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Substitution of Fish Meal by Local Vegetable Raw Materials in the Feed of Juvenile Nile Tilapia (*Oreochromis Niloticus, Linne, 1758)* in Senegal

Mamadou Sileye Niang(Corresponding Author)

Cheikh Anta Diop University of Dakar / Faculty of Sciences and Technical / ED-SEV / ED-SHA. E-mail : mamadou.niang83@gmail.com

Jean Fall

University Institute of Fisheries and Aquaculture, UCADII educational building, first floor, p.o. box : 5005

Masse Diago, Malick Diouf

Cheikh Anta Diop University of Dakar / Faculty of Sciences and Technical / ED-SEV / ED-SHA.

Diegane Ndong

Direction of Animal and Halieutic Resources, Department of Agriculture, Water Resources and Environment, UEMOA Commission, 380 Av. Pr. Joseph KI-ZERBO, 01 BP 543 Ouagadougou 01-Burkina Faso.

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Abstract

The study is a contribution to the development of a feed for juvenile tilapia *Oreochromis niloticus*, from local raw materials in order to reduce the cost of feeding farmed tilapia in Senegal. Three feeds were formulated from local raw materials. The basic composition of the tested feeds is as follows: A1 (peanut meal, rice bran, millet bran, maize meal and no fish meal); A2 (peanut meal, rice bran, millet bran, maize meal and 10% fish meal) and A3 (peanut meal, rice bran, millet bran, maize meal and 25% fish meal). All feeds contain 31% protein. The trial compared three batches, in 2 replicates, with different diets. The initial weight of the juveniles was 0.37± 0.5g. The daily ration was distributed at 9 am and 4 pm. After 90 days of experiment, the final mean weights were 2.45 ± 0.5g; 2.75±0.5g; and 4.67 ± 0.5g for A1, A2, and A3, respectively. A performance test, of which the objective was to compare growth parameters, was conducted. The results of the growth parameters of juveniles fed A3 were significantly higher ($p < 0.05$) than those fed A1 and A2. The weight growth study shows similar growth during the first month. However, from this date onwards, juveniles fed A3 show a faster growth, which is maintained throughout the experiment. On the other hand, the Protein Efficiency Coefficient and the Survival Rate showed no significant difference. The zootechnical parameters are not significantly different ($p > 0.05$) between the two tanks for the same feed treatment.

Keywords: nutrition, feed, fingerlings, *Oreochromis niloticus*, local raw materials, feed cost.

1. Introduction

With a growing world population expected to reach 9.6 billion in 2050, sustainably increasing food supply, and more specifically animal protein production, is a key challenge. Animals must not only become more numerous, but more importantly, they must also become more efficient in terms of production. (FAO, 2020). Farmed fish species offer an opportunity in this regard (de Verdal and al., 2017).

As a reminder, the history of fisheries production is marked by a slowdown in the growth rate of catches and a spectacular increase in that of aquaculture production around the 1980s (Lazard, 2014). This growth led to a break in 2010 (FAOSTAT, 2014) when aquaculture intended for consumption joined that of production from fisheries. This global aquaculture production is characterized by an unbalanced regional distribution (FAOSTAT, 2014). Asia, more particularly China, has for several decades been the world leader with approximately 89% of production. The share of world production for the other continents does not individually exceed 5%. In subtropical Africa, fish farming has a weak place in fish production. Apart from a few countries such as Nigeria and Ghana, the tonnages in this sector are very low.

Today the main problem of tilapia aquaculture, especially in Senegal, happens to be the availability of quality feed (high-performance feed that effectively meets the nutritional needs of tilapias) depending on the type of aquaculture operation to obtain levels significant production.

In aquaculture, feed represents an important part of the cost of fish production due to the use of fishmeal as the main protein source (Gougbedji and al., 2020; Burel and Medale, 2014; NRC, 2011; Hardy, 2010) Indeed, this input is becoming scarcer and more and more expensive, thus constituting a major limiting factor in fish production. It has therefore become necessary to find substitutes in order to limit the dependence of aquaculture on fishmeal (Burel and Medale, 2014; Medale and al., 2013; Medale and Khausik, 2009). Several studies have been initiated to find protein sources that cannot be directly used for human consumption (Burel and Medale, 2014; Hardy, 2010). The valorization of local agricultural by-products in fish feed could reduce competition between humans and animals but also production costs) (Zhao and al, 2010 and Medale and Khausik, 2009).

