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Tilapia (*Oreochromis Niloticus*) feeding trial without fish meal using local by-products from the Guinean forest region

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Abstract

An experiment on the feeding of tilapia *Oreochromis Niloticus* fry of initial weight (6.5±0.0g) was carried out for 56 days in above-ground basins on the site of the University of N'Zérékoré. An open-circuit system of 15 tanks was used to compare five treatments, with 3 tanks per treatment. Five isoprotein diets including one control. The diets tested contained *Azolla filiculoïdes* (dried), brewer's yeast, earthworms and broiler viscera at various substitution rates, while the control contained fish meal (A_0=29.8%; A_1=30.5%; A_2=30.7%; A_3=31%; A_4=31.9%). The fish were fed three times a day at four-hourly intervals.

The results showed that physico-chemical parameters such as temperature (28.6±1.2°C), pH (5.59±0.32) and dissolved oxygen content (4.93±0.89 mg/L) during the experiment were within acceptable ranges for the raised species. At the end of the experiment, mean final weights ranged from 10.80±0.54 to 14.90±0.48g, depending on the treatment. Fish fed the A_0 control feed showed a better specific growth rate (1.64±0.103%/d). Specific growth rates obtained in fish fed diets A_1 to A_4 ranged from 1.11±0.10 to 1.26±0.10 %/d. However, the feed conversion rate of diets based on local by-products ranged from 2.32±0.04 to 2.80±0.28. Diet A_4 had a better feed conversion rate than the other diets tested. In terms of economic analysis, treatment A_4 gave a better production cost per kg of *O. niloticus*. At the end of this study, the optimal rate of substitution of fishmeal by local by-products was set at 31.9%.

Keywords: *Oreochromis Niloticus*; Isoproteics; *Azolla Filiculoïdes*; Fish Meal

1. Introduction

The aquaculture sector in general and fish farming in particular in Guinea, as in all African countries, is struggling to develop despite the efforts of national and international institutions (Palliere et al., 2016). According to FAO (2024) and Enyidi et al., 2023, freshwater aquaculture production alone today represents more than 85 million tonnes in 2022, representing an average annual growth rate of 3.2% due to the rapid development of Nile tilapia farming and other species. However, the latest statistics in Guinea show an increase of around 30.17% in fish farmers in recent years, who have achieved a production of 5985 tonnes of fish (all species combined) against an estimated demand of over 30,000

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tonnes (C.N.S.H.B, 2023). Indeed, this production remains far below demand, as the per-capita fish consumption rate has risen from 10 kg to around 24 kg/capita/year (Pierre, 2012; C.N.S.H.B, 2023). To make up for this deficit, Guinea imports more than 25,676 tonnes each year (C.N.S.H.B, 2023). To date, fisheries production in Guinea is essentially provided by fishing in freshwater, brackish and marine waters (C.N.S.H.B, 2023). This dependence on imported fish products represents a major threat to food security and a loss of foreign currency, which the Guinean government can avoid by developing national potential through fish farming. Despite the limited quantity of fish products, some of them are used to manufacture animal feed. This is the case, for example, with fishmeal, considered the main source of protein in fish feed. For example, in 2010, fishmeal production and trade fell considerably due to the drop in Anchovy catches, thus increasing the cost of fishmeal (FAO, 2020). On the other hand, this main ingredient is expensive and of dubious quality. Other sources of protein not suitable for human consumption should therefore be used to replace fishmeal. Sources of protein include earthworms, chicken viscera, brewer's yeast and Azolla. Earthworms have an amino acid profile comparable to that of most animal proteins (Navarro et al. 1989) and, like fish, are rich in omega3 fatty acids (Dynes 2003, Lecerf, 2004). Similarly, Azolla, broiler viscera and brewer's yeast have good amino acid profiles (Csonka, 1935; Favre, 1936; Giri et al., 2000). African tilapias, particularly Nile tilapia, are among the fish that have been successfully introduced internationally (FAO, 2024). In fact, this species is the most widely exploited of all tilapias. It offers the prospect of sustainable protein production and is considered a candidate species for freshwater fish farming (FAO, 2000). Azolla and earthworms are protein sources that are not suitable for human consumption. Broiler viscera and brewer's yeast, which are rich in protein, are generally discharged into the environment.

