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Full Length Research Paper

Physical, chemical parameters and plankton in a tropical earthen pond catfish farm in Badagry, Nigeria

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The physico-chemical parameters and plankton abundance of four artificial fish ponds in Omageyu Farms, Ijotun, Badagry, Nigeria was studied and analysed using standard methods monthly from June to December 2015. Water temperature, pH and dissolved oxygen ranged from 27.80 to 32.00°C, 6.90 to 7.40 and 6.80 to 10.00 mg/l, respectively in the four ponds. Water temperature, pH, and dissolved oxygen in Pond A were significantly different from Ponds B, C and D. Forty-five planktonic organisms, including 40 phytoplankton and 5 zooplankton species, were identified. Shannon Weiner index was highest for pond A = 2.824 and decreased in the order: pond C = 2.81, pond B = 2.797 and pond D = 2.767. Margalef's index of species richness was greatest for pond D = 2.313 and least for pond A. Berger-Parker Dominance Index (BPDI) for the ponds decreased in order of ponds A = 0.2422, C = 0.2328, B = 0.192 and D = 0.1858. Total plankton in the four ponds showed positive correlation with dissolved oxygen. The class Chlorophyta was the prevalent group in the four ponds. The results showed that physico-chemical parameters have an influence on the distribution and diversity of plankton in earthen fish ponds.

Key words: *Clarias gariepinus*, earthen ponds, physicochemical parameters, phytoplankton, zooplankton.

INTRODUCTION

Fish appears as a cheap source of protein and an important international trade commodity in many regions and across the global market. It has contributed to the economic growth of various countries around the world. In Nigeria, aquaculture has produced an output of 15,489 tonnes per annum (Ozigbo et al*.,* 2014), which contributed 1% to the Fisheries subsector (FDF, 2005); this, however, seem to contribute to the fulfillment of protein demand across the country. The curtailing of food insecurity encourages employment opportunities, promoting income generation for individuals and employees across the sub-Saharan African Country. It implies that fisheries have contributed immensely to increasing the output of agriculture which further contributes 34% (Ozigbo et al*.,* 2014) to the country's Gross Domestic Product (GDP). The high cost of feed is related to fish-meal, whereas zooplanktons and other herbivorous aquatic organisms are seen as cheaper alternatives or supplements.

Water is the physical support in which aquatic

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organisms carry out their life functions such as feeding, breeding, digestion and excretion (Bronmark and Hansson, 2005). The monitoring of physico-chemical characteristics of a water body is vital for both short and long-term analysis, because the quality, distribution and productivity level of organisms in a water body are largely governed by its physico-chemical and biological factors (Ashton and Schoeman, 1983; Adakole et al., 2003). Water quality in fish ponds is often due to the interactions of several physico-chemical components and can have profound effects on pond productivity, the level of health and fish health.

Phytoplankton is important in fish farming because it is a primary producer (Yisa, 2006; Bwala et al., 2009). In the aquatic environment, all life forms depend on phytoplankton species, as they are at the base of the food chain, serving as food to zooplanktons and other herbivorous aquatic organisms (Verlencar and Desai, 2004). Phytoplankton occurs naturally in water bodies, but often it may be introduced from cultures to serve as food supplement for fish. Phytoplankton has also been reported to cause fish poisoning in many parts of the world, due to the ability of some species to form toxins during blooms (Cook et al*.,* 2004). Phytoplankton plays an important role as bioindicator of water quality (Tiseer et al., 2008). Zooplankton also plays an important role in the food chain, being in the second trophic level as primary consumer and also as contributors to the next trophic level (Rahman and Hassain, 2008). The zooplankton community is a dynamic system that responds quickly to environmental changes. The relationship between the physico-chemical parameters of water quality and plankton production in fish ponds is of great importance and essential for fish culture (Islam, 2007).

This study is designed to investigate the physico-chemical parameters, phytoplankton and zooplankton composition in earthen ponds. Results of this study will be of immense value to the local aquaculture industry in Nigeria.

MATERIALS AND METHODS

Study area

The four fish ponds studied are located in the Omageyu Farms, Ijotun, Badagry, Nigeria. The earthen ponds were constructed for fish production and holds water all year round, except for occasional changing of the water. The ponds were designated as: POND A- Culture pond for *Clarias gariepinus* fries to fingerlings (3-6 weeks), POND B- *C. gariepinus* Broodstock pond (4-5 years), POND C- *C. gariepinus* Table-size pond (5-9 months), POND D- *Heterotis niloticus* pond (2-3years). *C. gariepinus* fries to fingerlings (25,000) were stocked in 60 m wide × 80 m long × 1.5 m depth while *C. gariepinus* Broodstock (100), *C. gariepinus* Table-size (500), and *H. niloticus* (500) were stocked in the pond 30 m wide × 40 m long × 1.5 m depth respectively.

Water analysis

Water samples were collected monthly for seven months between June and December, 2015. Samples for physico-chemical analysis were collected in 1-L plastic jars from the middle of each pond. Dissolved Oxygen (DO), temperature (°C) and pH was determined using a Horiba U-10 water quality checker. Alkalinity and hardness were determined using methods described by APHA (1998).

Collection of plankton samples

A modified standard phytoplankton net, 55 µm mesh size was dragged for three minutes in each pond just below the water surface to collect plankton monthly for seven months (June to December, 2015), including small-celled phytoplankton, which was collected in a detachable bucket (glass jar) at the rear end of the equipment. After dragging, the water collected in the detachable bucket jar was transferred into plastic bottles enclosed in polystyrene to prevent the water from pouring out.

Qualitative plankton analysis

Identification of the phytoplankton species was done using a phase contrast light microscope (Olympus Tokyo) at 10×40 magnification (Model No: 602980). The magnification for all organisms viewed was x400. Quantitative analysis of phytoplankton was done on Sedgewick-Rafter counting chamber (S-R cell). Analysis involved transfer of 1 ml sub-sample from each of the samples to the Sedgewick-Rafter counter and counting of cells within 5 squares of the cells, chosen randomly. Plankton quality analysis and identification was done using internationally accepted taxonomic keys of Edmonton (1959), Prescott (1970) and Sharma (1986).

