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Integration of Fruit in the Formulation of Feed for Oreochromis Niloticus Breeding In the Region of Vakinankaratra, Madagascar

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Abstract:

To promote the nutrition of tilapia in farming, four foods were created using traditional raw materials and containing different quantities of locally produced banana flour. These foods, which contain 36% crude proteins and 8% lipids, were tested on tilapia fry with an initial weight of 8 grams. After 50 days of the experiment, the final weights of the fish fluctuated between 33.28 grams and 41.4 grams, depending on the treatments used. Foods containing 3% and 6% banana flour showed the highest growth and food conversion rates, with respective specific growth (SGR) rates of 3.98 and 3.62, as well as conversion rates (CI) of 1.8 and 1.69. Meanwhile, the food with 10% banana flour obtained an SGR of 2.92 and a CI of 2.01, while the control obtained an SGR of 3.3 and a CI of 1.7. Thanks to this test, we were able to observe the impact of bananas on the premature development of tilapia. We will continue to study the use of local agri-food byproducts and waste in feeding this fish.

Keywords:
Oreochromis niloticus; food; fishmeal; white chub; peanut; corn; cassava; banana.

I. Introduction

Madagascar is a country where the problem of malnutrition persists, particularly due to the lack of animal proteins in Malagasy diets. The production of white meat, especially fish flesh, is necessary to address this dietary imbalance. This issue is pervasive across all levels of society. Given Madagascar's abundance of water resources, fish farming stands out as one of the most viable and cost-effective means to alleviate this deficit.

While rice-fish farming is not uncommon in Madagascar, it has not been extensively developed for various reasons. These include a lack of training in livestock management, such as zootechnical standards and breeding densities, as well as the risk of flooding, which can undo efforts made in this direction.

Freshwater aquaculture is undoubtedly one of the oldest methods of aquatic resource production, with its origins dating back around 1500 years, as documented by Dabbadie et al. (2002).

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Global demand for fish has significantly increased over the past 50 years. Fish, appreciated by consumers for its organoleptic qualities (Ranson, 2003) and nutritional value, contains high-quality proteins, and lipids rich in polyunsaturated fatty acids, vitamins, and beneficial mineral elements for the body.

Freshwater fish in Madagascar inhabit various aquatic environments, including swamps, coastal lagoons, lakes, streams, and rivers (Kiener & Therezien, 1963). These waters also host numerous species of exotic fish, such as Oreochromis niloticus, which hold significant economic importance and contribute to the scientific and economic wealth of the Malagasy nation. Since 1962, the Malagasy State has initiated a fish production program known as "Operation at ground level" (Kiener & Therezien, 1963), making fish farming accessible and affordable for rural Malagasy families.

In their natural environment, freshwater fish feed on phytoplankton, zooplankton, aquatic insects, and various agricultural by-products like rice bran and cottonseed cake (Hastings, 1973; Billard, 1995). Successful fish farming requires meeting certain conditions, including rapid growth, reproductive behaviour, disease resistance, ease of handling and transport, adaptation to water conditions, and consumer preference (Lietar, 1984). With global protein supply becoming a concern, exploring alternative protein sources is crucial to increasing production.

Achieving success in fish farming depends not only on mastering reproduction techniques but also on a profound understanding of nutrition, which is a fundamental parameter in fish farming (Barnabe, 1991).

In the Vakinankaratra region, many breeders incorporate fruits into fish feed, such as ripe or green bananas, guava, pineapple, and others. However, limited research has been conducted on the impact of fruits in fish feed formulations.

Regardless of the fish species under consideration, formulating fish feed relies on fundamental principles. Using locally available raw materials, nutritionists aim to create a balanced mixture capable of meeting the nutritional requirements of the fish, all while keeping costs low.

The primary objective of this research is to determine the optimal composition of fish feed to promote rapid and healthy growth.

II. Reserach Methods

2.1 Experimental procedure

This study was conducted using hapas installed in an open circuit in Verezambola, situated in the Antsirabe I District of the Vakinankaratra Region, located in the highlands of Madagascar.

2.2 Terrain characteristics

The ponds are situated in a shallow area, facilitating water control. They enjoy ample sunlight, are relatively sloped, and are shielded from flooding. Upstream of the rice fields are two ponds; they serve the dual purpose of storing harvested fish and preparing for any unforeseen events, such as temporary water cutoffs.

