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Grow-out of *Oreochromis niloticus* (Linnaeus, 1758) fish (*Perciformes, Cichlidae*) on Local Feed in an Above-ground Tank Culture System in Kinshasa, Democratic Republic of Congo

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Abstract. Acquiring land that meets the required standards for lowland ponds is becoming an increasing problem in the city of Kinshasa in the Democratic Republic of Congo, and fish farming in above-ground concrete tanks is emerging as an alternative. The objective of this study was to follow the evolution of pre-growth of *Oreochromis niloticus* Linnaeus, 1758 in an above-ground concrete tank culture system using feed based on local agricultural by-products available in Kinshasa. A total of 198 fries were distributed in 3 tanks and fed three times a day. The experiments were conducted for 60 days between August and November 2021. The results obtained indicate a better survival rate (T1 = 75.75±4.32%; T2 = 60.6±9.76% and T3 = 83.33±4.96%). Feed T1 (mean weight = 33.15±2.78 g) and T2 (28.44±3.76 g) had a positive impact on fish weight growth. The cost of producing one kilogram of a feed ration varied depending on the ingredients used. It cost 2,843 FC to develop the T1 feed, 951 FC to produce the T2 feed and 5.000 FC to afford the T3 commercial feed sold in Kinshasa. Ration T2 is the one that gave a better compromise of price and quality by promoting good fish growth at a lower cost (1,692 Congolese Francs) than the other two feeds. These observations sufficiently show that during the experiment, the experimental structure (concrete tank) did not have negative effects on the zootechnical performance of the fry of the fish species studied. The economic aspect of the use of feed rations by fry showed the merits of rearing fish using local agricultural by-products rather than commercial feed. This study showed the merits of setting up an above-ground concrete tank fish farm to overcome the difficulty of acquiring land to meet fish farming requirements.

Keywords: feeding, free range, growth, *Oreochromis niloticus*, performance

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1. Introduction

For a long time, man has exploited water resources to satisfy his needs mainly for food through fishing as well as aquaculture. The first aquaculture trials began in Egypt in 4000 years BC with the production of the famous fish the Tilapia [1]. Currently, In the family *Cichlidae*, two species are particularly high: the Mozambique Tilapia (*Oreochromis mosambicus*) and the Nile Tilapia (*Oreochromis niloticus*) [2].

In intensive aquaculture, the feed item represents a significant part of the production cost of fish. The economic interest of this type of farming is therefore highly dependent on the availability and cost of feed [3]; [4]. Thus, the reduction of feed costs, and consequently the control of the production cost of farmed fish, is one of the priorities in aquaculture [5].

Nowadays, fish farming in ponds has experienced a great regression, due to ecological and socio-economic problems, low production, and difficulty in manufacturing feed for fish growth. Fish farmers are always looking for a way to fight against famine, their concern would be to make fish accessible to all, regardless of social rank. But so far the measures taken are almost zero [6].

In the Democratic Republic of Congo, the lack of experience, the absence of knowledge on good fish farming practices, and the difficulties related to the accessibility of good quality fry and feed have long been the blocking points for the development of fish farming [7]. In addition, there is the difficulty of acquiring land and space to accommodate rearing ponds in the lowlands that meet fish farming engineering standards [8].

Apart from ponds, it is possible today to develop above-ground fish farming in plastic tanks, happas, raceways, concrete tanks and others without being totally dependent on ecological and edaphic factors [9]-[10]. This fish farming practice, in tanks or above-ground ponds, is already practised in several countries of the world including some African countries including Ghana, Benin, Cameroon, Egypt, Zambia, etc. [11]-[12].

Regarding above-ground concrete bins, they can be placed at high or low altitudes, on a balcony of a building, near a stream and especially in a plot garden provided that there is a point where water (from a stream, borehole or tap) can be captured [7]. To break the difficulty linked to the acquisition of a plot of land but also the ecological constraint linked to obtaining a plot of land that meets the standards required for fish farming, it is appropriate today to promote above-ground fish farming in concrete tanks.

It is in this perspective that this study was conducted with the general objective of pre-growing fish *Oreochromis niloticus* Linnaeus, 1758 in a system of above-ground concrete tanks with food based on agricultural by-products available in Kinshasa in the Democratic Republic of Congo.

2. Material and Methods

2.1. Experimental Setting

The experiments took place at the Experimental Garden and Plot Farming (ONG/D JEEP) located on the University site of Kinshasa behind the Faculty of Sciences in the commune of Lemba in Kinshasa in the Democratic Republic of Congo. The experiments were conducted during 60 days (August to November 2021).

2.2. Biological Material

The biological material for this study consists of *Oreochromis niloticus* Linné, 1758 fish fry. These fry, produced by extensive mono-culture fish farming in low-lying ponds, were purchased from the La Kinoise des Poissons de Maluku farm, located in the commune of Maluku in the city of Kinshasa in the Democratic Republic of Congo.

A total of 198 fingerlings of average initial weight ranging from 6.08±1.25 g to 13.17±2.7 g and average initial size ranging from 60.84±2.41 mm to 90.27±2.69 mm divided into three batches were tested.

The choice of the species *Oreochromis niloticus* is explained by the fact that it has a very interesting growth rate, even unique compared to other species of the *Cichlidae* family, in addition, the species has a good food conversion rate associated with an excellent ability to accept artificial food [13]; [14]. Its diet corresponds to the lowest levels of the food chain (phytoplankton, detritus, etc.). Therefore, these assets allow the production of this species with relatively moderate and adequate production costs. This fish also adapts better to intensive farming conditions and withstands handling stress. Its culture is mastered throughout the world and in DR Congo in particular [15].

2.3. Methodology

2.3.1. Presentation of the Experimental Structure

Three (3) above-ground concrete tanks of 100 cm length, 100 cm width and 80 cm depth interconnected by ½ inch PVC pipes were set up during this experiment. These tanks (Figure 1) consist of a continuous closed-loop water renewal system. A 50 mm PVC overflow pipe is placed in a vertical position in each bin to discharge water into the concrete bins once the established depth is reached. The water discharged through the overflow pipe is collected by a 100 mm PVC pipe (serving as a collector) before reaching the filters. After filtration, the water will pass into a tank where the motor pump is placed. The motor pump will launch the water into two plastic barrels of 200 liters each linked to the aquaculture to feed the tanks.

Figure 1. An experimental structure used to rear *Oreochromis niloticus* fish (photo Lusasi, 2021)

2.3.2. Obtaining the Ingredients

The experimental ingredients (palm kernel cake, wheat bran, cassava flour, maize flour, palm oil and cooking salt) were purchased at the Kinshasa market. The fish meal was obtained by moulding the waste of dry fish unfit for human consumption. Apart from these sub-ingredients, food additives were also used. These are the vitamin-mineral complex for farmed fish purchased in one of the veterinary pharmacies of the city.

2.3.3. Manufacture of Experimental Feeds

The ingredients used in this study were selected according to their natural protein content, their assimilation rate by fish, their purchase price and also according to their accessibility to the local market. The crude natural protein content of the raw materials was previously determined according to the empirical Pearson square method proposed by Guillaume [16]; and Bocek [17]. The preparation of the feed rations followed the following steps [18]; [19]:

- Grinding the coarse ingredients in a cassava mill;
- Weighing the flour of each ingredient using an electronic scale (accuracy 0.1 g);
- Mixing the different proportions of ingredients by hand in a plastic container;
- Heat two liters of tap water in a pot until lukewarm;
- Mix the warm water with the flour of each food ration;
- Knead the mixture into a soft dough;
- Compact the dough into 1 mm spaghetti with a manual chopper;

- Dry the manufactured feed rations in the sun for 72 hours on trays;
- Keeping the food in plastic bags for the duration of the experiment.

