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Development of Grow-Out Fish Feed from Local Raw Materials for Oreochromis Niloticus (Tilapia) in Senegal

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I. Introduction

Over the past 30 years, global consumption of fish and shellfish has increased from 50 million tonnes (Mt) in 1980 to 131 million tonnes in 2011 (FAO, 2012). The year 2016 saw global fisheries production amount to 171 million tonnes, of which 88% or nearly 151 million tonnes were allocated for direct human consumption while the remaining share was converted into fishmeal and fish oil (FAO, 2016). Senegal is the second largest fish producer in the sub-region, behind Nigeria (530,000 T), with an annual catch rate of 450,000 T (FAO, 2020).

Fish consumption plays a very important role in satisfying the nutritional needs in animal proteins, with a contribution of 70%, equivalent to an average consumption of 20.7 kg/year/person in Senegal (DEME, 2020).

Similarly, fishing contributes about 1.8% to the country's total GDP and 12% of the GDP of the primary sector (ANSD, 2015). However, it should be noted that at the same time, fishing activities are very much under threat and for most fishery products at the beginning of the third (3rd) millennium (FAO, 2020). Indeed, the demersal and pelagic coastal and offshore resources along the country's 715 km of coastline are globally overexploited to fully exploited (ANSD, 2015).

Aquaculture, particularly fish farming, is therefore increasingly seen as an integral part of the means used to ensure global food security and economic development (FAO, 2009). This could explain why states with aquaculture potential, such as Senegal, are keen to develop these activities. This desire is expressed in the Plan Sénégal Emergent (PSE, 2014), which aims to increase the contribution of aquaculture to 10% of the total volume of fisheries catch.

As a result, the introduction of fish species with high nutritional and commercial value is being undertaken. The most important species in Senegal is the Nile Tilapia or Oreochromis niloticus chosen for its good adaptation to a tropical environment, its ability to feed on a wide range of natural food organisms and its accommodation to variable salinity levels (Amoussou et al., 2016). In Senegal, despite the efforts made by the state, the fish farming sector has not yet reached a viable economic dimension (Diouf, 1996). The low production can be justified by the lack of basic infrastructure and the low diversity of fish species raised. The major constraint to the emergence of this sector is mainly related to the high cost and low quality of the feed used (Diouf, 1996). The latter is lacking due to the lack of feed manufacturing structures, expertise in formulation, but also the relatively high cost of ingredients, especially fish meal (Bamba, 2007). Fishmeal is generally the major component of feeds used in aquaculture (40-60% in Tilapia) due to its richness in protein and especially in Essential Amino Acids (EAA) whose profile corresponds remarkably well to the needs of fish (Bamba, 2007).

Thus, in order to increase fish production and make feed accessible, different types of feed must be designed from local raw materials, to reduce their cost, which represents more than 50% of working capital requirements. For example, could fishmeal, the main source of animal protein, be replaced by locally available plant protein sources in tilapia feeds while maintaining or even increasing their zootechnical efficiency and financial profitability? To answer this question, it is necessary to study (i) the potential of plant nitrogen sources (cottonseed cake, groundnut cake, and Moringa oleifera leaves) in the formulation of feeds for tilapia, (ii) the effects of these feeds on the zootechnical and economic performance of the species.

It is in this perspective that this study was undertaken with the aim of developing fish feeds from local raw materials for Tilapia (O. niloticus) in the grow-out phase.

II. Materials and Methods

2.1. Study environment

The study was conducted on the IDEAL860 farm. It is located 500 m north of the village of Keur Ibra Niane in the commune of Thienaba, which is situated in the region and department of Thiès.

The farm's water supply is provided by a water tower with a capacity of 12 m3 for watering livestock, feeding people and irrigating plants. The water tower is filled by a pump immersed in an 18 m deep well. A solar photovoltaic system with twelve panels provides the farm with energy.

2.2 Equipment

2.2.1. Biological material

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The animal material consists of six hundred (600) juvenile male tilapia fish (Oreochromis niloticus) with an average individual weight of 34 ± 10 g. These juveniles were obtained from the Agence Nationale d'Aquaculture (ANA) site in Richard Toll, Senegal.

2.2.2 Farming infrastructure and feed manufacturing equipment

The feed manufacturing and storage equipment consists of: a grinder, a mixer, an extruder mill for the manufacture of feed, tarpaulins for drying the feed, plastic bags for storing the feed, a mill and accessories for grinding the raw materials that make up the feed, a mortar for reducing the feed particles to crumbs, 2 mm sieves for sieving the ingredients after grinding.

