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Use of zooplankton prey in aquaculture production of Nile Tilapia (*Oreochromis niloticus* Linnaeus, 1758) in Daloa, Côte D'Ivoire

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Abstract

The aim of the study carried out at the Ouattara N'golo fish farm in Daloa was to contribute to the improvement of fish production in Côte d'Ivoire through the production of Nile tilapia fed on zooplankton prey. Larvae of the Brazilian strain of *Oreochromis niloticus*, with an initial weight of 0.03 ± 0.01 g and an initial total length of 1.7 ± 0.1 cm, were distributed in triplicate in three plastic tanks. Fish in BAC 1 were fed only low-grade rice flour (LSRF), while those in BAC 2 were fed LSRF and live zooplankton (LSRF + ZOO). Fish in BAC 3 were fed mainly live zooplankton (ZOO). The main results show that fish fed with low-grade rice flour and live zooplankton (FBR + ZOO), and those fed mainly with live zooplankton (ZOO) recorded the highest survival rates (95.25 ± 0.0025% and 97.5 ± 0.005% respectively). Furthermore, weight and length growth at the end of the experiment were greater in fish fed with low-grade rice flour and live zooplankton (2.66 ± 0.01 g and 6.8 ± 0.1 cm) than in those fed with low-grade rice flour only (2.46 ± 0.02 and 5.8 ± 0.1 cm) and those fed mainly with live zooplankton (1.93 ± 0.03 and 5.5 ± 0.1 cm). The involvement of zooplankton prey in the diet of Nile tilapia larvae confers better survival and growth performance on these small fish, while at the same time reducing the expense of producing them.

Keywords: *Oreochromis niloticus*; Zooplankton; Survival; Growth

1. Introduction

Fish is an excellent source of fatty acids, some of which are essential for the development and functioning of the nervous system [1]. And thanks to these fatty acids, fish helps prevent cardiovascular disease [1]. As a result, it has become the most widely consumed animal in the world [2]. In Côte d'Ivoire, fish is the main source of animal protein for consumers [3]. But local production is too low to meet the fish needs of the Ivorian population. The country has therefore had to increase its local production by importing fish [4]. Despite all these efforts, the Ivorian population's demand for fish is far from being met. The government of Côte d'Ivoire has also invested in aquaculture to revitalise the fish production sector. Unfortunately, the aquaculture projects initiated by the government to increase fish production have all failed [5]. The government then went on to popularise fish farming in several regions of the country. In the Centre-West, Daloa is the area most interested in fish farming [6]. However, this aquaculture activity is essentially hampered by a problem of feeding from the larval stage to the adult stage [6]. The survival rate of fish from the larval stage to the fry and juvenile stages is low, and the market weight is not optimal, resulting in poor yields [7]. Good fish yields are closely linked to the survival and harmonious development of the larvae [8]. And these larvae require the presence of mobile prey of microscopic size that can meet their food and nutritional requirements [8], in this case zooplankton organisms [9]. In Western countries, zooplankton organisms are fed to fish to improve fish production [10, 11, 12, 13]. In Côte d'Ivoire, studies of animal plankton have focused mainly on their biology or diversity in various aquatic environments. Few

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studies have been devoted to the use of zooplankton in fish production in Côte d'Ivoire [14]. Yet zooplankton is the preferred live food of several fish species, including Tilapia [15]. Therefore, using zooplankton prey in the production of tilapia *Oreochromis niloticus* could be an alternative to satisfy the fish demand of the Ivorian population. The aim of this study is therefore to contribute to the improvement of fish production in Côte d'Ivoire through the production of Nile tilapia fed on zooplanktonic prey.

2. Materials and methods

2.1. Materials

21-day-old *Oreochromis niloticus* larvae of the improved Brazilian strain (Figure 1) were used. These fish were produced at the OUATTARA N'golo fish farm "Hatchery for the production of improved tilapia fry" in Daloa, Côte d'Ivoire. Average individual weight was 0.03 ± 0.01 g and total length 1.7 ± 0.1 cm. The stocking density was 800 larvae / m^3 of water [16].

Figure 1 Sample of reared *Oreochromis niloticus* larvae

2.2. Methods

2.2.1. Conduct of the experiment

Fish distribution

The larvae were placed in three plastic tanks (BAC 1, BAC 2 and BAC 3), each of which was tripled, giving a total of nine tanks (Figure 2). Each of these tanks, containing 500 liters of borehole water, was stocked with 400 *Oreochromis niloticus* larvae.