The number of organisms per mm was calculated using the following formula:

$$\text{Number of plankters per ml} = \frac{(T)\ 1{,}000}{AN} \times \frac{\text{Volume of concentrate (ml)}}{\text{Volume of Sample (ml)}}$$

Where,
T= total number of plankters counted
A= area of grids in mm^2
N= number of girds employed
1,000= area of counting chamber in mm^2

Source: GEMS/WATER (1977).

Data analysis

Descriptive statistics of data for water quality analyses and plankton was done using Microsoft Excel, while the paleontological statistics software package for education and data analysis was used to calculate the; Number of Species, Individuals, Shannon Weiner Index (H), Simpson Diversity index (1-D), Evenness (e^H/S), Menhinicks Index, Margalef's Richness index, Equitability_J, Fisher_Alpha and Berger-Parker dominance index. Analysis of variance (ANOVA) was used to test for statistical differences between the means of the physical and chemical parameters of the fish ponds. The strength and pattern of association between the water quality parameters and Plankton abundance in each pond within the sampling period was established using Pearsons Correlation Analysis in the SPSS version 20.0 software.

RESULTS AND DISCUSSION

Physico-chemical parameters

The results obtained from the monthly variation in

Table 1. Mean values of the physico-chemical parameters for each pond recorded within the sampling period (June – December, 2015).

Parameters	Pond A	Pond B	Pond C	Pond D
Ph	7.25±0.13^{a}	7.32±0.13^{bd}	6.98±0.05^{cd}	7.06±0.08^{d}
Dissolved oxygen (mg/l)	8.56±0.89^{a}	7.50±0.40^{b}	7.30±0.34^{b}	7.39±0.45^{b}
Alkalinity (mg/l)	30.14±6.6^{a}	27.14±5.6^{a}	27.43±4.20^{a}	27.00±4.80^{a}
Total hardness (mg/l)	67.27±3.36^{a}	66.03±3.4^{ab}	64.34±1.85^{ab}	63.49±3.57^{b}
Temperature(^{0}C)	29.31±1.32^{a}	29.50±1.16^{a}	29.19±1.16^{a}	29.14±1.01^{a}

Values in the same rows with the same superscript are not significantly different (ANOVA, $p > 0.05$).

physico-chemical parameters assessed between the months of June to December, 2015 are presented in Table 1. Temperature ranged between 27.80 to 32.00°C; Broodstock pond (B) had the highest mean temperature (29.50±1.16, range = 28 – 31.5°C) and Heterotis pond (D) the lowest (29.14±1.01, range = 28.2 – 30.9°C). Dissolved oxygen ranged from 6.80 to 10.00 mg/l with Catfish fries to fingerlings pond (A) having the highest mean DO (8.56±0.89, range = 8.2 – 10.0 mg/l) and Catfish Table-sized pond (C) the lowest (7.30±0.34, range = 6.8 – 7.9 mg/l). pH ranged from 6.90 to 7.40, Catfish Broodstock pond (B) had the highest mean pH (7.32±0.13, range = 6.90 – 7.32) and Catfish Table-sized pond (C) the lowest (6.98±0.05, range = 6.90 – 7.02). Alkalinity ranged from 21.00 to 40.00 mg/l with Catfish fries to fingerlings pond (A) having the highest mean alkalinity (30.14±6.6, range = 23 – 40 mg/l) and Heterotis pond (D) the least (27.00±4.80, range = 21 – 36 mg/l). Total hardness had a range of 61.00 - 72.06 mg/l with Catfish fries to fingerlings pond (A) having the highest mean hardness (67.27±3.36, range = 62 – 71.45 mg/l) and Heterotis pond (D) the least (63.49±3.57, range = 61 – 71.09 mg/l).

The physico-chemical parameters examined for the four ponds were in a suitable range of water quality for fish survival according to Erondu (1991), Akinwole and Faturoti (2007) and Hoff et al. (2001). According to Roberts et al. (1997), maximum temperature range for aquatic life is considered to be 20-33°C, and the temperature range recorded for the duration of the experiment was 27.8 - 32.0°C, which suggested that the range was suitable for fish growth and plankton proliferation.

Erondi (1991) reported that dissolved oxygen > 5 mg/l is necessary for the survival of fish and any aquatic organisms. The dissolved oxygen for the four ponds ranged between 6.8 - 10 mg/l, which was within the appropriate range (3.0 - 5.0 mg/L) recommended by the Federal Environmental Protection Agency (FEPA) (2003). Dissolved oxygen was relatively low during the peak of the rainy season (July) and high during the peak of the dry season (November). This may be due to an increase in turbidity during the rainy season and reduction during the dry season.

According to Hoff and Snell (2001), the optimum pH range for plankton production is between 6.5 and 9.5. The pH recorded within the sampling period ranged between 6.90 and 7.40, which is within the optimum range for plankton production and fish growth. Alkalinity normally reflects carbonate content of rocks and soils of water sheds and bottom mud (Jobbágy and Jackson, 2001). The relatively lower values of alkalinity recorded during the July may be attributed to the dilution effect of the rain during this period.

Relative abundance of plankton in the four ponds

Forty-five planktonic organisms were identified in the four ponds. They include 40 phytoplankton species like Green algae (21 species), Blue- green algae (4 species), Diatoms (5 species), Red algae (2 species), Golden-brown algae (2 species), dinoflagellates (2 species) and Euglenophytes (4 species). There were five zooplankton species including three (3) protozoans, one (1) crustacean and one (1) rotifer.

Figure 1 shows the relative abundance of plankters per ml in each pond observed within the period of study. Catfish fries to fingerlings Pond A had the highest number of plankters (231,200) followed by Catfish Broodstock Pond B with 229,200 individuals, Heterotis pond D with 180,800 individuals and Catfish Table-size Pond C with 163,200 individuals. Class Chlorophyta was the most abundant amongst the four ponds (100,000 individuals in Pond A; 126,000 individuals in Pond B; 92,800 individuals in Pond C and 86,400 individuals in Pond D). Pond D was found to be the richest in Class Chrysophyta, protozoa and rhodophyta. Class Crustacean was absent in ponds B and C throughout the period of sampling.