In this study, two feed rations were developed with a crude protein content between 27.09±0.6% (T2) and 36.87±0.54% (T1). A third feed ration consisting of 45±2.5% crude protein, considered a control feed, was purchased at the local market. The bromatological composition of the feed rations fed to *Oreochromis niloticus* fish fry is presented in Table 1.

Table 1. Bromatological Composition of Tested Feed Rations

Parameters	Food rations		
	T1	**T2**	**T3**
Moisture (%)	20.41±1.2	14.2±0.2	11.5±0.5
Protein (%)	36.87±0.54	27.09±0.6	45.07±2.5
Fat (%)	13.1±0.3	11.4±0.5	14.7±0.6
Ash (%)	8.4±0.7	4.8±0.3	8.4±1.2
Fiber (%)	7.3±0.5	5.5±0.4	7.2±0.1
Carbohydrates (%)	21.5±0.4	18.71±0.7	31.3±3.1
Energy (Kcal)	311.6±1.8	298.01±2.4	394.2±4.2

2.3.4. Measurement of the Physicochemical Parameters of the Water in the Tanks

The monitoring of the physico-chemical quality of the water in the experimental system was carried out every ten days. The environmental variables concerned are pH, temperature (°C), conductivity (µS/cm) and turbidity (ppm). The sampling of these parameters was carried out using a multiparameter probe of the brand HANNA Combo HI9812-5 pH/°C/EC/TDS.

2.3.5. Weighing and Measuring of Fish

Weighing and measuring of the fry took place during a control fishery organized every ten days. The weight of the different fish was taken with an electronic precision scale, and the measurement was done with a calliper.

2.3.6. Fish Feeding

The experimental fish were fed every day of the week. The feed was distributed by free hand three times a day: at 8:00 a.m., at 12:00 p.m. and at 3:00 p.m. The daily amount of feed given to the fish was 10% of their total weight [19]. Feed T1 was fed to fish kept in tank B1, experimented fry in tank B2 were subjected to feed T2 and fry kept in tank B3 received the control feed, T3.

2.3.7. Expression of Growth of Experimented Fry

To estimate the growth of pre-growth experimented *Oreochromis niloticus* fish fry, and to judge the efficiency of the use of feed rations during the experimental period, the following zootechnical parameters and indices were calculated [11], [18]-[19]:

- **Survival rate (SR):** the survival rate is calculated from the total number of fish at the end of the experiment and the number at the beginning of the rearing. It is calculated according to the following mathematical formula: T x100 where Ni is the initial number of fish and Nf is the final number of fish;

- **Average weight (AW):** the average weight is the ratio between the total weight of the fry and the total number of fish. It is calculated by the formula: MW (g) = B/NP where MW is the average weight (g) of the fry; B is the biomass (g) and NP is the total number of fish;

- **Average size (TM):** the ratio between the sum of the total lengths of the fry and the total number of fish. It is calculated by the formula: TM (mm) = SLt/NP where SLt (mm) is the sum of total fry lengths and NP is the total number of fry;

- **Body Mass Gain (BMC):** commonly called average weight gain, expresses the weight gained by the fish during a given time. It is calculated from the following formula: GMC (g);

- **Average Size Gain (ASG):** expresses the average size added by the fish during a given time. It is obtained from the following mathematical formula: GTM (mm) ;

- **Individual Daily Growth (IDG):** allows to appreciate the daily weight gain of the fish during the rearing. It is determined from the following relation: CIJ (g/d) = Pf - Pi/DE where Pf is the final weight (g), Pi expresses the initial average weight (g) and DE is the rearing duration (days);

- **Performance Index (PI):** this index is used in fish farming to determine the performance of an experimental feed. It is obtained by the formula: PI = TS x CJ where TS is the survival rate and CJ is the daily growth (g/d);

- **Feed Consumption Index (FCI):** is the ratio of the amount of feed consumed to the weight gain of the fry. It is expressed by the formula: QASI/GMC, QASI: Quantity of dry feed ingested (g) and GMC: Body Mass Gain (g);

- **Relation weight-total length:** allows to determine the type of growth that a fish undergoes in a natural environment or in rearing. It is obtained by the formula: Px a. Ltb of which; P expresses the Weight (g); a.Lt is the Logarithm of the Total Length and b translates the slope of the regression line.

2.3.8. Economic Aspects of Feed Rations

2.3.8.1. Cost of production of feed rations

The production cost of rations was estimated by multiplying the price of a given ingredient by its incorporation rate in the considered ration divided by 100. The total production price of one kilogram of a feed ration is the sum of the prices of each ingredient in the ration [18]-[19].

2.3.8.2. Cost of production of one kg of fish with feed rations

To estimate the cost of production of one kilogram of fish with the different feed rations tested, the production price of a given kilogram of feed was [18].

2.3.9. Data Analysis and Processing

The data obtained on the variation of physico-chemical parameters of the tank waters as well as the weight and linear growth, survival rate, weight gain and individual daily growth of the fry were encoded on the Excel 2013 spreadsheet. The obtained means were compared by analysis of variance with a classification criterion (ANOVA 1) [20] using Statistix version 10 software. To record the difference between the mean values of the variation of physicochemical parameters and growth indices obtained from different batches of fish, the Tukey HSD test [21] was used at the 95% confidence interval. The results obtained are presented in tables and graphs. Origin 6.1 software was used to generate the graphs. The mapping of the experimental site was done using ArcGIS (10.8) software from the geographical coordinates (longitude and latitude) recorded with the Garmin Etrex GPS.

3. Results

3.1. Physicochemical Parameters of the Water in the Tanks

The minimum, maximum and average values of the different physicochemical parameters recorded in the waters of the tanks used during the pre-growth of *Oreochromis niloticus* fish fry are recorded in Table 2.

Table 2. Average Values of the Physicochemical Parameters of the Waters of the Tanks (Mi = Minimum and Ma = Maximum)

Parameters	Types of Treatment								
	T1			T2			T3		
	Mi	Ma	Average	Mi	Ma	Average	Mi	Ma	Average
pH	7.4	7.9	7.61±0.17	7.4	8	7.65±0.19	7.5	7.9	7.7±0.13
Temperature (°C)	24	26.2	25.23±0.17	24.8	26	25.28±0.21	24.5	26	25.26±0.30
Conductivity (µS/cm)	24	36	28.33±5.11	25	37	29.89±3.4	23	37	27.66±3.55
Turbidity (NTU)	12	18	13.88±2.07	13	18	14.66±1.55	12	18	13±1.53

