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SUBSTITUTION OF THE FISH MEAL BY THE INVERTEBRATES (EARTHWORM, MAGGOT) AND SPIRULINA MEAL IN THE FEED OF NILE TILAPIA *OREOCHROMIS NILOTICUS* LARVAE

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ABSTRACT
The present study was conducted to evaluate the use of maggot meal, Spirulina meal, and earthworm meal as a protein source in the place of fish meal to feed tilapia larvae *Oreochromis niloticus* with average weights of 20 ± 4 mg. The control diet (fish diet [FD]) and the commercial diet (CD) were used to compare the tests diets ([maggot diet [MD], Spirulina diet [SD] and earthworm diet [ED]). The larvae were fed four times daily to triplicate groups at 30-20% body weight for consecutive 30 days. After this days, fish fed with MD had the highest mean daily gain [ADG] (24.33 ± 10 $mg.day^{-1}$) followed by fish fed FD (22.9 ± 20 $mg.day^{-1}$). Fish fed with ED had the lowest ADG (17.7 ± 10 $mg.day^{-1}$). 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* larvae to increase the growth of fish and reduce the cost of 1 kg of fish produced.

Keywords:
Nil tilapia, Spirulina and invertebrates feeds, Zootechnic and economics parameters

INTRODUCTION

The difficulty in the emergence of fish farming in developing countries is due in particular to the low level of technicality of the actors of the field, the availability of fry to sow the water bodies and the high cost of the feed [1]. Indeed, the feed item represents more than 50% of the cost of production on farms [2]. This high cost of the compound feed is due to the increasing price of fishmeal and fish oil on the international market [3]. In Ivory Coast, the current costs of fishmeal on the local market range from 300 to 700 F.CFA/kg. Thus, the inaccessibility of this feed is a source of abandonment of the fish farming activity by fish farmers with modest incomes for the most part. This situation is likely to threaten the survival of aquaculture and to increase the ratio between the fishery imports and domestic production.

Fishmeal is much more widely used in fish diets because of its high content of minerals and nitrogenous matter, with a balanced amino acid profile. Its metabolizable energy content is 3200 kcal with a protein content of around 51.1 - 72% dry matter and contains less than 12% of lipids [4]. Fish meal is rich in calcium (1.90 - 6.00%) and phosphorus (1.7 - 4.20%) [4]. and has an essential amino acid profile that covers the needs of fish and does not contain anti-nutritional factors [5]. However, substitution of fishmeal with other inexpensive protein sources in fish feed is necessary to reduce the cost of fish production and promote fish farming. Various works are nowadays oriented towards the partial or total use of agricultural by-products to offset the high cost of industrial feed made from fishmeal [6, 7]. In addition, other protein sources are currently being tested in various research projects and can validly replace fishmeal. These include earthworms, fly larvae (maggot) and

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Arthrospira algae (spirulina). Earthworms have similar amino acid profiles to fish [8] and have been used as additional protein in fish feed [9, 10]. As for maggots, their protein content is around 40 to 64% [11, 12, 13] and that of Spirulina is between 34 and 73% [14, 15]. Spirulina also contains high lipid levels (7-16%) [16]. However, recent research has shown better growth of fish when Spirulina is incorporated up to 75% in a fish meal diet [17]. In addition, growth stimulation in some cases is observed at less than 50% substitution for earthworms [18, 10] and maggots [13]. According to the same authors, the total substitution of fishmeal by these protein sources has not yet given satisfactory results in terms of fish growth performance even if the cost of production of fish is reduced in some cases [17]. Therefore, it is important in this study to evaluate growth, feed utilization, economic value and carcass composition of tilapia larvae *Oreochromis niloticus* fed with feeds formulated with maggot meal, earthworm meal and Spirulina meal without the addition of fishmeal.