This problem of formulating fish feed from local ingredients is increasingly apparent in Africa in countries where fish farming suffers from the supply of feed for intensive systems: Kouadio and al. (2020); Djekota and al, (2020); Tshinyama (2016); Asmah (2008) in Ghana; in the Democratic Republic of Congo-DRC; Kimu and al. (2016) in Ivory Coast.

In Senegal, studies have been conducted in this direction (Fall and al., 2012, Loum and al., 2013, Ndong and Fall, 2007, Sagne and al., 2013).

In fact, in semi-intensive fish farming, a complementary feed can be limited to one ingredient (rice bran, corn cake, etc.) or a mixture of two ingredients is largely sufficient to meet the needs of the species in farming. On the other hand, in intensive fish farming, the food must be composed and balanced in macronutrients (proteins, lipids, carbohydrates) as well as in trace elements so as to satisfy the nutritional requirements of the species to be raised (Webster and Lim, 2002; Guillaume and al., 1999; De Silva and al. Anderson, 1995).

As a result, the nutritionist must use several ingredients in order to better balance the compound feed and meet the nutritional needs of the species in question; while controlling its impact on the quality of the products, on the physiological well-being, the health of the fish and on the environment in which they are raised.

Inter-supplementation between by-products, having different limiting factors, would be more effective than each constituent taken in isolation.

However, raw materials of plant origin are very numerous and are less expensive than those of animal origin and have a certain binding power (Richter and al., 2003). On the other hand, none combines all the advantages of fishmeal. The first disadvantage of these materials is their low protein content. The essential amino acid composition of raw materials of plant origin is less well suited to the needs of fish, in particular due to the low content of methionine and lysine, compared to other sources of protein of animal origin. Knowing the needs of a farmed fish, one can either combine the by-products so as to provide a food balanced in these two essential amino acids, although this is often insufficient, or supplement the food with each of the amino acids deficient (Espe and al., 2006).

The general objective of this work was to develop feeds based on local vegetable raw materials at a reduced cost for juveniles (between 0.3 and 5g) of tilapia *O. niloticus* from groundnut cake, rice bran, millet bran and corn flour combined or not with fish meal in order to improve feed efficiency. Then, to evaluate the impacts of experimental feeds on the cost of feeding fish reared.

2. Material and Methods

2.1 Culture Conditions

The juvenile tilapia raised for this trial were obtained from the experimental aquaculture unit of the University of Dakar. Two hundred and seventy (270) *Oreochromis niloticus* fry, with an average initial weight of 0.37 ± 0.5g, were used in this experiment. The batches were made from individuals from the same breeding band. The batches were homogeneous, the rate of variation between the average weights was less than 5%, and the coefficient was less than 15% in each batch. Tilapia (*Oreochromis niloticus*) fingerlings were collected in the experimental aquaculture unit of the University of Dakar, Senegal. The fish were acclimated to the experimental conditions for a period of two weeks. To determine initial body composition, 20 randomly selected fish were killed, filleted and stored at -18°C for subsequent proximal analysis (AOAC, 1990). At the beginning of the experiment, two hundred and seventy fish were randomly divided into three different groups with two replicates containing 30 fish each. The fish were maintained in nine plastic tanks. Each tank was placed in an open system. An air compressor was used to continuously ventilate each tank. All tanks were cleaned daily in the morning and afternoon by siphoning off accumulated waste.

Three diets were formulated to contain different levels of digestible protein and approximately equal amounts of digestible energy. Of the total dietary protein, a portion was derived from fishmeal and the remainder from different ratios of maize meal, millet meal, Peanut meal and rice flour (Table 1).

Table 1. Composition of local test diets A1, A2 and A3 (g/100 0g) used for rearing juvenile *Oreochromis niloticus*