Generally speaking, the average values of the various physico-chemical parameters assessed in the waters of the experimental tanks are favorable for the rearing and growth of *Oreochromis* *niloticus* fish. The results in Table 2 show that during the experiment the water used has a neutral to basic hydrogen potential (T1 = 7.6±0.17; T2 = 7.6±0.19, T3 = 7.7±0.13). The analysis of variance applied to the pH data indicates that the difference is not significant (F = 0.41; p = 0.6658) between the different treatments. The Tukey HSD test value (0.2441) shows that the different pH means are similar. The values of the mean temperatures are almost constant and range from 25.23±0.17 °C in treatment T1, 25.28±0.19 °C in treatment T2 and 25.26±0.30 °C in treatment T3. The difference in temperature was not significant (F = 0.15; p = 0.8617) between the means of the treatments tested. Electrical conductivity analysis shows that this water is low in solution ion charge. Conductivity ranges from 27.66±3.55 µS/cm (T3) to 29.89±3.4 µS/cm (T2). The difference in temperature means was not significant (F = 0.15; p = 0.8617; Tukey HSD = 0.6113). Analysis of variance applied to the conductivity data (F = 0.47; p = 0.6284; Tukey HSD = 5.8526) of the three treatments. Total dissolved solids in water ranged from 13±1.53 ppm to 13.88±2.07 ppm. Analysis of variance applied to the turbidity data indicated that the difference was not significant (F = 0.44; p = 0.6474). The fish tested in the three treatments were therefore subjected to the same conditions of the physico-chemical parameters noted above. The physicochemical parameters of water are essential for the life of fish in a given aquatic ecosystem [22]. According to Chikou *et al*., [23], the two most important parameters for fish growth are temperature and dissolved oxygen. On the other hand, Yao *et al*., [22] report that a decrease in temperature, however small, slows down growth in fish. After analysis and processing of the different data, the results obtained on the physicochemical parameters of the waters used showed that the average values of the different parameters remained within the ranges of those required for the rearing of the *Oreochromis niloticus* fish studied. Our results are similar to those obtained by several authors including Yao *et al*., [24] (pH = 6.7 to 7.1; temperature = 27.1 to 29.91°C) in a fish pond. The hydrogen potential content varied 7.6±0.17 (T1) and 7.7±0.13 (T3). According to Yao *et al*., [22], fish are in the optimum in pH between 5.5 and 10. Iga-ga [25] states that the pH tolerance threshold is between 5 and 11 for *Oreochromis niloticus* fish. The average temperature remained almost constant in all tanks and ranged from 25.23±0.17°C (T1) to 25.28±0.19°C (T2). According to Thabet [2], the required temperature for the development of *Oreochromis niloticus* is between 26°C-32°C. The average temperature values found are similar to other work on surface waters such as Eblin *et al*., [26] who report, that in the humid tropics, the average water temperature is about 30°C. Yao *et al*., [27] report that solar radiation has the ability to penetrate the water thickness to warm it evenly. The high temperature recorded in the water of the tanks would thus be related to the heating of the water by the sun. Iga-iga [25] recommends that the maximum concentration of total dissolved solids in water should not exceed 1300 ppm in rearing *Oreochromis niloticus* fish; this is also the case for the average concentrations found in this study (average turbidity value ranging from 13±1.153ppm to 13.88±2.07ppm).

3.2. Evolution of the Growth of *Oreochromis niloticus* Fish Fry

The growth of *Oreochromis niloticus* fry experimented during this study depends on the treatment and on the zootechnical parameters. The indexed means of the same alphabetical letters are not statistically different (p>0.05).

3.3. Survival Rate

In general, the survival rate of fry remained below 100% between treatments (Figure 2). Analysis of variance applied to the fish survival data shows that the difference is not significant (F = 1.55; p = 0.2520) between the three treatment types. With the critical comparison value of 14, 078, the Tukey HSD test shows the survival rates obtained with the three treatments (T1 = 75.75±4.32a%; T2 = 60.6±9.76a% and T3 = 83.33±4.96a%) are almost similar. From the survival rate values obtained, it appears that we did not record any major problems with fry mortality despite the fact that the average fry survival rate remained low at the 100% level from one treatment to the other. The survival rate found remained lower than that obtained by Elegbe *et al*., [28] (survival rate between 96.89±1.91 and 100%) in *Oreochromis niloticus* fry. This difference would be related to the difference in days between control fisheries that was so large during their experiment compared to the present study. The mortality observed during the experiment would be due to handling stresses in accordance with the observations made by Pwema et al. According to the latter, intense handling stresses weaken the fry and are capable of causing death in less resistant individuals. This finding was also made by Lusasi *et al*., [18] noting that in most cases handling stress related mortalities occur most often in the hours following the end of handling. These survival rates attest to the fact that none of the feeds are therefore toxic to *Oreochromis niloticus* fry. The survival rate of 90% being generally accepted in rearing [25], and those obtained being slightly lower, we can therefore consider that our results are within the accepted norm. This observation also confirms that the experimental concrete tank structure is a good device for rearing this fish species.

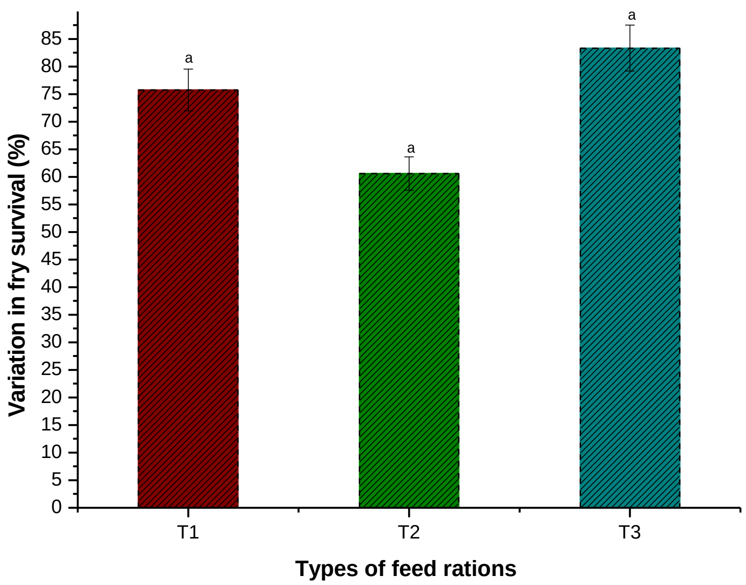

Figure 2. Variation in Fry Survival (%) in Relation to Feed Rations

3.4. Average Weight

The results visualized in Figure 3 show that the average weight of fish varied with each feed. The mean weight of fry fed T1 increased from 13.17±2.70g to 33.15±2.78a g; it increased from 6.08±6.25g to 28.44±3.76a g in fish fed T2 feed and the mean weight of fish fed T3 (imported) feed increased from 7±6.30g at the beginning of the experiment to 21.78±4.36b g at the end of the trial. Analysis of the data by one-factor comparison of variance showed that there was a significant difference (F = 1.20; p = 0.3362) between the means of the different treatments. Tukey HSD test (4.8682) indicates that T1 and T2 feed had a positive impact on the mean weight growth of fish than T3 feed. The efficiency of the T1 diet would be related to the high crude protein content and its composition, which would best suit the phytoplanktonphagous (microphytophagous herbivore with omnivorous tendency) diet of this species [29]; [30]. Our results are slightly higher than those obtained by Elegbe *et al.*, [28] in the same duration of the experiment. The *Oreochromis niloticus* fry experimented during eight weeks by the latter presented a final average weight coprised between 16 and 20 g. However, our results are lower than those obtained by Yao *et al.*, [24] The latter obtained a final average weight of 45.89±1.20 g for *Oreochromis niloticus* fish alvins experimented in an unfertilized fish pond and 66.61±1.61 g for the same species raised in a fertilized pond. This difference could be explained by the rearing structures used. Indeed, according to Bombéo *et al.*, [31], ponds offer the possibility of a greater development of natural productivity (primary production) than in concrete ponds.