The farming infrastructure and equipment used were circular tanks of 180 cm in diameter and 50 cm in height (capacity of just over 1 m3 of water each for rearing fish), landing nets for catching fish in the tanks, basins to contain the juveniles during handling, a brush for cleaning the tanks, aluminium trays for transferring and weighing the fish, tissues for wiping the fish during weighing sessions and a PCE electronic balance with a maximum capacity of 400 g and an accuracy of 0.001.

2.3 Methods

2.3.1. Description of the manufacturing process and feed composition

Four (04) types of feeds were used for feeding the fish. The three feeds (A1, A2, A3) were designed and prepared at the ANA of Richard Toll from the following raw materials: fish meal, groundnut cake, maize meal, baobab leaves (Adonsania digitata), Moringa oleifera leaves, mineral premix, vitamin premix, groundnut oil.

For the three manufactured feeds: A1, A2 and A3, baobab leaves and cottonseed cake were incorporated at equal doses of 6% and 2% respectively. On the other hand, the quantities of fishmeal, groundnut cake, maize meal and Moringa oleifera leaves varied from one formula to another in order to have iso-protein feeds with rates varying between 33 and 37%. Fishmeal is incorporated gradually at 10%, 15% and 20% in feeds A1, A2 and A3 (Table 1).

Table 1: Composition in % of total weight of the three feeds tested ingredients

Ingredients	Origin	Test Feed		
		A1	***A2***	***A3***
		Percentage		
Fish meal	Local industry	10	15	20
Groundnut meal	Local market	19	20	21
Maize meal	Local market	37	33	29
Baobab leaf	Local market	6	6	6
Moringa olifera leaf	Local market	20	18	16
Cottonseed cake	Local market	2	2	2
Mineral premix	Local industry	1	1	1
Vitamin premix	Local industry	1	1	1
Vegetable oil	Local market	4	4	4
Total		**100**	**100**	**100**

The experimental feeds were made mealy according to the method of Siddiqui and Al-Harbi (1995). Thus, the manufacturing process is successively as follows: grinding, sieving, weighing, mixing, incorporation of water, granulation, drying, packaging.

For each feed, the ingredients were weighed according to the values given in Table, and then mixed until a homogeneous powder was obtained, to which vegetable oil and a mineral-vitamin complex (the CMV) were added. Water was then added at a rate of 40% of the dry matter, so as to obtain a malleable paste. The mixture is passed through the die of an electronic press and filaments (spaghetti) are obtained. These filaments are then dried in the shade, broken down to the size of 2 mm, bagged and stored at a temperature of 20°C until use.

2.3.2. Experimental set-up

Twelve (12) circular concrete tanks with a capacity of 1 m^3 were used on the IDEAL860 farm. They are arranged in four (4) series (A, B, C and D) of 3 ponds each.

The study consisted firstly of placing a batch of 50 juveniles of the species Oreochromis niloticus with an average weight of 34±10 g in each tank, i.e. a biomass of 1.7 kg per tank.

Each feed (treatment) was tested in 3 different tanks. The assignment of feeds (treatments) to ponds was done randomly. The feeds were distributed to meet a daily feeding rate of 4% of the fish biomass. The design is thus a fully randomised experimental design with 4 treatments (feeds) repeated 3 times each.

2.3.3. Conduct of the trial

A six-day fasting period was carried out from the date of arrival of the juveniles on the site in order to reduce stress, acclimatise them and also empty their stomachs. The tanks were siphoned every 48 hours to make the environment viable.

The fish are manually rationed with feed at ratios of 4% of their total body weight. The feed was always placed in the same place to facilitate feeding and control refusals. The amounts of feed given to the fish were readjusted after each sampling according to the evolution of the biomass determined by the results of the weighing and the survivor count.

The daily amount of feed distributed is divided into two (2) portions served in two (2) meals, at 11:00 and 17:00 respectively. The frequency of meal distribution did not vary throughout the experiment, which lasted a total of 60 days.

2.3.4. Parameters studied

2.3.4.1. Fish biomass monitoring

Fishing was carried out every 15 days in each pond to monitor weight and survival. All dead fish are counted in each tank and the survivors are weighed individually using an electronic scale with a capacity of 30 kg and an accuracy of 2g. The fish are immediately returned to the tanks after weighing.

2.3.4.2. Measurement of feed quantities

At each feeding, the ration to be distributed is weighed. The quantities distributed are based on the total weight of the fish in each tank, taking into account the requirement to keep the feeding rate constant at 4% of this biomass.

