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SUBSTITUTION OF THE FISH MEAL BY MAGGOT MEAL IN THE FEED OF NILE TILAPIA *OREOCHROMIS NILOTICUS* AT DIFFERENT STAGES OF GROWTH

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ABSTRACT: *The present study was conducted to evaluate the use of maggot meal as a protein source in the place of fish meal to feed tilapia Oreochromis niloticus at different stages of growth. The average weight for larval stage (ST1) was 20 ± 4 mg and those of juvenile stage (ST2) and adult stage (ST3) were ranged respectively from 0.62-0.75 g and 20-29 g. The control diet (fish diet [FD]) and the commercial diet (CD) were used to compare the test diet (maggot diet [MD]). The fish were fed four times daily to triplicate groups at 30-20% body weight for consecutive 30 days for ST1 and at 10-7% body weight for consecutive 90 days for ST2. Concerning the adult stage, fish were fed twice times daily to duplicate groups at 5-2% body weight for consecutive 180 days. After this days, fish fed with MD had the highest ($p \leq 0.05$) mean daily gain (ADG) (24.33 ± 10 mg.day^{-1}, 0.3 ± 0.03 g.day^{-1} and 1.80 ± 0.83 g.days^{-1} respectively ST1, ST2 and ST3) compare to those obtained by fish fed FD (22.9 ± 20 mg.day^{-1}, 0.22 ± 0.18 g.day^{-1} and 1.59 ± 0.79 g.days^{-1} respectively ST1, ST2 and ST3). Therefore, the fish fed with CD had the lowest ($p \leq 0.05$) ADG (20.2 ± 10 mg.days^{-1}, 0.19 ± 0.12 g.day^{-1} and 1.47 ± 0.86 g.days^{-1} respectively ST1, ST2 and ST3) than those obtained by FD. The specific growth rate (SGR), feed conversion ratio (FCR), survival rate (SR), the production cost of 1 kg of fish (PC) and the carcass chemicals composition were evaluated. In conclusion, these results of this study indicate the possibility of completely using maggot meal as a source protein in the diet of Oreochromis niloticus at different stage of growth to increase the growth of this specie and reduce the cost of 1 kg of fish produced.*

KEYWORDS: Nil tilapia, maggot feeds, zootechnic and economics parameters

INTRODUCTION

Recent data from FAO (2018) indicate global human consumption of capture and aquaculture fish that more than duplicated between 1961 and 2016, from 60 to 171 million tones. According to the same source, consumption was progressed from 9.0 kg to 20.3 kg per year per inhabitant. In Ivory Coast, fish remains the primary source of animal protein, with an estimated national consumption of 278,463 tons / year for an annual production of about 43,000 tons, including fisheries and aquaculture (FAO, 2008). Every year, the state imports nearly 268,000 tons of fish products, more than 80% of the needs, worth more than 52 billion FCFA to cover the animal protein needs of the Ivorian population. It is therefore imperative to develop aquaculture in our countries to allow greater access to this protein very popular with the population. However, the difficulty in fish farming in developing countries is due in particular to cost of the feed very

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expensive. Fish feed in aquaculture is becoming more expensive because of the high cost of fishmeal used as the main source of protein. Fishmeal is increasingly expensive (current prices on the market, 300 to 700 F.CFA/kg) and fish feed represents more than 50% of the cost of production on farms (FAO, 2014, Coyle *et al*., 2004). It is therefore necessary to find other sources of protein in order to limit the dependence of aquaculture on fishmeal (Burel and Médale, 2014). In developing countries, the inaccessibility of fish feed is a source of abandonment of fish farming activity by small-scale fish farmers, most of them. Numerous studies have been conducted to replace or reduce the level of inclusion of fishmeal and to identify promising alternative sources of protein in aquaculture feeds. These protein sources include plant proteins (Koumi *et al*., 2009; Suarez *et al*., 2013, Bamba *et al*., 2017) and animal protein sources (Bai *et al*., 1998; Achi *et al*., 2017). However, less attention has been paid to the use of unconventional protein sources, which are promising feeds such as insect larva (maggot) meal in fish feed formulation. In recent years, considerable research has shed light on the effectiveness of these ingredients in the diet of several aquaculture species (Ogunji *et al*., 2008, Katya *et al*., 2017). The crude protein, crude lipid and essential amino acid content of insect larval flours resembles that of fishmeal. The crude protein content of maggots is around 40 to 64% (Aniebo *et al*., 2009, John, 2015). However, recent research has shown that growth stimulation in some cases is observed at less than 50% substitution for maggots (Ezewudo *et al*., 2015). According to these same authors, the total substitution of fishmeal by this protein sources has not yet given satisfactory results in terms of growth performance of fish. This work is therefore intended to evaluate growth, feed use, economic value, and carcass composition of tilapia *Oreochromis niloticus* fed with feed containing maggot meal as a substitute of fish meal in the feed at different stage of growth of this species.