The composition of phytoplankton community of the ponds agreed with reports that blue-green algae and green algae dominate most tropical water bodies (Adebisi, 1981; Ayodele and Ajani, 1999). It has been reported that increase in primary production (phytoplankton) is accompanied by increase in zooplankton abundance (Rocha et al., 1999). Zooplankton forms about 5% of the total plankton

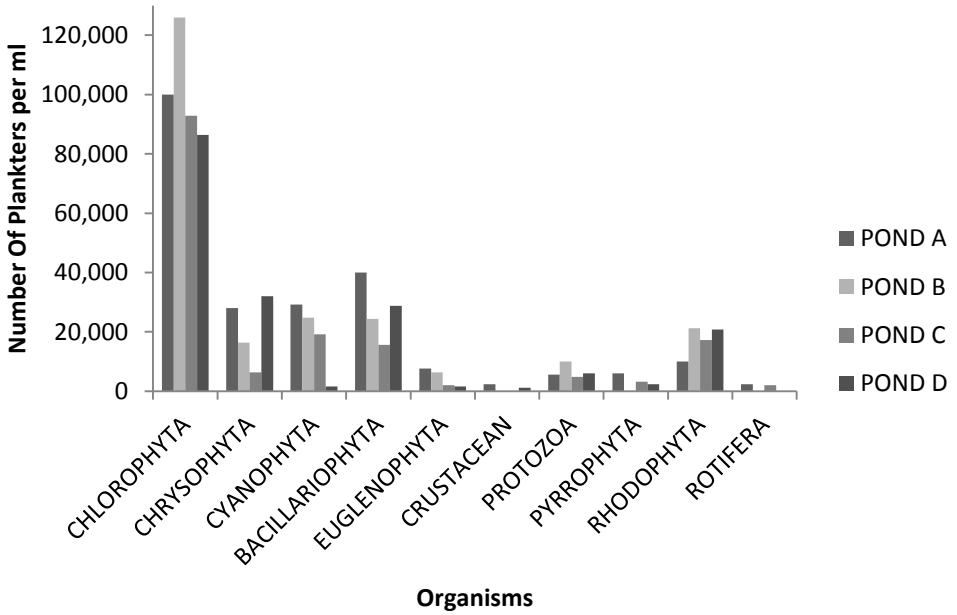

Figure 1. Relative abundance of plankters per ml in each pond within the period of study (June – December, 2015).

population in Catfish fries to fingerlings pond (A) and lesser in the other ponds.

Protozoa was the dominant zooplankton class in the four ponds. An increase in the zooplankton abundance in Catfish fries to fingerlings pond (A) resulted in a reduction in phytoplanktonic abundance as the zooplankton feed on phytoplankton. Within the sampling period, it was observed that Catfish fries to fingerlings pond had a green colouration which is an indication of its high Chlorophyte density.

Total abundance of plankters in each pond per month

Number of plankters per ml observed in each pond per month within the sampling period (June – December, 2015) is illustrated in Figure 2 where Pond A had the highest number of plankters in month of December.

Percentage abundance of plankters in specific ponds

In the Catfish fries to fingerlings Pond A, the chlorophytes had the highest percentage abundance (43.25%), followed by the Bacilliariophyte (17.30%), Cyanophyte group (12.63%), Chrysophyte (12.11%), Rhodophyte (4.33%), Euglenophyte (3.29%), Protozoa (2.42%), Pyrrophyte (2.60%), and then Rotifer and Crustacean (1.04%) the least abundant.

In the Catfish Broodstock Pond “B”, the Chlorophytes was the prevalent specie; it had the highest percentage abundance (54.97%), followed by the Cyanophyte group (10.82%), Diatom (10.65%), Rhodophyte (9.25%), Chrysophyte (7.16%), Protozoa (4.36%), and the least abundant Euglenophyte (2.79%).

In Catfish Table-Size Pond C Chlorophytes species prevailed (56.86%), followed by the Cyanophyte group (11.76%), Rhodophyte (10.54%), Diatom (9.56%), Chrysophyte (3.92%), Protozoa (2.94%), Pyrrophyte (1.96%) and the least abundant Euglenophyte and Rotifer (1.23% respectively).

In the Heterotis Pond “D” the Chlorophytes had the highest percentage abundance (47.79%) followed by the Chrysophyta group (17.70%), Diatom group (15.93%), Rhodophyte (11.50%), Protozoa (3.32%), Pyrrophyte (1.33%), Cyanophyte (0.88%), Euglenophyte (0.88%) and Crustacean (0.66%).

Correlation between total plankton and physico-chemical parameters

Correlation between total plankton in the four ponds and the physico-chemical parameters within the period of study was calculated. The total plankton in the four ponds had positive correlation with dissolved oxygen concentration (Pond A r = 0.441, Pond B r = 0.815, Pond C r = 0.463, Pond D r = 0.637). The correlation between total plankton in Catfish fries to fingerlings pond (A) and the physico-chemical parameters showed positive significant correlation with alkalinity (r = 0.809) and low positive correlation with pH (r = 0.353). Plankton showed negative correlation with temperature (r=-0.172) and 0.045 correlation value with water hardness meaning that