2.3.4.3. Measurement of the physico-chemical parameters of the water

The physico-chemical parameters such as the temperature and pH of the water in the tanks were measured twice a day, in the morning and in the evening before feeding the juveniles, using a pH meter coupled with a thermometer.

2.3.4.4. Bromatological analyses

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Bromatological analyses were carried out in triplicate according to the standard methods of the AOAC (1990) at the bromatological laboratory of ENSA in Thiès. They concerned the ingredients of the rations (raw materials constituting the feeds), the 4 feeds to be tested. Analyses were also carried out on homogenised carcasses of whole fish taken at random at the beginning of the experiment and 2 days after the end of the experiment in each of the 12 experimental ponds. Crude protein (% N x 6.25) was determined by the Kjeldahlet method, lipids by the hot Soxhlet method. Crude cellulose is analysed by the Weende method (No. 978.10). Dry matter is determined by measuring the weight loss after drying at 105°C in the oven for 24 hours (No. 943.01). Ash is determined after incineration of the samples in a muffle furnace at 550°C (No. 942.05) for 3 hours. The metabolizable energy (ME) was evaluated by the formula of Sybal 1980:

True ME (Kcal/kg.DM) = (3951 + 54.4 x EE - 88.7 x CB - 40.8 x Ce), the nutrient contents being expressed as percentage (%) of DM.

EE=Ethereal Extract; CB=Crude Cellulose; Ce=Ember.

2.3.5. Calculation of zootechnical performance

The raw data measured at each control session (weight of each subject, number of dead subjects, quantities of feed distributed) will be used to calculate the parameters that will allow the zootechnical response of the feeds studied to be assessed. The parameters calculated are: average weight gain (AWG) to assess the growth rate, fish survival rate (SR), feed conversion ratio (FCR) to measure the feed efficiency of the tested feeds, and production costs according to the procedure described by Khwuanjai Hengsawat and Pornchai Jaruratjamorn (1997) and Kanangire (2001).

Average weight gain (AWG) is also called body mass gain (BMG). It is expressed as an absolute (aBWG) or relative (rBWG) value.

$$AAWG = FAW - IAW$$

$$RAWG\ (\%) = ((FAW - IAW)/IAW) * 100$$

With :

AAWG: Average absolute weight gain

RAWG: relative average weight gain

FAW: Final Average Weight

IAW : Initial Average Weight

The Individual Daily Growth (IDG in g/d/ind) is the average daily weight (ADW) that allows to assess the daily weight gain of the farmed fish.

$$IDG = ((FAW\ (g) - IAW\ (g)) / (\Delta T\ (d)$$

With : ΔT=rearing time

The Specific Growth Rate (SGR in %/d) is used to evaluate the weight gained each day by the fish as a percentage of its live weight. This index is used in fish farming to estimate the production after a certain period.

$$SDG\ (\%) = (Ln\ (FAW) - Ln\ (IAW))/\Delta T * 100$$

ΔT: rearing time.

The feed conversion ratio (FCR) is a measure of feed efficiency that shows the degree of conversion of feed into fish flesh. It represents the ratio between the total amount of dry feed distributed to the fish and the obtained biomass gain.

$$TCA = (\text{Amount of feed ingested in DM}) / (\text{Fish biomass produced})$$

The survival rate (SR) is calculated from the number of fish obtained at the end of the experiment and the total number of fish at the beginning of the experiment (100% - mortality rate).

$$SR\ (\%) = (\text{Number of individuals at the end of the experiment}) / (\text{Number of individuals at the beginning of the experiment}) * 100$$

Protein efficiency ratio (PER):

It allows to evaluate the efficiency of use of proteins in the feed by the fish. It is the ratio of live weight gain to the amount of protein consumed.

$$PER = ((\text{Biomass produced (g)}) / (\text{Protein ingested (g)})) * 100$$

2.3.6. Data processing and analysis :

Excel spreadsheet and R-Studio software version 4.0.4 were used for data processing and analysis. The results of the zootechnical parameters calculated at the end of the experiment for each repeated treatment (mean values obtained per tank) were subjected to an analysis of variance (ANOVA) with one classification criterion (feed type with 4 variants or treatments). When the ANOVA detected a significant difference at a threshold of at least 5%, comparisons of the means were then made using the Student Newman Keuls (SNK) test. However, when the hypotheses of normality and equality of variances are not verified, the non-parametric Kruskal Wallis test will be used.