It is therefore important to valorize these by-products in fish farming. This could reduce the cost of aquaculture feed for intensive Nile Tilapia farming and improve food security for the Guinean population. The objectives of this study are to:

- Formulate and manufacture feeds from local by-products, taking into account their amino acid profile;
- Test feeds on *Oreochromis Niloticus* to determine zootechnical performance.

2. Materials and methods

2.1. Study environment

The present study was carried out on the experimental site of the University of N'Zérékoré (7°43'57.6''N ; 08°50'4.3''E altitude 7 m above sea level).

2.2. Experimental design

The experiment was carried out in an open circuit in 15 square above-ground concrete basins at the station. Each tank was filled with approximately 300 L of water. The circuit was supplied with water from a borehole drilled on the University site. Each tank was equipped with a water inlet and a central water evacuation system made of PVC pipe (diameter 60 cm) fitted with a fine-mesh net to prevent fry escape. Half the surface of each pond was covered with a screen to prevent direct sunlight penetration.

2.3. Experimental fish

A total of 750 Oreochromis fingerlings with an individual mean initial weight of 6.5±0.0g were acquired from the experimental farm of the Federation of Fish Farmers of Forest Guinea (FFFFG). These fish were distributed and acclimatized for one week at the University station. During the feeding period, the fish were hand-fed (ad-libitum) to apparent satiety three times a day, at 8am, 12pm and 4pm. The fish were not fed on the control days. The stocking density was fifty fry per tank, in triplicate per treatment.

2.4. Ingredients used in experimental diets

The fish meal used was that of fretin fish (Sardinella sp). Sardinella sp was purchased at the N'Zérékoré market and ground using a Moulinex mill. Azolla was produced in a rectangular basin, harvested and dried for 72 hours, then processed into flour. Broiler viscera were collected at the Boma market (N'Zérékoré) just after slaughter. The viscera were cleaned, boiled and dried in an oven at a temperature of 40°C. The earthworms were produced at the University of N'Zérékoré.

They are rinsed in water to remove sand and plant debris. The worms are then dried in the sun for 24 hours, followed by freeze-drying. The dried worms are ground in a grinder (Moulinex). The other ingredients used in the feed were purchased from a local feed mill.

2.5. Treatments applied

Five treatments (A0, A1, A2, A3, A4) were applied to three (03) replicates each. Feeding was carried out manually at apparent satiation three times a day, at 8h, 12h and 16h. Fry were considered satiated when they no longer paid any attention to the pellets. The experiment lasted 56 days.

2.6. Test feed

Table 1 Centesimal feed composition (g/100g feed)

Ingredients	**A0**	**A1**	**A2**	**A3**	**A4**
Azolla powder	0.0	20.0	15.0	10.0	7.0
Chicken Viscera	0.0	4.0	4,0	2.0	0.0
Rice bran	13.0	3.2	3.2	5.2	7.2
Fish meal	32.0	0.0	0.0	0.0	0.0
Soy flour	15.0	15.0	15.0	15.0	13.0
Brewer's yeast	0.0	10.0	10.0	10.0	10.0
Cottonseed cake	15.0	15.0	15.0	15.0	15.0
Corn bran	15.0	15.0	15.0	15.0	15.0
Earthworm meal	0.0	10.0	15.0	20.0	25.0
Palm oil	5.0	3.0	3.0	3.0	3.0
Vitamins	0.0	0.5	0.5	0.5	0.5
Minerals	0.0	0.5	0.5	0.5	0.5
Cassava	5.0	2.0	2.0	2.0	2.0
Methionine	0.0	0.7	0.7	0.7	0.7
Lysine	0.0	1.1	1.1	1.1	1.1
Total	100.0	100.0	100.0	100.0	100.0
Crude protein	30.8	31.5	31.7	32.0	32.9