Table 1. Pond characteristics

Location	Area (m^2)	Dam height (cm)	Dam thickness (cm)	Depth (m)	Slope (%)
Verezambola	123	50	60	60-120	10

Four diets, AT0, AT1, AT2, and AP3, with isoproteins (36%), intended for feeding Tilapia in the pre-magnification growth phase, were developed using conventional raw materials (see Table 1). Within these diets, banana flour is gradually incorporated at rates of 3%, 6%, and 10% (see Table 2). Raw ingredients are sourced from the local market and prepared by finely grinding and sifting them using a 400-micrometre sieve. Each ingredient is weighed and mixed until a homogeneous powder is obtained, to which vegetable oil and MVC (mineral-vitamin complex) is added. Water is then added at a rate of 60% dry matter to obtain a malleable paste. This paste is passed through an extruder die, resulting in filaments with a diameter of 1.2 mm (resembling spaghetti). These filaments are then fragmented into small granules of the desired size and dried in a dryer for 45 minutes. The dried granules are then bagged and stored at room temperature until distribution.

These foods were tested on juvenile Nile Tilapia (*Oreochromis niloticus*) with an initial average weight of 8.52 ± 0.91 g (mean weight ± standard error). The fish, numbering 320 individuals, were individually weighed and randomly distributed into 4 hapas of 20 m^2 each, totalling 80 fish per batch. This setup formed four treatments, each replicated in triplicate, corresponding to a specific food. The fish were acclimated to their new environment in the basins for 10 days before the start of the experiment.

Table 2. Biochemical composition of ingredients

Ingredient	**Protein**	**Lipids**	**Carbohydrates**	**Humidity**	**Ash**
Fishmeal	58.2	5.02	0.23	8.20	28.35
White chub	61.26	2.07	5.61	11.92	19.14
Peanut cakes	43.01	13.82	27.37	10.23	4.57
Corn flour	8.95	4.02	74.86	11.16	1.01
Cassava flour	1.4	0.59	97.9	1.8	0.019
Banana flour	5.18	0.69	81.78	9.49	2.86

Table 3. Formulation and biochemical composition of diets for Pre-growing Tilapia fry

Ingredient	**AT0**	**AT1**	**AT2**	**Ap3**

Fishmeal	14.5	15	14.5	
White chub	14.5	15	14.5	
Peanut cakes	30	30	30	
Corn flour	22	22	18	
Cassava flour	14	11	11	unknown
Banana flour	3	6	10	
Peanut oil	1.5	1.5	1.5	
MVC [1]	0.5	0.5	0.5	
Nutritional value	**AT0**	**AT1**	**AT2**	**Ap3**
Protein	36.26	36.65	36.4	36.39
Carbohydrate	36.91	36.64	36.79	37.26
Lipid	8.48	8.27	8.83	8.47
Ash	9.84	9.49	9.07	8.78
Humidity	8.57	8.95	8.91	9.1
Energy in Kcal	369	367.59	372.23	370.83

[1]: Mineral and Vitamin Supplement
MVC: mineral-vitamin complex
Vitamin (mg or IU. Kg-1): Vit A, 250,000 IU; Vit D3, 62500 IU; Vit K3, 100 mg; Vit B1, 412 mg; Choline, 2500 IU.
Minerals (mg. Kg-1): Fe, 1.5 g; Cu, 0.2 g; Mn, 1.75 g; Zn, 1.25 g; I, 0.01 g; Se, 0.0075 g; Co, 0.008 g; P, 0.082 g; that, 0.24 g; Na, 0.35 g.

The pond is supplied with spring water located 50 meters away, with a temperature of 24.5 ± 0.92 °C during the day throughout the study, and at a flow rate of 4 to 6 litres per minute, ensuring a renewal rate of at least once an hour, thus maintaining an oxygen level greater than 80% of saturation. The fish are manually fed with the experimental foods three times per day (at 9:00 a.m., 12:00 p.m., and 3:00 p.m.) seven days a week. The fish are considered to be full when they no longer pay attention to the rationed granules. Rationing rates applied were respectively 2.8%, 2.4%, and 2.1% of biomass, depending on the temperature. Every 10 days, the fish are weighed, and rotation of the bins is carried out to minimize any tank effects.

