nile tilapia. Data are presented as mean values. Comparisons of mean body weight and total length between dietary treatments at each sampling time were performed using Student's t-test. Differences were considered statistically significant at $p < 0.05$.

For overall growth performance parameters calculated over the entire experimental period, including DWG, WG, DGR, and SGR, data were analyzed using one-way analysis of variance (ANOVA). When significant differences were detected, Tukey's honestly significant difference (HSD) post hoc test was applied to identify differences between dietary treatments. Statistical significance was defined at $p < 0.05$. All statistical analyses were performed using RStudio (version 4.4.2).

Water quality. Water quality parameters were monitored throughout the experimental period. Water temperature, pH, and salinity were measured weekly in situ using a portable multiparameter probe (HI98194, Hanna Instruments, Romania). The aquaria were also equipped with air pumps connected to air stones to provide continuous aeration, as well as mechanical filtration systems to maintain water quality and environmental stability during the experiment.

Chemical composition of the diets. The formulated diet, hereafter referred to as Diet B, was primarily composed of *Azolla pinnata*, wheat flour, and fishmeal, and was supplemented with vegetable oil and a multivitamin premix. *A. pinnata* is recognized as a valuable plant protein source; in its dried form, it contains approximately 21.4% crude protein, 12.7% crude fiber, 2.7% ether-extractable lipids, 16.2% ash, and 47.0% carbohydrates (Alalade & Iyayi 2006).

The wheat flour used in the formulation was soft wheat flour, as described by Belagrouz (2021), and typically contains 65-72% starch, 10-13% protein, 14-16% moisture, 1-2% sugars, 1.2-1.4% lipids, and mineral contents ranging from 0.5 to 0.6% for type 55 flour to approximately 1.4% for type 150 flour.

Fishmeal is a high-protein ingredient widely used in aquafeeds. High-quality fishmeal typically contains about 60-72% crude protein (Ween et al 2017; Hussain et al 2024), while lipid content is commonly lower due to oil extraction during processing but may vary widely and can reach ~20% depending on the raw material and processing conditions; fishmeal is often produced from oily forage fish such as anchovy (*Engraulis encrasicolus*), sardine (*Sardina pilchardus*), herring (*Clupea harengus*), and menhaden

(*Brevoortia* spp.) (FAO 1986). It is also rich in essential minerals such as phosphorus, calcium, and selenium and includes key amino acids such as lysine, methionine, and threonine. Additionally the diet contained CPSP, a concentrated soluble fish protein hydrolysate comprising 80% protein and 4.7% lipids which enhances digestibility and palatability.

In contrast, Diet A, the commercial feed, was mainly composed of soybean and maize, both of which are commonly used ingredients in aquaculture nutrition due to their favorable nutrient profiles. Soybean (*Glycine max*), as reported by the United States Department of Agriculture (USDA), contains up to 35% crude protein, making it a preferred plant protein source in fish diets, while contributing relatively low levels of starch and minerals, estimated at around 5% (FAO 1992). Maize (*Zea mays*) is characterized by a high starch content, generally ranging from 60 to 72%, with additional components including 8-11% protein, 10-14% moisture, 3.5-5% lipids, 2-3% fiber, 1-3% sugars, and approximately 1-1.5% minerals, depending on cultivar and growing conditions (FAO 1986; Abiose & Ikujenlola 2014). The combined use of soybean and maize in commercial diets ensures a balanced energy to protein ratio suitable for the rapid growth requirements of Nile tilapia (Pinotti et al 2024).

Results

Water quality parameters. During the experimental period, water quality parameters remained relatively stable across all rearing tanks. The recorded water temperature ranged between 20 and 25°C, pH values averaged 8.35, and salinity was maintained at approximately 3.7‰. No marked fluctuations were observed throughout the trial, and similar conditions were recorded in all experimental units.

Evolution of average weight and length. The analysis of the data presented in Figures 1 and 2, as well as in Tables 1 and 2, reveals a continuous and statistically significant increase in the average weight and total length of the fish throughout the experimental period.