MATERIALS AND METHODS

Experimental diets

Proportion (%) of ingredients used in the composition of experimental diets is shown in Table 1. Two practical diets containing 40%, 30% and 28% crude protein at the larval, juvenile and adult stages respectively were formulated with fish meal and domestic fly meal as the main sources of protein. Fishmeal being replaced totally with housefly maggots. These ingredients were included in diet at the level 18-20%. An industrial commercial diet used as the reference was purchased in local markets of Abidjan. The proximate composition and cost of experimental diets and the commercial diet (CD) are shown in Table 2. Crude protein content of the commercial diet (CD) used at different stage is 34.5% (larval stage) and 29.5% (juvenile and adult stages). Housefly maggots used were produced in Ivory Coast from poultry droppings, pig manure and waste from fish evisceration following the description of Mpoame *et al*. (2004). The collected maggots were killed in hot water, oven dried at 70 °C for 24 h and ground into powder to obtain maggot meal. The two formulated diets were designated as MD (diet containing maggot meal) and FD (diet containing fishmeal). All diets were prepared according to the method of Bamba *et al.* (2014). In addition, the three different stages of growth of *Oreochromis niloticus* were designated as ST1 (Larval stage), ST2 (Juvenile stage) and ST3 (Male adult stage)

Table 1: Proportion (%) of ingredients used in formulated diets (FD and MD) at different stages of growth of *Oreochromis niloticus*

Ingredients (%)	Diets					
	ST1		ST2		ST3	
	FD	MD	FD	MD	FD	MD
Corn flour	8	5	26	20	29	20
Soybean meal	45	54	14	20	8	14
Cotton meal	14	14	10	15	10	15
Copra meal	6.5	4	20	17	17	17
Wheat bran	3.5	3	7	5	13	10
Fishmeal	20	--	20	--	20	--
Maggot meal	--	18	--	20	--	20
Palm oil	2	1	2	2	2	2
Premix[1]	0.25	0.25	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.1	0.1	0.1	0.1
Seashell flour	0.35	0.35	0.55	0.55	0.55	0.55
Lysine	0.05	0.05	0.05	0.05	0.05	0.05
Methionine	0.05	0.05	0.05	0.05	0.05	0.05
Total	100	100	100	100	100	100

FD = Fish Diet and MD = Maggot Diet
-- = Absents Ingredients.
***[1]Composition for 2.5 kg of premix**; Vitamins A=10 000 000 UI; Vitamins D3 = 2 000 000 UI ; Vitamins E= 6 000 mg ; Vitamins K3= 1500 mg ; Vitamins B1=500 mg ; Vitamins B2=1500 mg; Vitamins B6 = 800 mg Vitamins B12 = 5 mg ; Vitamins B9 = 1500 mg; Vitamins B3 = 8000 mg; Vitamins C = 10 000 mg ; Choline Chloride = 100 000 mg; Manganese = 60 000 mg; Cobalt = 100 mg; Zinc = 40000 mg; Selenium = 100 mg; Iodine = 500 g; Copper = 3000 mg; Iron = 40 000 mg; Antioxidant = 30000 mg.*
FD = Fish Diet, MD = Maggot Diet and CD= Commercial diet. ST1= Larval stage, ST2 = Juvenile stage, ST3 = Adult stage

Table 2: Proximate composition (%Dry matter) and cost of experimental diets at different stages of growth of *Oreochromis niloticus*

Component	Diets								
	ST1			ST2			ST3		
	FD	MD	CD	FD	MD	CD	FD	MD	CD
M	8.88	10.32	12.08	9.52	8.88	9.33	8.71	8.69	9.33
CP	39.81	39.62	34.5	30	30	29.5	28.10	28.10	29.5
Ash	10.51	7.6	12.42	7.1	5.74	7.3	6.53	5.52	7.3
CL	4.76	6.17	4.38	5.28	9.48	5.71	5.43	8.64	5.71
CF	5.37	5.45	6.2	5.82	6.18	6.1	5.52	6.29	6.1
NFE	30.67	30.83	30.42	42.28	39.72	42.06	45.72	42.8	42.06
GE ($kJ.g^{-1}$)	15.96	16.49	14.59	16.20	17.17	16.00	16.21	16.95	16.00
CF (FCFA. Kg^{-1})	400	296	310	309	207	300	293	188	300

M = Moisture, CP = Crude protein, CL = Crude lipid, CF= Crude fiber, NFE = Nitrogen free extract
Nitrogen free extract (NFE) = 100 – (% Moisture + % Protein+ % Ash +% Lipid + % Fiber)
GE= Gross Energy = 22.2 × % Protein + 38.9 × % Lipid + 17. 2 × % Nitrogen free extract (Luquet and Moreau, 1992), CF = Cost of feed
Price in CFA pound: 100 CFA= 0.18 $ based on 2017 exchange prices in Ivory Coast

Experimental condition and fish feeding

-Larval stage

The nutrition trial was carried out at the Blondey aquaculture station (5°6, N, 4°5, W), Ivory Coast. A total of 10500 of *Oreochromis niloticus* larvae were produced by placing 120 mature female and 60 mature male fish together in eight spawning hapas for 21 days. The 10500 fish averaging 20±4 mg were randomly distributed in fifteen hapas. The stocking density used was 700 larvae per hapa (2 cm × 1 cm × 0.75 cm). The feeding experiment was for a period of 30 days. Three hapas installed into concrete tank were then randomly assigned to each of three experimental diets. Fish were fed the experimental diets four times daily (08:00, 11:00; 14:00 and 17:00 hour) at 30% of wet body weight/day at the beginning and 20% of wet body weight/day at the end of the feeding trial for 2 weeks. At 2 weeks intervals, about 25% of the fish population in each hapas were randomly sampled, batch weighed. The average weight of the fish sampled in each hapa was determined and the amount of feed provided to the fish was adjusted accordingly. Wet weight was measured on an electronic digital balance SARTORIUS L 6200 S (accuracy of ± 0.001 g). At the end of the feeding period, all experimental hapas were emptied and fish in each hapas counted to determine fish survival. Additionally, one hundred and twenty (120) fish were randomly sampled per diet (fourty fish per hapa) to evaluate the chemical composition of fish body carcass.

