Comparative Study on the Effects of Extruded and Non-Extruded Local Feeds versus Commercial Feed on the Zootechnical Performance of *Oreochromis niloticus* (Linnaeus, 1758)

ABSTRACT

Aquaculture plays a crucial role in bridging the gap left by declining wild fisheries. However, the reliance on fish meal and fish oil for feeding farmed fish, along with the importation of industrial feed in developing countries like Senegal, limits the sector's growth. Thus, finding alternative solutions to these challenges is essential. The objective of this study was to compare the effectiveness of imported industrial feed with extruded and non-extruded local feeds, while also evaluating the effects of replacing fish meal entirely with poultry by-product meal on the zootechnical performance and economic profitability of *Oreochromis niloticus*. A total of 180 *O. niloticus* fry were used, divided into three feeding diets (in triplicate), and monitored over a 60-day period. pH and temperature were recorded twice daily before siphoning, tank refilling, and feeding. Fish were weighed biweekly to assess biomass and adjust feed rations. Prior to the study, the non-extruded local feed (R2) was formulated and produced. The results showed that the best weight gains (GPMa and GPMr, TCS), TCA and TS were observed in fish fed with industrial feed (R0) compared to those fed with non-extruded local feed (R2), which primarily contained poultry by-product meal. However, given the statistical results showing no significant differences between diet R0 and the economic profitability of diet R1, extruded local feed (R1) appears to be the optimal choice among the three.

Keywords: *Oreochromis niloticus*, fishmeal, poultry by-product meal, industrial feed, extruded local feed, non-extruded local feed

INTRODUCTION

Aquatic food products are a vital component of healthy, balanced diets worldwide (FAO, 2022). Fish, in particular, serves as a critical source of energy, protein, and various easily digestible nutrients with high biological value (Peng et al., 2014). In recent decades, global consumption of aquatic food products has significantly increased, and this trend is expected to continue. Global fish consumption per capita has risen from an average of 9.9 kg in the 1960s to an estimated 20.7 kg in 2022 (FAO, 2024).

However, fishery resources continue to decline due to overfishing, pollution, climate change, and inadequate management. As a result, aquaculture has become essential for increasing the production of aquatic animal protein to meet growing global demand. One of the primary challenges in aquaculture is feeding. While fish meal and fish oil are crucial ingredients in fish feed, their high cost contributes to rising feed prices (Olaniyi and Salau, 2013), and their continued use could lead to the depletion of certain fish species. Moreover, in developing countries like Senegal, there is a lack of efficient and affordable feed, leading to the importation of costly feed, which further increases production expenses.

Therefore, replacing fish meal with more affordable alternative protein sources and developing extruded local feeds are critical strategies to reduce production costs in aquaculture. Poultry by-product meal, with its high protein content and favorable essential amino acid profile (Tacon, 1993; Gaylord and Rawles, 2005), is a suitable and viable protein source for fish. Its wide availability and lower cost make it an ideal candidate for replacing fish meal in aquaculture feeds. Additionally, the production of extruded local feed offers a promising alternative to imported industrial feeds, potentially leading to significant reductions in production costs.

The integration of poultry by-products could reduce dependence on fish meal, while the extrusion of local feeds would contribute to the development of efficient, cost-effective feeds for farmed fish such as Nile tilapia (*Oreochromis niloticus*). Nile tilapia is one of the most widely farmed species globally due to its rapid growth and adaptability to various aquatic environments, and it serves as a crucial protein source for millions of people worldwide.

The primary objective of this study is to compare the effectiveness of imported industrial feed with local extruded and non-extruded feeds on the zootechnical parameters and biochemical composition of Nile tilapia (*Oreochromis niloticus*). This research aims to assess the viability of more sustainable and economical feeding solutions. The specific objectives are as follows:

• Evaluate the impact of different feeding regimes on growth, feed efficiency, survival, and biochemical composition of Nile tilapia fry.

•Analyze the production costs associated with each feeding regime to identify the most economical solution for tilapia farming.