Table 2 Zootechnical parameters

Paramètres	**A_0**	**A_1**	**A_2**	**A_3**	**A_4**
Average initial weight	$6.50±0.05^{a}$	$6.56±0.05^{a}$	$6.60±0.03^{a}$	$6.69±0.04^{a}$	$6,64±0.08^{a}$
Average final weight	$14.90±0.48^{a}$	$11.89±0.46^{b}$	$10.80±0.54^{b}$	$11.11±0.18^{b}$	$11.94±0.06^{b}$
IC	$1.83±0.09^{a}$	$2.37±0.09^{b}$	$2.80±0.28^{bc}$	$2.39±0.05^{b}$	$2.32±0.04^{bd}$
FE	$0.55±0.03^{a}$	$0.42±0.02^{b}$	$0.36±0.04^{bc}$	$0.42±0.01^{b}$	$0.43±0.01^{bd}$
SGR (%/d)	$1.64±0.10^{a}$	$1.26±0.10^{b}$	$1.11±0.10^{b}$	$1.14±0.03^{b}$	$1.25±0.04^{b}$
SR (%)	$86.00±1.16^{a}$	$95.33±2.67^{b}$	$90.67±2.91^{ab}$	$94.00±1.16^{b}$	$91.33±2.91^{ab}$
Lmi	$6.50±0.05^{a}$	$6.57±0.05^{ab}$	$6.6±0.03^{ab}$	$6.69±0.04^{b}$	$6.64±0.08^{ab}$
Lmf	$9.09±0.08^{a}$	$8.26±0.09^{b}$	$8.04±0.09^{b}$	$8.12±0.07^{b}$	$8.26±0.04^{b}$
K	$1.98±0.02^{a}$	$2.11±0.04^{b}$	$2.08±0.04^{ab}$	$2.08±0.04^{ab}$	$2.12±0.03^{b}$

A: Food (0; 1; 2; 3; 4). Values are expressed as mean ± standard deviation. Values in the same row with a letter in common are not significantly different (p>0.05).

Batches of Nile Tilapia are fed five different isoprotein diets in this experiment. Only the A_0 control diet contains fish meal. The experimental diets consist of Azolla, earthworms and broiler viscera at different incorporation rates. They also contain brewer's yeast at equal rates. The composition of the experimental diets is given in Table 1.

Table 3 Feed formulation, ingredient and experimental feed costs

Feeds	Ingredient prices	A_0	A_1	A_2	A_3	A_4
Ingredients (%)						
Azolla powder	0	0	20	15	10	7
Chicken Viscera	0	0	4	4	2	0
Rice bran	80	13	3.2	3.2	5.2	7,2
Fish meal	1000	32	0	0	0	0
Soy flour	450	15	15	15	15	13
Brewer's yeast	0	0	10	10	10	10
Cottonseed cake	175	15	15	15	15	15
Corn bran	200	15	15	15	15	15
Earthworm meal	0	0	10	15	20	25
Palm oil	750	5	3	3	3	3
Vitamins	5000	0	0.5	0.5	0.5	0.5
Minerals	5000	0	0.5	0.5	0.5	0.5
Cassava	200	5	2	2	2	2
Methionine	2500	0	0.7	0.7	0.7	0.7
Lysine	2500	0	1.1	1.1	1.1	1.1
Cost per kg from by-products alone	$GNF.Kg^{-1}$	6893.46	3405.30	3405.30	3427.28	3325.60
Expenses related to feed manufacturing	$GNF.Kg^{-1}$	1030.62	1058.10	1071.84	1016.88	1030.62
Feed cost	$GNF.Kg^{-1}$	9300,98	4463.40	4477.14	4444.16	4356.21
Cost of producing one kg of fish per pond ($GNF.Kg^{-1}$)		4122.47	3435.39	3229.27	3297.98	3325.46
Total production costs per kg of fish ($GNF.Kg^{-1}$)		13420.70	7898.79	7706.41	7742.41	7681.67

Table 4 Costs associated with fish production using the feeds tested

Treatments	A_0	A_1	A_2	A_3	A_4
Cost per kg of feed (GNF)	9300.98	4463.40	4477.14	4449.66	4356,21
Consumption index	1.83	2.37	2.80	2.39	2.32
Production cost per kg of fish (GNF)	17020.79	10578.26	12535.99	10634.69	10106.41
Price per kg of fish (GNF)	25000	25000	25000	25000	25000
Profit (GNF)	7979.21	14421.74	12464.01	14365.31	14893.59

The food was produced in a room at the University of N'Zerekore. The floury ingredients are carefully mixed by hand after weighing. Next, water and palm oil are added to the mixture to obtain a malleable dough. This dough is then transformed into spaghetti using an electric meat grinder (Moulinex HV81600w), then sun-dried to a moisture content of 10%.

2.7. Physico-chemical water analysis

Water quality was monitored by measuring physico-chemical parameters such as temperature, dissolved oxygen, pH, conductivity and TDS using a portable multifunction multimeter (GOnDO portable multifunction pH meter). These parameters were recorded before feeding (morning: 7:30 am and evening: 3:30 pm).