-Juvenile stage

The fish used for this experiment come from the experience of the larval phase which lasted 30 days at the Blondey Aquaculture Station (5°6, N, 4°5, W), Ivory Coast. At the end of this larval phase, 3600 fish of averaging weight 0.75 ± 1.93, 0.70 ± 3.55 and 0.62 ± 2.52 g respectively for MD, FD and CD were randomly distributed in 12 hapas for this present experience. The stocking density used was 400 juveniles per hapa (2 cm × 1 cm × 0.75 cm). The feeding experiment was for a period of 90 days. Three hapas installed into pond were then randomly assigned to each of three experimental diets. During this juvenile phase, the fish received feed containing 30% crude protein. These are the feed based on maggot meal, and fishmeal (control diet). The commercial diet used as the reference at the same juvenile contained 29.5% crude protein. Fish were fed the experimental diets four times daily (08:00, 11:00; 14:00 and 17:00 hour) at 10% of wet body weight/day at the beginning and 7% of wet body weight/day at the end of the feeding trial for 1 months. At 1 month intervals, about 25% of the fish population in each hapa were randomly sampled, batch weighed. The average weight of the fish sampled in each hapa was determined and the amount of feed provided to the fish was adjusted accordingly. Wet weight was measured on an electronic digital balance SARTORIUS L 6200 S (accuracy of ± 0.001 g). At the end of the feeding period, all experimental hapas were emptied and fish in each hapas counted to determine fish survival. Additionally, ninety (90) fish were randomly sampled per diet (thirty fish per hapa) to evaluate the chemical composition of fish body carcass.

- Adult stage

The fish used for this experiment come from the experience of the juvenile phase which lasted 90 days at the Blondey Aquaculture Station (5°6, N, 4°5, W), Ivory Coast. At the end of this juvenile phase, a manual sexing was done and 720 male fish of weight averaging 24.65 ± 5,15, 29.88 ± 5.88 and 20.33 ± 3.84 g respectively for FD, MD and CD were randomly distributed in 6 hapas for this present experimentation. The stocking density used was 120 male fish per hapa (5 cm × 4 cm × 0.75 cm). Two hapas installed into pond were then randomly assigned to each of tree experimental diets. During this adult stage, the fish received feed containing 28 % crude

protein. These are the feed based on maggot meal and fishmeal (control diet). The commercial diet used as the reference at the same juvenile stage contained 29.5% crude protein. Fish were fed the experimental diets three times daily (08:00, 12:00; and 17:00 hour) during 180 days at 5% of wet body weight/day at the beginning and 2% of wet body weight/day at the end of the feeding trial for 1 months. At 1 month intervals, all the fish population in each hapa were randomly sampled, batch weighed. The average weight of the fish sampled in each hapa was determined and the amount of feed provided to the fish was adjusted accordingly. Wet weight was measured on an electronic digital balance SARTORIUS L 6200 S (accuracy of ± 0.001 g). At the end of the feeding period, all experimental hapas were emptied and fish in each hapas counted to determine fish survival. Additionally, Twenty (20) fish were randomly sampled per diet (ten fish per hapa) to evaluate the chemical composition of fish body carcass

Analytical methods

The feed ingredients, experimental diets and fish samples were analyzed according to AOAC (1990) for dry matter, crude protein, crude lipid, crude fiber, nitrogen free extract (NFE) and ash. The gross energy contents of the diets and fish samples were calculated using factors of 22.22, 38.9 and 17.2 $kJ.g^{-1}$ of protein, lipid and nitrogen free extract respectively (Luquet and Moreau, 1992).

Measurement of growth performance, feeds utilization parameters and economic values

Weight Gain (WG) = final fish weight (g) – initial fish weight (g).
Average daily Gain (ADG) = Gain (g) / time (days).
Feed conversion ratio (FCR) = Feed intake (g) / Weight Gain (g).
Protein efficiency ratio (PER) = Weight gain (g) / Protein intake (g).
Survival Ratio (SR %) = (Final fish / initial fish) × 100.
Specific Growth Rate (SGR %) = [(LnFW-LnIW) × 100] / time (days).
Where FW is the final weight of fish, IW is the initial weight of fish and Ln is natural log.
Feed Used (FU) (kg) = Daily ration (kg) x rearing time (days).
Cost of Feed Used (CFU) (F.CFA) = Feed Used (kg) × CF (F.CFA).
Where CF is the cost of 1 kg of feed.
Production Cost (PC) (F.CFA)/kg fish produced = Cost of Feed Used / Weight Gain (kg).
Reduction Rate (RxR CF) of kg of tested feed compared to control feed (%) = [(Cost of 1 kg control feed – Cost of 1 kg tested feed) ×100] / Cost of 1 kg control feed.
Reduction rate (RxR PC) of feed cost to produce 1 kg of fish (%) = [(feed cost to produce 1 kg control fish – feed cost to produce 1 kg tested fish) x 100] / feed cost to produce 1 k g control fish.