MATERIAL AND METHODS

Methods

Raw Materials

Sourcing of Raw Materials

The ingredients for the non-extruded local feed were selected based on standard criteria for feed ingredient selection, including availability, accessibility, cost, and protein content. Some ingredients were sourced from the station, while others were purchased from the Tiléne market in Dakar

Processing Chicken By-Products into Meal

A specific processing method was used to convert chicken by-products into poultry meal. After purchasing the by-products, they were thoroughly cleaned and cooked for at least one hour to extract the oil. Following this, the by-products were sun-dried and then ground into a fine powder.

Biochemical Analysis of Raw Materials

To formulate a balanced diet that meets the nutritional requirements of *Oreochromis niloticus* fry, the ingredients used were analyzed for their protein and fat content. In this study, only the poultry by-product meal was analyzed (Table 1) at the biochemistry laboratory of the ESP (École Supérieure Polytechnique), while the nutritional profiles of other ingredients (such as fish meal, wheat bran, peanut cake, soybean cake, etc.) were sourced from the station's existing database**.**

Table 1: proximate composition of Chicken Viscera Meal

Chicken Viscera Meal	Results (%)
Protein Content	61.25
Fat Content	19.33

Formulation Method for Non-Extruded Local Feed

Feed Formulation

Feed formulation is the process of calculating the proportions of each ingredient (agricultural by-products, agro-industrial products, and animal products) required to create a balanced feed. The goal is to combine ingredients with varying nutritional qualities to produce a feed that meets the specific nutritional needs of the species. In this study, the formulation was done using the Pearson's Square method, resulting in a feed composition of 31% protein and 12% lipids derived from the selected ingredients (Table 2).

Table 2: Nutritional Composition of Different Diets

<table>
<tr><th colspan="2">Non-Extruded Local Feed</th><th>Extruded Local Feed</th><th>Commercial Feed (naturAlleva caliber 3mm)</th></tr>
<tr><th>Ingredients</th><th>IR (%)</th><th>Ingredients</th><th>Ingredients</th></tr>
<tr><td>Wheat bran</td><td>14</td><td rowspan="11">Fish meal
Sorghum flour
Corn flour
Wheat flour
Peanut cake
Baobab leaf powder (lalo)
Fish oil
Vitamins
Minerals
Yeast</td><td rowspan="11">Fish meal
Soybean meal
Sunflower cake
Rapeseed cake
Poultry meal
Blood meal
Peas dehulled
Guar germ cake
Whey protein
Monoammonium phosphate
Hydrolyzed animal proteins
Soy oil
Additives (vitamins, iron, iodine, etc.)</td></tr>
<tr><td>Soybean cake meal</td><td>16</td></tr>
<tr><td>Peanut cake meal</td><td>14</td></tr>
<tr><td>Corn flour</td><td>10</td></tr>
<tr><td>Cassava flour</td><td>6</td></tr>
<tr><td>Neocarya pulp</td><td>8</td></tr>
<tr><td>Chicken viscera meal</td><td>18</td></tr>
<tr><td>Yeast</td><td>5</td></tr>
<tr><td>Vitamins[a]</td><td>2</td></tr>
<tr><td>Minerals[b]</td><td>2</td></tr>
<tr><td>Chicken viscera oil</td><td>5</td></tr>
</table>

Total	**100**	**100**	**100**
Protein Contribution	**31%**	**37%**	**30%**
Lipid Contribution	**12%**	**7,39%**	**6%**

IR = Incorporation Rate

a=vit A 250000 UI; vit D3 250000UI; vit E 5000mg; vit B1 100mg; vit B2 400mg; vit B3(pp) 1000mg; vit B5 pantode Ca2000mg; vit B6 300mg; vit K3 1000g; vit C 5000mg; H biotin 15mg; choline 100g; anti-oxydant (BHT), crushed and calcined attapulgite qs 1000mg;

b=phosphorus 7%; calcium 17%; sodium 1,5%; potassium 4,6%; magnesium 7,5%; manganese 738mg; zinc 3000mg; iron 4000mg; copper 750mg; iodine 5mg; cobalt 208mg; calcined and ground attapulgite qs 1000g; fluorine 1.5% (approximately),

Note: For R0 (industrial or commercial feed) and R1 (extruded local feed), incorporation rates are not provided.