2.3. Biochemical analyzes

Biochemical analyses (including proteins, lipids, moisture, cellulose, and ash) were conducted in duplicate according to standard methods at the National Environmental Research Center (NERC) for both the ingredients and the four experimental foods.

- Crude proteins (% N x 6.25) were determined using the Kjeldahl method (Kjel-foss auto-analyzer).

- Fatty acids from lipids were extracted using the hot method (Soxhlet type) with hexane extraction followed by distillation.
- Dry matter content was measured by weighing the loss after drying for 24 hours in an oven set at 105°C.
- Ash content was determined by cremating the samples in a muffle oven at 550°C for 12 hours.
- Carbohydrate content was calculated by the difference from the values found for the other constituents of the diets.

2.4. Statistical analysis

For the statistical analysis of the results, the biometric data from each repetition are treated as individual observations. These results are statistically compared using one-way analysis of variance (ANOVA) according to the procedure in Excel, following prior verification of variance homogeneity and data normality. When the ANOVA yields significant results, the Tukey test is employed for multiple comparisons of means. A significance threshold of 5% is used for these comparisons.

2.5. Water quality monitoring

The quality of the breeding environment was monitored by measuring the following physicochemical parameters of water: pH, dissolved oxygen, conductivity, salinity, and temperature. pH and temperature were measured daily at 8 a.m. and 2 p.m., respectively, using a pH meter and a thermometer. The other parameters were measured every three days at 8 a.m. using an oximeter and a multifunction thermometer.

2.6. Expression of results

The following settings based on zootechnical criteria have been established*:*
- Weight Gain (WG, g) = Final Weight (g) – Initial Weight (g)*;*
- Daily Weight Gain (DWG, g) = (Final Weight (g) – Initial Weight (g)) / Number of days of follow-up*;*
- Specific Growth Rate (SGR, %/d) = [(Fw (Final Weight (g)) – Iw (Initial Weight (g))] / Number of days of follow-up) x 100*;*
- Survival Rate (SR, %) = 100 x Final Number of fish / Initial number of fish Survival Rate (SR, %) = 100 x Final Number of Fish / Initial Number of Fish;
- Apparent Food Conversion Index (CI) = Quantity of Food Distributed (g) / Weight Gain (g);
- Condition factor (K)= 100 x Final weight (g)/ (standard length Condition Factor (K) = 100 x Final Weight (g) / (Standard Length (cm)) $^{3.}$
- Daily Length Gain (DLG, cm/d) = (Final Length (cm) – Initial Length (cm)) / Number of days of follow-up
- Length gain (LG (cm)) = (Final length (cm) – Initial length (cm)
-

III. Results and Discussion

3.1. Results

a. Water quality

The average values of the physicochemical parameters of the breeding environments are presented in Table 3. The average water temperatures were 23.2 ± 1.04°C at 9 a.m. and 25.7 ± 0.82°C at 3 p.m. These temperatures were consistently observed in all hapas. The dissolved oxygen level averaged 7.1 ± 0.46 mg/L, with a pH of 7.8 ± 0.3. The average conductivity was 97 µS/cm across all four hapas, with an average salinity of 153 ± 0.5 ppm. The Secchi disk measured an average depth of 42 cm. These physicochemical parameters of the breeding environments, measured during this test, did not exhibit significant differences between treatments ($p < 0.05$).

Table 4. Average values of temperature, dissolved oxygen and pH, conductivity, salinity, and water clarity recorded during rearing

Settings	Dietary treatments			
	AT0	AT1	AT2	AP3
Temperature (*°C)*	*24.5±0.92*	*24.5±0.92*	*24.5±0.92*	*24.5±0.92*
Oxygen (*mg/L*)	*7.1±0.46*	*7.1±0.46*	*7.1±0.46*	*7.1±0.46*
pH	*7.8±0.3*	*7.8±0.3*	*7.8±0.33*	*7.8±0.3*
Conductivity (µS/cm)	*97±0.9*	*97±0.9*	*97±0.9*	*97±0.9*
Salinity (ppm)	*153±0.5ppm*	*153±0.5ppm*	*153±0.5ppm*	*153±0.5ppm*
Secchi disk (cm)	*42.03±3.75*	*42.03±3.75*	*42.03±3.75*	*42.03±3.75*