2.8. Growth monitoring

Control fishing took place every ten days of feeding, followed by emptying and cleaning of the tanks. The number and biomass of fish per tank were measured. A TANITAKD-192 electronic balance was used to measure biomass. At the end of the experiment, the biomass per tank, the total number of fry per tank, the weight and the total length of the individuals per tank were recorded.

2.9. Zootechnical parameters and production costs

The mathematical formulas used to determine these parameters are as follows:

Average initial weight (Wi)

$$Wi(g) = \text{Initial biomass (g)} / \text{Initial number of fish.}$$

Average final weight (Wf)

$$Wf\ (g) = \text{Final biomass (g)} / \text{Final number of fish.}$$

Survival rate (SR)

This rate was used to determine the effect of substituting poison meal with non-conventional by-products on fish survival.

$$SR \text{ in } \% = (\text{Number of individuals at end of experiment} / \text{Number of initial individuals}) \times 100.$$

2.9.1. Specific growth rate (SGR)

This coefficient evaluates the weight gained by the fish each day, as a percentage of its live weight. The SGR gives the instantaneous growth rate of the fish. It is expressed by the following formula

$$SGR \text{ in } \% / d = [Ln\ (Pmf\ (g) - Ln\ (Pmi\ (g)) \times 100 / \text{Experimentation duration}].$$

2.9.2. Consumption index (CI)

This coefficient is used to evaluate the effectiveness of the feed used on fish growth.

$CI = \text{Amount of feed distributed (g)} / \text{Weight gain (g)}.$

2.9.3. Feed Efficiency (FE)

$$FE = (Bf + Bm - Bi)/Rd = 1/IC$$

Condition factor K

Reflects fish overweight. It is expressed by the following formula:

$$K = (Wt / Lt^{b}) \times 100$$

Where Wt = total weight of fish in g; Lt = total length of fish in cm; b = allometry coefficient, is the exponent of the weight-length relationship $Wt = aLt^{b}$.

The average production cost of one kilogram of fish is calculated as follows

$$\text{Average production cost per kg of fish} = \text{Cost per kg of feed} \times IC$$

2.10. Statistical analysis

The data collected were encoded in Microsoft Excel spreadsheet. They were used to calculate the zootechnical parameters of the fish. For each parameter, the mean and standard deviation were calculated. The average data for each repetition is considered as one observation. For statistical analysis, STATVIEW statistical software (version 5.01) was used, with a probability threshold of 5%. Analysis of variance (ANOVA1) with one classification criterion was used to compare the zootechnical performance of the different treatments. A Fisher LSD (Least Significant Difference) test was used to make paired comparisons of the different means. In addition, an economic analysis was carried out to evaluate the production cost of each diet.

3. Results

3.1. Rearing water quality

Over the entire test period, the mean values measured were 28.6 ± 1.2°C for temperature, 4.93 ± 0.89 mgL^{-1} for dissolved oxygen and 5.59 ± 0.32 for pH, 67 ± 4.6 µs/cm for conductivity and 45.8 ± 3.2 ppm for TDS.

3.2. Zootechnical parameters and production costs

The various results obtained after 56 days of experimentation are presented in Table 11. The values shown represent the averages obtained per treatment ± standard deviations.

3.3. Consumption index (CI)

The lowest CI value (1.83±0.09) was obtained in the control diet (A_0) and the highest in the test diet (A_2) (figure 1). However, there was a significant difference ($P<0.05$) between the consumption indices of the A_0 control diet and the test diets (A_1; A_2, A_3; A_4). Similarly, there was a significant difference ($P<0.05$) in the consumption indices of the test diets (A_2 and A_4); however, there was no significant difference ($p>0.05$) between the test diets A_1 and A_2, A_3, A_4, or between the test diets A_2 and A_3, with the highest index obtained in the test diet A_2.