II.3.3 Feed Manufacturing Process

After formulating the non-extruded local feed, the manufacturing process (with a total production of 1 kg for this regime) involves several steps. Ingredients are sourced from the Tilène market. Before weighing the required quantities, the flours are sifted through a fine sieve to remove large particles and any undesirable materials. After weighing, the ingredients are manually mixed to ensure a homogeneous blend. Oil is added last, followed by the incorporation of 30% water to compact the mixture. A manual grinder (Moulinex) is used to convert the dough into long strands resembling spaghetti. The mixture is fed into the grinder, and the strands are collected in a container. The processed product, still moist from the machine, is left to dry for two to three days. This step ensures better preservation by preventing mold growth and making the feed easier to handle. In the final phase, the dried feed is ground into powder for appropriate feeding of the fry.

II.3.4 Rearing Conditions

This study begins with the collection of *Oreochromis niloticus* fry from the IUPA aquaculture station. After a 15-day acclimatization period, the fry were weighed and assigned to three feeding diets in triplicate, with a density of 20 individuals per tank for a duration of 60 days. Throughout this period, physicochemical parameters, including pH and temperature, are measured twice daily (morning and evening) before siphoning, refilling the basins, and feeding the fry. The fry were weighed biweekly to assess biomass and adjust the feed ration accordingly.

II.3.5 Growth, Survival, and Feed Efficiency Parameters

To estimate the growth and survival of the fish during the experiment and to assess the efficiency of the tested feeds, different parameters were calculated:

Specific Growth Rate (SGR, %/d) = ((ln IW-ln FW)/rearing time) x100

Absolute Mean Weight Gain (AMWG, g) = FW- IW, With IW = initial weight and FW= final weight of the fish

Relative Mean Weight Gain (RMWG, %) = (FW-IW) *100/IW. With IW = initial weight and FW=final weight of the fish

Survival rate (SR, %) = (FN/IN) *100, With FN: Final numbers; IN: initial Numbers

Feed Conversion rate (FCR)= Quantity of feed distributed/ absolute weight gain

Economic Analyses

Calculations were made for each of the three diets to evaluate the cost per kilogram of feed. The total feed cost was determined by summing the prices of all ingredients used, along with additional expenses such as transportation and labor ect. The production cost of one kilogram of fish was determined by multiplying the production cost of one kg of feed and the FCR.

Statistical Analysis

The collected data were entered and processed using Microsoft Excel. Data analysis was performed using the Statistical Analysis System (SAS-PC) software, with the results subjected to an analysis of variance (ANOVA). The Tukey test was applied to identify significant differences between treatments.

RESULTS AND DISCUSSION

RESULTS

Water quality parameters

The physico-chemical parameters, specifically temperature and pH, are summarized in Table 3. The average daily temperatures measured during the experiment ranged from 25.90°C to 26.03°C. The average temperature for diet R2 (25.94±0.026°C) was slightly higher than those for diets R0 and R1, which were 25.91±0.017°C and 25.94±0.026°C, respectively. However, no significant differences were observed among these three diets.

The pH values ranged from 7.26 to 7.38. The average pH values for all three diets were similar, with diet R0 showing a value of 7.26±0, and diets R1 and R2 having values of 7.30±0.069. No statistically significant differences were found among these regimes.

Table 3: Water quality parameters

Diets / Water parameters	R0	R1	R2
Average Temperature (°C)	25,91±0,017^{a}	25,94±0,026^{a}	25,98±0,055^{a}
Average pH	7,26±00^{a}	7,30±0,069^{a}	7,30±0,069^{a}

Note: a indicate no significant differences (P >0.05) between dietary treatments

Growth, Feed Efficiency, and Survival Parameters

During the experiment, various parameters were determined to evaluate the growth and survival of fish in each regime, as well as the efficiency of the feeds used. The results obtained are presented in Table 4.