Figure 2 Partial view of the fish rearing system

Ra = diet ; FBR = low-grade rice flour ; ZOO = live zooplankton

Feeding

The fish were fed different diets in the rearing tanks. They were fed three times a day at specific times of the day, with a daily ration equivalent to 10% of their weight according to [17]. Fish in BAC 1 media were fed only low-grade rice flour. Fish in BAC 2 were fed two meals of zooplankton prey and one meal of rice flour. The fish in BAC 3 were fed mainly zooplankton prey (Table 1).

The quantity of zooplankton organisms distributed to the fish during each meal was obtained by filtering 20 liters of water taken from the zooplankton prey production medium using a 50 µm mesh plankton net. The contents of the plankton net were then concentrated to 100 ml. An aliquot of 5 ml of this was fixed in pillboxes by the addition of an ethyl alcohol solution containing 70% alcohol, and then observed under an optical microscope. The rest of the 100 ml was poured into the tank containing the fish that were to receive a meal of live zooplankton.

To check whether the zooplankton organisms were being ingested by the fish, a 20-liter sample of water was taken from the tanks of the fish fed zooplankton and filtered every morning. The net residue was concentrated to 100 ml and fixed in pillboxes for observation under an optical microscope. The fish in each of these environments were fed for six days during the week, and on the seventh day they were fished to check their growth in size and weight.

Table 1 Daily feeding frequency of fish

Rearing environments	Days	Diets	Feed rations	Hours
BAC 1	Six days in the week	Low-grade rice flour	0,5 g	between 8 am and 9 am
		Low-grade rice flour	0,5 g	between 12 pm and 1 pm
		Low-grade rice flour	0,5 g	between 4 pm and 5 pm
BAC 2	Six days in the week	Live zooplankton	20 l filtered water	between 8 am and 9 am
		Low-grade rice flour	0,5 g	between 12 pm and 1 pm
		Live zooplankton	20 l filtered water	between 4 pm and 5 pm
BAC 3	Four days in the week	Live zooplankton	20 l filtered water	between 8 am and 9 am
		Live zooplankton	20 l filtered water	between 12 pm and 1 pm
		Live zooplankton	20 l filtered water	between 4 pm and 5 pm
	two days in the week	Live zooplankton	20 l filtered water	between 8 am and 9 am
		Low-grade rice flour	0,5 g	between 12 pm and 1 pm
		Live zooplankton	20 l filtered water	between 4 pm and 5 pm

Monitoring fishing

Fishing to monitor fish growth was carried out every seven days for the duration of the experiment. To do this, a sample representing 30% of the fish population in each tank was caught and weighed. The total length of some of the individuals in the sample was then measured. After these various measurements, the fish were immediately returned to their original tanks.

Measurement of physico-chemical parameters

The temperature and pH of the water in each tank were measured daily before each meal. These physico-chemical parameters, which significantly control fish growth [18], were measured using an APERA pH meter. After switching on the device and selecting the desired temperature unit (°C), its probe was dipped into the water of the rearing media and held until the pH and temperature values stabilized. This action was repeated twice (for a total of three measurements) in each medium.

2.2.2. Analysis of fish zootechnical performance

The growth performance of the fish was analysed by evaluating a number of indices according to [19]. These are changes in size and weight, survival rate (SR), absolute weight gain (AWG), daily weight gain (DWG) and specific growth rate (SGR).

Each of these indices is calculated according to an appropriate formula, as follows:

SR = (Final number of fish / Initial number of fish) x 100

AWG (g) = Final weight - Initial weight

DWG (g / d) = (Final weight - Initial weight) / Rearing time

SGR (% / d) = [(ln Final weight) - (ln Initial weight)] x 100 / Rearing duration

2.3. Statistical analysis of the data

The data were processed using Statistica 7.1 software in Excel.

3. Results

3.1. Variations in physico-chemical parameters of culture media

The effects of the diets on the temperature and pH of the fish culture media are shown in figures 3A and 3B, respectively. The lowest temperature value (24.2 °C) was observed with the FBR diet, and the highest value (28.8 °C) with the ZOO diet. pH values fluctuated between 6.6 (FBR) and 8.3 (ZOO). The variations in these physico-chemical parameters were not significantly different for all the diets (Kruskal-Wallis test, $p > 0.05$).