III. Results

3.1 Bromatological composition of the ingredients used and of the foods tested

The bromatological analyses were carried out on all the ingredients used in the composition and the feeds tested (Table 2 and 3).

The analysis of Table 3 shows that the protein and lipid contents of fish meal and peanut cake are higher than those of the other ingredients. On the other hand, baobab leaves are less rich than the other raw materials studied for most of the constituents except for ash and cellulose which have relatively high values.

Table 2: Results of bromatological analyses of the feed inputs used.

Ingredients	Protein (%)	Fat (%)	Ash (%)	Cellulose (%)	DM (%)
Fish meal	62,88	13,10	26,40	3,42	95,27
Groundnut meal	54,59	10,69	7,50	15,67	95,27
Corn flour	21,17	4,01	1,44	2,80	91,07
Baobab leaves	17,39	2,96	13,24	16,25	90,80
Moringa oleifera leaves	37,35	4,45	9,71	8,87	92,71
Cottonseed cake	36,47	9,52	4,80	32,03	94,62

Source: Bromatology analysis laboratory of the ENSA of Thiès

The analysis of the composition of the tested feeds (Table 3) shows that the lipid and cellulose contents of the three manufactured feeds are higher than the control feed. On the other hand, the protein content (40.45%) of the control feed (At) is very high compared to an average of 35.83% of the manufactured feeds. At the same time, there was no significant difference between the crude fibre content of the A3 and At feeds. On the other hand, the metabolizable energy of A2 and At feed is higher than that of A1 and A3 feed.

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Table 3: Bromatological composition of the tested feeds

Feed	Protein (%)	Fat (%)	Ash (%)	Cellulose (%)	DM (%)	ME (Kcal/kg)
A1	33,74	10,27	8,76	7,06	94,70	3526,1
A2	35,83	11,24	9,67	6,60	94,71	3582,5
A3	37,93	11,62	9,83	5,75	94,80	3672,0
At	40,45	6,34	8,30	4,16	89,48	3588,3

ME: Metabolisable energy

3.2. Physico-chemical parameters

The average values of the abiotic variables (temperature and pH) measured are presented in Table 4. Temperature did not vary significantly (p = 0.87) from one feed treatment to another. The average values observed ranged from 19.7 ± 0.4°C in the morning to 23.03 ± 1°C in the evening. As for the pH, it was generally more or less basic (above 7) with respective minimum and maximum values of 7.29 ± 0.1 (in the morning) and 7.8 ± 0.3 (in the evening). However, the ANOVA results show that the pH at treatment A2 was higher than at the other treatments during sunset.

Table 4: Average temperature and pH of the pond water during the experiment

	A1	A2	A3	At	Average
T°C Morning	20,27a	19,63a	19,57a	19,32a	19,70 ± 0,4
T°C Evening	23,29a	23,44a	23,87a	21,51a	23,03 ± 1
pH Morning	7,15a	7,4a	7,44a	7,18a	7,29 ± 0,1
pH Evening	7,59a	8,17b	7,82a	7,62a	7,8 ± 0,3

Values with the same subscript letter on the same line are not significantly different (P > 0.05) at the 5% threshold.

3.3. Survival rate

The analysis of variance (ANOVA) performed on survival rate revealed a significant difference (p=0.006) between the dietary treatments. The best survival rate during the whole experimental period was recorded with feed A3 for which mortality was zero. However, it was noted that the overall mortality rate was very low for all feed treatments (Table 5).

Table 5: Variation in survival rate over the course of the experiment

	D15	D30	D45	D60	Average
A1	99	99	99	99	99 ± 0,2 ab
A2	100	100	100	99	100 ± 0,5 b
A3	100	100	100	100	100 ± 0,0 b
At	99	98,67	96	96	97 ± 1,6 a

3.4. Fish growth performance

The main results obtained for body weight gain (BWG), individual daily growth (IDG) and specific growth rate (SGR) are shown in tables 6 and 7 below:

Table 6: Evolution of individual mean weight (g) of fish by feed treatment.

Feed	D0	D15	D30	D45	D60
A1	37 ± 5 b	43 ± 10 a	44 ± 3 a	51 ± 7 a	60 ± 4 a
A2	34 ± 2 a	44 ± 3 a	48 ± 1 b	50 ± 3 a	51 ± 3 b
A3	32 ± 3 a	44 ± 6 a	40 ± 6 c	52 ± 5 a	60 ± 2 a
At	33 ± 5 a	40 ± 1 b	42 ± 3 d	46 ± 11 b	53 ± 11 c

Values with the same letter in the index in the same column are not significantly different (P > 0.05) at the 5% threshold.