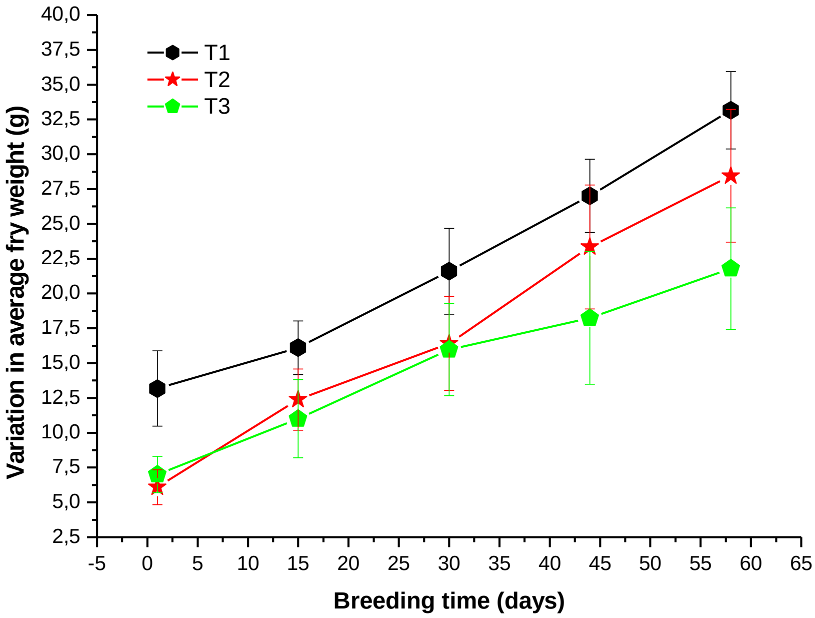

Figure 3. Variation of Average Fry Weight (g) with Rearing Duration

3.5. Average Size

The average size of the fry changed from one period to another and with the type of food fed to the fish. The analysis of variance applied to the fish sizes indicated that there was no significant difference (F = 0.93; p = 0.4211) between the mean sizes of the fish in the different treatments.

The Tukey HSD test (40.413) shows that all three feed types had the same influence on linear growth of fry. The mean size of fish fed T1 feed increased from 90.27±7.69 mm at the beginning of the experiment to 140.36±4.75a mm at the end of the trial; The average size of fish fed with feed T2 increased from 61.45±2.87 mm to 130±4.71a mm at the end of the experiment and that of fry fed with control feed (T3) increased from 60.84±2.41 mm to 123.64±6.67a mm at the end of the study (Figure 4).

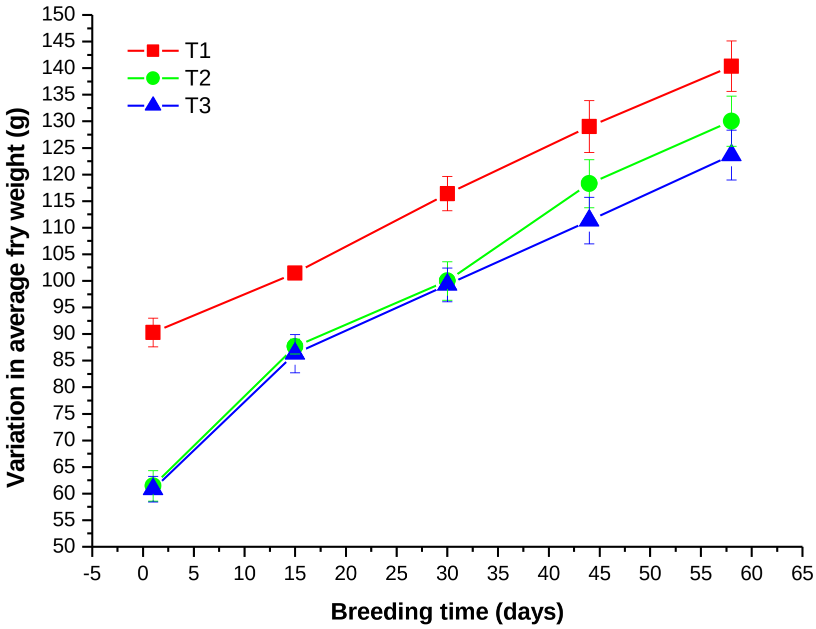

Figure 4. Variation in Mean Fry Size (mm) with Rearing Time

3.6. Average Weight Gain

Analysis of variation applied to fish weight gain values indicates that the difference is significant ($F = 6.08$; $p = 0.031$). The value of the Tukey HSD test (3.2431) indicates that feed ration T2 (mean weight gain = 26.36a g) significantly increased the mean weight of fry than feed rations T1 (mean weight gain = 19.98b g) and the control (mean weight gain = 14.78b g) (Figure 5). In Tunisia, a study carried out on the elaboration of dry feeds for *Oreochromis niloticus* by Derouiche *et al*., [32] showed that the best growth and feed conversion rates were obtained by feeds containing 20% and 30% fish meal. The high average weight gain obtained in fry-fed the T1 diet composed largely of fish meal would be the reason.

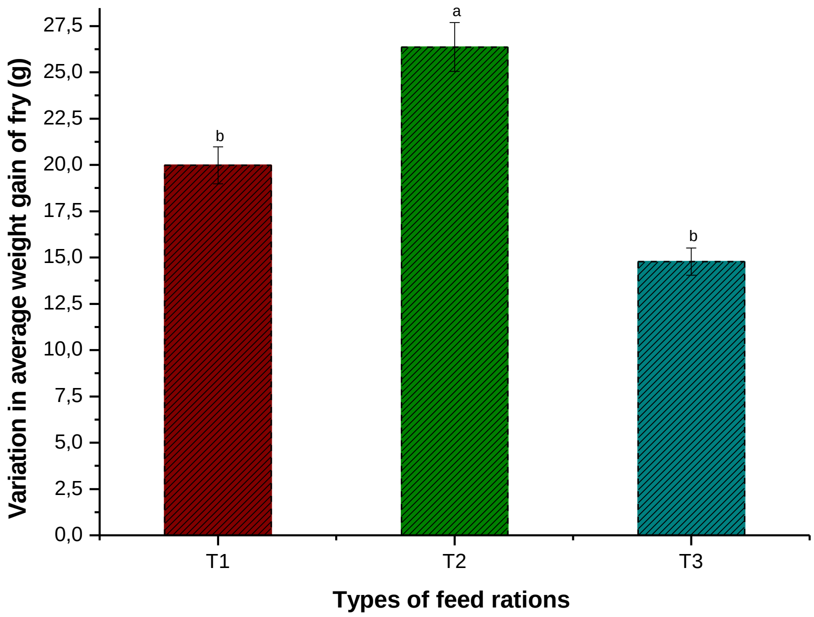

Figure 5. Variation in Average Fry Weight Gain (g) as a Function of Feed Rations

3.7. Average Size Gain

The average size gain of fish varied from 49.39b mm (T1) to 68.65a mm (T2) (Figure 6). According to the treatments allowed, the analysis of variance shows a significant difference ($F = 10.57$; $p = 0.0023$) in the mean size gain of the fry. With a critical value of 4.2613, the Tukey HSD test reveals that feed T1 significantly impacted fish size than feed rations T2 and T3.