MATERIALS & METHODS

Experimental diets

Proportion (%) of ingredients used in the composition of experimental diets is shown in Table 1. Four isoproteic practical diets (40% crude protein content) were formulated with fishmeal, housefly maggot meal, Spirulina meal and earthworm meal as the main protein sources. Fishmeal being replaced totally with Spirulina (*Arthrospira platensis*), earthworms (*Eudrilus eugeniae*), and 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 formulate diets and the commercial diet (CD) are shown in Table 2. Crude protein content of the commercial diet (CD) used at the same larval stage is 34.5%. Spirulina (*Arthrospira platensis*) used was produced in culture media prepared in three basins of capacity 198 liters by-each according to the method of Zarrouk [19] . The harvested Spirulina was sun-dried then crushed following the method of Fox [20]. The dried Spirulina was crushed into powdery to obtain Spirulina meal. 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*. [21]. 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 earthworm was produced according to the method of Sogbesan and Madu [22]. The earthworm *Eudrilus eugeniae* was cultured for three months. After these days, they are sorted, washed, killed with hot water and then dried in an oven at 80 °C and crushed into powdery to obtain earthworm meal. The four formulated diets were designated as SD (diet containing Spirulina meal), MD (diet containing maggot meal), ED (diet containing earthworm meal) and FD (diet containing fishmeal). All diets were prepared according to the method of Bamba *et al.* [7].

Table 1: Proportion (%) of ingredients used in formulated diets (FD, SD, MD and ED)

	Diets			
Ingredients (%)	**FD**	**SD**	**MD**	**ED**
Corn flour	8	5	5	5
Soybean meal	45	53	54	53
Cotton meal	14	14	14	14
Copra meal	6.5	3.5	4	3.5
Wheat bran	3.5	1.5	3	1.5
Fishmeal	20	--	--	--
Spirulina (Algae)	--	20	--	--
Maggot meal	--	--	18	--
Earthworm meal	--	--	--	20
Palm oil	2	2	1	2
Vitamins	0.25	0.25	0.25	0.25
Salt	0.30	0.30	0.30	0.30
Seashell flour	0.35	0.35	0.35	0.35
Lysine	0.05	0.05	0.05	0.05
Methionine	0.05	0.05	0.05	0.05
Total	100	100	100	100

FD = Fish Diet, SD = Spirulina Diet, MD = Maggot Diet, and ED = Earthworm Diet
-- = Absents Ingredients.

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Table 2: Proximate composition (%Dry matter) and cost of experimental diets.

Components (%)	Diets				
	FD	SD	MD	ED	CD
Moisture	8.88	11.14	10.32	9.14	12.08
Crude Protein	39.81	39.37	39.62	39.46	34.5
Ash	10.51	9.14	7.6	11.04	12.42
Crude Lipid brut	4.76	4.14	6.17	4.77	4.38
Crude fiber	5.37	5.68	5.45	5.56	6.2
NFE	30.67	30.53	30.83	30.03	30.42
Gross energy ($kJ.g^{-1}$)	15.96	15.60	16.49	15.78	14.59
Cost (F.CFA/kg)	400	204116	296	310	310

FD = Fish Diet, SD = Spirulina Diet, MD = Maggot Diet, ED = Earthworm Diet and CD= Commercial Diet
NFE = Nitrogen free extract = 100 – (% Moisture + % Protein+ % Ash +% Lipid + % Fiber)
Gross Energy = 22.2 × % Protein + 38.9 × % Lipid + 17. 2 × % Nitrogen free extract [23]
Price in CFA pound: 100 CFA= 0.18 $ based on 2017 exchange prices in Ivory

Experimental condition and fish feeding

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 five 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, 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 mg). 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.

Analytical methods

The feed ingredients, experimental diets and fish samples were analyzed according to AOAC [24] 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 [23]

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).
Net Biomass (kg) = Final Biomass (kg) – Initial Biomass (kg)
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 / Net Biomass (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.
Production Time (PT)/kg fish produced = Rearing time (days) / Weight gain (kg).

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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*. [25]. 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 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 are summarized in Table 3. The water temperature ranged from 27.3 ± 0.8 to 28.2 ± 0.9 °C, pH from 6.4 ± 0.08 to 6.9 ± 0.06. Dissolved oxygen from 8.70 ± 0.47 to 9.43 ± 0.38 $mg.L^{-1}$. nitrate nitrogen ranged from (NO^-_3) 0.38 ± 0.01 to 0.43 ± 0.02 $mg.L^{-1}$, nitrite nitrogen from (NO^-_2) 0.04 ± 0.02 to 0.06 ± 0.05 $mg.L^{-1}$, ammonium from (NH_4^+) 0.24 ± 0.02 to 0.27 ± 0.01 $mg.L^{-1}$ and phosphorus from (PO^{3-}_4) 0.16 ± 0.02 to 0.21 ± 0.03 $mg.L^{-1}$. There were no significant differences in the water quality parameters among the treatment during the whole experimental period.

