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Valorization of the duckweed (*Spirodela polyrhyza*) in the feeding of mono sex male fry of Oreochromis niloticus: Zootechnical performance and economic profitability

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Abstract

In order to evaluate the effect of *Spirodela polyrhiza* using in diets of *Oreochromis niloticus* fingerlings, an experiment was conducted on the farm "Awara" in the village of Agongo in Sèmè - Kpodji during 70 days. The initial average weight of fry is about 1g. The stocking density was 13 fry / m². Three experimental diets made with local by-products were tested: T0 (0% *S. polyrhiza* Meal), T1 (5% *S. polyrhiza* Meal) and T2 (mixed feed composed of 70% T0 and 30% fresh *S. polyrhiza*). At the end of the experiment, the survival rate was 100% for all treatments. The best zootechnical parameters were obtained with T1 with a final average weight of 11.67 ± 2.52 g and a consumption index of 1.17 ± 0.30. The highest gross profit margin was also obtained with T1. The lowest economic profitability was obtained.

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Introduction

Aquaculture is now a booming sector in the world. In addition to providing employment, it generates profits and participates in the diversification of animal protein diets. One of the critical issues facing this activity is the availability and cost of a balanced feed (Siddhuraju and Becker, 2003) that can adequately cover the nutritional needs of farmed tilapia. The importation of granulated feeds and fishmeal is the main cause of the high cost of production. It is therefore essential to seek new sources of cheap protein and local agro-industrial by-products and aquatic plants in order to reduce the cost of fish production (Fiogbe *et al.,* 2009).

The main considerations in the choice of ingredients to be incorporated in the formulation of fish diets are: their nutritional value, digestibility, palatability, availability and cost (Lovell, 1991; De Silva and Anderson, 1994; Rodriguez *et al.,* 1996).

Several studies have already been carried out on the trial of adding value to agricultural by-products, fish and poultry co-products and various aquatic and terrestrial plants in fish diets (Bello and Nzeh, 2013; Hêdji *et al.,* 2014; Bashir and Suleiman, 2018; Dibala *et al.,* 2018 and Dorothy *et al.,* 2018). Worldwide, tilapia are the highest ranking fish. Indeed, they are very hardy, reproduce easily in natural environments and controlled systems, accept and value natural and pelleted feeds, and grow rapidly (Abou, 2007).

The use of diets formulated from raw materials available on the local market has shown evidence in the feeding of tilapia (Abou, 2007; Bamba *et al.,* 2008). Global production of tilapia is about 3.5 million tons/year. Fish farms alone produce almost half of this amount (FAO, 2010).

Various studies conducted on the Nile tilapia (*Oreochromis niloticus*) have shown that it is an omnivore that consumes various macrophytes in its natural habitat (Leng *et al.,* 1995; El Sayed *et al.,* 1999). The duckweed (*Spirodela polyrhyza*) is one of the aquatic macrophytes most consumed by the Nile tilapia (Teferi, 1997; Setlikova and Adamek, 2004). *S. polyrhyza* is very rich in protein (15-40%) and has a good profile in Essential Amino Acids (Skillicorn *et al.,* 1993; Xiaolong *et al.,* 2018). It also has a low fiber content (Skillicorn *et al.,* 1993).

It can develop rapidly in ponds, pits or swamps (Bou *et al.,* 2012; Heuzé and Tran, 2015). The incorporation of *S. polyrhyza* meal in the diet of certain fish species such as *Piaractus brachypomus* has resulted in high zootechnical performance and economic profitability (Cruz - Velasquez *et al.,* 2014).

Very few studies have been carried out on the valorization of duckweed (*S. polyrhyza*) in the feeding of fry of *O. niloticus*. This study was then initiated in order to develop a feed formula based on local conventional raw materials and duckweed.

Materials and methods

Experimental device

The experiment took place on the Awara farm in the commune of Sèmè Podji (Republic of Benin). A pond of 200 m² containing six happas was used for this experiment. These happas are arranged in two series of three on each side of the pond. Each happa is 3 m² in area and 0.7 m deep. These snags are covered with nets to protect the fish from predators.

Three diets (Table 1) that cover the nutritional requirements (Lazard, 2007 cited by Iga - Iga, 2008) of *Oreochromis niloticus* fry have been formulated and manufactured with local ingredients.

The choice of ingredients is based on their nutritional quality, quantity, availability, and price on the local market (Guillaume, 1999). These diets were tested in this experiment with one repetition per treatment.