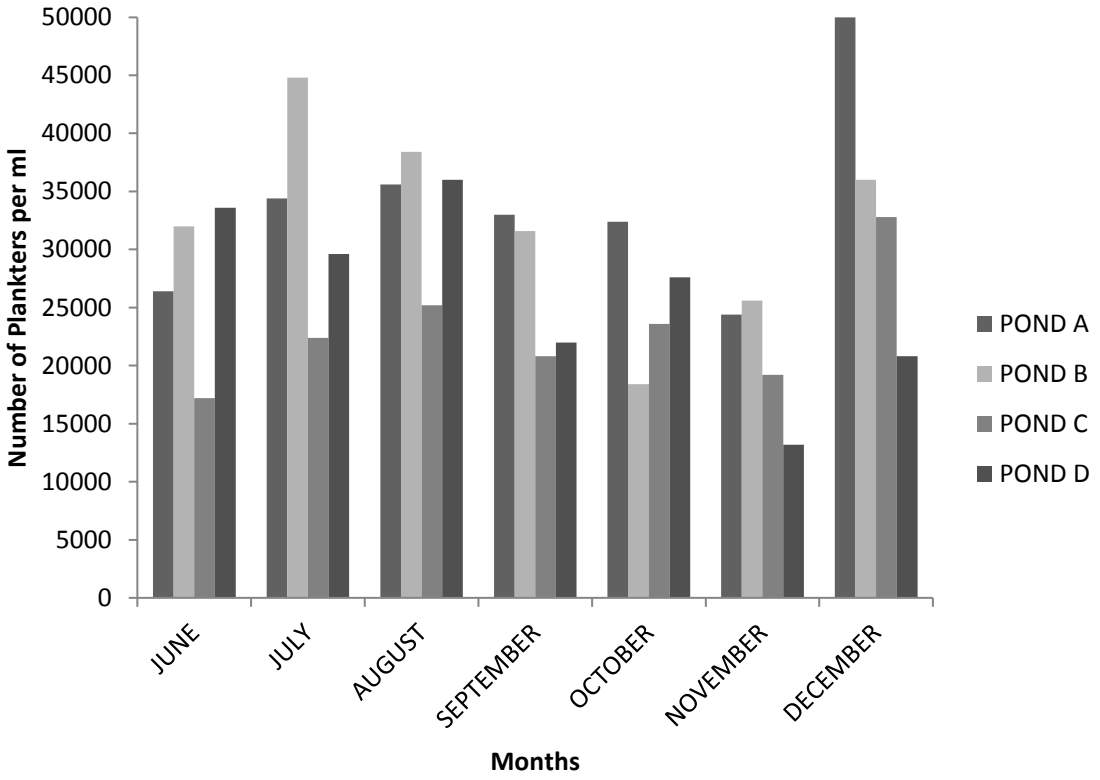

Figure 2. Number of plankters per ml observed in each pond per month within the sampling period (June – December, 2015).

Table 2. Correlation values of physico-chemical parameters and total plankton in each pond recorded within the sampling period (June – December, 2015).

Parameter	Pond A	Pond B	Pond C	Pond D
Total Plankton / Dissolved Oxygen	0.441	0.815	0.463	0.637
Total Plankton / Temperature	-0.172	0.115	-0.241	-0.769
Total Plankton / Water Hardness	0.045	0.007	-0.331	-0.037
Total Plankton /Alkalinity	0.809	0.485	-0.205	0.584
Total Plankton / pH	0.353	-0.118	0.807	0.719

an increase in temperature and water hardness levels led to a decrease in plankton abundance.

In Catfish Broodstock Pond (B), total plankton revealed high positive correlation with alkalinity (r = 0.485) and low positive correlation with temperature (r = 0.115) and water hardness (r = 0.007). The correlation between total plankton and pH was negative, r = -0.118.

Total plankton in Table sized pond (C) showed negative correlation values with temperature (r = -0.241), water hardness (r = -0.331) and alkalinity (r = -0.205) and a high positive correlation value with pH (r = 0.807).

Total plankton in the Heterotis pond (D) showed positive correlation with alkalinity (r = 0.584) and pH (r = 0.719) and negative correlation with temperature (r = -0.769) and water hardness (r = -0.037) (Table 2).

Diversity Indices

Shannon Weiner index was highest for Catfish fries to fingerlings pond (A) = 2.824 and decreased in the order Catfish Table-sized pond (C) = 2.81 to Catfish Broodstock pond (B) = 2.797 and Heterotis pond (D) = 2.767. Evenness of distribution was highest for Catfish fries to fingerlings pond (A) = 0.624 and lowest for Heterotis pond (D) = 0.5489. Margalef's index of species richness was greatest for Heterotis pond (D) = 2.313, and least for Catfish Fries to fingerlings pond A. Berger-

Table 3. Diversity indices for each pond measured within the sampling period.

Diversity index	Pond A	Pond B	Pond C	Pond D
No. of Species	27	29	27	29
Individuals	231200*	229200	163200**	180800
Shannon Weiner Index (H)	2.824*	2.797	2.81	2.767**
Simpson Diversity index (1-D)	0.9064	0.9131*	0.907	0.9061**
Evenness (e^H/S)	0.62*	0.5655	0.6151	0.5489**
Menhinicks Index	0.05615**	0.06057	0.06683	0.0682*
Margalef's Richness index	2.105**	2.269	2.166	2.313*
Equitability_J	0.8569*	0.8307	0.8526	0.8219**
Fisher_Alpha	2.348**	2.542	2.429	2.601*
Berger-Parker	0.2422*	0.192	0.2328	0.1858**

* Highest values for the indices; ** Lowest values.

Parker Dominance Index (BPDI) for the ponds decreased in order of pond A = 0.2422, pond C = 0.2328, pond B = 0.192 and pond D = 0.1858 (Table 3).

Conclusion

The results showed that phytoplankton composition and their abundance are variable in freshwater fish ponds even within the same farm environment. Temperature, dissolved oxygen, photo-period, insolation, water pH, wind, seasonal variations, water characteristics, nutrient enrichment and predator-prey relationship may be related to variable changes in the phytoplankton distribution and their abundance in ponds' water.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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Full Length Research Paper

Substitution of the fish meal by the earthworm and maggot meal in the feed of Nile tilapia *Oreochromis niloticus* reared in freshwater

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The present experiment was conducted to evaluate the efficacy of dietary protein from maggot meal and earthworm meal to replace fish meal protein in *Oreochromis niloticus* juvenile feed. The fish used for this experiment come from the experience of the larval phase during which fish were fed with the formulated diets [fish diet (FD), maggot diet (MD) and earthworm diet (ED)] content 40% crude protein and the commercial diet (CD) content 34.5% crude protein. At the end of this larval phase, the average weights were 0.75 ± 1.93, 0.71 ± 3.55, 0.55 ± 2.52, 0.62 ± 2.52 g for FD, MD, ED and CD respectively. These different weights constitute the initials weights for this experience. In this experimental, the formulated diets (FD, MD and ED) content 30% crude protein and 29.5% crude protein for CD. Fish were fed four times daily to triplicate groups at 10.7% body weight for consecutive 90 days. After these days, fish fed with FD gave significantly higher average daily gain (ADG, 0.3 ± 0.03 g.day^{-1}) than MD (0.22 ± 0.18 g.day^{-1}). Fish fed with ED had the lowest ADG (0.14 ± 0.12 g.day^{-1}). The specific growth rate (SGR) were higher in fish group fed with FD, MD and CD and shows no significant difference (p > 0.05) compared to ED. Feed conversion ratio (FCR), protein efficiency ratio (PER) and survival rate (SR) show no significant difference (p > 0.05) in the all test. 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 *O. niloticus* juvenile to increase the growth of fish and reduce the cost of 1 kg of fish produced.