Ingredients	**A1**	**A2**	**A3**
Fishmeal	0	10	25
Peanut meal	56	44	20
Millet bran	15	15	15
Rice bran	10	10	10
Corn flour	6	8	17
Fish oil	5	5	5
Binder (*Sterculia gum*)	2	2	2
Yeast	4	4	4
MIN[a]	1	1	1
VIT[b]	1	1	1
Crude Protein (%)	31	31	31
Crude Lipid (%)	**13**	**13**	**12**

a VitA250000UI;VitD3 250000UI;VitE5000mg;VitB1 100mg;VitB2 400mg;Niacine 1000mg; PantothenateCa2000mg;VitB6 300mg;VitK3 1000g;VitC5000mg; Biotine15mg;Choline100 g ; BHT 1000 mg;

b Phosphorus 7%; Calcium 17%; Sodium 1.5%; Potassium 4.6%; Magnesium 7.5%; Manganese 738 mg; Zinc 3000 mg; Iron 4000 mg; Copper 750 mg; Iodine 5 mg; Cobalt 208 mg; Calcium and ground attapulgite qs 1000 g ; Fluoride 1.5%

The test aims to compare three batches (Figure 1), in 2 replicates, with different diets. Three diets were tested in duplicate: Diet A1, without fishmeal. Diet A2 incorporates 10% fishmeal and diet A3 25% fishmeal. The basic composition of the diets tested is as follows: peanut meal, millet bran, corn meal, rice bran, yeast, binder and fish oil. The diets are isoprotein and isoenergetic: A1, A2 and A3 (31% protein and 13% fat) (Table 1). The main protein sources (corn flour, millet bran, peanut meal and rice bran) already ground in the mill were sieved through a No. 40 (425µm) mesh screen. The mineral mixture and the vitamin mixture were purchased from Aquavet in Thiès, Senegal. After mixing the ingredients well, an appropriate amount of water (30% per 100 g of mixed ingredients). The formulation of the feeds was done by the Pearson method. After formulation, the diets were prepared by mixing the ingredients and proximal analysis was performed. The diets were supplemented with 10% fish oil (FO). The paste was passed through an extruder to produce spaghetti and dried at 37°C for two days. The dried feed was packed in plastic bags and stored frozen.

2.2 Growth Parameters

Growth response parameters were calculated as follows: weight gain (WG, g/ fish) = final mean body weight - initial mean body weight; specific growth rate (SGR, % /day) = ((In Wt- In Wi) /T) x 100, where Wt is the weight of fish at time t, Wi is the weight of fish at time 0 and T is the rearing period in days; feed conversion rate (FCR) = total dry feed fed g/ fish / total wet weight gain g/ fish. Survival rate (%) = 100 (number of fish which survived/initial number of fish). Also called daily weight gain (DWG), this index makes it possible to assess the daily weight gain of farmed fish. It is determined from the relationship below. Daily Individual Growth (DIG (g/d)) = Final weight (g) – Initial weight (g) / Duration of breeding (d). Protein efficiency coefficient (PEC), to assess the efficiency of use of the proteins contained in the diet. PEC = Body mass gain (g)/Proteins ingested (g)

2.3 Water Quality Measurement

The abiotic parameters were measured in situ using a multi-parameter to measure the temperature in degrees Celsius and the pH simultaneously.

These parameters are measured twice per day (morning and afternoon). Air diffusers are permanently added.

2.4 Statistical Analysis

Data were analyzed using the statistical system (SAS-PC) (Joyner, 1985) and subjected to one-way analysis of variance (ANOVA). Treatment effects were considered significant at $P<0.05$; Tukey's test was used to compare significant differences between treatments. Results are presented as mean (±) standard deviation.

3. Results

Water quality

The results of the water quality parameters of the experimental tanks are summarized in Table 2. The temperature varied from 20 to 29.1°C over the entire duration of the experiment. The average values are all close to 27 ± 0.5°C. The low temperature values are observed at the end of the experiment (the last 15 days), coinciding with the start of the cool season in Dakar.

The dissolved oxygen values recorded varied from 2 to 4.1mg/l, with averages of 3 ± 0.5; for all breeding tanks. With regard to the pH values, the values measured are between 5.1 and 8.32, with averages of 7 ± 0.5 in all the tanks. However, the statistical analysis shows that the difference between the water quality in all the experimental tanks is not significant ($P > 0.05$).

We can say that the water quality is within the recommendations for the duration of the experiment.