Table 3: Physicochemical parameters of water

Parameters	Diets				
	FD	**SD**	**MD**	**ED**	**CD**
T (°C)	27.8 ± 0.7^a	27.6 ± 0.6^a	27.3 ± 0.8^a	28.2 ± 0.9^a	27.9 ± 0.7^a
pH	6.9 ± 0.06^a	6.6 ± 0.05^a	6.8 ± 0.04^a	6.4 ± 0.08^a	6.5 ± 0.04^a
O_2 ($mg.L^{-1}$)	9.09 ± 0.43^a	8.70 ± 0.47^a	9.22 ± 0.51^a	9.43 ± 0.38^a	8.5 ± 0.52^a
NO^-_2 ($mg.L^{-1}$)	0.05 ± 0.04^a	0.04 ± 0.02^a	0.05 ± 0.04^a	0.06 ± 0.05^a	0.06 ± 0.04^a
NO^-_3 ($mg.L^{-1}$)	0.38 ± 0.01^a	0.40 ± 0.04^a	0.42 ± 0.01^a	0.43 ± 0.02^a	0.39 ± 0.03^a
NH_4^+ ($mg.L^{-1}$)	0.25 ± 0.02^a	0.24 ± 0.02^a	0.26 ± 0.01^a	0.27 ± 0.01	0.25 ± 0.02^a
PO^{3-}_4 ($mg.L^{-1}$)	0.21 ± 0.03^a	0.18 ± 0.03^a	0.19 ± 0.01^a	0.20 ± 0.01^a	0.16 ± 0.02^a

Each value is the mean of three readings ± Standard deviation. Means has the different letters in the same row are significantly different at $P \leq 0.05$

FD = Fish Diet, SD = Spirulina Diet, MD = Maggot Diet, ED = Earthworm Diet and CD = Commercial Diet

NO^-_2, = Nitrite, NO^-_3 = Nitrate, PO^{3-}_4 = Phosphorus, NH_4^+ = Ammonium.

Nutrient profile of protein ingredients

The proximate compositions of fishmeal, Spirulina meal, maggot meal, earthworm 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, earthworm meal, Spirulina meal and maggot meal respectively. On the other hand, crude lipid was recorded to be highest for maggot meal followed by earthworm meal, copra meal, fishmeal, soybean meal and Spirulina 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 earthworm meal followed by fishmeal, Spirulina meal, and maggot meal compared to other ingredients.

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

Components	Ingredients								
	FM	**SPM**	**MM**	**EM**	**CF**	**SM**	**CM**	**COM**	**WB**
M (%)	7.8	11	8.99	9.01	10.05	11.88	6.99	8.24	10.79
Ash (%)	18	15.14	10.12	11.28	1.57	6.1	5.6	6.05	4.6
CP (%)	56	40.7	40.34	41.17	11.8	45	41.56	21	15.3
CL (%)	5.76	6.77	25	23.68	3.62	5.11	2.04	6.95	2.88
Fiber (%)	0	2	2	1	1	3	11	16	9
NFE (%)	12.44	24.39	13.55	13.86	71.96	28.91	32.81	41.76	57.43

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Values are average from duplicate groups of samples.
FM= Fishmeal, SPM = Spirulina meal, MM= Maggot meal, EM= Earthworm 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) [24].

Growth performance, feed utilization and production time

Significant effects ($P < 0.05$) of the dietary total replacement of fish meal with dried Spirulina meal, maggot meal, earthworm meal on the growth performance of *Oreochromis niloticus* larvae were observed (Table 5). Use of maggot meal in fish feed gave similar values (FW and SGR) to those obtained by FD. 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 (P > 0.05) with those obtained by the fish fed with SD and CD for SGR. However, fish fed with MD obtained the highest ADG (24.33 ± 10 mg.day^{-1}) compared to those obtained by FD (22.9 ± 20 mg.day^{-1}).The lowest values (FW, ADG) were obtained in fish group fed on diet containing earthworm meal (551 ± 141 mg and 17.7 ± 10 mg.day^{-1} respectively). Survival rate (SR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were similar (P > 0.05) for all diets. Use of earthworm meal as protein source has negative effect in production time of kg fish produced (26.83 ± 1.4 days.kg^{-1} of fish produced) when compared to the others. In contrast, the use of maggot meal as protein source in *Oreochromis niloticus* larvae feed resulted in decrease of production time (20.22 ± 1.9 day.kg^{-1} of fish produced).