Key words: Ivory Coast, fish nutrition, replace fishmeal, invertebrates meal, zootechnic, economics parameters.

INTRODUCTION

Fishmeal is so far the main source of protein for composing fish feed. However, fishmeal is increasingly expensive (current prices on the market, 300 to 700 F.CFA/kg) and fish feed represents more than 50%

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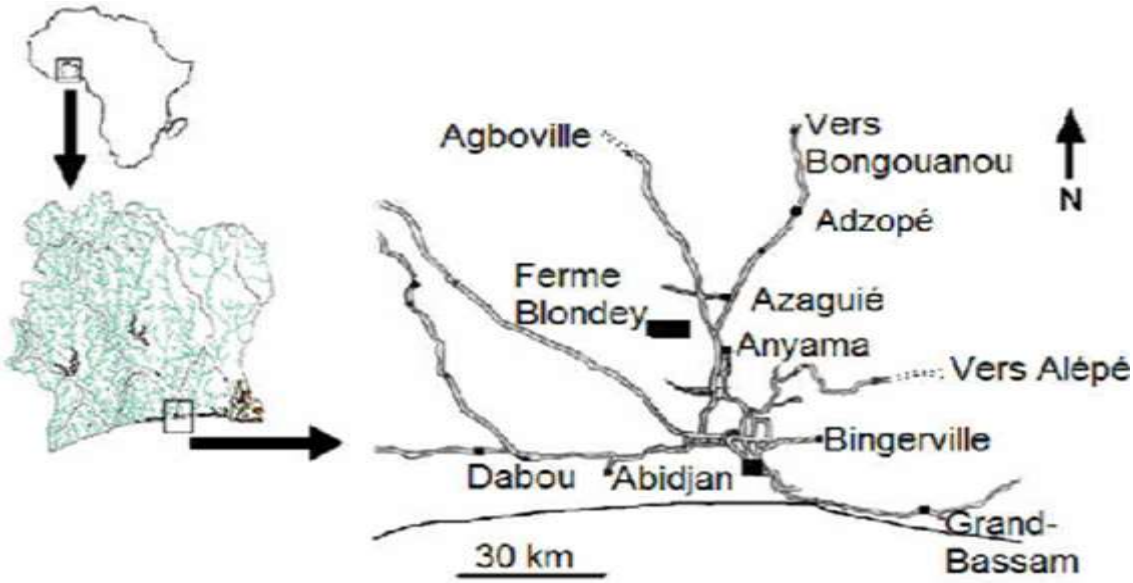

Figure 1. Map of the study area.

of the cost of production on farms (FAO, 2014; Coyle et al., 2004). Its inaccessibility is a source of abandonment of fish farming activity by small-scale fish farmers, most of them in developing countries. Nevertheless, aquaculture has become the fastest growing food industry in the world. That is why, the introduction of others protein sources as alternatives to replace fishmeal in fish feed is necessary to enhance the efficient production of aquaculture (Suarez et al., 2013; Katya et al., 2014). 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; Bamba, 2017) and animal protein sources (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 and earthworm 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, including tilapia, *Oreochromis niloticus*, *Lates calcarifer* and *Litopenaeus vannamei* (Ogunji et al., 2008; Katya et al., 2017; Cummins et al., 2017). The crude protein, crude lipid, and essential amino acid content of insect larval flours (maggot) resemble that of fishmeal. The crude protein content of maggots is around 40 to 64% (John, 2015). Earthworms have similar amino acid profiles to fish (Dedeke et al., 2010) and have been used as additional protein in fish feed (Sogbesan et al., 2007; Monebi and Ugwumba, 2013). However, recent research has shown that growth stimulation in some cases is observed at less than 50% substitution for earthworms (Sogbesan and Madu, 2008) and maggots (Ezewudo et al., 2015). According to these same authors, the total substitution of fishmeal by these protein sources has not yet given satisfactory results in terms of growth performance of fish. Therefore, it is important in this study to evaluate growth, feed use, economic value, and carcass composition of juvenile tilapia *O. niloticus* fed with feeds formulated with maggot and earthworm proteins without the addition of fishmeal.

MATERIALS AND METHODS

Description of the study area

The place of the experiments is the Blondey fish farm, 25 km from Abidjan (Ivory Coast) in the sub-prefecture of Azaguié (Ivory Coast). It is located between 5° and 6° North Latitude and between 4° and 5° West longitude. This farm has an area of three hectares whose feed water comes from a 3 ha dam also (Figure 1). According to Eldin (1971), this region is home to a warm equatorial climate composed of four seasons. First there is a succession of a great rainy season (from April to July) and a short dry season (from August to September). Then, we have a small rainy season (October and November) and finally a long dry season that runs from December to March. Concerning the hydrographic network, this zone abounds several rivers and in particular a river (Comoé). Examples include the Agnéby River, secondary courses (Mé, Nieky, and Betté) that are in flood during the long rainy season (Girard et al., 1971).

Experimental diets

Proportion (%) of ingredients used in the composition of experimental diets is shown in Table 1. Three isoproteic practical diets (30% crude protein content) were formulated with fishmeal, housefly maggot meal, earthworm meal, soybean meal, cotton meal, copra meal, corn flour and wheat bran meal as the main protein

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

Ingredients (%)	Diets		
	FD	MD	ED
Corn flour	26	20	20
Soybean meal	14	20	20
Cotton meal	10	15	15
Copra meal	20	17	16
Wheat bran	7	5	6
Fishmeal	20	--	--
Maggot meal	--	20	--
Earthworm meal	--	--	20
Palm oil	2	2	2
Vitamins (premix[1])	0.25	0.25	0.25
Salt	0.1	0.1	0.1
Seashell flour	0.55	0.55	0.55
Lysine	0.05	0.05	0.05
Methionine	0.05	0.05	0.05
Total	100	100	100

FD: Fish diet, MD: maggot diet, ED: earthworm 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.