Table 2. Values of the water quality parameters of the experimental tanks

DIETS	TANKS	T°C MIN	T°C AVG	T°C MAX	O_2 mg/l MIN	O_2 mg/l AVG	O_2 mg/l MAX	pH MIN	pH AVG	pH MAX
A1	TANK1	20.3	26.1	28.9	2	3.2	4	5.01	7.36	8.2
	TANK2	20.4	26.7	29	2.1	2.9	3.9	6	7.4	8.02
A2	TANK3	20.3	26.3	29.1	2.2	3	4.1	6.1	7.27	8.01
	TANK4	20.2	27.1	29	2	2.7	3.9	6.3	6.98	8.32
A3	TANK5	20.1	26.8	28.8	2	3.1	3.8	6.2	7.3	8.20
	TANK6	20.4	26.5	29	1.9	2.8	3.9	6.1	7.07	7.9

Growth rate

Figure 2 shows the growth rate over the entire rearing period of *O. niloticus* subjected to diets A1, A2 and A3. After the first 30 days of rearing, the batches of fish fed with feeds A1 and A2 (0 and 10% fishmeal respectively) had almost similar growth. Beyond this period, two groups can be distinguished. Juveniles fed with diet A1 and A2 show lower weight gain than those fed with diet A3 during the last two months. Fish fed diet containing low fishmeal showed more growth, which was maintained throughout the experiment.

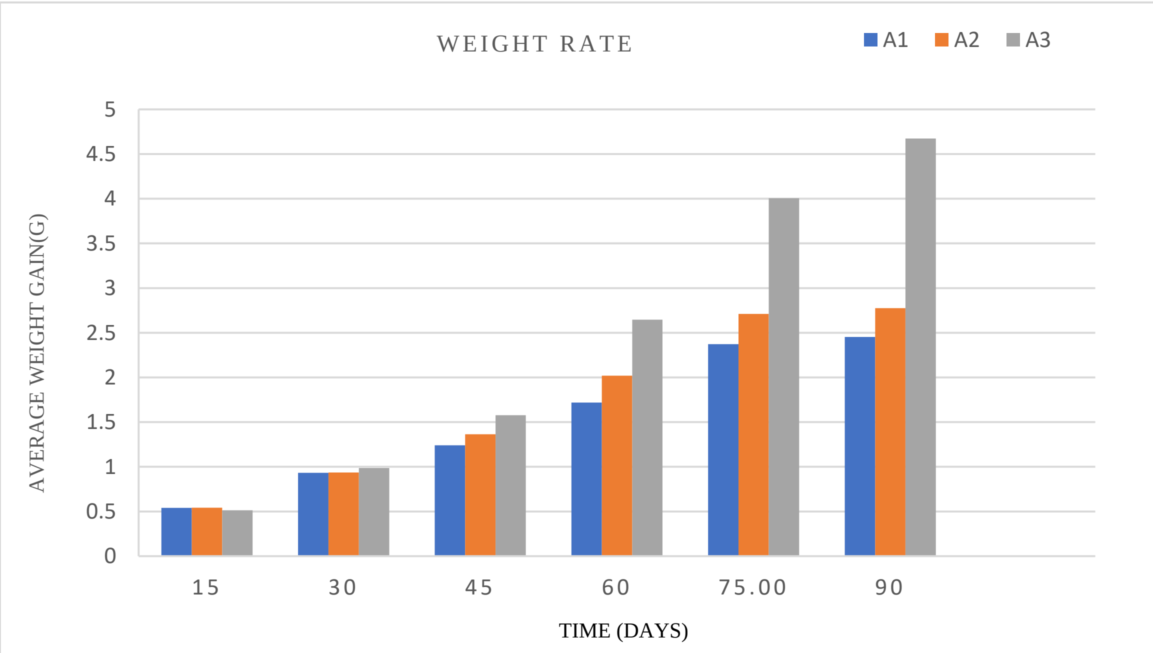

Figure 2. Variation in the growth rate of *Oreochromis niloticus* in the tanks as a function of time and type of diet at constant density

Zootechnical parameters

A summary of the partial results of the trial is presented in Table 3. For all the zootechnical parameters studied, namely the Feed Conversion Rate (FCR) and Specific Growth Rate (SGR), Daily Individual Growth (DIG), Absolute Average weight gain (AWGa) and Relative Average weight gain (AWGr), a significant difference is noted between the fish fed with food A1 and A2 and those fed with A3.

The results of the growth parameters (Average weight gain: AWG, Specific Growth Rate: SGR, Daily individual growth: DIG) of juveniles fed with diet A3 (25% fish meal) are clearly superior (ANOVA; $p < 0.05$) to those of juveniles receiving diets A1 and A2 (0 and 10% fishmeal respectively).