Table 5: Growth performance, survival rate, feed conversion ratio, protein efficiency ratio, production time/kg of fish produced

	Diets				
Parameters	**FD**	**SD**	**MD**	**ED**	**CD**
SR (%)	96.23 ± 2.26^a	96.31 ± 0.15^a	96.34 ± 1.79^a	97.45±0.74^a	94.85 ± 1.08^a
IW (mg)	20 ± 4^a	20 ± 4^a	20 ± 4^a	20 ± 4^a	20 ± 4^a
FW (mg)	707± 237^{cd}	677 ± 225^{bc}	750 ±168^d	551 ± 141^a	626 ± 191^{ab}
WG (mg)	687 ±53^d	657 ±46^d	730 ±35^d	531 ±31^d	606 ±38^d
ADG (mg.day^{-1})	22.9 ± 20^c	21.9 ± 20^c	24.33 ± 10^d	17.7 ± 10^a	20.2 ± 10^b
SGR (%.day^{-1})	11.88 ± 2.7^b	11.74 ± 2.9^b	12.08 ± 2.08^b	11.05 ± 2.2^a	11.48 ± 0.28^{ab}
FCR	0.60 ± 0.56^a	0.62 ± 0.38^a	0.57 ± 0.26^a	0.65 ± 0.24^a	0.69 ± 0.25^a
PER	4.12 ± 1.3^a	4.11 ± 1.87^a	4.37 ±1.2^a	3.89 ± 1.13^a	4.15 ± 1.17^a
PT (days.kg^{-1})	21.26 ± 1.3^a	22.12 ± 1.8^a	20.22 ± 1.9^a	26.83 ± 1.4^c	24.46 ± 1.6^b

Each value is the mean of three readings ± Standard deviation. Means has the different letters in the same row are significantly different at P < 0.05

Chemical composition of *Oreochromis niloticus* larvae body carcass

The chemical composition of *Oreochromis niloticus* larvae at the end of feeding experiments is presented in Table 6. No significant differences (P > 0.05) 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 < 0.05). The carcass protein content was higher in fish fed MD (14.02 ± 0.15%) compared fish group fed FD, SD and CD. In contrast, the lowest values were obtained in the fish group fed with ED (11.81 ± 0.13%). The results also showed that the lipid were higher in fish group fed ED (13.07 ± 0.12%). In contrast, the lowest values for lipid were obtained in the fish group fed with FD, CD, SD and MD. No significant differences were found in the carcass gross energy content. This values ranged from 7.08 ± 0.08 (FD) to 7.7 ± 0.11 kJ.g^{-1} (ED).

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Table 6: Carcass chemical composition of Oreochromis niloticus fed with experimental diets

Parameters	Diets				
	FD	SD	MD	ED	CD
M (%)	80.99 ± 0.19[a]	81.5I ± 0.16[a]	78.28 ± 0.14[a]	81.40 ± 0.12[a]	83.015±0.11[a]
CP (%)	13.13 ± 0.14[b]	13.12 ± 0.12[b]	14.02 ± 0.15[c]	11.81 ± 0.13[a]	12.68± 0.12[ab]
Ash (%)	2.98 ± 0.19[a]	2.54 ± 0.24[a]	2.75 ± 0.23[a]	2.56 ± 0.2[a]	2.58 ± 0.17[a]
CL (%)	10.73 ± 0.11[a]	11.64 ± 0.10[a]	11.76 ± 0.10[a]	13.07 ± 0.12[b]	11.58 ± 0.10[a]
GE (kJ.g^{-1})	7.08 ± 0.08[a]	7.44 ± 0.12[a]	7.68 ± 0.10[a]	7.7 ± 0.11[a]	7.32 ± 0.09[a]

Each value is the mean of three readings ± Standard deviation. Means has the different letters in the same row are significantly different at $P < 0.05$
M = Moisture, CP = Crude protein, CL = Crude lipid, GE = Gross Energy