Water quality parameters

Water quality parameters were monitored during rearing period. Water temperature, dissolved oxygen, and pH were measured daily 08:00 hour using YSI 6920 V2. Nitrate, nitrite, ammonium and phosphorus were measured once twice in month using HACH DR/2000 spectrophotometer by the method of Golterman *et al*. (1978). The mean data of physicochemical parameters of water measured in the hapas were showed in Table 3.

Statistical Analysis

Results were presented as mean ± SD (standard deviation) for three or two replicates. The statistical analyses were carried out using one-way analysis of variance (ANOVA). The Tukey's multiple range test and Duncan's multiple-range test were used to compare differences

among treatment means. Treatment effects were considered significant at $P \leq 0.05$. The analyses were performed using Statistica 7.1 software

RESULTS

Physicochemical parameters of water

Water quality characteristics monitored throughout the study period at different stages are summarized in Table 3. As concerning the larval stages (ST1), the water temperature ranged from 27.3 ± 0.8 (MD) to 27.9 ± 0.7°C (CD), pH from 6.5 ± 0.04 (CD) to 6.9 ± 0.06 (FD). Dissolved oxygen from 8.5 ± 0.52 (CD) to 9.22 ± 0.51mg.L^{-1} (MD). There were no significant differences ($p > 0.05$) in the water quality parameters among the treatment during the whole experimental period at larval stage. As for the juvenile stage, there were no significant differences ($p > 0.05$) in the water temperature, pH and dissolved oxygen among the treatment during the whole experimental period. The water temperature ranged from 28.8 ± 0.5 (CD) to 29.3 ± 0.6°C (MD), pH from 6.6 ± 0.08 (FD) to 6.9 ± 0.05 (CD). Dissolved oxygen ranged from 7.6 ± 0.33 (FD) to 7.77 ± 0.37 mg.L^{-1} (CD). During the Adult stage, the water temperature ranged from 27.5 ± 0.6 (FD) to 28.7 ± 0.5 °C (CD), pH from 6.5 ± 0.03 (FD) to 7.2 ± 0.02 (MD). Dissolved oxygen from 8.09 ± 0.43 (FD) to 8.22 ± 0.51 mg.L^{-1} (MD). Therefore, there were no significant differences ($p > 0.05$) in the water quality parameters among the treatment during this stage.

Table 3: Physicochemical parameters of water

Stages	Parameters	Diets		
		FD	MD	CD
ST1	T (°C)	27.8 ± 0.7[a]	27.3 ± 0.8[a]	27.9 ± 0.7[a]
	pH	6.9 ± 0.06[a]	6.8 ± 0.04[a]	6.5 ± 0.04[a]
	O_2 (mg.L^{-1})	9.09 ± 0.43[a]	9.22 ± 0.51[a]	8.5 ± 0.52[a]
ST2	T (°C)	29.1 ± 0.5[a]	29.3 ± 0.6[a]	28.8 ± 0.5[a]
	pH	6.6 ± 0.08[a]	6.8 ± 0.07[a]	6.9 ± 0.05[a]
	O_2 (mg.L^{-1})	7.6 ± 0.33[a]	7.60 ± 0.42[a]	7.77 ± 0.37[a]
ST3	T (°C)	27.5 ± 0.6[a]	28.4 ± 0.7[a]	28.7 ± 0.5[a]
	pH	6.5 ± 0.03[a]	7.2 ± 0.02[a]	6.7 ± 0.03[a]
	O_2 (mg.L^{-1})	8.09 ± 0.43[a]	8.22 ± 0.51[a]	8.3 ± 0.52[a]

Each value is the mean ± Standard deviation. Means with the same letters in the same row are not significantly different (P>0.05). ANOVA and HSD Tukey's multiple test.
FD = Fish Diet, MD = Maggot Diet and CD = Commercial Diet.
ST1= Larval stage, ST2 = Juvenile stage, ST3 = Adult stage

Nutrient profile of protein ingredients

The proximate compositions of fishmeal, maggot meal, soybean meal, cotton meal, copra meal, corn flour and wheat bran meal used as the major protein ingredients in this study were presented in Table 4. The crude protein content was found to be highest for fishmeal followed by soybean meal, cotton meal, and maggot meal respectively. On the other hand, crude lipid was recorded to be highest for maggot meal followed by copra meal, fishmeal and soybean meal respectively. Whereas, copra meal and cotton meal exhibited higher fiber content compared to others ingredients meal. As for the ash concentration of the ingredients, the high values were observed in fishmeal followed by maggot meal compared to other ingredients.

Table 4: Analyzed nutrient composition (% Dry Matter) of protein ingredients

Parameters	Diets						
	FM	**MM**	**CF**	**SM**	**CM**	**COM**	**WB**
M (%)	7.8	8.99	10.05	11.88	6.99	8.24	10.79
Ash (%)	18	10.12	1.57	6.1	5.6	6.05	4.6
CP (%)	56	40.34	11.8	45	41.56	21	15.3
CL (%)	5.76	25	3.62	5.11	2.04	6.95	2.88
Fiber (%)	0	2	1	3	11	16	9
NFE (%)	12.44	13.55	71.96	28.91	32.81	41.76	57.43

Values are average from duplicate groups of samples.
FM= Fishmeal, MM= Maggot meal, CF= Corn flour, SM= Soybean meal, CM= Cotton meal, COM= Copra meal, WB= Wheat bran, M = Moisture, CP = Crude protein, CL = Crude lipid, NFE = Nitrogen free extract
Nitrogen free extract (NFE) = 100 – (% Moisture + % Protein+ % Ash +% Lipid + % Fiber) [18].