The evolution of the average individual weight of the fish per feeding treatment during the experiment is illustrated in figure 1 and table 6:

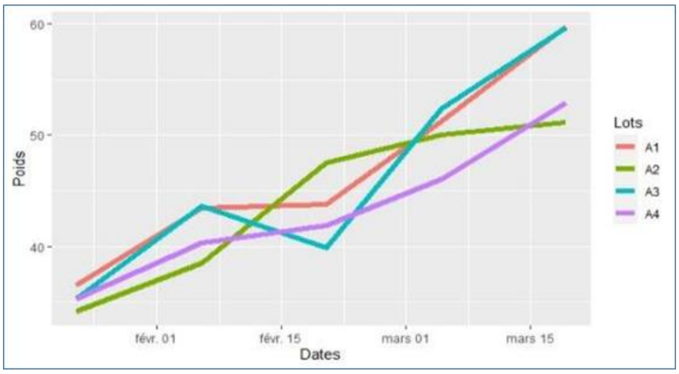

Figure 1: Weight growth of fish per feed as a function of time.

The average individual weight of fish per feed over the course of the experiment increased rapidly at the first control, followed by a slowdown at the second control for treatments A1, A3, and At, at which time the animals fed with feed A2 continued to grow steadily. From the third control onwards, the weights of the fish fed with A1, A3 and At increased rapidly until the last control, in contrast to those fed with A2. Batch A1 obtained the best initial weight (37 ± 5 grs) compared to the others (34± 5, 32±3 and 33±5 grs for A2, A3 and At respectively). At the end of the experiment, batches A1 and A3 were heavier with an average weight of 60 grams each, compared to 51±3grs and 53±1grs respectively for batches A2 and At. It was between the sixth and eighth week of the experiment that the weight evolution of the fish in the three treatments A1, A3 and At was clearly more visible. In contrast, the fish in treatment A2 only increased their weight slightly from the fourth week onwards.

Table 7: Mean values (± standard deviation) of weight gains during the experiment.

	A1	A2	A3	At
BMG (g)	23 ± 3 bc	17 ± 4 a	27 ± 5 c	21 ± 16,3b
IDGR (g/j)	0,4 ± 0,05 a	0,3 ± 0,1 a	0,4 ± 0,1 a	0,4 ± 0,27 a
SGR (%/j)	1 ± 0,2 a	0,7 ± 0,1 a	1 ± 0,2 a	1 ± 0,62 a

BMG: Body Mass Gain
IDGR: Individual daily growth rate
SGR: Specific growth rate

For each variable, values with the same subscript letter on the same line were not significantly different (P > 0.05).

The analysis of variance (ANOVA) performed on body mass gain (BMG) between the beginning and the end of the experiment revealed a significant difference (p=0.0088) between the feeding treatments. However, there was no significant difference in individual daily growth (IDGR) (P= 0.95) and specific growth rate (SGR) (P= 0.97). With an average body weight gain of 27 ± 5 grs achieved during the 8 week experiment, batch A3 showed the best growth performance compared to the other triplicates, followed by batch A1 which showed an average weight gain of 23±3 g. In contrast, fish from batches At and A2 performed the worst with body weight gains of 21±16.3 and 17±4 g respectively.

3.5. Feed intake

Table 8 shows the amounts of feed distributed during the experiment per period and per treatment as a function of biomass. The average amounts of feed given to the animals fed with the test feed (A1, A2 and A3) are higher compared to the fish in the control treatment.

Table 8: Quantities of feed distributed (in grams) according to treatments and by period

	A1	A2	A3	At
J0	219	205	198	191
J15	257	231	262	240
J30	259	285	240	248
J45	303	300	314	265
Mean and standard deviation	260±35	255±45	253±48	236±32

3.5.1. Feed efficiency

The calculation of the main commonly used indices, namely the protein efficiency ratio (PER) and the feed conversion ratio (FCR), was used to assess the feed utilisation efficiency of the test feeds.

The different average values obtained per feed treatment during the experiment are shown in Table 9 below:

Table 9: Main feed efficiency indices over the total duration of the experiment (60 days)

	A1	A2	A3	At
CI	1,7 a	2,0 b	1,7 a	1.9 b
CEP	2±0 c	1,75±0,5 bc	1,5±0,6 b	1±0 a

For each variable, values with the same index letter on the same line are not significantly different ($P > 0.05$).