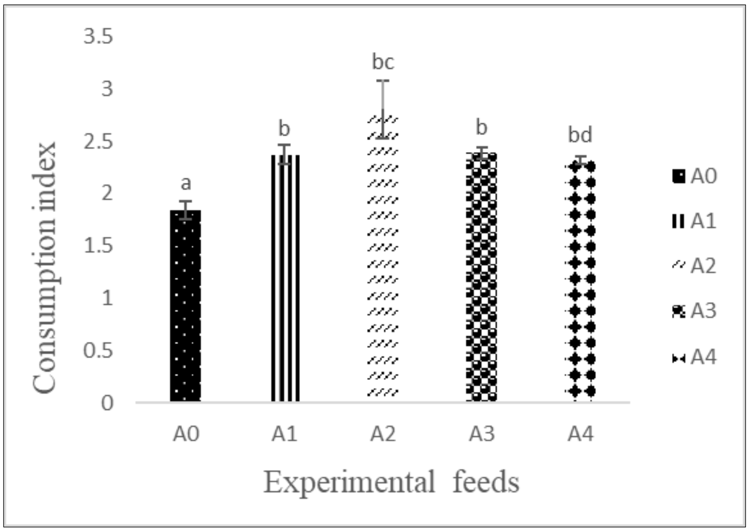

Figure 1 Consumption index for various experimental feeds

3.4. Specific growth rate

Specific growth rates observed in this study ranged from 1.11±0.10 to 1.64±0.10%/d (figure 2). However, there was no significant difference ($P>0.05$) between the diets tested (A_1; A_2; A_3; A_4). On the other hand, there was a significant difference ($p<0.05$) between the control diet (A_0) and the test diets, and the highest specific growth rate was recorded in the control diet (A_0).

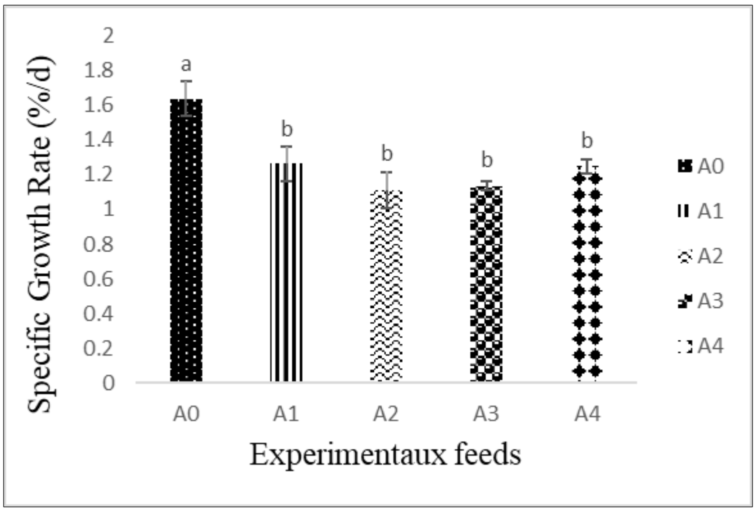

Figure 2 Specific growth rate as a function of different experimental feeds

3.5. Average final weight

Mean final weight varied significantly (P<0.05) between fish fed the control diet (A_0) and the test diets (A_1; A_2; A_3; A_4 (figure 3). On the other hand, there was no significant difference (P>0.05) between fish fed the test diets. The highest final average weight was obtained in the control diet (A_0).

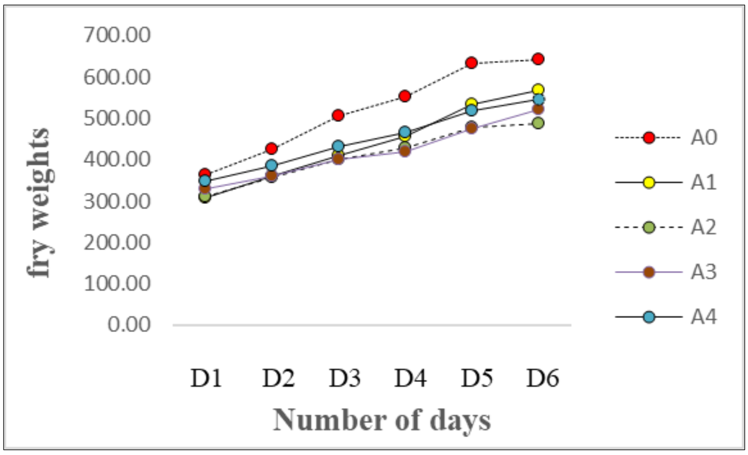

Figure 3 Evolution of fry weight following control fishing and according to the different treatments**.**

3.6. Condition factor (K)

The condition factor varied from 1.98±0.02 (A_1) to 2.12±0.03 (A_4) (figure 4). No significant difference (P>0.05) could be shown between the tested diets (A_1; A_2, A_3; A_4) on the one hand, and between the control diet (A_0) and the tested diets (A_2, and A_4) on the other. On the other hand, there was a significant difference (p<0.05) between the control diet (A_0) and the tested diets (A_1 and A_4), with diet A_3 showing the highest condition coefficient.