Growth performance and feed utilization at different stages

- Larval stage
Significant effects ($p \leq 0.05$) of the dietary total replacement of fish meal with maggot meal, on the growth performance of *Oreochromis niloticus* larvae (ST1) were observed (Table 5). Use of maggot meal in fish feed gave similar values (FW and SGR) to those obtained by FD at larval stage. These values ranged from 707± 237 (FD) to 750 ± 168 mg (MD) for FW and from 11.88 ± 2.7 (FD) to 12.08 ± 2.08%.day^{-1} (MD) for SGR. These values were no significant differences with those obtained by the fish fed with CD for SGR. However, fish fed with MD obtained the highest ($p \leq 0.05$) ADG (24.33 ± 10 mg.day^{-1}) compared to those obtained by FD (22.9 ± 20 mg.day^{-1}). Concerning, survival rate (SR), feed conversion ratio (FCR) and protein efficiency ratio (PER), they were similar ($p > 0.05$) for all diets at larval stage.

-Juvenile stage
As for the juvenile stage, significant effects ($p \leq 0.05$) of the dietary total replacement of fish meal with maggot meal, on the growth performance of *Oreochromis niloticus* were observed (Table 6). Use of maggot meal in the fish feed gave higher final weight (FW) and average daily gain (ADG) than fish diet (FD) and commercial diet (CD). These values were 27.64 ± 7.02 g (MD) and 0.3 ± 0.03 g.day^{-1} (MD) for FW and ADG respectively. Interestingly, *Oreochromis niloticus* juveniles fed with FD and CD showed no significant differences ($p > 0.05$) between the FW and ADG. These values ranged from 17.28 ± 3.56 (CD) to 20.82 ± 4.71 g (FD) for FW and ADG from 0.19 ± 0.12 (CD) to 0.22 ± 0.18 g.day^{-1} (FD). Survival rate (SR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were similar ($p > 0.05$) for all diets.

-Adult stage
Concerning adult stage, significant effects ($p \leq 0.05$) of the dietary total replacement of fish meal with maggot meal on the growth performance of *Oreochromis niloticus* male were observed (Table 7). Use the maggot meal in fish feed gave higher ($p \leq 0.05$) final weight (FW) followed by fish fed with fishmeal. *Oreochromis niloticus* male fed with commercial diet got the lowest FW compared to that of fish fed with fish diet. No significant difference observed between ADG when fish fed with MD and FD. These values ranged from 1.59 ± 0.79 (FD) to

1.80 ± 0.83 g.day^{-1} (MD). The lowest value are obtained among fish fed with CD (1.47 ± 0.86 g.day^{-1}). Survival rate (SR), specific growth rate (SGR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were similar (p> 0.05) for all diets.

Table 5: **Growth performance, survival rate, feed conversion ratio and protein efficiency ratio at larval stage (ST1)**

Parameters	Diets		
	FD	**MD**	**CD**
SR (%)	96.23 ± 2.26^{a}	96.34 ± 1.79^{a}	94.85 ± 1.08^{a}
IW (mg)	20 ± 4^{a}	20 ± 4^{a}	20 ± 4^{a}
FW (mg)	707± 237^{cd}	750 ±168^{d}	626 ± 191^{ab}
WG (mg)	687 ±53^{d}	730 ±35^{d}	606 ±38^{d}
ADG (mg.day^{-1})	22.9 ± 20^{c}	24.33 ± 10^{d}	20.2 ± 10^{b}
SGR (%.day^{-1})	11.88 ± 2.7^{b}	12.08 ± 2.08^{b}	11.48 ± 0.28^{ab}
FCR	0.60 ± 0.56^{a}	0.57 ± 0.26^{a}	0.69 ± 0.25^{a}
PER	4.2 ± 1.3^{a}	4.37 ±1.2^{a}	4.15 ± 1.17^{a}

Each value is the mean ± Standard deviation. Means has the different letters in the same row are significantly different at p ≤ 0.05. ANOVA and Tukey's multiple test

Table 6: **Growth performance, survival rate, feed conversion ratio and protein efficiency ratio at juvenile stage (ST2)**

Parameters	Diets		
	FD	**MD**	**CD**
SR (%)	88.95 ± 5.6^{a}	88.5 ± 4.3^{a}	89.41 ± 4.7^{a}
IW (g)	0.71 ± 3.55^{b}	0.75 ± 1.93^{b}	0.62 ± 2.52^{a}
FW (g)	20.82 ± 4.71^{b}	27.64 ± 7.02^{c}	17.28 ± 3.56^{b}
WG (g)	20.11 ± 3.31^{b}	26.89 ± 5.11^{c}	16.66 ± 2.73^{b}
ADG (g.day^{-1})	0.22 ± 0.18^{b}	0.30 ± 0.03^{c}	0.19 ± 0.12^{b}
SGR (%.day^{-1})	3.75 ± 0.33^{a}	4.01 ± 0.09^{a}	3.69 ± 0.28^{a}
FCR	1.61 ± 0.66^{a}	1.47 ± 0.43^{a}	1.64 ± 0.45^{a}
PER	2.07 ± 0.48^{a}	2.26 ± 0.42^{a}	2.03 ± 0.38^{a}