Four isoprotein diets: *AT0, AT1, AT2 et A*

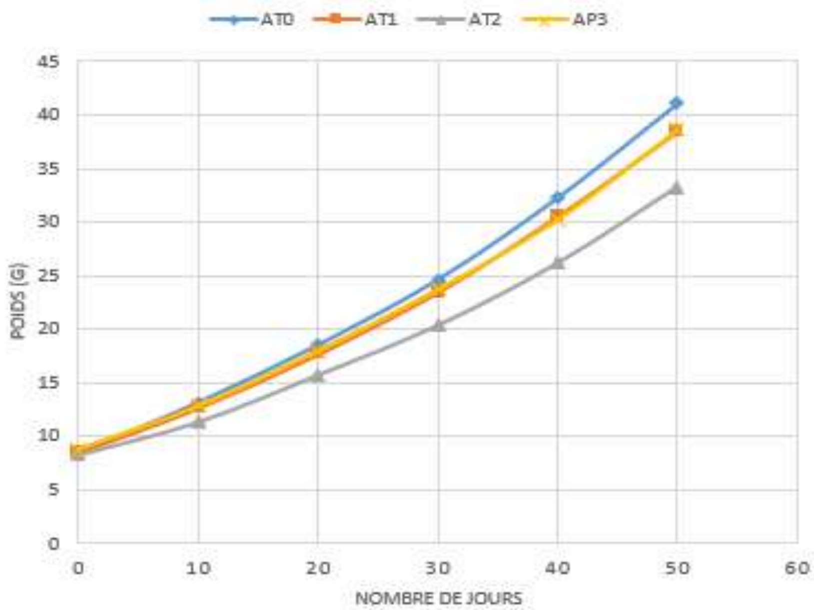
b. Zootechnical parameters

Zootechnical and food utilization parameters in O. niloticus fry after 50 days of rearing are presented in Table 4. Survival rates ranged from 98.75% to 97.5% across the four hapas. No significant difference was observed between the survival rates recorded during this trial ($p > 0.05$). The condition factors of the fish subjected to the different food treatments varied from 1.40 to 1.49. These extreme values were recorded in fish subjected to ATO and AT1 diets, respectively. However, a significant difference was observed between the condition factors of fish subjected to different treatments ($p < 0.05$). The final average weights (MFT) of the fish varied by treatment, although the initial average weights were identical, ranging from 33.28 ± 0.87 g to 41.1 ± 0.53 g. The lowest weight was observed in fish fed the AT2 diet, and the highest was in the AT0 diet.

The weight gain (WG), specific growth rate (SGR), and daily weight gain (DWG) varied respectively from 32.26 ± 0.99 to 24.93 ± 1.10 g/fish, from 2.77 ± 0.24 to 3.16 ± 0.19% per day, and from 0.64 ± 0.019 to 0.49 ± 0.02 g/day. The highest values of these three parameters were observed in fish fed with ATO, and the lowest in those fed AT2. However, fish-fed ATO and AT1 presented significantly similar values of FW, WG, SGR, and DWG ($p > 0.05$).

The length gain (LG) and daily length gain (DLG) varied respectively from 7.52 ± 0.45 to 7.93 ± 1.25 cm/fish and from 0.13 ± 0.02 to 0.14 ± 0.02 cm/day. The highest values were observed in fish fed with ATO, and the lowest in those fed AT2.

Furthermore, the growth performance recorded in fish fed with AT2 is lower compared to those observed in fish fed with ATO, AT1, and the AP3 control. Unlike survival rates and condition factors, the results show significant differences ($p < 0.05$) in growth performance among batches of fish subjected to the four dietary treatments. The weight evolution of fish subjected to different forms of food presentation (see Figure 2) shows that during the first 10 days, the growth rates are approximately identical among fish fed with the four types of food: AT0, AT1, AT2, and AP3. However, slower weight growth is observed in fish subjected to AT1, AT2, and AP3 from the 10th day of breeding.



In terms of the food conversion index (CI), values ranged from 1.64 to 2.01. While there was no significant difference between the CIs of fish fed AT1 and AP3 compared to those fed AT0, the highest values were observed in fish fed AT2 and the lowest in fish fed AT0. The results of food utilization parameters for the fry show significant differences ($p < 0.05$) among the different food treatments. The condition factor (K) ranged from 1.40 to 1.49, with all values being different from each other. The maximum was observed in fish fed ATO, and the minimum in those fed AT2.