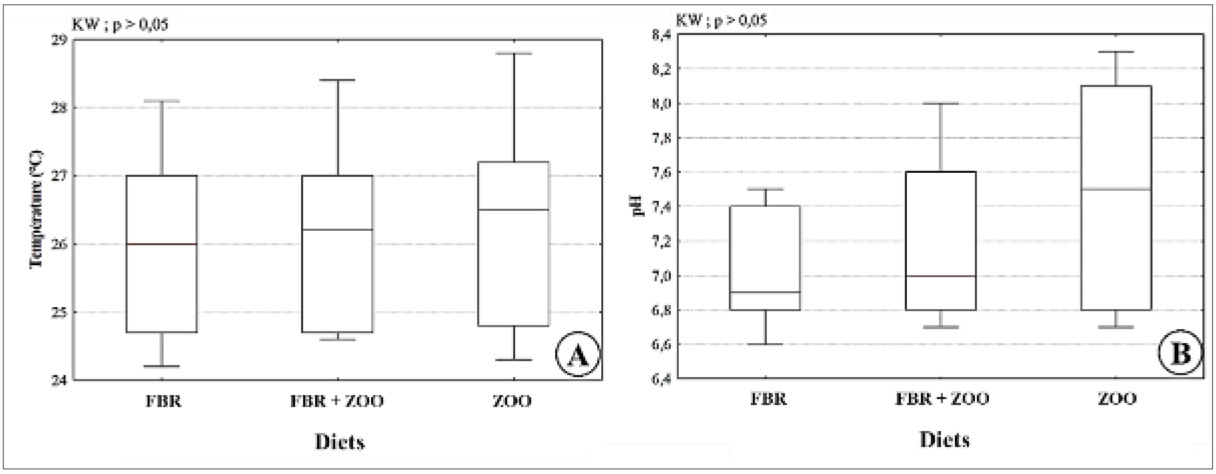

Figure 3 Temperature (A) and pH (B) variations with different diets

3.2. Quantity of feed distributed during rearing

A total of 130 g of inert feed (low-grade rice flour) and 1,982,916 live zooplankton individuals were distributed to the fish. In terms of inert feed, the fish on the FBR diet received the largest proportion (90 g). They were followed by the fish on the FBR + ZOO diet with 30 g. The fish on the ZOO diet had the smallest amount of this food (10 g). These quantities of inert feed distributed to the different batches of fish were significantly different (Kruskal-Wallis test, $p < 0.05$ and Mann-Whitney test, $p < 0.05$). More live food (zooplankton) was distributed to fish fed the ZOO diet (1,184,132 individuals) than to those fed the FBR + ZOO diet (798,784 individuals). The quantity of live zooplankton distributed to fish on the ZOO diet was significantly different from that distributed to fish on the FBR + ZOO diet (Mann-Whitney test, $p < 0.05$) (Table 2).

Table 2 Quantities of feed distributed to fish by diet during 10 weeks of rearing

			Diets		
Food			FBR	FBR + ZOO	ZOO
Live food	Zooplankton	Rotifers		32341 ± 8192 ind/d	48061 ± 12288 ind/d
		Copepods		12331 ± 8192 ind/d	25804 ± 3431 ind/d
		Cladocerans		8580 ± 1600 ind/d	12524 ± 1600 ind/d
		Total		53252 ± 12080 ind/d	86389,8 ± 16248 ind/d
Inert food	Low-grade rice flour		90[a] g	30[b] g	10[c] g

3.3. Changes in fish size and weight

At the end of the first week of rearing, the size of all the fish on the three different diets had increased from 1.7 ± 0.1 cm to 2.2 ± 0.1 cm. After this first week, fish on the FBR and FBR + ZOO diets showed greater growth in length than fish on the ZOO diet. But after the third week of rearing, the fish on the FBR + ZOO diet showed much faster growth in length. While these fish reached 6.8 ± 0.1 cm at the end of the experiment, those on the FBR diet and those on the ZOO diet measured 5.8 ± 0.1 cm and 5.5 ± 0.1 cm respectively (Figure 4A). Fish on the FBR + ZOO diet grew significantly faster than those on the other diets (Kruskal-Wallis test, $p < 0.05$ and Mann-Whitney test, $p < 0.05$). With regard to weight growth, during the first two weeks of the experiment, all the fish had almost the same weight, increasing from 0.03 ± 0.01 g to 0.12 ± 0.03 g, whatever the diet. From the second week of rearing, the fish on the FBR + ZOO diet stood out from the other two batches of fish by their rapid weight gain until the end of the experiment when they weighed 2.66 ± 0.01 g, while those on the FBR and ZOO diets weighed 2.46 ± 0.02 g and 1.93 ± 0.03 g respectively (Figure 4B). Despite the high weight of fish on the FBR + ZOO diet compared with fish on the FBR diet, there was no statistically significant difference between these two batches of fish. However, the weight growth of fish fed the FBR diet differed significantly from that of fish fed the ZOO diet (Kruskal-Wallis test, $p < 0.05$ and Mann-Withney test, $p > 0.05$).