Table 4: Zootechnical Parameters

Diets / **Parameters**	**R0**	R1	R2
IMW (g)	0,11^{a}	0,11^{a}	0,11^{a}
FMW(g)	2,63±0,74^{a}	1,69±0,11^{ab}	0,81± 0,21^{b}
AMWG (g)	2,52±0,74^{a}	1,58±0,12^{ab}	0,70±0,21^{b}
RMWG (%)	2282,86±665,36^{a}	1447,87±104,90^{ab}	639,25 ± 189,42^{b}
SGR (%/d)	5,61±0,49^{a}	4,89±0,12^{ab}	3,53± 0,48^{b}
FCR	1,43±0,21^{a}	1,68±0,04^{ab}	2,08± 0,18^{b}
SR (%)	96,67±5,77^{a}	85±0^{ab}	71,67±7,64^{b}

Note: a,b indicate significant differences ($P < 0.05$) between dietary treatments.

IMW: initial mean weight, FMW: final mean weight, AMWG, absolute mean weight gain, RMWG, relative mean weight gain, SGR: specific growth rate, FCR: feed conversion ratio, SR: survival rate.

The growth parameters (FMW, AMWG, RMWG, and SGR) obtained in this study reveal a significant difference between diets R0 and R2. Diet R0 achieved the best results, with a FMW of 2.63±0.74g, a AMWG of 2.52±0.74g, RMWG, of 2282.86±665.36%, and a SGR of 5.61 ±0.49%/day. However, no significant differences were observed between R0 and R1, nor between R1 and R2.

Regarding the feed conversion ratio (FCR), the most efficient diet is the one with the lowest value. The results show that R0 (1.43±0.21) is significantly different from R2, which has a FCR of 2.08±0.18. R1, with a FCR of 1.68±0.04, shows no significant difference compared to either R0 or R2.

The survival rates (SR) observed during the experiment ranged from 71.67±7.64% for R2 to 96.67±5.77% for R0. A significant difference was found between R0 and R1. However, R1, with a survival rate of 85±0%, showed no significant difference when compared to R0 and R2.

Flesh Analysis

The biochemical composition of initial fry of *O. niloticus* and those obtained at the end of the experiment is presented in Table 6.

Table 5: Composition of Fry Flesh

Samples	Crude Protein (%)	Crude Fat (%)	Crude Ash (%)
Initial fish	15,61±0,01[a]	8,16±0,02[a]	4,44±1,74[a]
R0	14,55 ±0,80[a]	8,21 ±0,20[a]	3,19 ±0,23[a]
R1	15,70 ±0,40[a]	6,09 ±0,61[b]	3,73 ±0,23[a]
R2	15,2 ±2,32[a]	9,18 ±0,88[a]	3,78 ±1,33[a]

Note: a,b indicate significant differences ($P < 0.05$) between dietary treatments.

Statistical analysis indicates no significant difference in crude protein and ash content among the fry fed different experimental regimes. The crude protein content of Nile tilapia fry ranged from 14.55±0.80% to 15.70±0.40%, while the ash content varied from 3.19±0.23% to 3.78±1.33%. No statistical differences were observed between the initial fish and those from the different regimes (R0, R1, and R2).

Regarding fat content, fish fed R0 and R2 exhibited the highest levels, with values of 8.21%±0.20 and 9.18%±0.88, respectively. In contrast, the fat content of fry fed R1 (6.09%±0.61) showed a significant difference compared to fish fed diets R0 and R2, as well as the initial fish

Economic Estimation of Feeds

The estimated costs of the experimental feeds are presented in Table 6.