In the control group (Diet A - commercial feed), the average weight increased from 24.0 g in week 1 to 32.50 g by week 5. In contrast, fish fed Diet B - formulated with 41% *Azolla* - showed a greater weight gain, reaching 35.15 g from an initial weight of 25.15 g. Similarly, average total length increased from 9.70 cm to 13.91 cm in Group A, and from 10.40 cm to 14.52 cm in Group B.

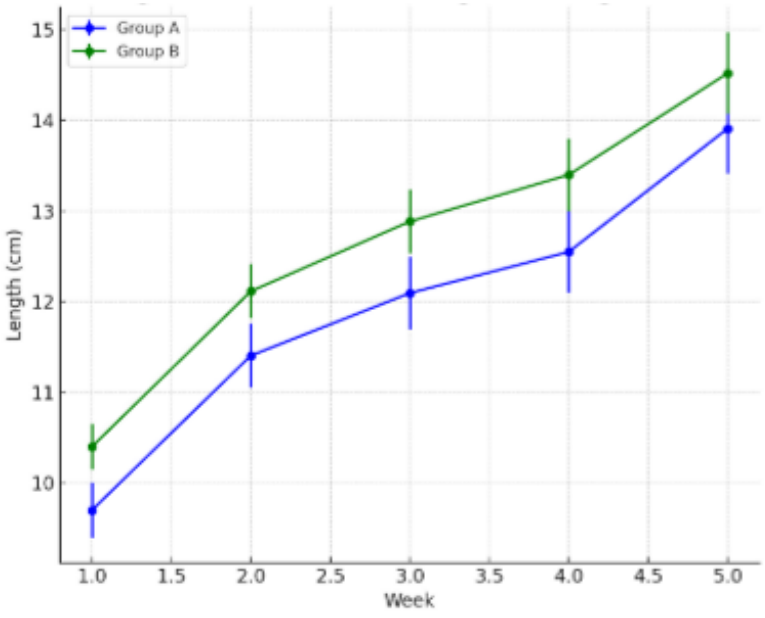

Figure 1. Weekly trend in mean length of fish fed two different diets (Group A and Group B).

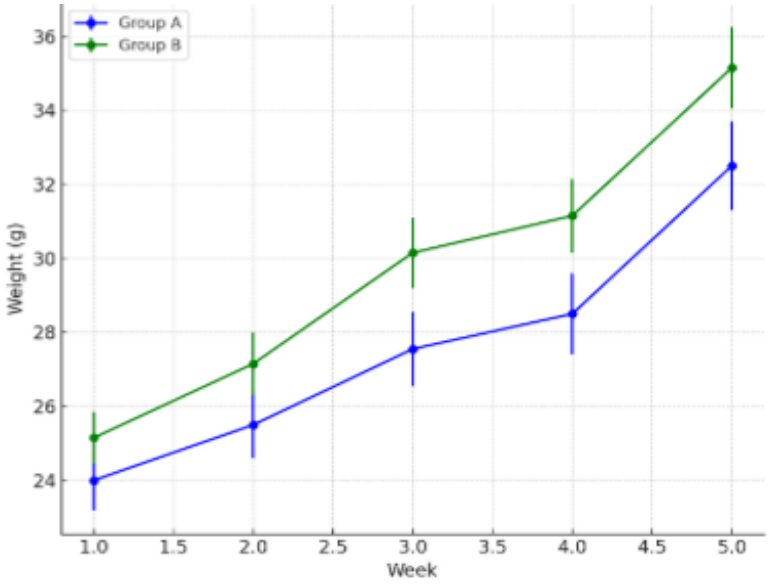

Figure 2. Weekly trend in mean weight of fish fed two different diets (Group A and Group B).

Table 1

Weekly evolution of mean body weight (g) of Nile tilapia juveniles fed two experimental diets over the 75-day experimental period

Week	*Mean weight – Group A (g)*	*Mean weight – Group B (g)*	*Statistical significance*
W1	24.00	25.15	NS ($p > 0.05$)
W2	25.50	27.15	NS ($p > 0.05$)
W3	27.55	30.15	*($p < 0.05$)
W4	28.50	31.15	*($p < 0.05$)
W5	32.50	35.15	*($p < 0.05$)

Notes: NS = not significant ($p > 0.05$) ; * indicates a statistically significant difference ($p < 0.05$) ; Group A = fish fed Diet A (commercial feed: Dziraponic); Group B = fish fed with Diet B (formulated feed based on *Azolla*). Values represent weekly mean body weights based on measurements of 10 fish per tank, with two replicate tanks per dietary treatment. Comparisons were made using Student's *t*-test.