Cost-benefit analysis

The data on the kilogram costs of the feeds used, and the rates of reduction of these costs, were evaluated (Table 7). The costs per kilogram of feed (CF) were 400, 204116, 296, 310 and 310 F.CFA respectively for FD, SD, MD, ED 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, 126053, 168, 202 and 217 F.CFA respectively for FD, SD, MD, ED and CD. The analysis of financial profitability shows that, the use of maggot meal and earthworm meal as a source of protein in the feed of *Oreochromis niloticus* larvae 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. Relatively to the cost linked to the total quantity of different feeds used to produce the kilogram of juveniles, the recorded values were 240, 126053, 168, 202 and 217 F.CFA respectively for FD, SD, MD, ED and CD. Regarding this production cost of kilogram of juveniles, it was lower in fish group fed with maggot diet followed by fish fed with earthworm diet. In addition, the use of MD and ED feeds also helped reduce the production cost per kilogram of fish by 30% (MD) and 15.83% (ED) compared to FD. This production cost per kilogram of fish also was reduce by 22.58% (MD) and 6.91% (ED) compared to CD. However, the use of Spirulina meal resulted in an increase in the cost of the kilogram of feed and the cost per kilogram of fish produced.

Table 7: Cost-benefit analysis of Oreochromis niloticus larvae

Parameters	Diets				
	FD	SD	MD	ED	CD
INF	2145	2145	2125	2160	2135
FNF	2064	2066	2047	2105	2025
IB (g)	42.90	42.90	42.50	43.20	42.70
FB (g)	1459.25	1398.68	1535.25	1159.85	1267.6
NB (g)	1416.35	1355.78	1492.75	1116.65	1224.9
QFU (g)	852.30	837.27	851.99	727.39	855.74
CF (F.CFA)	400	204116	296	310	310
CFU (F.CFA)	340.92	170900	252.18	225.49	265.28
PC (F.CFA.kg^{-1})	240	126053	168	202	217
RxR CF/FD (%)	--	--	26	22.5	--
RxR PC/FD (%)	--	--	30	15.83	--
RxR CF/CD (%)	--	--	4.52	0.00	--
RxR PC/CD (%)	--	--	22.58	6.91	--

INF = Initial number of fish, FNF = Final number of fish, IB = Initial Biomass, FB = Final Biomass, NB = Net Biomass, QFU = Quantity of feed used, 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
-- = Absents values

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DISCUSSION

The average values of physicochemical water parameters recorded during the period of the experiment did not differ from one hapa to another. They are between 27.3 ± 0.8 and 28.2 ± 0.9 °C for temperature and 6.4 ± 0.08 and 6.9 ± 0.06 for pH. These values are consistent with the recommended limits for tilapia breeding. For Balarin & Haller [26], the optimum temperature for tilapia growth and survival is between 25 °C and 30 °C. In addition, these species can survive in water with pH values ranging from 5 to 11 [27]. As for the dissolved oxygen during the experiment, the values obtained are between 8.5 ± 0.52 and 9.43 ± 0.38 $mg.L^{-1}$. These mean values of dissolved oxygen in the hapa are consistent with the recommended limits for tilapia breeding. They can survive an oxygen concentration of 1.2 $mg.L^{-1}$ [28]. The concentrations of nitrite (0.04 ± 0.02 to 0.06 ± 0.05 $mg.L^{-1}$), nitrate (0.38 ± 0.01 to 0.43 ± 0.02 $mg.L^{-1}$), ammonium (0.24 ± 0.02 to 0.27 ± 0.01 $mg.L^{-1}$) and phosphorus (0.16 ± 0.02 to 0.21 ± 0.03 $mg.L^{-1}$) of the water in the hapa, are within the recommended limits for good survival larvae. According to Boyd [29], the nitrite concentration must be less than 0.3 $mg.L^{-1}$. The concentration of ammonium must be between 0.2 and 2 $mg.L^{-1}$ and the concentration of phosphorus must vary between 0.005 to 0.2 $mg.L^{-1}$ for good survival of fish.