Tableau 6: Estimated Costs of Experimental Feeds and fish

Non-Extruded Local Feed			Extruded Local Feed		Commercial Feed NaturAlleva (3mm)	
Ingredients	**Price/kg**	**Price/%TI**	**Ingredients**	**Price/kg**	**Ingredients**	**Price/kg**
Wheat bran	125	17,5	Fish meal Sorghum flour Corn flour Wheat flour Peanut cake Baobab leaves (lalo) Fish oil Vitamins Minerals Others		Fish meal Wheat flour Canola cake Sunflower cake Poultry meal Blood meal Defatted peas Guar germ meal Monoammonium phosphate Whey protein Soybean oil Additives (vitamins, iron, iodine…)	
Soybean cake	400	64				
Peanut cake	200	28				
Corn flour	200	20				
Cassava flour	150	9				
Neocarya pulp	150	12				
Chicken viscera meal	250	45				
Yeast	3000	150				
Vitamins	2380	47,6				
Minearals	760	15,2				
Viscera oil	250	12,5				
Others		82				
TOTAL		**420,8Fcfa**		**661,4Fcfa**		**1050Fcfa**
TCA	**2,08**			**1,68**		**1,43**
Production Cost of fish	**875 Fcfa**			**1110Fcfa**		**1500Fcfa**

The table 6 shows that the prices per kilogram of the three feeds range from 420,8 FCFA (local non-extruded feed) to 1050 FCFA (industrial feed). The price of the extruded local feed is estimated at 661.4 FCFA per kilogram. Thus, the local non-extruded feed is the cheapest, followed by the extruded local feed. However, based on the FCR results from this study, the non-extruded local feed presents the best fish production cost at 875FCFA /kg, compared to the extruded local feed and commercial diet, which cost 1110 and 1500 FCFA/kg, respectively.

DISCUSSION

Physicochemical Parameters

The recorded temperature values during this study ranged from 25.90°C to 26.03°C. These values align with the findings of Balarin and Hatton (1979), who reported that the thermal tolerance range for *Oreochromis niloticus* in laboratory conditions is between 8°C and 40°C, with optimal growth occurring between 24°C and 28°C. Our results are also consistent with those of Diago (2019), who recorded temperatures ranging from 25°C to 29.4°C. These findings suggest that temperature did not limit the growth of *O. niloticus* fry during the study.

Regarding pH, the values ranged from 7.26 to 7.38, falling within the optimal range identified by Malcolm et al. (2000), which is between 6.5 and 8.5 for optimal biological and physiological performance in *O. niloticus*. Our results also support the findings of Bahnasawy et al. (2009), who found that *O. niloticus* fry grow best at a pH between 7 and 9. Therefore, we can conclude that the pH conditions during our study were suitable and did not hinder the growth of Nile tilapia fry.

Growth, Feed Efficiency, and Survival Parameters

Growth Parameters

The results of the experiment show that fry fed the R0 diet (commercial feed) had the highest average daily weight gain (ADWG) of 2.52±0.74 g, followed by those fed the R1 diet (extruded local feed), which had an ADWG of 1.58±0.12 g. However, no significant difference was observed between these two diets. These results indicate that the extrusion of the feed made from local ingredients positively impacted the growth of Nile tilapia fry.

In contrast, fry fed the non-extruded local feed (R2) showed the lowest performance, with an ADWG of 0.70±0.21 g. These findings are consistent with those of Fall (2023) and Hong et al. (2019), who reported better growth performances in control diets containing only fish meal, with weight gains of 3.34 g and 15.83 g, respectively, compared to diets containing poultry by-products. This could be explained by the lower levels of methionine and lysine in poultry by-product meal and the high inclusion rate of poultry meal in the non-extruded local feed. Koch et al. (2016) suggested that the use of poultry meal supplemented with lysine, methionine, and taurine leads to the best growth outcomes in juvenile Nile tilapia.

Tacon et al. (2009) recommended poultry by-product meal inclusion levels of 5% to 25% in fish feed, and Turker et al. (2005) found no significant reduction in growth performance when turbot was fed diets containing 25% poultry by-product meal compared to fish meal-based control diets. These findings underscore the importance of optimizing feed formulations to maximize the growth of aquaculture fry.

Feed Efficiency Parameters

Feed efficiency results indicated that diets R0 and R1 achieved the best feed conversion ratios (FCR), with values of 1.43±0.21 and 1.68±0.04, respectively. However, the R2 diet showed a significantly higher FCR of 2.08±0.18 compared to the control diet. These results suggest that incorporating poultry meal into the diet was not effective for *O. niloticus* fry. Similar findings were reported by Hong et al. (2019) and Fall (2023), who observed the best FCRs (1.75 and 1.69) in control diets containing only fish meal and noted significant differences between the control and poultry by-product meal diets.