The consumption index (CI) calculated over the total duration of the experiment was significantly different ($p= 0.037$) between the foods. The CIs of the two feeds A1 and A3 (1.7) were better than those of A2 and At, which were 2.0 and 1.9 respectively.

Regarding the protein efficiency ratio (PER), the ANOVA showed a significant difference ($P =0.003$) between the feed treatments. Fish fed with feed At, A3 and A2 had a higher protein efficiency with values of 1, 1.5 and 1.75 respectively, while fish fed with feed A1 had a PEC of 2.

3.5.2. Bromatological analysis of fresh fish flesh

In order to better evaluate the protein efficiency ratio, analyses were performed on the fresh fish flesh at the beginning and end of the experiment. The results of the biochemical analyses of the fish fed with the four feeds are shown in table 11.

Table 10: Biochemical composition of fresh fish flesh at the beginning and end of the experiment.

Feed	Protein (%)	Fat (%)	OM (%)
Etat initial	**16,92**	**0,98**	**93,41**
A1	18,29	0,83	95,66
A2	18,51	0,72	93,92
A3	18,81	0,83	93,72
At	18,94	0,96	93,30
Mean end of experiment	**18,64**	**0,83**	**94,15**

No significant difference ($P=0.067$) was found on the protein content of the fish flesh between the beginning and the end of the experiment. On the other hand, a very significant difference ($P < 0.001$) was observed for the fat content of the flesh of the different batches of animals at the end of the experiment. However, the average protein content of the fish at the end of the experiment was higher than that of the initial sample. Regarding lipid content, the results show that fish from batch A2 had the lowest lipid content compared to those fed with feed A1, A3 and At, which were less fatty at the end than at the beginning of the experiment.

IV. Discussion

4.1. Physico-chemical parameters

In general, the physico-chemical parameters of the water are not within the recommended optimal value ranges. Nevertheless, the temperatures recorded (19.7-23.03 °C) during this experiment are similar to those obtained by Sarr et al. (2015), Balarin and Halton (1979) who found values in the range of 13.5 - 33 °C. But according to Ndour et al. (2011), cited by SARR et al. (2015) and Mélard (1999), the temperature optimum for the growth of O, niloticus and Clarias gariepinus is between 26-30 °C. While Edna and Boyd (1997) cited by Fiogbe (2009) reported that the optimal temperatures for the growth of tilapia are between 28 and 32 °C. Given the results of these authors, the average temperature range recorded during the experiment could inhibit the appetite and poor growth of pond-reared fish.

The recorded pH levels (7.29 - 7.8) are within the optimal limits for the growth of O, niloticus. This is a result of the constant renewal of the water. Indeed, good growth of O, niloticus is obtained at a pH between 7 and 9 (Bahnasawy et al. 2009) cited by SARR et al. (2015).

4.2. Survival rate

Overall, the survival rate, which averaged 96% for all batches combined and over the total duration of the experiment, seems acceptable. According to Lacroix (2004), the normal mortality rate in fish farming with a balanced diet varies from 10 to 15% for the production of tilapia fingerlings and from 2 to 5% for siluriformes. Furthermore, the mortality rates noted do not seem to be related to the diet, but rather to the stress of the control tests, as the deaths occurred during the 3 days following the manipulations. The minimum survival rate obtained at the end of the experiment was 97%. These results are very similar to those reported by Iga-Iga (2008). The latter obtained more than 97% survival rate with feeds based on local by-products in Gabon. The survival rates recorded are much higher than those obtained by Schouveller (1996) and Abou (2007) in ponds, which ranged from 22.5 to 49.4% and 67.1 to 70.5% respectively. This could be explained, among other factors, by the quality of the feed and the quality of the water with a favourable pH due to its frequent renewal. In addition, there seems to be a positive correlation between fish survival and zootechnical performance. Indeed, Bamba et al (2003) demonstrated a close correlation between survival rate, performance expression and pond water quality. The better the

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water quality, the better the survival rate and performance expression.

4.3. Growth performance of the fish

The analysis of growth performance showed that the best results (GMC) were obtained with feeds A3, A1 and At. Feed A2, on the other hand, gave the lowest average daily growth and specific growth rates. These results could be explained by the higher or lower lipid content of the A1 and A3 feeds compared to the At feed. According to Bamba, (2008), an increase in lipid content, at reasonable proportions in the feed, can induce a saving in protein use of 35% to 48%, without altering the quality of the feed. Fat is the primary source of energy, with the energy content of one gram of fat (9.1 Kcal gross energy) being twice as high as that of one gram of protein (5.5 Kcal) or one gram of carbohydrate (4.1 Kcal). This would indicate that the observed differences in growth could be related to the nature of the ingredients used as highlighted by Burel et al. (2014) and Köprücü & Özdemir (2005).