Each value is the mean ± Standard deviation. Means has the different letters in the same row are significantly different at p ≤ 0.05. ANOVA and Tukey's multiple tests

Table 7: **Growth performance, survival rate, feed conversion ratio and protein efficiency ratio at adult stage (ST3)**

Parameters	Diets		
	FD	**MD**	**CD**
SR (%)	100 ± 0,00	100± 0,00	100± 0,00
IW (g)	24.65 ± 5,15^{ab}	29.88 ± 5.88^{b}	20.33 ± 3.84^{a}
FW (g)	310.4 ± 23.19^{a}	354.31 ± 21.9^{b}	284.43 ± 21.11^{a}
WG (g)	285.75 ± 23.01^{a}	324.43 ± 21.2^{b}	264.1 ± 21.4^{a}
ADG (g.day^{-1})	1.59 ± 0.79^{ab}	1.80 ± 0.03^{b}	1.47 ± 0.12^{a}
SGR (%.day^{-1})	1.41 ± 0.33^{a}	1.40 ± 0.09^{a}	1.46 ± 0.28^{a}
FCR	1.50 ± 0.14^{a}	1.51 ± 0.17^{a}	1.45 ± 0.19^{a}
PER	2.26 ± 0.21^{a}	2.36 ± 0.25^{a}	2.34 ± 0.3^{a}

Each value is the mean ± Standard deviation. Means has the different letters in the same row are significantly different at p ≤ 0.05. ANOVA and Tukey's multiple tests

Chemical composition of body carcass at different stages

The carcass chemical composition of *Oreochromis niloticus* at the end of feeding experiments of each stage is presented in Table 8.

-Larval stage

No significant differences were found in the carcass moisture content and ash of fish fed different experimental diets. In contrast, crude protein, crude lipid content were significantly affected by experimental treatment ($p \leq 0.05$). The carcass protein content was higher in fish fed MD (14.02 ± 0.15%) compared fish group fed FD and CD. The crude lipid content ranged from 10.73 ± 0.11 (FD) to11.76 ± 0.10 % (MD) and gross energy content ranged from 7.29 ± 0.08 (FD) to 7.68 ± 0.08 $kJ.g^{-1}$ (MD). No significant differences were found in the carcass crude lipid and carcass gross energy content from one diet to another.

-Juvenile stage

There are no significant differences were found in the carcass moisture content of fish fed different experimental diets. In contrast, crude protein content were significantly affected by experimental treatment ($p \leq 0.05$). The carcass protein content was higher in fish fed MD (49.43 ±0.19%) followed by fish group fed FD and CD (48.4 ± 0.22% and 48.1 ± 0.20% respectively). Concerning carcass ash content, it were higher ($p \leq 0.05$) in fish group fed FD (19. 53 ± 0.14%) and CD (19.32 ± 0.12%) compare to those fed with MD (17.43 ± 0.17%). No significant differences ($p > 0.05$) were found in carcass lipid and gross energy content of fish from one diet to another. This values ranged from 17.34 ± 0.12 (CD) to 17.63 ± 0.14% (MD) for crude lipid and from 17.42 ± 0.12 (CD) to 17.83 ± 0.13 $kJ.g^{-1}$ (MD) for gross energy.

-Adult stage

The chemical composition of male of *Oreochromis niloticus* at the end of feeding experiments is presented in Table 8. No significant differences ($p> 0.05$) were found in the carcass moisture, crude protein, crude lipid and gross energy content of fish fed different experimental diets. In contrast, ash content were significantly affected by experimental treatment ($p \leq 0.05$). The carcass ash content was higher in fish fed FD and CD (19.82± 0.84 % and 19.64± 0.63% respectively) followed by fish group fed with MD (18.56 ± 0.45%). However, no significant different ($p > 0.05$) between these values

Table 8: Carcass chemical composition of *Oreochromis niloticus* at different stages

Stages		Diets		
	Parameters	**FD**	**MD**	**CD**
ST1	**M (%)**	80.99 ± 0.19^{a}	78.28 ± 0.14^{a}	83.015±0.11^{a}
	CP (%)	13.13 ± 0.14^{b}	14.02 ± 0.15^{c}	12.68± 0.12^{b}
	Ash (%)	2.98 ± 0.19^{a}	2.75 ± 0.23^{a}	2.58 ± 0.17^{a}
	CL (%)	10.73 ± 0.11^{a}	11.76 ± 0.10^{a}	11.58 ± 0.10^{a}
	GE (kJ.g^{-1})	7.08 ± 0.10^{a}	7.68 ± 0.08^{a}	7.32 ± 0.09^{a}
ST2	**M (%)**	78.12 ± 0.18^{a}	77.32 ± 0.23^{a}	78.30 ± 0.17^{a}
	CP (%)	48.4 ± 0.22^{b}	49.43 ±0.19^{c}	48.1 ± 0.20^{b}
	Ash (%)	19. 53 ± 0.14^{b}	17.43 ± 0.17^{a}	19.32 ± 0.12^{b}
	CL (%)	17.42 ± 0.12^{a}	17.63 ± 0.14^{a}	17.34 ± 0.12^{a}
	GE (kJ.g^{-1})	17.52 ± 0.10^{a}	17.83 ± 0.13^{a}	17.42 ± 0.12^{a}
ST3	**M (%)**	74.89 ± 0.32^{a}	75.34 ± 0.25^{a}	75.47 ± 0.45^{a}
	CP (%)	63.78± 0.08^{a}	64.13± 0.05^{a}	63.45± 0.06^{a}
	Ash (%)	19.82± 0.84^{a}	18.56 ± 0.45^{a}	19.64± 0.63^{a}
	CL (%)	20.23± 0.57^{a}	21.13 ± 0.35^{a}	20.21± 0.62^{a}
	GE (kJ.g^{-1})	22.02 ± 0.13^{a}	22.45 ± 0.11^{a}	21.95 ± 0.16^{a}