Table 2

Weekly evolution of mean total length (cm) of Nile tilapia juveniles fed two experimental diets over the 75-day experimental period

Week	*Mean total lenght Group A (cm)*	*Mean total lenght Group B (cm)*	*Statistical significance*
W1	9.70	10.40	NS ($p > 0.05$)
W2	11.41	12.12	NS ($p > 0.05$)
W3	12.10	12.89	*($p < 0.05$)
W4	12.55	13.40	*($p < 0.05$)
W5	13.91	14.52	*($p < 0.05$)

Notes: NS = not significant ($p > 0.05$) ; * indicates a statistically significant difference ($p < 0.05$) ; Group A = fish fed Diet A (commercial feed: Dziraponic); Group B = fish fed with Diet B (formulated feed based on *Azolla*). Values represent weekly mean total lengths based on measurements of 10 fish per tank, with two replicate tanks per dietary treatment. Comparisons between groups were performed using Student's *t*-test.

Statistical comparisons using Student's t-test showed no significant differences between the two groups during the first two weeks ($p > 0.05$). However, from week 3 onward, differences between the groups became statistically significant for both body weight and total length ($p < 0.05$), as indicated in Tables 1 and 2. These results demonstrate that fish fed the *Azolla*-based diet exhibited improved growth performance compared with those fed the commercial diet.

Figures 1 and 2 visually illustrate this divergence, showing a steeper growth trajectory in Group B for both body mass and linear development. This enhanced growth performance may be attributed to the nutritional quality of *Azolla*, particularly its high digestible protein content and beneficial micronutrients.

Overall, the results demonstrate that the *Azolla*-based diet (Diet B) significantly improves growth performance from the third week onward ($p < 0.05$), confirming its potential as a cost-effective and sustainable feed alternative for improving the aquaculture productivity of Nile tilapia under controlled rearing conditions.

Growth parameters. Table 3 presents the average growth values recorded during the experimental period (75 days). These indicators include DWG, WG, DGR, and SGR.

The results show that the highest growth performance was observed in fish fed Diet B. The recorded values were: DWG = 0.20 g day^{-1}, WG = 39.76%, DGR = 0.53% day^{-1}, and SGR = 0.45% day^{-1}. In contrast, fish fed Diet A displayed slightly lower performance: DWG = 0.11 g day^{-1}, WG = 35.42%, DGR = 0.47% day^{-1}, and SGR = 0.40% day^{-1}.

Statistical analysis using Tukey's HSD test revealed that these differences were statistically significant ($p < 0.05$) for all parameters, confirming that Diet B had a positive and significant effect on the growth performance of Nile tilapia under the experimental conditions.

Table 3

Growth performance of Nile tilapia fed with two different diets (A and B) over a 75-day experimental period in Cherchell

Parameter	*Group A (Diet A)*	*Group B (Diet B)*	*Statistical significance*
Daily weight gain (DWG, g day^{-1})	0.11	0.20	*($p < 0.05$)
Weight gain (WG, %)	35.42	39.76	*($p < 0.05$)
Daily growth rate (DGR, % day^{-1})	0.47	0.53	*($p < 0.05$)
Specific growth rate (SGR, % day^{-1})	0.40	0.45	*($p < 0.05$)

Notes: * Indicates a statistically significant difference ($p < 0.05$) according to Tukey's HSD test; Group A = fish fed Diet A (*Azolla*-based formulated feed); Group B = fish fed Diet B (commercial feed: Dziraponic). Values represent mean performance per group over the entire experimental period (n = 10 fish per group).