The A1 and A3 feeds would also have a better degree of convertibility due to their composition. Indeed, maize bran, moringa leaves and fish meal discriminated the test feeds (A1, A2 and A3) because of their different incorporation rates in these feeds. On the other hand, those of A2 and At remained low. This difference in performance could be explained by a better degree of convertibility of the feeds. In other words, A3 and A1 feeds have acceptable crude fibre levels that are easily assimilated by fish. Köprücü & Özdemir (2005) indicate that the digestibility of a feed depends on the nature of its ingredients. Furthermore, according to Bamba (2007), maize bran (37% in A1 and 29% in A2) provides better growth for fish than wheat and rice bran. Moreau (2001) points out that in case of artificial feeding, vitamin and mineral premixes should be added at a rate of 2 and 4% of the dry weight of the feed respectively. Sarr et al. (2015) also state that the feed produced at the National Aquaculture Agency (ANA) station with 11% lipid, 1% mineral and 1% vitamin premix per kilogram gave better growth performance compared to the other feeds tested.

The growth parameters calculated in this experiment for the four treatments show that feed At (control) and A2 showed the lowest growth performance despite the high protein content (40.54%) for At. The ICY values (0.3 to 0.4 g/d) found are lower than those reported in the studies of Jauncey et al (1982) which indicate ICYs of 1.5 to 1.9 g/d with a feed containing 30% crude protein, 2% vitamin premix, and 4% mineral premix. The individual daily growth rates obtained in the present study are relatively low, being less than 1 g/d. Indeed, according to Pouomogne (1994), the individual daily growth of Oreochromis niloticus varies between 1 g/d and 3 g/d. However, they are much higher than the 0.05 g/d to 0.02 g/d obtained by Fiogbe et al. (2009) in the same rearing systems.

Fish SCTs varied from 0.7 to 1%/d depending on the feed. The lowest rate was obtained with feed A2 (based on 15% fish meal and 20% groundnut cake). These results are less interesting than those reported by Jauncey et al (1982) who found a TCS of 3%/d. However, they are equivalent to those of Nobah et al. (2008) in floating cages with values of 0.74%/d. The poor performance found in this study may be partly due to the low degree of convertibility (by fish) of the ingredients used in the formulation of feeds based on agricultural by-products (Köprücü et al., 2005).

The difference in fish growth could be explained by variations in feed nutrient value, voluntary intake, or differences in feed utilisation efficiency. Indeed, Kaushik et al (1993) point out that the incorporation of plant proteins, which may be deficient in amino acids for fish, or anti-nutritional factors, may alter digestibility. And the metabolic utilisation of nutrients may also be affected. This can result in poorer performance and, as a consequence, higher nitrogen and phosphorus pollution.

The crude protein of feed At (40.45%) with a CEP of 1 is less valuable than that of feed A1 (33.74%), A2 (35.83%) and A3 (37.93%), which have CEPs of 2.0, 1.75 and 1.5 respectively. The quality of the ingested protein might have influenced the digestibility of the feed. Fishmeal and different sources of protein intake such as Moringa leaves, maize meal, groundnut cake and cottonseed cake would probably have allowed a better assimilation of the proteins present in the A1, A2, and A3 feeds. The incorporation of animal proteins greatly increases digestion and growth performance (Stickney, 1979). Indeed, according to this author Stickney (1986), in O, niloticus, the replacement of animal proteins by plant proteins up to 25% appears acceptable. Jauncey and Ross (1982) also showed that the substitution of 11% fishmeal for peanut meal in a 45% protein diet did not affect growth in O. niloticus fry. However, results showed that Nile Tilapia fed a diet containing 0% fishmeal and 60% soybean meal showed the same growth performance as a commercial diet containing fishmeal (Shiau et al., 1990).