Each value is the mean ± Standard deviation. Means with the same letters in the same row are not significantly different (p>0.05). ANOVA and Duncan's multiple-range test.
M = Moisture, CP = Crude protein, CL = Crude lipid, GE = Gross Energy, ST1= Larval stage, ST2 = Juvenile stage, ST3 = Adult stage

Cost-benefit analysis at different stages

The data on the kilogram costs of the feeds used, and the rates of reduction of these costs at different stages, were evaluated (Table 9).

-Larval stage

The costs per kilogram of feed (CF) were 400, 296 and 310 F.CFA respectively for FD, MD and CD. Relatively to the cost linked to the total quantity of different feeds used to produce the kilogram of juveniles, the recorded values were 240, 168 and 217 F.CFA respectively for FD, MD and CD. The use of maggot meal as a source of protein in the feed of *Oreochromis niloticus* at larval stage has decrease the cost of kg of feed (cost/kg of feed) compared to the cost of kg of fishmeal-based feed. In addition, the use of MD feeds also helped reduce the production cost per kilogram of fish by 30% (MD) compared to FD. This production cost per kilogram of fish also was reduce by 22.58% (MD) compared to CD.

-Juvenile stage

The costs per kilogram of feed (CF) were 309, 207 and 300 F.CFA respectively for FD, MD and CD. Relatively to the cost linked to the total quantity of different feeds used to produce the

kilogram of juveniles, the recorded values were, 305, 493 and 498 F.CFA respectively for MD, CD and FD feeds. The analysis of financial profitability shows that, the use of maggot meal as a source of protein in the feed of *Oreochromis niloticus* juveniles resulted in a decrease in the cost of kg of feed (cost/kg of feed) compared to the cost of kg of fishmeal-based feed (33%) and commercial diet (31%). Regarding the production cost of kilogram (PC) of juveniles, it was lower in fish group fed with maggot diet. In addition, the use of maggot meal as a source of protein in the feed of *Oreochromis niloticus* juveniles also helped reduce the production cost of kilogram of fish by 38.75% (MD) compared to FD. This production cost per kilogram of fish also was reduce by 38.13% (MD) compared to CD.

-Adult stage

The costs per kilogram of feed were 293 F.CFA for FD, 188 F.CFA for MD and 300 F.CFA for CD. Relatively to the cost linked to the total quantity of different feeds used to produce the kilogram of juveniles, the recorded values were 284, 436 and 441 F.CFA respectively for MD, CD and FD. The analysis of financial profitability shows that, the use of maggot meal as a source of protein in the diet of *Oreochromis niloticus* resulted in a decrease the cost of 1 kg of feed (cost/kg of feed) compared to cost of 1 kg of others diets. In addition, the use of maggot diet to fed fish also helped reduce the production cost of 1kilogram of fish by 35.60% compared to FD and by 34, 86% compared to CD.

Table 9: Cost-benefit analysis of *Oreochromis niloticus* at different stages

		Diets		
Stages	**Parameters**	**FD**	**MD**	**CD**
ST1	**CF (F.CFA)**	400	296	310
	CFU (F.CFA)	340.92	252.18	265.28
	PC (F.CFA/kg)	240	168	217
	RxR CF/FD (%)	--	26	--
	RxR PC/FD (%)	--	30	--
	RxR CF/CD (%)	--	4.52	--
	RxR PC/CD (%)	--	22.58	--
ST2	**CF (F.CFA)**	309	207	300
	CFU (F.CFA)	13120	7264	8853
	PC (F.CFA/kg)	498	305	493
	RxR CF/FD (%)	--	33	--
	RxR PC/FD (%)	--	38.75	--
	RxR CF/CD (%)	--	31	--
	RxR PC/CD (%)	--	38.13	--
ST3	**CF (F.CFA)**	293	188	300
	CFU (F.CFA)	30234	22063	27605
	PC (F.CFA/kg)	441	284	436
	RxR CF/FD (%)	--	35.84	--
	RxR PC/FD (%)	--	35.60	--
	RxR CF/CD (%)	--	37.33	--
	RxR PC/CD (%)	--	34.86	--

CF= Cost of 1 kg of feed, CFU= cost of feed used, PC= production cost of 1 kg of fish, RxR CF/FD = Reduction Rate of CF compared to fish diet (FD), RxR PC/FD= Reduction Rate of PC compared to fish diet (FD), RxR CF/CD = Reduction Rate of CF compared to commercial diet (CD) and RxR PC/CD = Reduction Rate of PC compared to commercial diet (CD).
Price in CFA pound: 100 CFA= 0.18 $ based on 2017 exchange prices in Ivory Coast
ST1= Larval stage, ST2 = Juvenile stage, ST3 = Adult stage.
-- = Absents values.