On the other hand, for the Protein Efficiency Coefficient (PEC) and the Survival Rate (SR), there is no significant difference. The zootechnical variables do not differ significantly ($p > 0.05$) from one tank to another for the same feed treatment.

Table 3. Zootechnical parameters in *Oreochromis niloticus* subjected to five dietary treatments for 90 days

PARAMETERS	A1	A2	A3
AIW g	0.37±0[a]	0.37±0[a]	0.37±0[a]
AFW g	2.45±0.09[a]	2.75±0.12[a]	4.67±0.53[b]
AWGa g	2.01 ±0.27[a]	2.35±0.35[a]	4.31±0.56[b]
FCR	3±0.34[a]	2.35±0.26[a]	1.85±017[b]
SGR %/d	2.22±0.20[a]	2.38±0.71[a]	3.03±0.43[b]
AWGr %	547±57.6[a]	639.5±45.30[a]	1175±60.42[b]
PEC %	0.11±0. 06[a]	0.11±0.03[a]	0.17±0.04[a]
DIG %	0.03±0.004[a]	0.03±0.007[a]	0.05±0.006[b]
SR	87±6.8[a]	97±2.01[a]	92±3.03[a]

*For each parameter, the values which are not assigned the same letter are significantly different ($p < 0.05$, and those with at least one same letter in common, are not significantly different ($P>0.05$).

4. Economic Approach

The price per kg of feed was determined from the price of raw materials available on the local market and the percentage of incorporation of different ingredients in the formulation. The process is summarized in Table 4.

The cost of one kilogram of feed for diets A1, A2 and A3 is 0.51, 0.58 and 0.77 USD respectively.

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Table 4. Estimated cost of producing one kilogram of feed

Ingredient prices (USD)*	Price of one kg of diet A1	Price of one kg of diet A2	Price of one kg of diet A3
Fishmeal = 0.86	(0 x 0.86)/100	(10 x 0.86 100	(25 x 0.86)/100
Fish oil = 0.71	(5 x 0.71)/100	(5 x 0.71100	(5 x 0.71)/100
Peanut meal = 0.35	(56 x 0.35) /100	(44 x 0.35)/100	(20 x 0.35)/100
Corn flour = 0.43	(6 x 0.43) /100	(8 x 0.43)/100	(17 x 0.43)/100
Millet bran = 0.26	(15 x 0.26) /100	(15 x 0.26)/100	(15 x 0.26)/100
Rice bran = 0.26	(10 x 0.26) /100	(10 x 0.26)/100	(10 x 0.26)/100
Vitamins = 3.46	(1 x 3.46) /100	(1 x 3.46)/100	(1 x 3.46)/100
Minerals = 4.32	(1 x 4.32) /100	(1 x 4.32)/100	(1 x 4.32)/100
Yeast = 0.86	(4 x 0.86) /100	(4 x 0.86)/100	(4 x 0.86)/100
Binder (Lalo) = 0.52	(2 x 0.52) /100	(2 x 0.52)/100	(2 x 0.52)/100
Transport, Electricity and Workforce: 0.086 USD/kg	0.086	0.086	0.086
Total	**0.51 USD**	**0.58 USD**	**0.77 USD**

*1 USD = 578.04 FCFA

5. Discussion

Regarding the survival rate; we have no significant difference (P>0.05) between juveniles fed with diets A1, A2 and A3. The survival rate is between 87 and 97%. Our results are similar to those of Fiogbé and al. (2009); (86.67 to 97.78% survival) and Bamba and al. (2014) (89 to 93% survival) and below those of Dibala and al. (2018). The few deaths counted during the experiment do not seem to be related to feed. Mortalities are more related to handling and rain. Deaths often occurred after each period of heavy rain, the water entered the tanks and filled them and the fish came out of these breeding tanks. Handling stress also caused some mortality. None of the diets are therefore toxic to *O. niloticus* tilapia. The survival rate of 90% being generally accepted in breeding (Bamba and al. 2003), and those obtained being the major part above; we can therefore consider that our results are within the accepted standard.

The results of the statistical analysis show that the growth performances of the batches fed with the A3 feed are significantly better than those of the others (P < 0.05). The Feed Conversion Rate (FCR) values between 3 (A1) and 1.85 (A3). These results corroborate those of Sagne and al. (2013) (1.77; 2.67; 1.45, 1.98; and 1.37). However, diet A3 with a percentage of 25% fishmeal has the best conversion rate. This result is confirmed by authors, who claim that fishmeal is the ideal source of protein for aquaculture fish. Because it has an excellent essential amino acid profile and is rich in long polyunsaturated fatty acids (PUFA) from the omega 3 series as well as vitamins and minerals that perfectly match the needs of farmed fish (Médale and Kaushik, 2009; Hertrampfet Piedad-Pascual, 2000).

