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Valorization of two sources of maggots in the diet of Nile tilapia *Oreochromis niloticus*

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Abstract
In order to improve the production of Nile tilapia using an economical feed based on black soldier fly maggot flour, a growth performance test was carried out at the Donomade Model Farm over a period of 3 months. In total, 360 Nile tilapia fry with an average weight of 2.41±0.27 g were distributed in 12 hapas of 1m 3 placed in a 100 m² pond at a rate of 30 fish per hapa. They were subjected to four isoprotein diets at 30% crude protein in triplicate. This is A1, a control food without maggot flour; A2, a diet with 15% maggot flour from palm kernel cake; A3, a diet with 15% maggot meal from poultry droppings and AC, a commercial feed (Raanan). Each batch of fish was fed 3 times per day at a rate of 15% to 8% of its biomass from the first to the fourth month of the test. For the total duration of the trial, the survival rate varied from 70.0±3.92% to 84.4±3.20% for batches A1 and A2 respectively. The growth performance of fish was significantly affected by the different diets. The commercial feed gave the best results but the best performance with local feed was obtained in lot A3; i.e., a Daily Weight Gain (DWG) of 0.66±0.04 g/d and a feed efficiency of 2.48±0.14. The economic analysis reveals a positive gross profit margin (1395 CFA francs) for A3 and negative for the other treatments. It appears from this study that the diet A3 seems to present the best quality/price compromise.

Keywords: Food, black soldier fly, *Oreochromis niloticus*, growth, hapa

1. Introduction

In aquaculture, feed represents a significant part of the cost of fish production. In intensive farming systems, this cost can represent or even exceed 50% of total costs because the economic interest of intensive fish production is very dependent on the availability and cost of food (Hishamunda and Ridler, 2006) [11]. Thus, reducing feed-related costs and especially controlling the cost of producing farmed fish is one of the priorities in aquaculture (Kiasotuka *et al*., 2021) [7]. Fish meal is generally the major component of aquaculture feeds and represents 40 to 60% of total protein in feeds formulated for cichlids (Azaza *et al*., 2005) [4]. According to Siddhuraju and Becher (2003) [22], the use of fish meal as the main source of protein in aquaculture feeds is responsible for the high cost of these feeds. Due to its availability as well as the fluctuations in its price on the market, research has been focused on other alternative sources of proteins of animal origin that are cheaper and not usable for human consumption (Jahan *et al*., 2020) [14].

Maggot meal is increasingly used because of its high biological value in breeding animals. Note that black soldier fly meal contains nutrients that improve fish growth (Kenis *et al*., 2014; Dzepe, 2021) [16, 9]. It contains protein which varies between 37.20 and 55%; lipid between 12.52 and 35.5% and ash varying between 7, 15 and 11.65% (Ogunji *et al*., 2008; Ossey *et al*., 2012) [20, 22]. Furthermore, it is an ingredient that can be accessible to producers in order to reduce production costs. But data on the source of substrate for production of this maggot in tilapia are rare (Okore *et al*., 2016) [21]. Hence the importance of carrying out a comparative study of 2 sources of black soldier fly maggots in the diet of this species. Specifically, the aim is to evaluate the effect of these maggot flour in diet on the growth performance of Nile tilapia fries and to carry out the economic analysis of the four diets.

2. Materials and methods

2.1 Materials

2.1.1 Study area

Our trial was carried out at the Donomade Model Farm (FeMoDo); an agro-ecological farm created in 2015 and managed by the Etoile Verte association in partnership with the NGO HAPPY TOGO located in Switzerland. It is located in the Maritime region, 27 km northeast of the town of Tabligbo in Yoto prefecture. It is installed on an area of approximately 6 hectares and located 4 km from the village of Donomade on the edge of the Togodo-sud forest. It enjoys a subequatorial or Guinean climate (southern Togo climate) characterized by 2 rainy seasons (March-July and September-October) and 2 dry seasons (November-February and August).

2.1.2 Biological material

The experiment was carried out on monosex male fry of *Oreochromis niloticus* with an average weight of 2.41±0.27 g. These fish come from the Shalom farm, located in Kovie (Zio Prefecture) in Togo.