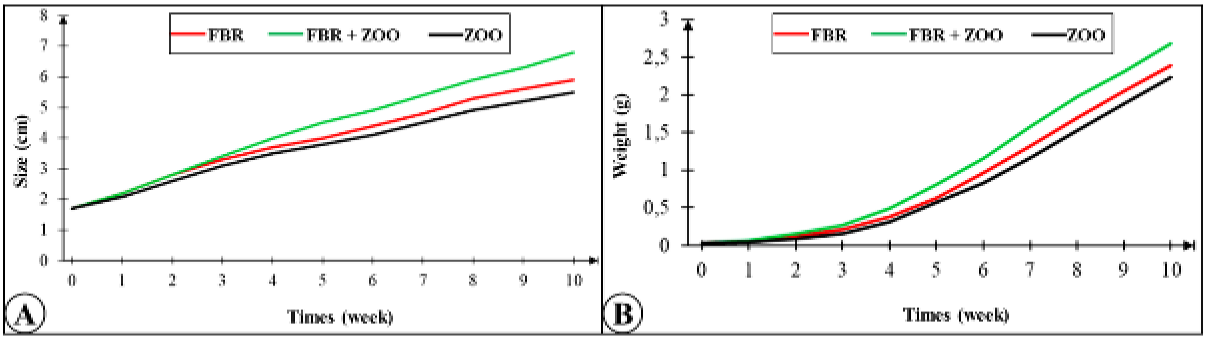

Figure 4 Changes in the size (A) and weight (B) of fish fed different diets

3.4. Variation in zootechnical parameters

Fish survival rates, absolute and daily weight gains and specific growth rates are presented in table 3.

3.4.1. Fish survival rates

During the experiment, fish fed the ZOO diet showed the best survival rates (97.5 ± 0.005 %). This was followed by fish on the FBR + ZOO diet (95.25 ± 0.0025 %). The lowest survival rates (87.25 ± 0.0025 %) were observed in fish fed the FBR diet. The survival rates of fish fed the ZOO and FBR + ZOO diets were, together, significantly different from the survival rates of fish fed the FBR diet (Kruskal-Wallis test, $p < 0.05$ and Mann-Whitney test, $p < 0.05$).

3.4.2. Absolute and daily weight gain

Weight gain was greatest in fish fed the FBR + ZOO diet (2.63 ± 0.01 g), with a daily weight gain of (0.037 ± 0.00 g). They were followed by fish on the FBR diet (2.43 ± 0.02 g). The weight of the latter increased by 0.034 ± 0.00 g each day. Weight gain was lower in fish fed the ZOO diet (1.9 ± 0.03 g), which gained 0.027 ± 0.00 g daily. Their weight gain was significantly different from that observed in fish fed the FBR and FBR + ZOO diets (Kruskal-Wallis test, $p < 0.05$ and Mann-Whitney test, $p > 0.05$).

3.4.3. Specific growth rate

Fish fed with live zooplankton and low-grade rice flour (FBR + ZOO) showed the highest specific growth rate (6.39 ± 0.007 % / d). They were followed by fish fed only with low-grade rice flour (FBR) (6.27 ± 0.012 % / d), then by those whose diet consisted mainly of live zooplankton (ZOO) (5.92 ± 0.022 % / d). The specific growth rates of fish fed the FBR and FBR + ZOO diets were, together, significantly different from the specific growth rate of fish fed the ZOO diet (Kruskal-Wallis test, $p < 0.05$ and Mann-Whitney test, $p > 0.05$).

Table 3 Variation in zootechnical parameters according to diet during experimentation

	Diets		
Zootechnical parameters	FBR	FBR + ZOO	ZOO
Initial number	400	400	400
Final number	349 ± 1	381 ± 3	390 ± 5
Survival rate (%)	87,25 ± 0,0025^{a}	95,25 ± 0,0025^{b}	97,5 ± 0,005^{b}
Initial mean weight (g)	0,03 ± 0,01	0,03 ± 0,01	0,03 ± 0,01
Final mean weight (g)	2,46 ± 0,02^{a}	2,66 ± 0,01^{a}	1,93 ± 0,03^{b}
Absolute weight gain (g)	2,43 ± 0,02^{a}	2,63 ± 0,01^{a}	1,9 ± 0,03^{b}
Daily weight gain (g / d)	0,034 ± 0,00^{a}	0,037 ± 0,00^{a}	0,027 ± 0,00^{b}
Specific growth rate (% / d)	6,27 ± 0,012^{a}	6,39 ± 0,007^{a}	5,92 ± 0,022^{b}