Table 5. Zootechnical parameters in juveniles of *O. niloticus* subject to different forms of food presentation for 50 days

Zootechnical parameters	**Food**			
	AT0	AT1	AT2	AP3
IAW (g)	8.37 ± 0.81 [a]	8.54 ± 0.83[a]	8.355 ± 1.05 [a]	8.82 ± 0.95 [a]
FAW (g)	41.1 ± 0.53[a]	38.48 ± 0.44 [b]	33.28± 0.87[c]	38.58 ± 0.41 [b]
WG (g)	32.26 ± 0.99[a]	29.41 ± 0.1.04 [b]	24.94 ± 1.04[c]	29.75 ± 0.75[b]
DWG (g/d)	0.64 ± 0.019[a]	0.59 ± 0.02[b]	0.49 ± 0.02 [c]	0.59 ± 0.015[b]
SGR(g)	3.98 ± 0.39	3.62 ± 0.69	2.92 ± 0.42	3.3 ± 0.23
CI	1.6	1.8	2.01	1.7
SR (%)	98.75	98.75	93.75	97.75
K	1.49	1.40	1.40	1.42
IL (cm)	7.54± 0.63[a]	7.88± 0.74[b]	7.52± 0.45[a]	7.59± 0.52[a]
FLG cm)	14.93± 0.92[a]	14.88± 0.40[a]	14.08± 0.75[b]	14.63± 0.43[c]
LG (cm)	7.93± 1.25[a]	7±1.02 [b]	6.56± 1.05[c]	7.04±0.8 [b]
DLG (cm/d)	0.14± 0.02[a]	0.14± 0.19[a]	0.13± 0.02[a]	0.14± 0.015[a]

On each line, the values (average± SDM, n = 3) assigned by different letters, are significantly different ($P < 0.05$), Tukey test. The presence of the same letter on the same line indicates an absence of significant difference ($P>0.05$).

SDM: Standard deviation of the mean
AT0, **AT1**, **AT2**, **AP3**: four isoprotein diets

IAW: Initial average weight (g)	**FAW**: Final average weight (g)	**WG**: Weight Gain (g)
DWG: Daily Weight Gain (g)	**SGR** : Spécifique Growth Rate (d)	**SR**: Survival Rate (%)
CI: Apparent Food Conversion Index	**K**: Condition factor (K)·	**DLG**: Daily Length Gain (cm/d)
IL: Initial Length (cm)	**LG**: Length gain (cm)	**FLG**: Final Length Gain
DLG: Day Length Gain		

3.2 Discussion

The water quality was maintained within suitable limits for breeding freshwater fish such as *O. niloticus*. The average values of dissolved oxygen and pH observed for all treatments fell within the recommended intervals by Makori et *al.* (2017), ranging from 5 to 23 mg/l for dissolved oxygen and from 6.5 to 9.0 for pH, which is optimal for the growth of this species of fish. High survival rates (more than 80%) recorded in the present study indicate that the fish responded well to all experimental treatments. Furthermore, the survival rates obtained in this work ranged from 93.75% to 98.75%, consistent with those observed in most studies on this species by numerous authors (**Bamba et *al.*, 2008; Makori et *al.*, 2017; Sissao et *al.*, 2019**). However, it is worth noting that a majority of fish were observed stuck in the separations during collections.

Our results exceed the known standards in cooler areas. In commercial fish farms in Egypt, the typical weight of Tilapia nilotica after six months of breeding is 500 g, equivalent to a weight gain of 2.7 g per day. The difference observed in our study may be attributed to various factors besides food, including infrastructure and technical practices involved in Tilapia breeding. The growth of fry fed with the experimental diet is comparable to the standard. At water temperatures ranging from 24 to 27 °C in the pond, the growth of fish during the study remains acceptable compared to the maximum growth temperature (28 to 30 °C). According to Petit (1980), the basal metabolism increases significantly with temperature, while the maintenance and growth requirements increase only up to a maximum tolerated temperature. Temperature not only influences growth but also affects protein requirements.