According to Spring and Burel (2008), the use of plant ingredients increases the risk of introducing mycotoxins into the fish feed. In other words, only aflatoxin-free or less than 1.25 mg/kg aflatoxin meals can be used; above this threshold, they are questionable and incorporation rates should be reduced. These cakes can be used extensively up to 50% for fish (Chow, 1984). In this study, however, the incorporation rates of peanut meal are lower and range from 19 to 21% depending on the test feed. As in other animal species, aflatoxin has carcinogenic effects in fish (Wolf and Jackson, 1963, cited by Burel, (2014)). Studies show that plants rarely contain a single anti-nutritional factor and interactions between different substances are suspected (Krogdahl et al., 2010; cited by Burel, 2014). In addition, Richter et al. (2003) were able to incorporate 10% Moringa oleifera leaf meal without negative consequences on the growth of Oreochromis niloticus. The same authors showed that incorporating 20% of this material reduced growth by 73% compared to the control feed. This was not verified in our study, where 20% moringa leaf was successfully incorporated into the A1 feed, which nevertheless showed the best feed efficiency criteria (CI, CEP). The poor feed conversion, related to the level of incorporated plant material, depends according to Keembiyehetty and De silva (1993) and Yusuf et al. (1994) on certain mechanisms determining the efficiency of digestibility and assimilation caused by the high fibre (cellulose) content. In addition, the presence of anti-nutritional factors in plant materials affects directly (trypsin inhibitors, phytic acids) or indirectly (fibres, tannins, glucosinolates), the digestive capacity of fish (Francis et al., 2001). Indeed, the efficiency of a feed depends not only on its chemical composition and palatability, but also on its capacity to be digested and absorbed through the intestinal mucosa (Azaza, 2006).

4.4 Feed efficiency

As regards the consumption indices, the values obtained seem to contrast with the GMC. This would be related to the very remarkable substitution of fishmeal by proteins of plant origin. The CIs obtained in this study (1.7 to 2.0) are similar to those (1.7 to 3.0) reported by several authors for foods incorporating more than 25% of non-conventional protein sources as a substitute for fish meal. This is the case for Leacaena replacing peanut, cotton or soybean meal (Jackson et al., 1982) and (Carraro, 1983, Antoine et al., 1987). It is important to stress that the quantities of feed taken into account in the calculation of the CI may significantly exceed the quantities actually consumed by the fish. In our experiment, it was assumed that the quantities of feed distributed were totally consumed by the fish, which we were unable to verify, as we did not check the refusals. Pouomogne and Ombredane (2001) showed that by feeding tilapia six times a day instead of two or three times as in the present study, higher fish growth and improved feed conversion rate were recorded.

4.5. Value of fresh fish flesh

The flesh of Nile tilapia is rich in protein. The levels found were 16.92% and 18.64% at the beginning and end of the experiment respectively. This indicates a high dietary value of the tilapia flesh. These results are supported by the studies of Dergal, (2015) who found an average value of 17.3 ± 0.40%. But the incorporation of fishmeal and peanut meal in the feed does not result in a high lipid content. The levels recorded are 0.98% at the initial state and 0.83% at the end of the experiment. From this it can be deduced that Nile tilapia is a lean fish. This was confirmed by Zakhia, 1992 who proposed a classification of fish according to the lipid content of their flesh into lean (<5%), semi-fat (5 to 8%) and fat (8 to 25%).

The A1 and A3 feeds, which are considered to be the best in terms of fish growth performance, contain 10% and 20% fishmeal respectively. Thus, plant products represent the majority share in the test feeds. It would therefore be interesting to deduce that a wide variety of plant products and by-products deserve to be used in the feeding of farmed fish in tropical environments. Moreover, the yields observed and the evaluation of the performance/cost ratio for each of the feeds studied would justify the possibility of using plant proteins as a partial replacement for fish meal.

V. Conclusion

The main objective of this experimental study was to propose one or more fish feeds made from local raw materials that would be interesting for feeding tilapia during the grow-out phase. The nutrient content of the three locally produced feeds and their effects on the zootechnical performance of tilapia were evaluated and compared to a control feed.

The study revealed significant differences in the criteria considered such as bromatological composition of the ingredients, TS, mean final weights, GMC, CEP, feed conversion ratio and temperature. The different fry populations fed with the test feeds (A1 and A3) showed significantly better zootechnical performance than those fed with the commercial feed (At).

Compared to the industrial commercial feed, the test feeds showed a reduction of 64.07% and 61.33%, respectively, compared to the A1 and A3 treatments. In view of the growth performance and especially the production cost of one kilogram of fish, the feeds developed in our study (A1 and A3) have the advantage of being locally available, relatively accessible (financially) to fish farmers, in contrast to the commercial industrial feed.

Given the results obtained and the conditions of the experiment, it would be wise to continue the study with A1 and A3 feeds, whose quality is very promising for the development of fish feeds made from raw materials and capable of competing with imported feed.

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