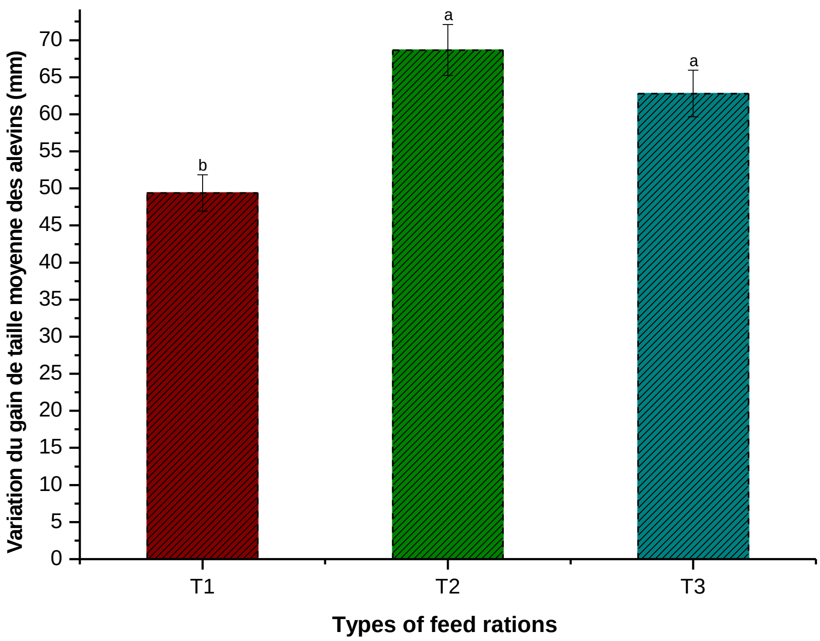

Figure 6. Variation in Mean Fry Size Gain (mm) as a Function of Feed Rations

3.8. Individual Daily Growth

Fry fed with feed T2 recorded an individual daily growth of 0.34a g/d followed by fish fed with feed T1 with 0.30a g/d and fry fed with control feed show an individual daily growth of 0.22b g/d (Figure 7). The three feed types differed significantly ($F = 8.12$; $p = 0.0062$); with the critical comparison value of 3.8621, the Tukey HSD test indicated that feed T1 and T2 influenced the individual daily growth of fry more than the control feed (T3). The values recorded on individual daily growth of fry are close to the figures reported by several authors [18]; [19]; [25] for diets incorporating more than 25% protein source ingredients. However, our results are less interesting compared to the reported data. The three types of diets differed significantly (F = 8.12; p = 0.0062). In addition, with the critical comparison value of 3.8621, Tukey HSD test indicated that feeds T2 (0.34a g/d) and T1 (0.30a g/d) significantly influenced the individual daily growth of fry than the control feed T3 (0.22b g/d). Our results are close to those obtained by Elebge *et al.*, [28] (0.18±0.04 g/d and 0.23±0.01 g/d). on the other hand, our results remain relatively low compared to those obtained by Yi *et al.*, (2001) (1.1-1.7 g/d); Yi *et al.*, [33] (1.7-1.9 g/d) in soilless culture and Yi *et al.*, [33] (2.2 g/d); Phanindra [35] (2.31 g/d) in integrated pond cage system. The low individual daily growth rates may be due to the (balanced) composition of the diets fed to the fry. The control diet was largely composed of ingredients (cassava and maize flours, brewer's grains and wheat bran) of plant origin. It is indeed known that in most teleosts, the cellulose of the diet in its raw state is poorly digestible [25]. According to Viola *et al.*, [35], tilapia would efficiently use complex polysaccharides and cellulose (up to a certain content) to cover its energy needs. In this regard, Jauncey and Ross [5]; Lazard [10], and many others, recommend a cellulose level below 10%, for tilapia feeding.

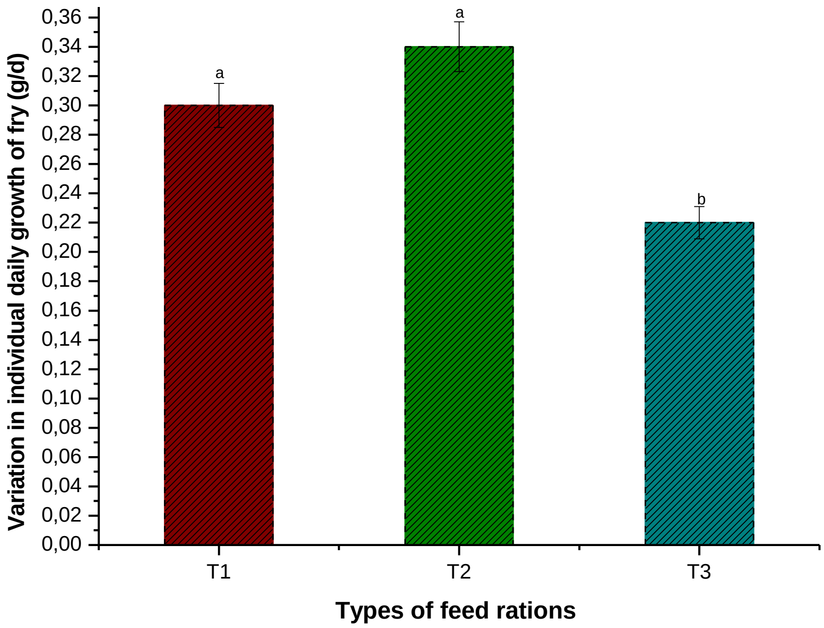

Figure 7. Variation in Individual Daily Growth of Fry (g/d) as a Function of Feed Rations

3.9. Performance Index

From the results visualized in Figure 10 below, it appears that fry fed with feed T1 had a high-performance index (22.72a %) followed by fish fed with feed T2 (20.15a %) and finally those fed with feed T3 (18.83a %) (Figure 8). The analysis of variance applied to the data shows that the difference is not significant (F = 18.00; p = 0.8142). The Tukey HSD test (11.007) indicates that the different performance indices obtained are almost similar.

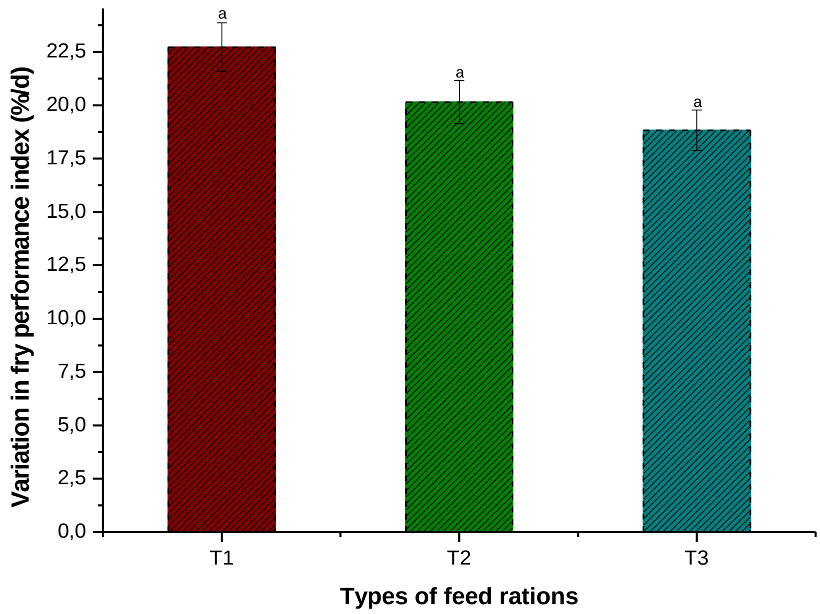

Figure 8. Variation in Fry Performance Index (%/d) With Feed Rations

3.10. Feed Consumption Index

The results visualized in Figure 11 below show that fish fed with feed T2 had a high feed consumption index (FCI = 1.78) followed by fry fed with feed T3 (FCI = 1.43) and finally those fed with feed T1 (FCI = 1.17) (Figure 9). The analysis of variance indicates that the difference is not significant (F = 8.26; p = 0.0714) between the three types of treatments tested. The high FCI in feed ration T1 would be due to the losses of distributed feed because the developed feed rations float less than the control feed (T3). The FCI values recorded for the three feed types is close to the one recommended by Nyinawamwiza [2007] for intensive cage culture of *Clarias gariepinus* which is 1.8.