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

Components (%)	Diets			
	FD	MD	ED	CD
Moisture	9.52	8.88	8.74	9.33
Crude protein	30	30	30	29.5
Ash	7.1	5.74	7.44	7.3
Crude Lipid	5.28	9.48	6.71	5.71
Crude fiber	5.82	6.18	5.93	6.1
Nitrogen free extract (NFE)	42.28	39.72	41.18	42.06
Gross energy ($kJ.g^{-1}$)	16.20	17.17	16.35	16.00
Cost ($F.CFA.kg^{-1}$)	309	207	214	300

FD: Fish diet, MD: maggot diet, ED: earthworm diet, CD: commercial diet. Nitrogen free extract (NFE) = 100 – (% Moisture + % Protein+ % Ash +% lipid + % fiber). Gross Energy = 22.2 × % protein + 38.9 × % lipid + 17.2 × % Nitrogen free extract (Luquet and Moreau, 1989). Price in CFA pound: 100 CFA= 0.18 $ based on 2017 exchange prices in Ivory Coast.

sources. Fishmeal was replaced totally with earthworms (*Eudrilus eugeniae*) and housefly maggots. These ingredients were included in diet at the level 20%. An industrial commercial diet used as the reference was purchased in local markets of Abidjan. The proximate composition (% Dry matter) and cost to formulate diets and the commercial diet (CD) are shown in Table 2. The crude protein content of the commercial diet (CD) used at the same juvenile stage is 29.5%. 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 earthworm was produced according to the method of Sogbesan and Madu (2003). 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 three formulated diets were designated as MD (diet containing maggot meal), ED (diet containing earthworm meal) and FD (control diet containing fishmeal). All diets were prepared according to the method of Bamba et al. (2014).

Experimental condition and fish feeding

The fish used for this experiment come from the experience of the

Table 3. Physicochemical parameters of water in pond.

Parameter	Diets			
	FD	MD	ED	CD
T (°C)	29.1 ± 0.5[a]	29.3 ± 0.6[a]	29.4 ± 0.8[a]	28.8 ± 0.5[a]
pH	6.6 ± 0.08[a]	6.8 ± 0.07[a]	6.5 ± 0.04[a]	6.9 ± 0.05[a]
O_2 (mg.L^{-1})	7.6 ± 0.33[a]	7.60 ± 0.42[a]	7.14 ± 0.32[a]	7.77 ± 0.37[a]
NO^-_2 (mg.L^{-1})	0.052 ± 0.03[a]	0.041 ± 0.05[a]	0.05 ± 0.05[a]	0.04 ± 0.05[a]
NO^-_3 (mg.L^{-1})	0.46 ± 0.01[b]	0.42 ± 0.04[b]	0.31 ± 0.03[a]	0.40 ± 0.02[b]
NH_4^+ (mg.L^{-1})	0.05 ± 0.02[a]	0.04 ± 0.02[a]	0.05 ± 0.01[a]	0.05 ± 0.02[a]
PO^{3-}_4 (mg.L^{-1})	0.42 ± 0.03[b]	0.32 ± 0.02[a]	0.33 ± 0.02[a]	0.39 ± 0.01[b]

Each value is the mean of three readings ± Standard deviation. Means has the different letters in the same row are significantly different at $p < 0.05$. NO^-_2, = Nitrite, NO^-_3 = Nitrate, PO^{3-}_4 = Phosphorus, NH_4^+ = Ammonium.

larval phase which lasted 30 days at the Blondey Aquaculture Station (5°6, N, 4°5, W), Ivory Coast. During this larval phase, the fish received feed containing 40% crude protein. These are the feed based on maggot meal, earthworm meal and fishmeal (control diet). The commercial diet used as the reference at the same larval stage contained 34.5% crude protein. At the end of this larval phase, 4800 fish of averaging weight 0.75 ± 1.93, 0.70 ± 3.55, 0.55 ± 2.52, and 0.62 ± 2.52 g respectively for FD, MD, ED and CD were randomly distributed in 12 hapas for this present experience. The stocking density used was 400 juveniles per hapa (2 × 1 × 0.75 cm^3). The feeding experiment was for a period of 90 days. Three hapas installed into pond were then randomly assigned to each of the four experimental diets. Fish were fed the experimental diets four times daily (08:00, 11:00; 14:00 and 17:00 h) 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 month. At 1 month intervals, 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 mg). 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.

Analytical methods

The feed ingredients, experimental diets and fish samples were analyzed according to AOAC (1990) for moisture, 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, 1989).

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 %.day-1) = [(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) × 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 (R×R 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 (R×R 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) × 100] / Feed cost to produce 1 k g control fish

Production time (PT)/kg fish produced (Days.kg-1) = Rearing time (days) / Weight gain (kg)

Water quality parameters

Water quality parameters were monitored during rearing period. Water temperature, dissolved oxygen, and pH were measured daily 08:00 h 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 are shown in Table 3.