Incorporating poultry meal into fish diets can reduce feed efficiency (Hatlen et al., 2015). Davis et al. (1991) noted that some poultry by-products are deficient in essential amino acids such as lysine and methionine (Yang et al., 2004), which can affect feed quality unless supplemented. However, Dawood et al. (2020) found the best FCR (1.22) in fish fed a diet containing 20% fermented poultry by-product meal, suggesting that fermentation may improve the nutritional quality of poultry by-products and increase feed efficiency.

Survival Parameters

The highest survival rate was observed in fish fed the R0 diet (96.67%±5.77%), followed by those fed the R1 diet (85%±0%). The R2 diet showed the lowest survival rate (71.67%±7.64%), which was significantly different from the R0 diet. The low mortality rate observed in the R0 and R1 diets seems to be unrelated to feeding, as most mortalities occurred one to two days after fish handling or tank cleaning, likely due to stress or handling accidents.

For the R2 diet, mortalities appeared to be linked to the feed quality. Fish on this diet appeared thin, weak, and showed very slow growth. This could be attributed to the high poultry meal content, which led to poor feed quality and slow adaptation to the diet. These results contrast with those of Palupi et al. (2020), who reported 100% survival in tilapia fed diets containing varying levels of poultry by-product meal replacing fish meal.

Flesh Analysis

Bromatological analysis of the fish flesh revealed that fish from the R1 and R2 diets had the highest protein contents, at 15.70% and 15.2%, respectively, which were slightly higher than the initial fish (15.61%). In contrast, the R0 diet had a slightly lower protein content. This can be explained by the differences in protein content among the three tested feeds, which were 30% for R0, 37% for R1, and 31% for R2. Ahmad et al. (2012), Tidwell et al. (2005), and Pedro et al. (2001) report that flesh protein content increases with higher dietary protein levels.

The lipid content of fish from the R1 diet (with the highest protein intake of 37%) significantly decreased to 6.09%±0.61 ($P<0.05$). In contrast, the fat content in fish from the R0 and R2 diets (8.21%±0.20 and 9.18%±0.88, respectively) was slightly higher than in the initial fish (8.16%±0.02), but no significant difference was observed. These results are consistent with Bahnasawy (2009), who noted that fat content decreases as dietary protein increases.

Conversely, these findings do not align with Loum (2013), who recorded the highest crude fat content (9.4%) in fish fed a diet with the highest protein intake of 45.50%. Regarding ash content, no significant differences were found among the three diets, although the values were slightly lower than those of the initial fish.

Economic Estimation of Feeds

Economic analysis revealed that the R2 diet (420,8 FCFA/kg) was the cheapest, followed by the R1 diet (661.4 FCFA/kg), while the R0 diet had the highest cost (1050 FCFA/kg). However, considering feed efficiency (FCR), and feed production costs, the extruded local feed (R1) proved to be the most economically viable option. The results from this diet showed satisfactory performance compared to the R2 diet (non-extruded feed) and were statistically similar to those from the R0 diet (commercial feed).

Conclusion

Reducing the reliance on fishery products such as fish meal and fish oil in aquaculture feeds through partial or total substitutions is a major challenge for the future of global aquaculture. Similarly, the high dependence on imported, expensive feeds threaten the economic viability of local producers in developing countries.

The primary objective of this study was to compare industrial feed with local feeds (extruded and non-extruded) to identify which one promoted better growth and survival of Nile tilapia fry while being economically feasible. This approach aims to tackle issues related to the use of wild fish stocks and the lack of efficient and affordable feeds for fish farmers, contributing to the growth of aquaculture in Senegal and other developing countries.

The study found that the R0 diet (non-extruded local feed) offered the best cost-to-benefit ratio. Future research could further explore the effects of incorporating poultry by-products in extruded local feeds for other aquaculture species, as well as the potential economic and environmental benefits of replacing fish meal with locally sourced alternatives.

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