After 30 days 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. On the other hand, the growth of *Oreochromis niloticus* larvae fed with earthworm diet is low compared with that obtained in any breeding. However, the larvae fed on the Spirulina diet and the commercial diet registered intermediate growth. These growths of *Oreochromis niloticus* larvae were reported by El-Sheekh *et al.* [17] when Spirulina (*Arthrospira plantensis*) is incorporated 100% into the diet without fishmeal. For these authors, the best results were obtained when dried Spirulina replaces fish meal at a rate of 75% in a diet based on fishmeal. The low growth rates of larvae fed with earthworm diet corroborated the results of Nandeesha *et al.* [30]. For these authors, in common carp without free access to abundant natural food resources, the replacement of fishmeal by dried earthworm meal (*Eudrilus eugeniae*,) resulted in reduced growth [30]. In addition, some authors indicate that the replacement of fishmeal with earthworm meal at an inclusion level of 50 to 75% is appropriate for optimal growth and optimum utilization of nutrients in fish [10]. The higher values of growth performance obtained with fish fed maggot meal diet were in agreement with those obtained by Samuel & Nyambi [31]. For these authors, 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.* [13]. For these authors, the growth performance of fish is better when the fishmeal is replaced by maggot meal at a rate of 50% in a diet based on fishmeal. In this study, maggot meal, Spirulina meal and earthworm meal could reduce the mortality rate in *Oreochromis niloticus* larvae (96.34 ± 1.79, 96.31 ± 0.15 and 97.45 ± 0.74% respectively). These results agreed with Vonshak [16], who showed that *Arthrospira plantensis* improves growth rate and reduce mortality. These survival rate values in this study are also close to those obtained (100%) by Ogunji *et al.* [32] when maggot meal is used in fish feed. The results of the current study showed that feed utilization (feed conversion ratio, protein efficiency ratio) was similar in all group of larvae one diet to another. These results were in agreement with those obtained by Dawah *et al.* [33]. For these authors, feed conversion ratio and protein efficiency ratio were better when the fish were maintained on artificial diets with 10% and 20% dried algae. The similarity observed between the FCR and PER values from one diet to another and especially the lowest values of FCR obtained overall clearly show that the feed were used by the fish. These results agree with those obtained by Dedeke *et al.* [34] who concluded that fish meal can be substituted with earthworm meal up to 25% in the diet of *Clarias gariepinus* fry without adverse effects on growth and nutrient utilization. The crude carcass lipids did not differ in all fish groups except, the group of fish fed with Earthworm diet. In addition, the crude protein content of the carcasses is low in fish fed with earthworm diet, unlike other groups. This indicates that the larvae of *Oreochromis niloticus* effectively used the crude lipid supplied by maggot meal, Spirulina meal and fishmeal in the diets. These results also indicate that the formulated feed based on the Earthworm meal would not be efficiently used for the growth of the *Oreochromis niloticus* larvae, but increased the lipid deposits.

In this study, the cost (cost/kg of feed) of Spirulina is overprice followed those of fishmeal. Fishmeal and fish oil is overprice in international market [3]. In addition, the production of dried Spirulina is overprice. The high cost of ingredient prices (fish meal and Spirulina meal) resulted in an overestimation of the cost of producing kg of fish. The production of maggot meal and earthworm 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.* [12] who concluded that 100% maggot meal can be included in the diet of *Oreochromis niloticus* to reduce cost and maximize profit. However, the time required to produce 1 kg of fish increased in fish fed with ED. It is 26.83

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days.kg^{-1} of fish produced for ED. The increase in production time (PT) observed with the ED would be a consequence of the reduction in growth observed.

CONCLUSION

The present study concludes that maggot meal positively improved growth performance and feed efficiency of *Oreochromis niloticus* larvae as well. These growth performances of fish fed on the feed formulate with maggot meal approach those of fish fed with fish diet. Maggot diet reduced the cost /kg of fish produced and the time/ kg of fish produced. The earthworm meal slows down the growth of the larvae and increases the production time of kg of fish produced. Spirulina meal very expensive cost and could be the source of abandonment by aquaculture farmers with modest incomes. This study revealed that maggot meal can completely replace fish meal in the diets of *Oreochromis niloticus* larvae without adverse effects on fish growth and carcass composition. And most importantly, reduce the cost of producing one kg of fish and promote semi-intensive and intensive fish farming in developing countries.

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