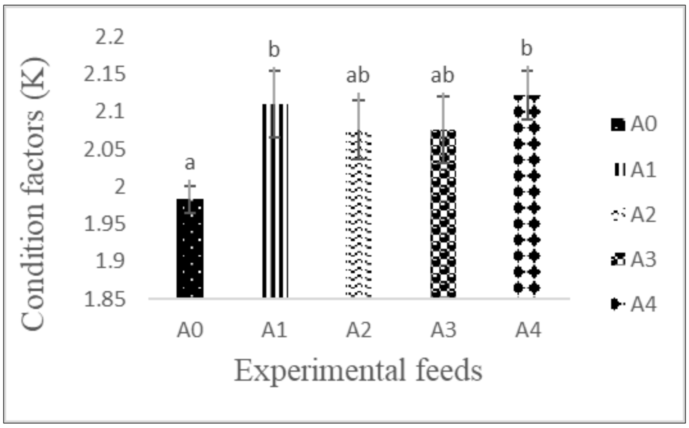

Figure 4 Condition coefficients for different experimental feeds

3.7. Survival rates

Figure 5 shows the variation in survival rates in O. niloticus according to the various diets tested. The survival rates obtained in fish at the end of this experiment ranged from 86.00±1.16 to 95.33±2.67%. The survival rates observed in fish fed the diets tested (A_1; A_2; A_3; A_4) did not vary. There was therefore no significant difference in survival rates (P>0.05). On the other hand, there was a significant difference between the survival rates of fish fed the control diet A_0 and the test diets (A_1 and A_3) (P<0.05).

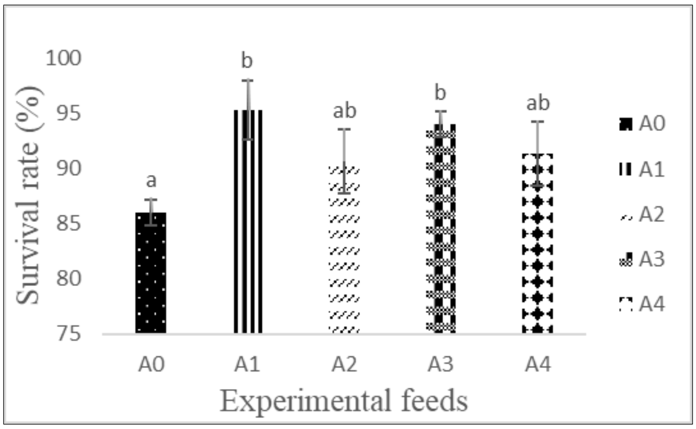

Figure 5 Survival rates for different experimental feeds

3.8. Production costs

Production depends largely on the cost of feed. These various factors have been calculated to assess the production cost of our experiment.

3.9. Estimating the cost of producing one kilogram of fish

The production of one kg of fish was evaluated by multiplying the price of one (1) kg of feed by the consumption index. This table shows that the cost of producing one kilogram of fish varies from 8514.94 GNF or 0.98 dollars to 18720 GNF or 2.16 dollars for the tested diets and is 24560.72 GNF or 2.84 dollars for the control. However, the diets tested (1 to 4) gave the best growth performance and are therefore deemed economically profitable.

4. Discussion

4.1. Water physico-chemical parameters

The temperature obtained during our experiment lies within the range of temperatures varying between 13.5 and 33°C tolerated by *O. niloticus* in the natural environment (Nobrega *et al*. 2020) (26-35°C). The average pH value obtained during the experiment also fell within the pH range of 5-11 tolerated by the species in the natural environment, but ideally between 6.5 and 8.5 (Malcolm *et al.*, 2000). In fact, a pH of between 7 and 9 enables Tilapia to grow well (Borges, 2009). The dissolved oxygen level obtained in our study was higher than the 0.1 $mg.L^{-1}$ reported by authors (Mélard and Philippart, 1980; Leveque and Quensiere, 1988). This may be explained by the fact that photosynthesis is virtually non-existent at night, whereas respiration is continuous, resulting in high oxygen consumption and carbon dioxide production at night.