The T0 treatment contains 0% *S. polyrhiza*, the T1 treatment contains 5% dry *S. polyrhiza* powder and the T2 treatment is composed of mixed feed (70% T0 feed and 30% fresh *S. polyrhiza*). Duckweed (*S. polyrhiza*) was produced and harvested in the ponds of the experimental site.

Table 1. Centesimal composition of experimental regimens.

Ingrédients	*S. polyrhiza* content of experimental diets (%)	
	T0 (0)	T1 (5)
Fish meal	33	28
Soybean cake	33	33
Cotton cakes	31	31
Cassava flour	1	1
S. polyrhiza dry	0	5
Red oil	1	1
Minero-Vitamin Concentrate	1	1
Total	100	100

The nutritional value and cost price of each experimental regimen is presented in Table 2.

Table 2. Nutritional value and cost price of experimental diets.

Nutritional value and cost price	T0	T1	T2
Protein (%)	42.16	41.51	40.01
Fat (%)	5.99	5.64	5.69
Brute energy (MJ/100g)	1.80	1.76	1.71
Protein/ Energy (g/MJ)	23.42	23.58	23.40
Cost price of akg of feed (FCFA)	356.40	341.10	249.48

In this experiment, single-sex male tilapia O. niloticus fry of individual average weight 1±0.1g were used. These fry were purchased from the JDA (Youth and Agricultural Development) farm. The stocking density was thirty-nine (39) fry per happa, i.e. 13 fry/m². The ration is maintained at 30% of live weight and distributed manually 2 (two) times a day (8 am and 5 pm). During the experiment, the physico-chemical parameters (temperature, dissolved oxygen, pH) of the water were measured twice a week. The temperature was 27.71 ± 0.22°C. The dissolved oxygen level was 6.29 ± 0.43mg/L and the pH was 6.29 ± 0.37. Growth control peaches were carried out every 14 days. During these control fisheries, all fish were harvested by happas. They are then counted and weighed.

Samples from each experimental regime were taken and subjected to bromatological determinations. Proteins were determined after acid digestion (H_2SO_4) concentrated at 440 °C of a feed sample by the N-Kjeldahl method. Dietary lipids were determined by the method of Bligh and Dyer, 1959.

Zootechnical parameters and statistical analyses

The following parameters have been calculated for each treatment:

- Survival Rate (SR in%) = 100 x Nf/Ni where Nf = Final Number, Ni = Initial Number ;
- Average Daily Gain (ADG in g/d) = (Wf - Wi)/Δt, where Wf = Final body weight, Wi = Initial body weight and Δt = Duration of the experiment ;
- Specific Growth Rate (SGR in%/D) = 100 (LnWf - LnWi)/Δt where LnWf = Naperian logarithm of final body weight, LnWi = Naperian logarithm of initial body weight, Δt = duration of experiment;
- Consumption Index (CI) = RD / (Bf- Bi) where Bf = Final Biomass, Bi = Initial Biomass, RD = Distributed Ration ;
- Production (P inkg/ha) = 10000 x (Bf - Bi)/Surface area of each catch;
- Annual Production (AP inkg/ha/year) = Production x 365 days /Trial duration in days ;
- Gross Cost of onekg of Fish (GCF in FCFA) = Cost price of onekg of feed x CI;
- Annual Gross Production Cost (AGPC in FCFA) = AP x GCF;
- Total Cost of Feed Distributed (TCFD in FCFA) = GCF x Total Quantity of Feed Distributed;
- Total Selling Price of Fish (TSPF in FCFA) = AP x 1500;
- Gross Profit Margin (GPM in FCFA) = TSPF - (TCFD + Purchase Price of Fish).

The statistical analysis was performed using the Statistica software (version 5.5) by the analysis of variance method with one classification criterion (ANOVA 1). Hartley's test was used to test the homogeneity of the variances (Dagnelie, 1975). Saville's, 1990 Least Significant Difference (LSD) test was used to assess the differences between treatments for each calculated zoo technical parameter. A probability threshold of 5% was used. The means obtained for each parameter were presented ± the standard deviation.

Results

Survival rates and growth parameters

The survival rate was 100% for the three treatments T0, T1, T2 during this experiment. The experimental diets did not then have a significant impact on the survival rate of the fry used in this study (P>0.05). Mean final fry weights of *O. niloticus* fry ranged from 10.32 ± 2.60g to 11.67 ± 2.52g depending on the treatments (Fig. 1).