2.1.3 Système d'élevage

For this study on feed test, 12 hapas with a capacity of 1 m³ were used. They were attached to bamboo stakes installed at the bottom of the pond of 100 m². The pond is supplied with water by a borehole operating under a solar regime of nine panels which supply the farm with electricity. The solar drilling system transports water from the borehole then stores it in a 5 m3 tank, placed above a castle located approximately 100 m from the water source. The water then goes down through a canal to feed the ponds. The drain channels communicate with a large drainage channel dug behind the ponds. This canal thus drains the water to the market gardening plots. Each happa can support a carrying capacity of 40 kg/m3 of fish (Lingofo Yantalo, 2016) [19].

2.1.4 Expérimental ingredients

Eight ingredients were retained in the case of this work. These are corn, rice bran, roasted soya, black soldier fly maggot mea from palm kernel meal or poultry droppings, fish meal, vitamin mineral concentrate (CMV) and palm oil.

2.2 Methods

2.2.1 Experimental procedure

In order to evaluate the effect of the source of black soldier fly maggot meal on the growth performance of Nile Tilapia, 360 monosexe male *Oreochromis niloticus* fry with an average weight of 2.41±0.27g were used. Upon their arrival, the fries were accustomed to the new rearing conditions for 17 days and then randomly distributed into 12 hapas of 1m3 placed in a pond of 100 m² at a rate of 30 fish per hapa. The fish were subjected to four isoprotein diets with 30% (crude protein. These are AC (commercial fish feed, control), A1 (feed without maggot meal), feed A2 and A3 (based on maggot meal from different sources) as shown in Table 1. The fish were fed using serving spoon three times a day (8 a.m., 12 p.m. and 4 p.m.), every day for three months with the four diets at the rate of 15 to 8% of the fish biomass. The water physicochemical parameters (temperature, pH, dissolved oxygen and transparency) were recorded twice a week and remained within the range of values recommended for the rearing of *O. niloticus*, i.e. respectively 31.5±1.1 °C, 7.9±0.5, 5.3±1.6 mg/L and 40.4 cm (Suresh, 2003; Abdel-Tawwab *et al*., 2014) [24, 1]. Water was completed once a week. Control fishing was carried out every two weeks in order to collect data for the calculation of production parameters (Table 2) and readjust the ration according to the biomass of fish per happa.

2.2.2 Experimental diets

The study was conducted with four iso protein diets with 30% crude protein, one commercial tilapia feed as a control and three locally manufactured feeds according to Adjanke (2018) [2] based on eight (08) ingredients whose composition is presented in Table 1.

Table 1: Composition of local diets per kilogram

Ingredients (g)	Diets		
	A1	**A2**	**A3**
Maize	250	240	240
Maggot meal*	-	150	-
Maggot meal**	-	-	150
Fishmeal	250	180	180
Rice bran	150	200	200
Roasted soybean	300	180	180
Vitamin mineral concentrate	20	20	20
Palm oil	30	30	30
Total	1000	1000	1000
Crude protein	30.5	30.4	30.4

The composition of the commercial feed, Raanan, according to the manufacturer's sheet is 30% crude protein.
* : maggot meal from palm kernel meal, ** : maggot meal from poultry droppings.

2.2.3 Calculated parameters

The data collected during the experiment allowed us to calculate certain parameters in order to evaluate the effectiveness of use of the experimental diets, the growth of the fish and make an economic analysis (Table 2).

Table 2: Production and economic parameters formulas

Production parameters	Formulas
Weight gain (g)	WG = Fw – Iw
Daily weight gain (g/d)	DWG = WG (g)/ Test duration (days)
Food conversion ratio	FCR = D / (Fb + Db – Ib)
Survival rate (%)	S = 100 x (Fn / In)
Economic parameters	**Formulas**
Cost of fish production (FCFA)	CP = Cost price of one kg of feed x FCR
Labour cost (FCFA)	LC = Feeding cost + control fisheries fees
Gross profit (F CFA)	GP = Total product – Total expenses

Iw: Initial weight; Fw: Final weight; D: quantity of feed distributed; Ib: Initial biomass; Db: Dead biomass; Fb: Final biomass; In: Initial number; Fn: Final number

2.2.4 Statistical analyzes
The data collected as well as the calculations carried out were processed using STATISTICA version 5.1 software. Statistical analysis was carried out using the standard method of one-way analysis of variance (ANOVA I). Fischer's LSD test was used to compare the means at the 5% significance level.