Statistical analysis

Results were presented as mean ± standard deviation (SD) 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

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

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

Values are average from duplicate groups of samples. M: Moisture, CP: crude protein, CL: crude lipid, NFE: nitrogen free extract, FM: Fishmeal, MM: maggot meal, EM: earthworm meal, CF: corn flour, SM: soybean meal, CM: cotton meal, COM: copra meal, WB: wheat bran. Nitrogen free extract (NFE) = 100 – (% Moisture + % Protein+ % Ash + % lipid + % fiber).

differences among treatment means. Treatment effects were considered significant at $p < 0.05$. 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. 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 29.4 ± 0.8°C (ED), pH from 6.5 ± 0.04 (ED) to 6.9 ± 0.05 (CD). Dissolved oxygen ranged from 7.14 ± 0.32 (ED) to 7.77 ± 0.37 mg.L-1 (CD). Nitrate nitrogen (NO-3) values were 0.40 ± 0.02 (CD), 0.42 ± 0.04 (MD) and 0.46 ± 0.01 mg.L-1 (FD). These highest values of nitrate nitrogen were not significantly different ($p > 0.05$) in the water content of fish fed with FD, MD and CD. The water containing the fish fed with ED obtained the low values (0.31 ± 0.03 $mg.L^{-1}$) of nitrate nitrogen. Nitrite nitrogen ranged from (NO^{-}_{2}) 0.04 ± 0.05 (CD) to 0.052 ± 0.03 $mg.L^{-1}$ (FD), ammonium from (NH_4^{+}) 0.04 ± 0.02 (MD) to 0.05 ± 0.01 $mg.L^{-1}$ (FD, ED and CD). There were no significant differences ($p > 0.05$) in the water NO^{-}_{2} and NH_4^{+} among the treatment during the whole experimental period. The highest values of phosphorus were obtained in the water content of fish fed with FD and CD. These ranged from (PO^{3-}_{4}) 0.39 ± 0.01 (CD) to 0.42 ± 0.03 $mg.L^{-1}$ (FD) and these values were not significantly different ($p > 0.05$). Therefore, the low values of phosphorus were obtained in the water content of fish fed with MD (0.32 ± 0.02 $mg.L^{-1}$) and ED (0.33 ± 0.02 $mg.L^{-1}$).

Nutrient profile of protein ingredients

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

Growth performance, survival rate, feed utilization and production time

Significant effects ($p < 0.05$) of the dietary total replacement of fish meal with maggot meal and earthworm meal on the growth performance of *O. niloticus* juveniles were observed (Table 5). Use of fishmeal in the fish feed gave higher final weight (FW) and average daily gain (ADG) than maggot diet and commercial diet. These values were 27.64 ± 7.02 g and 0.3 ± 0.03 $g.day^{-1}$ for FW and ADG respectively. Interestingly, *O. niloticus* juveniles fed with MD 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 (MD) for FW and ADG from 0.19 ± 0.12 (CD) to 0.22 ± 0.18 $g.day^{-1}$ (MD). The lowest values (FW, ADG) were obtained in fish group fed on diet containing earthworm meal (13.38 ± 3.72 g and 0.14 ± 0.12 $g.day^{-1}$ for FW and ADG, respectively). Survival rate (SR), feed conversion ratio (FCR) and protein efficiency ratio (PER) were similar for all diets. Use of earthworm meal as protein source increased the production time (PT) of kg fish produced (6.81 ± 0.28 $days.kg^{-1}$ of fish produced) as compared to the others group. In contrast, the use of maggot meal as protein source in *O. niloticus* juvenile feed resulted in decrease PT (3.12 ± 0.09 $days.kg^{-1}$ of fish produced).

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

Parameter	Diets			
	FD	MD	ED	CD
SR (%)	88.5 ± 4.3^{a}	88.95 ± 5.6^{a}	85.33 ± 6.9^{a}	89.41 ± 4.7^{a}
IW (g)	0.75 ± 1.93^{b}	0.71 ± 3.55^{b}	0.55 ± 2.52^{a}	0.62 ± 2.52^{a}
FW (g)	27.64 ± 7.02^{c}	20.82 ± 4.71^{b}	13.38 ± 3.72^{a}	17.28 ± 3.56^{b}
WG (g)	26.89 ± 5.11^{c}	20.11 ± 3.31^{b}	12.83 ± 2.43^{a}	16.66 ± 2.73^{b}
ADG (g.day^{-1})	0.3 ± 0.03^{c}	0.22 ± 0.18^{b}	0.14 ± 0.12^{a}	0.19 ± 0.12^{b}
SGR (%.day^{-1})	4.01 ± 0.09^{b}	3.75 ± 0.33^{b}	2.017 ± 0.28^{a}	3.69 ± 0.28^{b}
FCR	1.47 ± 0.43^{a}	1.61 ± 0.66^{a}	1.69 ± 0.45^{a}	1.64 ± 0.45^{a}
PER	2.26 ± 0.42^{a}	2.07 ± 0.48^{a}	1.97 ± 0.38^{a}	2.03 ± 0.38^{a}
PT (days.kg^{-1})	3.12 ± 0.09^{a}	4.13 ± 0.33^{b}	6.81 ± 0.28^{d}	5.0 ± 0.28^{c}

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

Table 6. Carcass chemical composition (% Dry matter) of *Oreochromis niloticus* juveniles fed experimental diets.

Parameter	Diets			
	FD	MD	ED	CD
Moisture (%)	77.32 ± 0.23^{a}	78.12 ± 0.18^{a}	77.28 ± 0.16^{a}	78.30 ± 0.17^{a}
Crude protein (%)	49.43 ±0.19^{c}	48.4 ± 0.22^{b}	45.75±0.17^{a}	48.1 ± 0.20^{b}
Ash (%)	19. 53 ± 0.14^{b}	17.43 ± 0.17^{a}	16.32 ±0.14^{a}	19.32 ± 0.12^{b}
Crude Lipid (%)	17.63 ± 0.14^{a}	17.42 ± 0.12^{a}	18.22 ± 0.15^{a}	17.34 ± 0.12^{a}
Gross Energy (kJ.g^{-1})	17.83 ± 0.13^{a}	17.52 ± 0.10^{a}	17.24 ± 0.11^{a}	17.42 ± 0.12^{a}