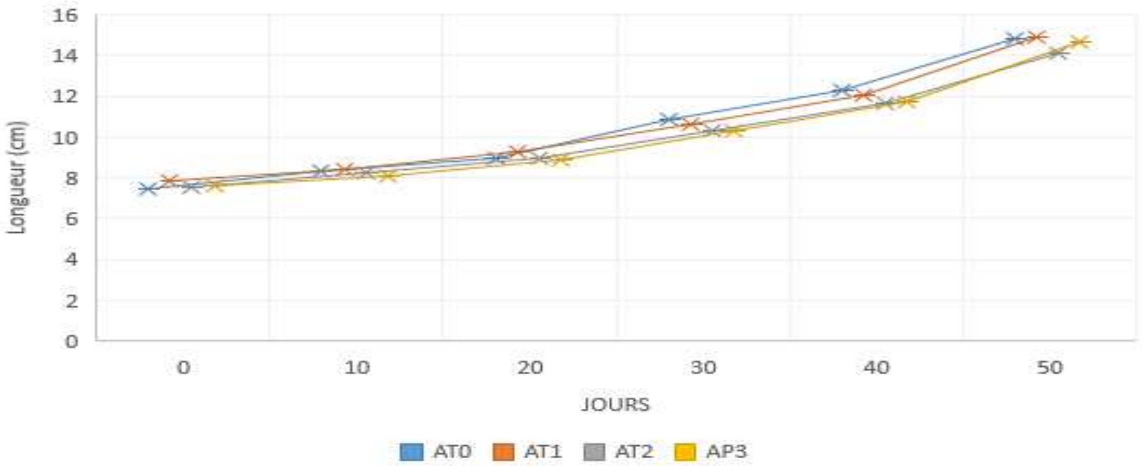


Figure 2. *Evolution of length over time*

Conductivity measurement allows us to quickly but very approximately evaluate the overall mineralization of the water and to monitor developments (**Rodier *et al.*, 2009**). The measured conductivity values fluctuate between 95 µS/cm and 98 µS/cm. According to Rodier *et al.,* 2009 a conductivity < 100µS/cm: very low mineralization corresponding to fresh water. Salinity is the amount of mineral salts dissolved in water (**Alcántar-Vázquez et *al.*, 2014**). The highest salinity recorded in the pond is 160 *ppm,* and the lowest value is 146 ppm. The salinity of the pond water is normal because according to March et *al.* (1999), all tilapia are tolerant to brackish water.

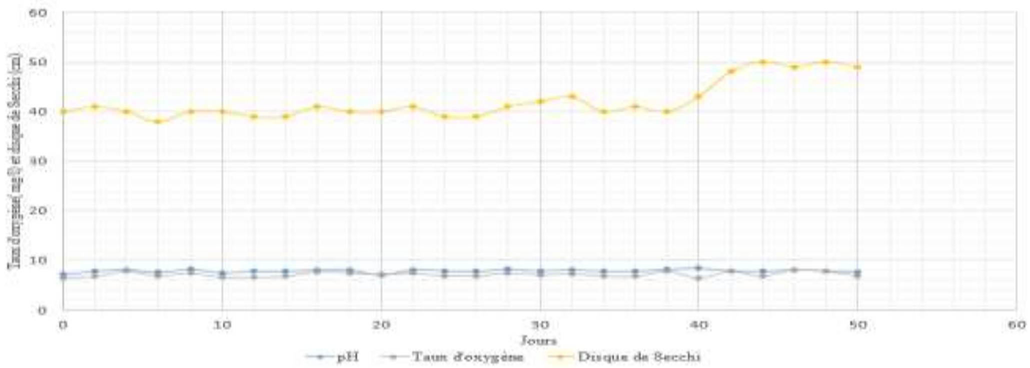


Figure 3. *Change in water quality over time*

The solubility of oxygen in water is influenced by factors such as pH and water clarity. It is observed that as the pH of water increases, its capacity to dissolve oxygen also increases compared to water with lower pH levels. Additionally, water clarity plays a role; unclear water with low oxygen levels at depths less than 40 cm may exhibit slightly lower oxygen levels than average, while depths greater than 40 cm may show higher oxygen levels during the study period. According to FAO recommendations, a depth of 40 to 60 cm on the Secchi disk is considered normal for the supply of phytoplankton and zooplankton in fish farming.