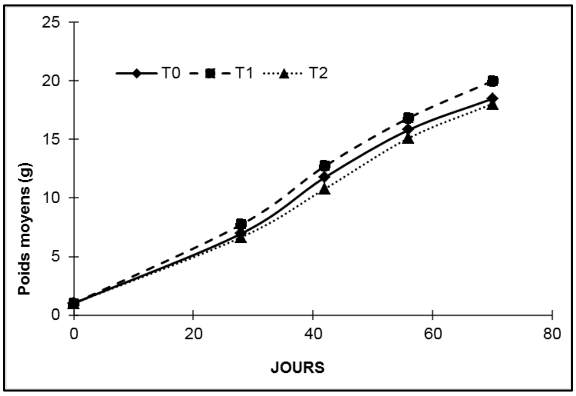

Fig. 1. Variation in mean fry weights as a function of treatment.

Fry fed with the local feed containing 5% dry *S. polyrhiza* had the highest weight growth (11.67 ± 2.52g). On the other hand, fry fed with the mixed feed obtained the lowest average final weight (10.32 ± 2.60g). However, no significant difference was shown between the different final mean weights obtained at the end of this experiment (P>0,05). The analysis in Table 3 shows that *O. niloticus* fry fed the diet containing 5% dry *S. polyrhiza* had the best Average Daily Gains (ADG) and Specific Growth Rate (SGR). The values obtained for these two growth parameters were 0.27 ± 0.07 g/d and 5.63 ± 0.57%/d, respectively. The analysis of variance shows that there are no significant differences in fry ADG and SGR for different treatments (P>0,05).

Table 3. Zootechnical parameters of *O. niloticus* fry as a function of treatment.

Trématent	ADG (g/j)	SGR (%/j)	CI
To	0.24±0.06 a	5.44±0.53 a	1.27±0.31 a
T1	0.27±0.07 a	5.63±0.57 a	1.17±0.30 a
T2	0.23±0.07 a	5.30±0.64 a	1.37±0.41 a

Results were presented ± standard deviation. Values in the same column and sharing the same letter are not significantly different (P > 0.05).

Food utilization parameters

The food utilization parameters during this experiment are presented in Table 3. The Consumption Index (CI) varied between 1.17 ± 0.31 (T1) and 1.37 ± 0.41 (T2). There is no significant difference at the 5% threshold between the CI (P>0,05) obtained for the different treatments applied.

Economic profitability

Table 4 shows the results of an economic study of the production of O. niloticus with the different diets used in this study. The Gross Production Cost of onekg of fish varied from 341.78 FCFA (Q2) to 452.62 FCFA (To). The highest annual production (Kg/ha/year) was obtained in Q1. With a selling price perkg of tilapia (live weight) of 1.500 FCFA on the local market, the sale of the total production harvested with the T1 treatment allows the producer to collect 20.857.410 FCFA. This revenue will enable him to generate a gross profit margin of 10.464.865.28 FCFA. The lowest gross profit margin comes from the batch of fish fed with the To treatment (7.991.440.75 FCFA).

Table 4. Economic Profitability Study.

Headings	To	T1	T2
Gross production cost of onekg of fish (FCFA)	452.62	399.08	341.78
Purchase price of fish (FCFA/year)	3.900.000	3.900.000	3.900.000
Production (kg/ha)	2.465	2.666.7	2.406.7
Annual production (kg/ha/year)	12.853.21	13.904.94	12.549.05
Annual Gross Production Cost (FCFA)	5.817.619.91	5.549.183.45	4.289.014.31
Total amount of feed distributed (kg/year)	16.323.57	16.268.78	17.192.20
Total cost of feed distributed (FCFA/year)	7.388.374.25	6.492.544.72	5.875.950.12
Total selling price of fish (FCFA/year)	19.279.815	20.857.410	18.823.575
Gross profit margin (FCFA/year)	7.991.440.75	10.464.865.28	9.047.624.88

Discussion

Survival rate

The experimental regimens did not significantly influence the survival rates (100%) obtained during this experiment. These results are similar to the 100% obtained by Dibala *et al.,* 2018. However, they are better than those obtained by Fiogbe *et al.,* 2009 which were 86.67 and 97.78% in fry of the same species reared in ponds. These rates are much higher than those of 22.5 to 49.4% and 67.1 to 70.5% respectively obtained by Schouveller, 1996 and Abou, 2007 by feeding tilapia *O. niloticus* with *Azolla* in the pond.

Growth parameters

Growth performance varied according to the treatments. The best Mean Final Weights (MWf), Average Daily Gain (ADG) and Specific Growth Rate (SGR) were obtained with the T1 diet containing 5% *S. polyrhiza* flour.