3. Results and Discussion
3.1 Results
The results of the growth performance of *Oreochromis niloticus* obtained during this experiment are presented in Tables 3 and 4. They concern growth parameters (Table 3) such as survival, feed utilisation and fish growth, and economic parameters (Table 4) like cost of fish production, labour cost and gross profit.

Table 3: Growth performance of *O. niloticus* according to treatments

Variables	Treatments			
	A1	**A2**	**A3**	**AC**
Iaw (g)	2,41±0,34ª	2,42±0,13ª	2,39±0,32ª	2,43±0,27ª
Faw(g)	44,57±2, 09ᵇ	44,31±0,43ᵇ	58,20±3,36ª	60,16±2,49ª
WG (g)	42,16±2, 08ᵇ	41,89±0,40ᵇ	55,81±1,02ª	57,73±1,56ª
DWG (g/d)	0,50±0, 02b	0,50±0,02b	0,66±0,04a	0,68±0,03a
FCR	3,04±0, 05a	3,01±0,04a	2,48±0,14b	2,26±0,04c
S (%)	70,00±3, 92c	84,44±3,20a	81,11±0,33a	77,78±1,92b

A1, A2, A3 and AC: batches of fish fed with diet A1, A2, A3 and commercial Raanan feed respectively. Iaw: initial average weight; Faw: final average weight; WG: weight gain; DWG: daily weight gain; FCR: feed conversion ratio; S: survival rate. Different letters in the same row of the table indicate a significant difference between treatments ($p<0.05$).

3.3.1 Survival
The average survival rate at the end of the experiment was between 70.00% and 84.44%. This rate was high in batches A2 and A3 and relatively low in batches A1 and AC. Statistical analysis shows a significant difference between the survival rate of the different treatments ($p<0.05$).

3.3.2 Use of feed
The use of food is characterized by the food conversion ratio whose values varied between 2.26 (AC) and 3.04 (A1). We note that the feed was poorly converted by the batches having received the A1 and A2 treatments compared to the batches A3 and AC with a significant difference between the different batches ($p<0.05$).

3.3.3 Fish Growth
After 84 days of rearing, the final average weights obtained varied from 13 to 38 g (Figure 1). Nevertheless, growth was effective in all batches. It was similar in all batches from start-up until the 14th day of the study ($p>0.05$). However, from the 14th day until the end of the experiment, the fish from batches A1 and A2 showed a delay in growth compared to those from batches A3 and AC. A significant difference is observed between batches A3 and AC ($p<0.05$), unlike batches A1 and A2 where the difference is not significant at the end of the experiment ($p>0.05$).
Daily weight gain (DWG) varied from 0.50 to 0.68 g/d. We note that the fish from batches A1 and A2 gained less daily than those from batches A3 and AC, with a significant difference between these two groups ($p<0.05$).

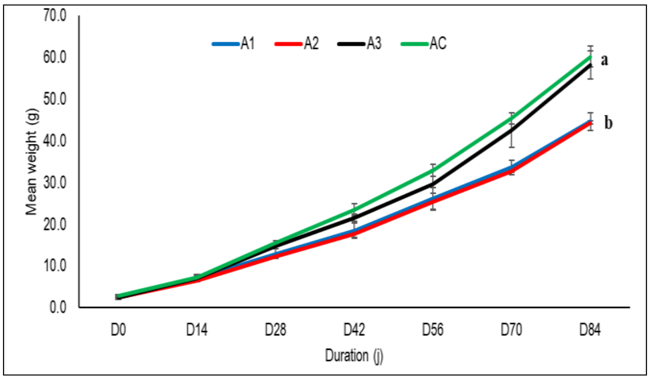

Fig 1: Weight evolution of *O. niloticus* batches fed different diets.

A1, A2, A3 and AC: batches of fish fed with diet A1, A2, A3 and commercial Raanan feed respectively. Curves with the same letter are not significantly different (P>0.05).

3.1.4 Economic analyzes
3.1.4.1- Estimation of one kg of feed and fish cost
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 feed cost to produce one kg of fish was estimated by multiplying the price per kg of food by the consumption index. Producing a kilogram of fish with A2 and AC feeds costs more than with A1 and A3 feeds (Table 4).