Moreover, pH levels can also affect water quality; extremely low or high pH levels can trigger reactions that may impact the availability of oxygen to aquatic organisms.

The similarity in growth speed observed during the first 10 days in fish subjected to different treatments could be explained by the adaptation of the fish to the forms of food presentation. Previous studies have noted the adaptability of *O. niloticus* to feeding modes and systems such as on-demand feeders (**Fortes-Silva, et *al.*, 2010; Pratiwy & Kohbara, 2017**). Presentations of foods with lower levels of banana flour are more effective than those with higher levels, as evidenced by the lower food consumption indices and higher specific growth rates observed. Towards the end of the study, we observed a higher quantity of food for AT0, AT1, and AP3 compared to AT2, indicating excellent diet utilization.

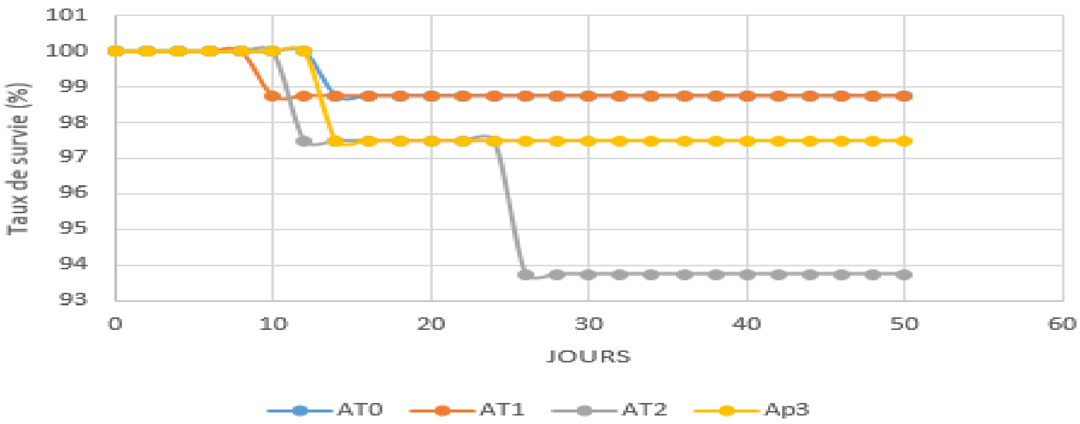


Figure 4. *Evolution of length over time*

In terms of size, rapid growth rates ranging between 0.13 and 0.14 cm/day were observed. According to the FAO, tilapia weighing between 5 to 50g typically experience a length gain of 0.117 to 0.113 cm/day. With a conversion factor greater than 1.4, we observe well-proportioned fish, indicating optimal nutrition and favourable environmental conditions for breeding.

The results obtained are consistent with research conducted on other Tilapia species such as *O. aureus* and *O. mossambicus*, indicating that the incorporation of animal proteins greatly increases the digestibility of food and consequently improves growth performance (**Mathavan & Paudian, 1976; Davis & Stickney, 1978**).

The food consumption indices obtained range from 1.6 to 2.01, which aligns with the range of 1.7 to 3.0 reported by several authors for diets incorporating more than 25% unconventional protein sources as substitutes for fish meal. Examples include *Leucaena* or copra, as well as cakes made from peanuts, cottonseed, or soybean (**Carraro, 1983; Antoine et *al.*, 1987**).

The specific growth rate observed in *O. niloticus* in this experiment is high, ranging from 2.77% to 3.16% per day. The highest growth rate (3.98% per day) is similar to that reported by Middendorp (1995) in mixed breeding of *O. niloticus* with *C. gariepinus*. However, these specific growth rates are lower than those obtained by Antoine et *al.* (1987) and Micha et *al.* (1988).

IV. Conclusion

This study demonstrates that incorporating fruit into fish feed can result in fish production equivalent to that achieved with commercial floating pellets. The use of banana flour in tilapia feeding has shown promising effectiveness. Banana flour, serving as a source of carbohydrates and certain nutrients, can be a beneficial supplement in tilapia diets. However, its effectiveness depends on precise feed formulation, its percentage in the diet, and the rearing environment. Additionally, it would be interesting to evaluate other fruits with high energy values to further enhance the growth of pellet-fed fish and to conduct additional research on the use of banana flour feeds in various rearing environments.

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