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

Carcass chemical composition of *O. niloticus* juveniles

The chemical composition of *O. niloticus* larvae at the end of feeding experiments are shown in Table 6. No significant differences were found in the carcass moisture content and ash of fish fed different experimental diets. In contrast, crude protein content was significantly affected by experimental treatment ($p < 0.05$). The carcass protein content was higher in fish fed FD (49.43 ±0.19%) followed by fish group fed MD and CD (48.4 ± 0.22 and 48.1 ± 0.20%, respectively). In contrast, the lowest values were obtained in the fish group fed with ED (45.75±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 18.22 ± 0.15% (ED) for crude lipid and from 17.24 ± 0.11 (ED) to 17.83 ± 0.13 kJ.g^{-1} (FD) for 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 309, 207, 214 and 300 F.CFA, respectively for FD, 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 455, 334, 362, and 493 F.CFA, respectively for FD, MD, ED, and CD feeds. The analysis of financial profitability shows that the use of maggot meal and earthworm meal as a source of protein in the feed of *O. niloticus* juveniles resulted in a decrease in the cost of kg of feed (cost/kg of feed) as compared to the cost of kg of fishmeal-based feed and commercial diet. Regarding the production cost of kilogram (PC) of juveniles, it was lower in fish group fed with maggot diet followed by fish fed with earthworm diet. In addition, the use of maggot meal and earthworm meal as a source of protein in the feed of *O. niloticus* juveniles also helped reduce the production cost of kilogram of fish by 26.59% (MD) and 20.44% (ED) as compared to FD. This production cost per kilogram of fish also was reduced by 32.25% (MD) and 26.57% (ED) as compared to CD.

DISCUSSION

The average values of physicochemical water parameters

Table 7. Cost-benefit analysis of *Oreochromis niloticus* juveniles.

Parameter	Diets			
	FD	MD	ED	CD
INF	1214	1222	1214	1211
FNF	1076	1087	1038	1084
IB(kg)	0.91	0.86	0.67	0.75
FB(kg)	29.74	22.65	13.88	18.73
NB (kg)	28.83	21.79	13.21	17.98
QFU(kg)	42.46	35.09	22.31	29.51
CF (F.CFA)	309	207	214	300
CFU (F.CFA)	13120	7264	4775	8853
PC (F.CFA/kg)	455	334	362	493
R×R CF/FD	--	33	30.74	--
R×R PC/FD	--	26.59	20.44	--
R×R CF/CD	--	31	28.66	--
R×R CP/ CD	--	32.25	26.57	--

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, R×R CF/FD: reduction rate of CF compared to fish diet (FD), R×R PC/FD: reduction rate of PC compared to fish diet (FD), RxR CF/CD: reduction rate of CF compared to commercial diet (CD), R×R 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.

recorded during the period of the experiment did not differ from one hapa to another. They are between 28.8 ± 0.5 and 29.4 ± 0.8°C for temperature and 6.5 ± 0.04 and 6.9 ± 0.05 for pH. These values corroborated the results of Bamba et al. (2014) in the same station which found 23.6 to 31.6°C for temperature and 6.32 to 9.11 for pH. These values were within the tolerant range of *O. niloticus*. As for the dissolved oxygen during the experiment, the values obtained are between 7.14 ± 0.32 and 7.77 ± 0.37 $mg.L^{-1}$. 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 $mg.L^{-1}$ (Coche, 1978). The highest values of nitrate nitrogen in the water containing the fish fed with FD, MD and CD could be explained by the actual use of dietary nitrogen by fish as reported by Chakraborty et al. (1992). Fishmeal contains a high level of phosphorus (NRC, 1993). The greater part of this phosphorus is present in the feed in the form of tri calcium phosphate. Because of this, it cannot be absorbed by certain species of fish, particularly Cichlidae (Yone and Tochima, 1979) and is rejected in the breeding environment. This would explain the high phosphorus content of pond water when the *O. niloticus* species is fed FD and CD feeds. Indeed, FD and CD have been formulated based on fishmeal. According to Boyd (1998), 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 and 0.2 $mg.L^{-1}$ for good survival of fish.

After 90 days of fish monitoring, juveniles fed with the fish diet obtained the higher final weight (FW) followed by fish fed with maggot diet when compared with those of other group. On the other hand, the growth of *O. niloticus* juvenile fed with earthworm diet is low when compared with that obtained in any breeding. However, the juveniles fed on the commercial diet registered similar growth with those fish fed MD. The similarities observed between SGR when the fish were fed FD and MD show that the feed formulated with maggot meal is of interest for aquaculture. 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). 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. (2015). 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. The low growth rates of juvenile fed with earthworm diet corroborated the results of Nandeesha et al. (1988). For these authors, in common carp without free access to abundant natural food resources, the replacement of fishmeal by dried earthworm meal (*E. eugeniae*) resulted in reduced growth. 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 (Monebi and Ugwumba, 2013). In the present study, the survival rate values obtained 85.33 ± 6.9% (ED) and 89.41 ± 4.7% (CD) were low. These survival rate values in this study are also inferior to those obtained (100%) by Ogunji et al. (2008) 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 groups of juvenile, one diet to another. However, feed conversion ratio (FCR) was the lowest in fish fed FD and MD, indicating that they were most efficient in converting their food to body growth. Protein efficiency ratio (PER) were the highest in fish fed fish meal and maggot meal diet, an indication of good protein digestibility and bioavailability for optimum body protein increase and growth. In this study, the values of FCR and PER observed with fish fed ED show no significant difference with those obtained in all livestock. These results show that feed based-earthworm meal was also used by these fish. These results agree with those obtained by Dedeke et al. (2013) 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. These results corroborated with those of Ali et al. (2015). These authors indicate that the used maggot meal as ingredients in *O. niloticus* feed did not affect the palatability of the diets. The crude carcass lipids are not different in all fish groups. In addition, the crude protein content of the carcasses is low in fish fed with earthworm diet, unlike other groups. This indicates that the juvenile of *O. niloticus* is effectively used the crude lipid supplied by maggot 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 *O. niloticus* juvenile, but increased the lipid deposits. In this study, the cost (cost/kg of feed) of fish diet as those of CD were overprice. Fishmeal and fish oil is overprice in international market (FAO, 2014). 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. (2015) who concluded that 100% maggot meal can be included in the diet of *O. niloticus nilotcus* to reduce cost and maximize profit. However, the time required to produce 1 kg of fish increased in fish fed with ED. It is 6.81 ± 0.28 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 *O. niloticus* juveniles as well. It reduced the cost of kg of fish produced and the time/kg of fish produced. The earthworm meal slows down the growth of the juveniles and increases the production time of kg of fish produced. This study revealed that maggot meal can completely replace fish meal in the diets of *O. niloticus* juvenile 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.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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