4.2. Zootechnical and economic parameters

The survival rates observed in our experiment (86.00±1.16 to 95.33±2.67%) are higher than those obtained by Bamba et *al*. (2008) and Cheraghi et al., 2023 , who used agricultural by-products (soybean meal, cottonseed meal, maize and rice bran) to feed *Oreochromis Niloticus*. Similarly, they are close to those obtained by Fiogbe et al, (2009) who fed *O. niloticus* with agricultural by-products (corn bran, palm kernel cake, cottonseed cake, Azolla, Brewery dried grain). These results are lower than those obtained by Tabinda et al. (2012), who fed chicken viscera instead of fish meal to herbivorous carp. This could be explained by the handling of fish during control fishing. Mortality would therefore be due to handling stress.

Compared with the final average weights, they are comparatively lower than the 37.31±5.73 to 54.69±7.76 obtained by Bamba *et al*. (2008). This could be explained by the loading density and duration of the experiment. The results are higher by 9.290g to 12.113g recorded by Tabinda *et al*, (2013) and could be explained by the broiler viscera drying technique and also the experimental conditions. They also differ from 31.20±1.00 to 36.28±1.77 obtained by Fiogbe *et al*. (2009) and are explained by low protein levels (26.0 to 31.9%), below the recommended protein level (35%) for tilapia *O. niloticus* from 2 to 35g in weight (Yacouba *et al.,* 2008). Specific growth rates recorded in our experiment ranged from 1.34±0.21 to 1.94±0.26. However, they are lower than those of Gotur e*t al*. (2009), who incorporated soybean and maize meal, fish meal and tomato meal to feed *O. niloticus*, due to the contribution of tomato and the conditions of the study environment. In the same vein, our results are better than those recorded by Fiogbe *et al*, (2009) and are close to those obtained by Tabinda *et al*. (2013). This could be explained by the protein content of their treatment. They are also higher than those obtained by Abou (2007) in ponds ($0.1 g.d^{-1}$) and also those of 1.65 $g.d^{-1}$ obtained by Kanangiré (2001). As for the consumption indices recorded during our experiment, they are comparatively low compared to those obtained by Fiogbe *et al*. (2009). This could be explained by the quality of the feed and the shape of the feed (powder). They are close to those obtained by Iga-Iga Robert, 2008 (1.56±0.59 to 2.57±0.37) who substituted fishmeal with brewer's spent grain, broken maize and peanuts and smoked sardines. This can be justified by the level of protein provided, the ingredients used and the shape of the feed (pellets). Our data are also close to the results recorded by Tabinda *et al.* (2013). It is important to note that our data are close to those reported by many authors (1.7 to 3.0) for diets in which non-conventional protein sources incorporated are more than 25% to replace fishmeal. This is the case for non-conventional protein sources such as *Leacaena* or Copra and groundnut, cotton or soybean meal (Jackson *et al.,* 1982), Azolla (Antoine *et al.,* 1987). The economic analysis of the different plans shows better costs compared to the control plan. However, the most expensive feed is not beneficial for producers. To produce 1kg of *O. niloticus* biomass, the A_4 treatment is better with 14893.59 GNF or 1.71 USD followed by the A_1 treatment with 14421.74 GNF or 1.66 USD per kilogram of fish. Due to their growth performance, from the point of view of quality, price and consumption indexes, the A_4 regime is therefore considered better. These results also show a significant reduction in the cost of experimental feeds compared to controls, which are excessively expensive for the fish farmer. The low production obtained in the A_2 and A_3 diets leads to an increase in the costs associated with the production of a kilogram of fish with feeds based on non-conventional by-products.

5. Conclusion

O. *Niloticus* fed a diet based on local by-products from the Guinean forest region yielded acceptable results in terms of specific growth and feed conversion rates. This would constitute an unwavering contribution to Guinean fish farming. The results of this work could attempt to solve the problem of the unavailability of low-cost, high-quality fish feed available to average fish farmers. The A4 diet offers good zootechnical performance and better fish farming profitability. The substitution of by-products such as broiler viscera, brewer's yeast, Azolla and earthworms as well as other by-products used in the feed made it possible to gain a reduction in the price of the feed and therefore a reduction in the cost of production, which would have a positive impact on the financial management of an aquaculture farm.

Highlights

- In Africa, aquaculture plays a vital role in direct nutrition and creates millions of jobs.
- The A4 diet offers good zootechnical performance and better fish farming profitability.
- Formulation of fishmeal-free feed reduces the cost of production and is a way to develop fish farming.

- The use of local by-products in fish feed promotes the development of aquaculture and increases fish productivity at a lower cost.
- The recovery of agricultural waste is a kind of ecological sanitation.

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