The Specific Growth Rate (SGR) obtained with diet A3 (3.03%/d) is significantly higher than those obtained with diets A1 (2.22%/d) and A2 (2.38%/d). These results found with the A3 diet are similar to those reported by Jauncey et al. (1982) with a SGR of 3%/d. It is however interesting to note that the SGR observed with the diets A1 and A2 are not low compared with the results of other authors such as Loum and al. (2013), Garduno-Lugo1 and Olvera-Novoa, (2008), Koumi and al. (2011), and Dibala and al, (2018). This performance gap between the fish fed diet A3 and the others could also be explained by the presence of antinutritional factors in the plant ingredients. Indeed, according to Rivière (1978); Arzel and al. (1999), rice bran has a high cellulose content. These authors also indicated the presence of pythium phosphorus in millet. In maize we note the presence of phytoestrogens, cellulose, Pythic acids, invertase and proteinase inhibitors. These antinutritional factors lead to enormous delays in growth. They would act in particular by reducing food intake (Richter et al, 2003), disrupting the activity of pancreatic enzymes and the Krebs cycle (Shimeno and al., 1993), modifying the absorption surfaces (Ostaszewska and al., 2005; Heikkinen and al., 2006) promoting the development of liver lesions and tumors (Lovell, 1989). This results in a decrease in the digestion and absorption of nutrients and a reduction in their efficiency which, in the long term, leads to growth retardation, mortality and therefore a drop in productivity.

In addition, other authors have shown that the total replacement of fishmeal by plant products causes a decrease in growth rate and feed efficiency in high trophic level species, even if all the necessary nutrients are present in the food (Gómez-Requeni and al, 2004; Vilhelmsson and al., 2004; Panserat and al., 2008; Dupont-Nivet and al., 2009; Alami-Durante and al., 2010; Le Boucher and al., 2012, 2013a).

Another parameter to take into account which is not the least is the presence of mycotoxin. According to the authors Spring and Burel (2008) the use of vegetable ingredients increases the risk of introducing mycotoxins into fish feed. These toxins have detrimental effects on fish performance and health.

It is also important to remember that these feeds are not extruded. The use of extrusion and some technological treatments could eliminate all these anti-nutritional factors and mycotoxins, in order to make our foods more digestible and more efficient.

Regarding feed costs, A1 and A2 are less expensive than feed A3. The results of this study are similar to those of Coyle and al. (2004), who reported a cost reduction at a rate of 20% for the diet without fishmeal compared to the reference diet.

Moreover, it is more relevant to calculate the cost of one kilogram of feed fish per unit of biomass on adult fish, because we know that the conversion index and the feed efficiency decrease according to the size of the fish Pisces. This calculation will allow us to know the cost of producing one kilogram of fish. However, with the price of feed A1 and A2, if we manage to manufacture extruded feed (to improve the digestibility of these feeds), which contain the same percentages of local vegetable raw materials, we will apparently have a more profitable production of *O. niloticus*. These results can be confirmed by another test with the same food, but on adult tilapias.

6. Conclusion

The results of this study prove the supremacy of fishmeal over vegetable proteins. They also show that the substitution of fishmeal with local vegetable raw materials is a real opportunity for tilapia aquaculture in Senegal. Opportunity for the reduction of the pressure exerted on the halieutic resources (increased use of fishmeal) and opportunity from the economic point of view (reduction of feed costs). The main objective was to identify, among the manufactured foods, the candidate local vegetable raw materials, which could be used in the composition of tilapia feeds and which effectively meet the nutritional needs of tilapias, economically profitable, available on the local market. Currently, the main problem of Senegalese aquaculture is the availability of quality local industrial feed accessible to fish farmers. If we manage to improve the efficiency of these feeds by technological treatment, the problem of aquaculture feed in Senegal could be solved. The studies are to be continued with trials on adult fish, then in breeding with the same formulas and also with extruded feed in breeding to confirm the interest of building a national industrial feed factory for the needs of Senegalese aquaculture.

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