3.1.4.2- Evaluation of the Gross Profit Margin (MMB) of the plans used
The MBB is what remains in the business after deducting total expenses from Total Income. Negative ones indicate that there has been a loss at this level and that the food is therefore not beneficial; on the contrary, positive MMBs indicate profitable foods.

Table 4: Estimation of Gross Profit (GP)

Headings		Treatments			
		A1	**A2**	**A3**	**AC**
Biomass produced (kg)		2,8	3,36	4,26	4,21
Price per kilogram of fish (FCFA)		2000	2000	2000	2000
Production value (FCFA)		5600	6720	8520	8420
Total product (FCFA)		5600	6720	8520	8420
Quantity of food distributed (kg)		8,84	9,88	10,59	9,49
Cost of one kg of food (FCFA)		412,75	465,1	465,1	1000
Labour (FCFA)	Feeding	700	700	700	700
	Control fishing	1500	1500	1500	1500
Total charges (FCFA)		5848,71	6795,19	7125,41	11690
Gross Profit (FCFA)		-248,71	-75,19	1394,59	-3270

3.2 Discussions
For the total duration of the experiment, the average survival rate obtained varied from 70.0±3.92 to 84.4±3.20%. These values are lower than those obtained by Daudpota *et al.* (2016) [8] in an above-ground tank (100%); however, they are comparable to those obtained by INSTM (2009) [12] (68-84%) in geothermal waters and are even higher than those obtained by CTA (2015) [7] (49.64%) in fresh waters. The differences between the results obtained in the present study and those found by these different researchers can be explained by the difference in ecological conditions, the state of the experimental equipment and the rearing structures used during the experiment. The few deaths recorded during the test occurred one or two days after handling during control

fishing and after rains accompanied by high winds. Mortality would therefore be due to the stress caused during handling, to high turbidity caused during control fishing and to thermal stress due to the sudden change in temperature following the mixing of wind and rain in the pond. We can therefore consider that our results are within the accepted norm.

Furthermore, the highest final average weights observed in the fish were 58.20±3.36 g and 60.16±2.49 g, these results are comparable to that obtained by Camara (53.24 g) in 2008 in the Senegal River. The highest DWG, respectively 0.66±0.04 g/d and 0.68±0.03 g/d, are higher than those of Avit *et al*. in 2014 (0.50 g/d) in a pond in the same species. The different growth observed between the various batches would therefore be linked to the nature of the ingredients used as highlighted by Burel *et al*. (2000) [5]. Indeed, with regard to the biochemical composition of the foods and considering that none of the foods tested apparently have a repellent character (unpalatability), the difference in growth observed between the different batches could be linked to a difference in digestibility and assimilation which are functions of the nature of the ingredients used as highlighted by Köprücü and Özdemir (2005) [18]. In the same vein, Kaushik *et al*. (1993) [15] point out that the incorporation of plant proteins, which may present amino acid deficiencies for fish or even antinutritional factors, can modify digestibility. Also the metabolic utilization of nutrients may be affected; which can lead to poorer performance.

The use of conventional ingredients in the development of dry foods for Nile tilapia allowed Azaza *et al*. (2005) [4] in the geothermal waters of southern Tunisia to record TCAs of between 1.96 and 1.49; the CTA, for its part, recorded a TCA of 1.32 in 2015. These values turned out to be more interesting than ours, between 2.26±0.04 and 3.04±0.05; our diets would be less valued due to the higher temperature in our ponds.

The economic analysis of the production results obtained at the end of the trial shows that the commercial feed, that without maggot flour and that with 15% maggot flour from palm kernel cake are not profitable (negative MMB) compared to the food with 15% maggot meal from very beneficial poultry droppings (1394.591F). This demonstrates the economic interest in using the latter rather than the first 3 foods; because in fact, the fish seem to make the most of it while maintaining their growth performance at an average level. In addition, this analysis corroborates the studies of Iga-Iga (2008) [13] in Gabon which demonstrated that food made from local ingredients was the most interesting in terms of quality/price ratio compared to the manufactured control food; because according to the author, the best food is that which best covers the nutritional needs of the animal at the lowest cost and which optimizes economic results.

4. Conclusion

From the result of our investigation we can advise any entrepreneur wishing to engage in a fish farming activity with the aim of making his production profitable could adopt for Nile tilapia a diet based on poultry droppings black soldier fly maggot flour at a rate greater than or equal to 15%, because it is the most beneficial of the 4 diets.

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