DISCUSSION

The average values of physicochemical water parameters recorded during the period of the experiment did not differ from one hapa to another. These values corroborated the results of Bamba *et al*. (2014) in the same station for temperature and for pH. These values were within the tolerant range of *Oreochromis niloticus*. As for the dissolved oxygen during the experiment, the values obtained are consistent with the recommended limits for tilapia breeding. According Coche (1978), the tilapia can survive an oxygen concentration of 1.2 $mg.L^{-1}$.

After different stage of fish monitoring, larvae fed with the maggot diet and fish diet were obtained the growth performances (FW and SGR) similar. These values higher than those fish fed in other larval groups (CD).

At juvenile stage (after 90 days of fish monitoring), fish fed with the maggot diet obtained the higher final weight (FW) followed by fish fed with fish diet (control diet) when compared with fish fed commercial diet. After 180 days of fish monitoring, male adult fish fed with the maggot diet obtained the higher final weight (FW) followed by fish fed fish diet. On the other hand, the growth of *O. niloticus* male adult fed with commercial diet is low when compared with that obtained in any breeding. However, the similarities were observed between SGR when the fish were fed FD, MD and CD. This show that the feed formulated with maggot meal is of interest for aquaculture, an indicating that maggot meal protein were converted for growth. Nearly similar values of growth performance obtained in fish fed with MD and fish fed FD were in agreement with those obtained by Samuel and Nyambi (2013). These authors were found that at the *Clarias gariepinus* fingerling growth is proportional when fish meal is totally replaced by that of maggot. However, these obtained values are in contradiction with the results of Ezewudo *et al*. (2015) and Katya *et al*. (2017). For these authors, the growth performance of fish is better when the fishmeal is replaced by maggot meal at inclusion level less than 50% in a diet based on fishmeal. In the present study, the survival rate values obtained is low (88.5 ± 4.3 - 89.41 ± 4.7%) at the juvenile stage and higher at the larval and adult stages (96.23 ± 2.26 - 100 ± 0.00 %). These survival rate values at larval and adult stages in this study are also similar to those obtained (100%) by Ogunji *et al.* (2011) when maggot meal is used in fish feed. However, these low survival rates among juveniles could be explained by the stress of handling and transporting fish during their transfer from hapas to concrete ponds. Otherwise, these survival rate values are almost similar to those (86.1 ± 10.3%) obtained by Katya *et al.* (2017) when maggot meal completely replaces fishmeal in the diet of *Lates calcarifer*. The results of the current study indicate that use maggot meal in fish feed improves growth rate and reduce mortality. The results of this study showed that feed utilization (feed conversion ratio, protein efficiency ratio) was similar in all group of fish one diet to another at different stages. The similarity observed between the feed conversion ratio and protein efficiency ratio values from one diet to another and especially the lowest values of feed conversion ratio obtained overall clearly show that the feed were used by the fish. In addition, the crude protein and crude lipid content of the carcasses were similar in fish fed all diets. This indicates that the fish effectively used the crude lipid supplied by maggot meal and fishmeal in the diets. Moreover, the best feed utilization parameters observed in this study between fish fed with MD and FD feed during the three stages would result from the best degree of convertibility of the ingredients incorporated into these foods by these fish. In other words, MD and FD foods would be more digestible and easily assimilated by fish. Köprücü and Özdemir (2005) indicate that the digestibility of a food

depends on the nature of the ingredients used. These authors indicate that ingredients may appear to be excellent sources of nutrients, but of low nutritional value, because of the variability of their digestibility, absorption and nutrient availability factors (amino acids, minerals). They also mention that the performance of a compound feed is highly dependent on the variability of the digestibility and adsorption coefficient and the availability of the nutrients it contains. According to Viola *et al.* (1994), industrial food manufacturers commonly use synthesized or crystallized amino acids to produce a balanced diet. However, Rønnestad *et al.* (2000) demonstrated that tilapia and other fish value and assimilate these artificially synthesized inputs less efficiently than those derived from natural by-products. In this study, the proportions of natural inputs used for the composition of FD and MD foods are high. This would explain the growth gap between these formulated foods (MD and FD) and the commercial diet (CD). With regard to the commercial diet (CD), the poor performance recorded during the experiment could be explained by the lack of appetite by the fish as mentioned by Bamba *et al.* (2007). In this study, the cost (cost/kg of feed) of fish diet (FD) as those of CD were overprice. Fishmeal and fish oil is overprice in international market (FAO, 2014). The production of maggot meal is less costly resulting in the reduction of the cost /kg of feed formulated and the cost/kg of fish produced. These results agree with those obtained by Ali *et al*. (2015) who concluded that 100% maggot meal can be included in the diet of *O. niloticus nilotcus* to reduce cost and maximize profit.

CONCLUSION

The present study concludes that maggot meal positively improved growth performance and feed efficiency of *Oreochromis niloticus* as well. It reduced the cost of kg of fish produced. The fishmeal improved growth of *Oreochromis niloticus*, but increases the cost of kg of fish produced during the three stage (larval, juvenile and male adult stage). This study revealed that maggot meal can completely replace fish meal in the diets of *Oreochromis niloticus* at different stage without adverse effects on fish growth and carcass composition. And most importantly, reduce the cost of producing 1 kg of fish and promote semi-intensive and intensive fish farming in developing countries. However, it would be important to be interested in the future study of diseases related to the use of maggot meal in fish farming.

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