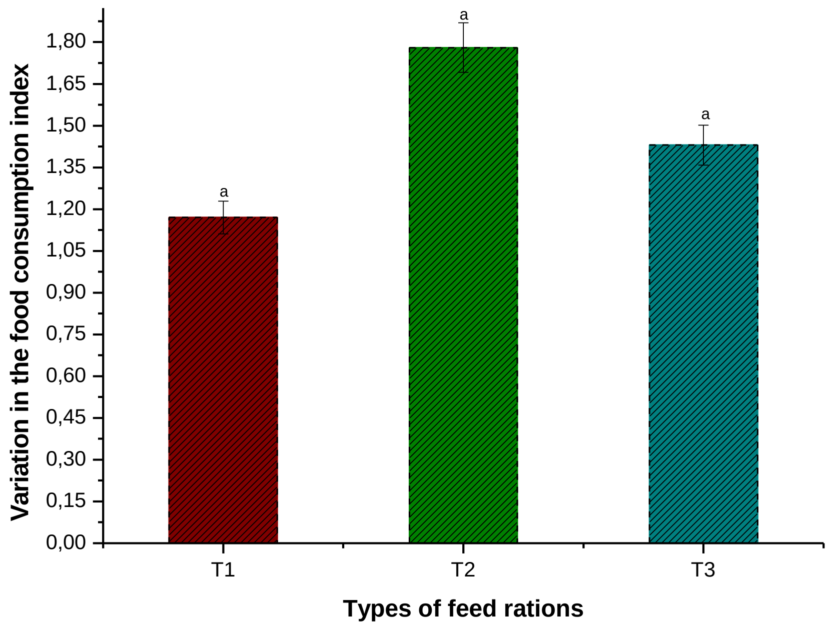

Figure 9. Variation of Food Consumption Index as a Function of Feed Rations

3.11. Relationship Between Weight and Total Length of Fry

The relationship between weight and length of fifty fish specimens pooled at treatment T1 as presented in Figure 12 below shows that fish fed with feed ration T1 exhibit a minorizing halometry (b = 0.53), thus the weight of the experienced *Oreochromis niloticus* fish fry increases relatively less rapidly than their size (Figure 10). Fish fed with food ration T2 show a minorizing halometry (b = 0.76) (Figure 10). During the experiment, the weight of *Oreochromis niloticus* fish fed this diet increased less rapidly than their size. From the results visualized in Figure 10C, it is clear that the alvins submitted to the control feed (T3) show a halometry that is minorizing (b = 0.61). The weight of *Oreochromis niloticus* fish fed this diet increased less rapidly than their size during the experiment. Regarding the type of growth experienced by the experimented fry, a positive correlation was found between the average weight and total length of the fry grouped in the different treatments. It was observed during the trial that the fish underwent a growth type of halometry minoring (T1: b=0.53; T2: b=0.7...) and T3 (b=0.76; T3: b=0.61); i.e. their weight evolved less rapidly than the size. These results support the observations made by Azaza *et al*., [13]. According to the latter, *Oreochromis niloticus* shows a late maturity and a rapid growth in average weight under stable conditions and under unstable conditions, the fry shows a slow weight and linear growth. Ouattara *et al*., [30] established a positive correlation between the average weight and total length of the two species of *Cichlidae* including *O. niloticus*. According to these authors, during growth, the weight of the fish *O. niloticus* evolves less quickly than the size. These observations show sufficiently that during the experiment, the experimental structure (concrete tank) did not have negative effects on the zootechnical performance of the fry of the specimens of the studied fish species.

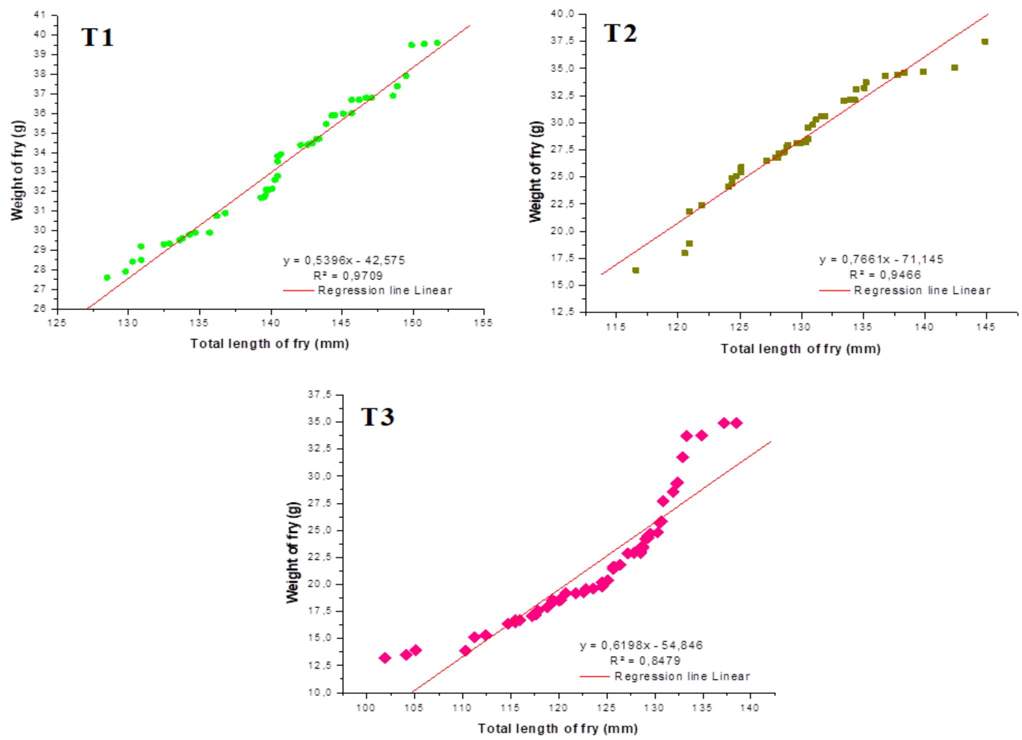

Figure 10. Relationship between Weight (g) and Total Length (mm) of Fry in T1, T2 and T3

3.12. Economic Approach of the Formulated Feed Rations

3.12.1. Cost of one kilogram of feed

The financial cost of production and acquisition of one kilogram of the three types of feed rations used in this study is recorded in Table 3.

Table 3. Production and Acquisition Cost of the Experimental Feed Rations (+ = used and - = not used; 1 USD = 2.000 Congolese Francs)

Ingredients	Price (CF)/kg	Types of food rations		
		T1	**T2**	**T3**
Wheat bran	250	250×10/100 = 25	250×2/100 =5	+
Fish meal	2.000	2000×100/100 = 2000	2000×6 /100 = 120	+
Palm kernel cake	500	500×50/100 = 250	500×8.5/100 = 42.5	-
Cassava flour	1.000	1000×10/100 = 1000	1000×1.5/100 = 15	+
Corn flour	1.200	1200×10/100 = 1200	1000×2/100 = 20	+
Vitamin and mineral premix	250.000	500×2/100 = 10	25000×2/100 = 500	+
Palm oil	2.000	2000×35/100 = 700	2000×35/100 = 700	+
Table salt	1.000	1000×50/100 = 500	1000×50/100 = 500	+
Total quantity (g)		**2.000**	**2.000**	**2.000**
Total cost in CF		**5.685**	**1.902**	**10.000**

The data in Table 3 above show that it costs 5.685 CF to produce two kilograms of T1 feed, 1.902 CF francs to produce two kilograms of T2 feed, and 10.000 CF to buy the commercial feed sold in Kinshasa. The economic approach was based on the comparison of the economic results obtained in the use of the T1 and T2 feed rations and the commercial feed (control), which gave very similar growth performances; in order to identify the most profitable feed. The economic balance sheet of a fish farm traditionally consists of an account showing the total expenses and the operating income [25]. In the case of our study, as this is a pre-growth trial, we have deliberately omitted the other expenses inherent to the operation, and have only compared the cost of production of one kilogram of a feed ration as well as that of the production of one kilogram of *Oreochromis niloticus* fish with the different rations tested. Assuming that the feed item represents nearly 70% of the total production costs [16]; [29] (the price of the feed is the most important factor in the general costs), the approach addresses a forecasting approach on the gross profit margin that can be generated by the use of each feed. The results obtained on this aspect showed that the acquisition of one kilogram of the commercial feed T3 is more expensive (5.150FC) than the two other formulated feeds (T1 = 2.326 CF and T2 = 1.28 CF).