Discussion. The physico-chemical parameters recorded during the experiment, including water temperature (20-25°C), pH (8.35), and salinity (3.7‰), were all within the tolerance limits of Nile tilapia and therefore suitable for rearing. Tilapia species such as *Oreochromis niloticus* are known to be euryhaline and capable of tolerating a wide range of salinities, including brackish and moderately saline environments, with survival and growth reported under various salinity levels and culture systems (Fridman et al 2012; Mirera & Okemwa 2023; Djouahra et al 2026). In addition, Chervinski (1982) reported that pH variations had little effect on Nile tilapia, with survival observed between pH 5 and 11. Regarding thermal tolerance, Tine et al (2022) showed that Nile tilapia can survive at water temperatures ranging from 13.5 to 33°C, although optimal growth has been reported at temperatures between 28 and 30°C (Azaza et al 2008). The values noted in this paper were several degrees below growth optimum, but remained well within the physiological tolerances for the species to ensure survival and normal growth. As such, the differences in growth performance by treatments are more likely due to the dietary regimes tested rather than conditions variability.

Growth performance analysis revealed a significant advantage for Diet B, compared to Diet A. Fish fed with Diet B achieved a DWG of 0.20 g day^{-1}, compared to 0.11 g day^{-1} for those fed with Diet A. Similarly, the other indicators like WG, DGR, and SGR were all higher in the Diet B group, with statistically significant differences ($p < 0.05$).

These findings are consistent with previous studies. Abou et al (2007) reported DWG values of 1.15 and 1.26 g day^{-1} for Nile tilapia fed *Azolla*-based diets, while Azaza

et al (2008) recorded values between 0.99 and 1.15 g day^{-1}. Although our results are slightly lower, they remain comparable and confirm the potential of *Azolla* as an effective dietary ingredient to enhance tilapia growth in controlled aquaculture systems. Diet B thus appears to offer strong zootechnical potential, both in terms of performance and in terms of sustainability.

The improved performance observed with Diet B could be attributed to the higher digestibility of its components. Previous studies, such as those by Hundare et al (2018), have shown that the nutritional quality of a diet depends not only on its composition but also on the digestibility, absorption, and bioavailability of nutrients (amino acids, minerals, etc.). According to Lazard et al (1990), the digestibility coefficients of proteins in soybean and maize are 96% and 85%, respectively, compared to 87% for fishmeal, suggesting that some sources are more bioavailable than others are.

Furthermore, Fiogbé et al (2009) demonstrated that incorporating 45% dried *Azolla* into the diet of Nile tilapia significantly improved growth performance while also reducing production costs. In our study, a 41% *Azolla* inclusion rate was sufficient to yield highly encouraging results. In addition to promoting growth, *Azolla* has been reported to improve the trophic quality of aquaculture systems by contributing organic matter and nutrients, while also serving as a sustainable and locally available plant protein source. Several studies have highlighted the nutritional value of *Azolla* and its potential to partially replace conventional protein sources in fish diets, thereby enhancing sustainability and reducing feed costs (Basak et al 2002; El-Sayed 2007; Hundare et al 2018).

In summary, despite equal feeding schedules across the four tanks, fish fed with Diet B exhibited significantly better growth, reflecting superior nutrient utilization from the *Azolla*- and wheat-based formulation. These results highlight the relevance of incorporating alternative ingredients such as *Azolla*, which are cost-effective, locally accessible, and efficient in enhancing aquaculture productivity.

Conclusions. This study demonstrated that the experimental diet containing 41% *Azolla*, supplemented with fish and wheat meal, significantly enhanced the growth performance of Nile tilapia (*Oreochromis niloticus*) compared to the commercial feed. The observed daily weight gain of 0.20 g day^{-1} on Diet B reflects the high efficiency of this locally formulated, cost-effective, and well-adapted feed under controlled rearing conditions.

Nile tilapia, a hardy species with rapid growth and high environmental tolerance, represents a strategic opportunity for the development of Algerian aquaculture, especially in a context of declining marine fisheries resources. Its culture can reduce dependence on marine fish stocks while providing a sustainable and affordable source of animal protein. Therefore, the integration of *Azolla* into tilapia diets presents a promising avenue to boost national aquaculture productivity while contributing to food security and local economic development.

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Conflict of interest. The authors declare that there is no conflict of interest.

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