4. Discussion

The temperature and pH of the water in the fish rearing environments varied between 24.2 °C and 28.8 °C and between 6.6 and 8.3 respectively during the experiment. These temperature and pH ranges are favourable for rearing Nile tilapia [20], allowing them to feed well and develop better [210]. It is therefore clear that the temperature and pH conditions in the rearing environments could not have been a limiting factor in the survival and growth of the fish. Consequently, the survival and growth of the fish in the rearing environment were essentially conditioned by the quality and quantity of the feed they were given. Fish fed only low-grade rice flour (FBR) had more food. However, it was in the latter group that more fish died during the experiment. This situation would therefore be linked to the nutritional quality of this agricultural product. According to [7], this food, which is not very digestible, causes morphological anomalies in the digestive system of fish larvae that consume it. These anomalies could reduce the ability of the larvae to absorb, digest and assimilate nutrients efficiently, leading to the death of these small fish. On the other hand, in fish fed meals including zooplankton prey (fish fed FBR + ZOO and ZOO diets), survival rates were very high (95.25 ± 0.0025 % and 97.5 ± 0.005 %). These larval survival rates are similar to those obtained by [10, 12, 13] when feeding zooplankton to the larvae of *Cyprinus carpio*, *Lota lota* and *Clarias anguillaris* respectively. Nile tilapia larvae have the same dietary requirements as those of other fish species. Indeed, all fish larvae are essentially carnivorous, and require the presence of microscopic prey for their survival [8]. But it seems that the effectiveness of zooplankton is limited to ensuring better survival for fish. In fact, in the present experiment, fish fed mainly with zooplankton organisms (fish on the ZOO diet) were characterized by poor weight growth even though they each received 216 ± 40.62 zooplankton prey per day, a quantity that even exceeded the useful quantity (163 zooplankton prey per fish larvae per day) recommended by [22]. The poor growth of fish fed in this way is thought to be linked to the period over which larval fish should be fed with zooplankton. [22] points out that the effectiveness of zooplankton for weight gain in fish extends over a period of 30 days from the first day of the larva's life. However, in the present study, fish that were already 21 days old were fed live zooplankton for 60 days, when they had just over a week left to partially do without this live food. This is why, beyond the first week of rearing in the present study, either after around 30 days of life, the growth in size and weight of these larval fish changed moderately, while the other fish gained much more in length and weight. These findings show that zooplanktonic prey are more useful for the survival of fish larvae than for their growth. However, when these micro-organisms are added to low-grade rice flour on a daily basis, they can ensure that fish larvae grow well throughout their lives. And this growth is even better than that observed in larvae fed on low-grade rice flour (FBR) alone. This suggests that zooplanktonic prey fill the protein deficit in low-grade rice flour [7], acting as a food supplement. It is clear that with a small quantity of zooplankton prey, added to a small quantity of low-grade rice flour, the harmonious development of fish fed these two types of meal on a daily basis is guaranteed [7]. The use of this food supplement in fish farming has been of vital importance in the production of *Oreochromis niloticus*, in terms of the specific growth rate. Larvae fed daily with zooplankton and low-grade rice flour gained more weight than fish fed otherwise. This rate of specific growth thus remained better in these fish up to fry age. [13] also obtained high specific growth rates in *Clarias anguillaris* fed on zooplankton prey. These microscopic organisms are thought to play a role in the optimal growth of fish larvae. In fact, zooplanktonic prey, in this case Rotifers, Copepods and Cladocerans, improve the growth performance of the larvae of several species of fish [23, 24, 25, 26, 27]. Furthermore, the effects of the consumption of zooplanktonic prey by fish larvae are felt by the latter after a certain time in their larval stage. In fact, zooplankton organisms constitute a bank of polyunsaturated fatty acids, phospholipids, essential amino acids, proteins and vitamins, including vitamin B [11]. Therefore, the ingestion of these micro-organisms by small fish enables them to continue their growth until they become juveniles or adults [28, 29].

5. Conclusion

In view of the evolution of the size and weight of the fish reared in the present experimental study, it should be noted that the use of zooplanktonic organisms in the feeding of *Oreochromis niloticus* larvae confers better survival and growth performance on these small fish. What's more, adding zooplankton organisms to low-grade rice flour could help reduce the quantity of this agricultural product that has to be used to produce market fish.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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