3.12.2. Production cost of one kilogram of *Oreochromis niloticus* fish

The cost of producing one kilogram of *Oreochromis niloticus* fish with one kilogram of the three types of feed rations tested is shown in Table 4.

Table 4. Production Cost of One Kilogram of *Oreochromis niloticus* Fish With Different Types of Feed (FCI = Food Consumption Index)

Types of feed	Price (CF)	ICA	Cost (CF) of production
T1	2.492	1.17	2.915
T2	951	1.78	1.692
T3	5.000	1.43	7.150

It is more expensive to produce one kilogram of *Oreochromis niloticus* fish with feed T3 (production price of one kilogram of feed = 5.000 FC and the production price of one kilogram of fish = 7.150 FC) than with feed T1 (production price of one kilogram of feed = 2.492 FC and the production price of one kilogram of fish = 2.492 FC) and feed T2 (production price of one kilogram of feed = 2.492 FC) (production price of one kilogram of feed = 2.492 FC and the production price of one kilogram of fish = 2.492 FC) and feed T2 (production price of one kilogram of feed = 951 FC and the production price of one kilogram of fish = 1. 692 FC). Economic simulations of the production of one kilogram of fish with the three types of feed revealed that it is more expensive to produce one kilogram of Oreochromis niloticus fish with feed T3 or 7,150 CF than with feed T1 or 2,492 CF and feed T2 or 1,692 CF. These observations corroborate with those made by Lusasi *et al*., [18] ; Pwema *et al*., [19]. The latter found that it is less expensive to produce fish using local agricultural by-products than with imported feeds. According to Lusasi *et al*., [18], a better feed is the one that best covers the nutritional requirements of fish at the lowest cost and optimizes the economic results. Referring to the zootechnical data obtained in fish subjected to T1 and T2 diets, we notice a better price and quality compromise with these two feed rations.

4. Conclusion

The general objective of this study was to pre-grow fish *Oreochromis niloticus* Linnaeus, 1758 in a concrete above-ground tank culture system using feed based on local agricultural by-products available in Kinshasa, Democratic Republic of Congo. In general, the weight and linear growth performance of *O. niloticus* fry varied according to the type of feed ratio. The feed rations developed during this study were found to be effective in positively influencing fish growth. The economic aspect of the use of the feed rations showed a good compromise of price and quality and the appropriateness of producing the fish using local agricultural by-products rather than commercial feed. This study has shown the merits of setting up a fish farm in above-ground concrete tanks in order to overcome the difficulty of acquiring land that meets the requirements of fish farming.

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REFERENCES

[1] FAO, ‘‘Culture aquatic species fact sheets: *Oreochromis niloticus* (Linnaeus, 1758),’’ *Fisheries & Aquaculture, Disponible sur http://www.fao.org/fishery/culturedspecies/Oreochromis_niloticus/fr,* 2017.

[2] R. Thabet, ‘‘Etude comparative de l’élevage du Tilapia du Nil “*Oreochromis niloticus*” entre les eaux douces et géothermales en Tunisie,’’ Mémoire de fin d’études en Aquaculture, Institut Supérieur de Pêche et d'Aquaculture de Bizerte, Tunisie, p. 72, 2017.

[3] A. G. J. Tacon, ‘‘Feeding tomorrow’s fish,’’ *World aquaculture,* vol. 27, no. 3, pp. 20 – 32, 1996.

[4] L. C. Hoffman, J. F. Prinsloo, and G. Rukan, ‘‘Partial replacement of fish meal with either soybean meal, brewer’s yeast or tomato meal in the diets of African sharptooth catfish *Clarias gariepinus,*’’ *Water SA,* vol. 23, pp. 181-186, 1997.

[5] K. Jauncey and B. Ross, ‘‘A guide to Tilapia feed and feeding,’’ *Institute of Aquaculture, University of Stirling, Scotland.* p. 111, 1982.

[6] FAO, ‘‘La situation mondiale des pêches et de l’aquaculture : Contribuer à la sécurité alimentaire et à la nutrition de tous,’’ Rome, p. 224, 2016.

[7] S. W. Lusasi, M. A. Mayoni, K. C. Munganga, N. T. Lundika, B. Y. Mogbaka, I. Manikisa, M. S. Kavumbu, and K. V. Pwema, ‘‘Synthèse sur l’Etat de lieu de la pisciculture en République Démocratique du Congo: Enjeux et perspectives,’’ International Journal of Progressive Sciences and Technologies, vol. 32, no. 1, pp. 73-91, 2022.

[8] S. W. Lusasi, M. P. Makiese, N. L. Kunonga, K. C. Munganga, M. S. Kavumbu, and K. V. Pwema, ‘‘Proportion de vente des poissons frais locaux et importés dans les marchés de Kinshasa en République Démocratique du Congo (cas des marchés de la Liberté de Masina et Central de Kinshasa),’’ *Journal of Applied Biosciences,* vol. 141, pp. 14353-14363. *https://dx.doi.org/10.4314/jab.v141i1.2*, 2019.

[9] Y. Fermon, ‘‘La pisciculture de subsistance en étangs en Afrique: Manuel technique,’’ *ACF - international net work,* p. 294, 2008.

[10] J. Lazard, ‘‘Les paradoxes et les questionnements soulevés par l’exploitation de la biodiversité (autochtone et introduite) en aquaculture,’’ *Potentiels de la science pour l’avenir de l’agriculture, de l’alimentation et l’environnement, CIRAD,* France, p. 13, 2013.

[11] E. C. Adouvi, ‘‘Effets de la substitution de la farine de poisson par la farine des graines de Néré (Parkia biglobosa) et de la farine du tourteau de soja (*Glycine maxima*) sur la croissance et la survie des juvéniles de *Clarias gariepinus* (Burchell, 1822),’’ Benin, Universite d’abomey calavi, p. 43, 2013.

[12] P. T. Agbohessi, R. E. O. Pelebe, and A. Houndji, ‘‘Utilisation des farines d’asticots, de poisson et feuilles de *Moringa oleifera* comme sources de proteins alimentaires chez les larves de *Clarias gariepinus* (Burchelle, 1822),’’ *Agriculture, Environnement et Sciences de l’Ingénieur*, vol. 15, no. 1, pp. 1-23, 2019.

[13] M. S. Azaza, Mensi F., and M. M. Kraiem, ‘‘Rapport sur le suivi de l'essai de grossissement du Tilapia du Nil (*Oreochromis niloticus*, L., 1758) en cages flottantes dans la retenue du barrage de Sidi Saad,’’ INSTM, p. 15, 2004.

[14] M. S. Azaza, F. Mensi, A. Abdelmouleh, and M. M. Kraïem, ‘‘Elaboration d’aliments Secs Pour Le Tilapia de Nil *Oreochromis niloticus* (Lineatus, 1758) en élevage dans les eaux géothermales du Sud Tunisien,’’ *Bulletin de l’Institut National des Sciences et Technologies de la Mer de Salammbô,* vol. 32, pp. 23–30, 2005.