The highest Average Daily Gain was obtained with the diet containing 5% dry *S. polyrhiza* (0.27 ± 0.07 g/d). This value is higher than those obtained by Fiogbe *et al.,* 2009 and Abou, 2007, who respectively valued dried and fresh *Azolla* in the diet of pond reared *O. niloticus* fry. These authors found ADGs of 0.10 g/d and 0.07 g/d, respectively. Our results are also superior to those observed by Elègbe *et al.,* 2015, who had ADGs ranging from 0.18 ± 0.04g/d to 0.23 ± 0.01g/d. The specific growth rate in this study is higher (5.63 ± 0.57%/d) in the 5% dry *S. polyrhiza* feed than in the other two experimental diets. However, the SGRs obtained with all our treatments are higher than the 1.88±0.03%/d and 0.38%/d observed respectively by Elègbe *et al.,* 2015 and Fiogbe *et al.,* 2009. Fasakin *et al.,* 1999 by substituting 5 or 10% of the fishmeal with that of the leaves of *S. polyrhyza* obtained a SGR equal to 2.4 in the fry of *O. niloticus*. Richter *et al.,* 2003, by incorporating 12% of the *Moringa Oleifera* leaf meal in the feed of *O. niloticus* fry obtained a SGR of 2.4 ± 0.28%. Setlikova and Adamek, 2004, obtained a SGR of 3.18 ± 1.49 by feeding the fry of *O. niloticus* exclusively to plants.

Food utilization parameters

The best consumption index (1.17 ± 0.30) is obtained with feed containing 5% *S. polyrhiza* flour. This result is close to that of Richter *et al.,* 2003 who had an CI of 1.0 ± 1.3 by incorporating 20% *M. oleifera* leaf meal in the feed of *O. niloticus* fry. Our CI is lower than the 4.3 obtained by Fasakin *et al.*,1999 by incorporating more than 20% *S. polyrhiza* meal in the feed of *O. niloticus* fry. Fiogbe *et al.,* 2009 recorded consumption indices between 1.7 and 3.0. Abdelhamid *et al.,* 2012 and Ahmed *et al.,* 2013 also had consumption indices ranging from 2.81 to 4.09 and 1.40 to 1.51, respectively, in valuing unconventional food resources in the feeding of Nile Tilapia fry.

In general, the results of zootechnical parameters (MWf, ADG, SGR and CI) obtained in this study are more interesting than those obtained by several authors who valorized local raw materials in the feeding of Nile Tilapia fry. We can then deduce that our experimental diets are well digested and used by the fish to which they were distributed. The best growth and feed utilization performances were obtained with the diet containing 5% *S.polyrhiza* dry leaf meal. This result is consistent with those observed by Fasakin *et al*., (1999; 2001) who recommend levels of 5-10% in diets for *O. niloticus* fry. Incorporation of duckweed at high levels in fish diets results in lower feed consumption, lower growth and feed utilization parameters (Gaigher *et al.,* 1984; Fasakin *et al.,* 2001; Anthonius *et al.,* 2018; Dorothy *et al.,* 2018). Indeed, *S. polyrhiza* sometimes contains high amounts of calcium oxalate which may limit the consumption of the diets in which it is incorporated (Gizen and Khonder, 1997; Fasakin *et al.,* 1999; Mwale and Gwaze, 2013). Macrophytes often contain anti-nutritional factors such as tannins, phenol, phytates and saponins that give an unpleasant taste to diets containing them (Fasakin *et al.,* 1999; Mwale and Gwaze, 2013). Also, the presence of phytates in food can reduce the bioavailability of minerals, reduce protein digestibility through the formation of phytic acid-protein complexes and damage the cecum pyloricum and decrease nutrient absorption (Francis *et al.,* 2001).

Economic profitability

The cost prices of our experimental diets varied between 356.40 and 249.48 FCFA per kilogram. These prices per kilogram of food are close to the values obtained by Iga-Iga, 2008 for food made from local by-products (410

FCFA/Kg and 192.5 FCFA/Kg). The highest gross profit margins were obtained with T1 and T2 diets containing duckweed (*S. polyrhiza*). This result confirms the work of Fasakin *et al.*, 2001; Chowdlwry *et al.,* 2008, Tabukdar *et al.*, 2012; Cruz - Velasquez *et al.,* 2014 which showed that the incorporation of macrophytes in the diet of tilapia (*O. niloticus*) leads to sustainable production and a significant increase in the economic profitability of the farm.

Conclusion

The results obtained at the end of this experiment show that the duckweed (*Spirodela polyrhyza*) can be valued in the feed without hindering the zoo technical performance of male mono sex fry of *Oreochromis niloticus*. The best zoo technical performance was obtained with T1 (5% *S. polyrhyza* meal). However, economic profitability is higher with diets containing duckweed (meal or fresh). We can then recommend T1 and T2 diets to fish farmers.

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