[15] M. C. Mikobi, N. A. Kusonika, T. T. Tangou, S. Mutambwe, K. C. Mulaji, S. W. Lusasi, and K. V. Pwema, ‘‘Mise au point et évaluation d’un système aquaponique domestique dans la ville province de Kinshasa (République Démocratique Du Congo),’’ European

Scientific *Journal*, vol. 16, no. 24, pp. 70-87, *URL:http://dx.doi.org/10.19044/esj.2020.v16n24p70*, 2020.

[16] J. Guillaume, S. Kaushik, P. Bergot, and R. Metailler, ‘‘Nutrition et alimentation des poissons et crustacés,’’ *INRA Editions*, p. 489, 1999.

[17] A. Boeck, ‘‘Alimentation du poisson, récolte de l’eau et aquaculture pour développement des zones rurales,’’ *International center for Aquaculture and Aquatic Environnements Aurburn University*, p. 12, 2007.

[18] S. W. Lusasi, K. V. Pwema, and S. Mutambwe, ‘‘Mise au point d’un aliment pour *Distichodus maculatus* Boulenger, 1898,’’ *Editions Universitaires Européennes, Lativa, Riga, ISBN 978-613-8-49503-1*, p. 77, 2019.

[19] K. V. Pwema, M. A. Mayoni, M. S. Kavumbu, K. C. Munganga, M. N. Bipendu, N. A. Kusonika, and S. W. Lusasi, ‘‘Evaluation of the cost of production of fish *Clarias gariepinus* Burchell, 1822 (*Siluriformes*, *Clariidae*) with three types of food based on local agricultural by-products in the Democratic Republic of Congo,’’ *Agricultural Science*, vol. 2, no. 1, pp. 205-216, *https://doi.org/10.30560/as.v2n1p205,* 2020.

[20] B. Scherrer, ‘‘Biostatistique,’’*Gaëtan Morin: Québec*, p. 850, 1984.

[21] D. J. Saville, ‘‘Multiple comparaison procedures : the pratical solution,’’ *American Statistician*, vol. 44, no. 2, pp. 174-180, 1990.

[22] K. S. A. Yao, and K. E. Ahoussi, ‘‘Caractérisation physico-chimique des eaux de surface dans un environnement minier du Centre-Ouest de la Côte d’Ivoire : cas du Département de Divo,’’ *European Scientific Journal*, vol. 16, no. 12, pp. 293-315. *URL:http://dx.doi.org/10.19044/esj.2020.v16n12p293,* 2020.

[23] A. Chikou, P. A. Lalèyè, V. Raemakers, P. Vandewalle, and J-C. Philippart, ‘‘Etude de l’âge et de la croissance chez *Clarias gariepinus* (*Pisces*, *Clariidae*) dans le delta de l’Ouémé au Benin (Afrique de l’Ouest),’’ *Int. J. Biol. Chem. Sci.* Vol. 2, no. 2, pp. 157-167, 2008.

[24] A. N. Yao, C. André, K. N. Akpolët, and Y. Kouakou, ‘‘Effet de la fertilisation organique des étangs à partir des fientes de poulets sur la survie et la croissance des alevins d’*Oreochromis niloticus* (Linnaeus, 1758),’’ *European Scientific Journal*, vol. 17, no. 14, pp. 246-255, *https://doi.org/10.19044/esj.2021.v17n14p246*, 2021.

[25] R. Iga-iga, ‘‘Contribution à la mise au point d’aliments pour tilapia à base d’intrants locaux : cas du Gabon,’’ *Mémoire de Master en Sciences Agronomiques, Spécialité Sciences Halieutiques et Aquacoles Dominante Aquaculture, AGRO CAMPUS Ouest*, p. 37, 2008.

[26] A. P. G. Eblin, N. Sombo Soro, O. Aka, and N. O. Mbiré, ‘‘Hydrochimie des eaux de surface de la région d’Adiaké (sudest côtier de la Côte d’Ivoire),’’ *Journal of Applied Biosciences 75 :6259– 6271 ISSN 1997– 5902*, 2014.

[27] A. A. Yao, K. M. Konan, L. Doumbia, A. Ouattara, and G. Gourene, ‘‘Diversité et structure du peuplement ichtyologique du Bassin Inférieur du Fleuve Comoé (Côte d’Ivoire),’’ *European Scientific Journal*, vol. 15, no. 6, pp. 244-268. *URL:http://dx.doi.org/10.19044/esj.2019.v15n6p244*, 2019.

[28] A. H. Elegbe, I. I. Toko, P. Agbohessi, C. Ble, A. Banag, A. Chikou, E. M. Eyango, and P. Laleye, ‘‘Co-culture *Clarias gariepinus-Oreochromis niloticus*: quels avantages pour l’amélioration des performances zootechniques et économiques des poissons élevés dans les « whedos » du delta de l’Ouémé au Bénin ?,’’ *Int. J. Biol. Chem. Sci*, vol. 9, no. 4, pp. 1937-1949, *DOI : http://dx.doi.org/10.4314/ijbcs.v9i4.19*, 2015.

[29] M. C. Blé, Y. I. Alla, and F. Kervarec, ‘‘Régimes alimentaires de trois principale espèces piscicoles élevées en cote d’ivoire,’’ F.*Tech. & Doc.Vulg.*, p. 10-14, 2008.

[30] N. I. Ouattara, A. Iftime, and L. E. Mester, ‘‘Age et croissance de deux espèces de *Cichlidae* (*Pisces*): *Oreochromis niloticus* (Linnaeus, 1758) et *Sarotherodon melanotheron* Rüppell, 1852 du lac de barrage d’Ayamé (Côte d'Ivoire, Afrique de l'Ouest),’’ *Travaux du Muséum National d’Histoire Naturelle « Grigore Antipa », LII: 313-324*, 2009.

[31] R. F. Bombéo, A. C. Fermin, and J. D. Tanfermin, ‘‘Nursery rearing of the Asian catfish, *Clarias macrocephalus* (Günther) at different stocking densities in cages suspended in tanks and ponds,’’ *Aquaculture Research*, vol. 33, no. 13, pp. 1031-1036, 2002.

[32] E. Derouiche, M. S. Azaza, and M. Kraiem, ‘‘Essai d’acclimatation du Tilapia du Nil, *Oreochromis niloticus* dans la retenue de barrage de Lebna (Cap bon, Tunisie),’’ *Bull. Inst. Natn. Scien. Tech. Mer de Salammbô*, vol. 39, pp. 87-92. *Disponible sur* www.instm.agrinet.tn/images/Bulltin/Bull.2009/9%20emna.doc, 2009.

[33] Y. Yi and C. K. Lin, ‘‘Effects of biomass of caged Nile Tilapia (*Oreochormis niloticus*) and aeration on the growth and yields in an integrated cage-cum-pond system,’’ *Aquaculture*, vol. 146, pp. 205–215, 2001.

[34] S. Phanindra, ‘‘Integrated cagecom-pond culture system with walking catfish (*Clarias batrachus*) in cages and Tilapia (*Oreochromis niloticus*) in open ponds. Mémoire de Master en Sciences in fisheries management,’’ Department of Fisheries Management, Bangladesh Agricultural University, Mymensingh, p. 50, 2005.

[35] S. Viola, S. Mokady, D. Behar, and U. Cogan, ‘‘Effects of polyunsaturated fatty acids in feeds of tilapia and carp,’’ Body composition and fatty acid profiles at different environmental temperatures. *Aquaculture*, vol. 75, no. 1988, pp. 127-137, 1988.

[36] L. Nyinawamwiza, ‘‘Valorisation des sous-produits agro-industriels dans l’élevage du poisson-chat africain *Clarias gariepinus* au Rwanda: Effet sur les performances de croissance et de reproduction,’’ These de Doctorat en Sciences Biologiques, FUNDP. Namur, p. 188, 2007.