Effect of substitution of fish meal by cricket meal (*Acheta domesticus*) on the growth of fry of *Oreochromis niloticus* (Linnaeus, 1758)

ABSTRACT

Aims: This study evaluates cricket meal (*Acheta domesticus*) as an alternative to fishmeal in feeding tilapia fry (*Oreochromis niloticus*) to valorize of alternative protein sources in aquaculture feeding in Benin.
Study design: A randomized block experimental design
Place and Duration of Study: Agro-fish farm "ASSIKY", Department of Ouémé, commune of Akpro-Missérété, district of Vakon, village Ahohouèssa, between June 2018 and August 2018.
Methodology: A control diet (R0) based on fishmeal and a diet (R100) containing 100% cricket meal. Four fine mesh happa (2 m x 1 m) were installed in a 500 m² pond. Each tank was stocked with 20 tilapia fry with an initial average weight of 10.41 +/- 0.5 g. The test was repeated thrice, and the two treatments were randomly assigned to the tanks. The fry were fed twice daily at 10 A.M. and 5 P.M., with a feeding rate of 6% of the total biomass. Parameters measured included survival rate, average daily gain, Consumption Index, and specific growth rate.
Results: The results showed that fry-fed R100 achieved significantly better performance ($P < 0.05$) than those fed R0. The Average Daily Gain (ADG) of fry varied from 0.09 +/- 0.01 g/d to 0.17 +/- 0.03 g/d. The specific growth rate (TCS) was 1.30 +/- 0.15 in R100 and 0.75 +/- 0.08 in R0. Consumption Index was lower for R100 (3.85 +/- 0.99) compared to R0 (6.91 +/- 0.86). Survival rate was 100% in both groups.
Conclusion: These results highlight the potential use of insects as an alternative protein source to fishmeal in aquaculture diets, and it is recommended that these results be validated under a variety of rearing conditions and over extended periods to ensure their robustness.

Keywords: Feed; growth; Tilapia; Ouémé department

1. INTRODUCTION

In 2022, global aquaculture production reached 130.9 million tonnes [1], of this tonnage, aquatic animal production accounts for 94.4 million tonnes and algae production accounts for 36.5 million tonnes [1]. Additionally, the amount of fish consumed per capita has grown, rising from 9.1 kg in the 1960s to 20.6 kg in 2022. According to preliminary projections for 2032, consumption may surpass 21.3 kg per capita, a 12% rise [1]. Fishmeal remains a key ingredient in aquaculture feeds due to its high content of easily digestible protein and good palatability, making it an essential component in fish diets [2]. Aquatic animal products account for approximately 15% of animal protein and 6% of total protein consumed globally. They provide essential nutrients such as omega-3 fatty acids, minerals and vitamins [1].

However, diet formulation challenges remain, including the need to provide feeds that are tailored to different fish species and meet their nutritional requirements at each stage of development. These challenges remain paramount for both commercial feed production and local feeding practices [3]. According to some researchers, the continued use of fishmeal as the main protein source in aquaculture diets is contributing to increasing feed costs [4,5,6]. However, the increase in fish production for human consumption, overexploitation of wild stocks and the impact of climatic events such as El Niño have caused instability in fishmeal production, leading to increased production costs [2,7]. Therefore, new sustainable protein sources are being explored that can provide nutritional value equivalent to that of fishmeal to ensure optimal fish growth [2,7]. The use of insect meal in fish feed, especially for fry, could offer comparable performance to that obtained with fishmeal. On average, 2 kg of feed materials (agricultural by-products or organic residues) are required to produce 1 kg of insects [8].

Many studies have focused on the use of insects as an alternative source of animal protein in the manufacture of aquafeeds, replacing fishmeal [2,9,10,11,12,13]. The house cricket (*Acheta domesticus*), belonging to the order Orthoptera, is particularly promising as a novel protein-rich feed. It has rapid reproduction, adaptability to various environments, and a low ecological footprint compared to conventional cattle, pig, or poultry farming [2]. Cricket meal has been shown to be able to partially or completely replace fishmeal in fish feed, due to its high nutritional quality [14,15]. In addition to a high protein (64.9%) and fat (17.4%) content, cricket meal also contains essential vitamins and minerals [14,16]. It is in this perspective that we have chosen to incorporate *Acheta domesticus* into the feed for Oreochromis niloticus fry, replacing fishmeal. The objective is to enhance the value of this alternative source in the form of powder while evaluating the zootechnical performances of the fry fed with this feed.

2. MATERIAL AND METHODS

2.1 Study environment

The study was conducted at the agro-fish farm "ASSIKY", located in the department of Ouémé, commune of Akpro-Missérété, district of Vakon, precisely in the village of Ahohouèssa, about one kilometer from the Porto-Novo–Pobè Interstate Road. The farm covers an area of 7,000 m² and is mainly dedicated to intensive fish farming of two key species: tilapia (*Oreochromis niloticus*) and African catfish (*Clarias gariepinus*). The study environment is characterized by high average temperatures (25 °C to 30 °C), relative humidity often above 80%, and annual rainfall of 1100 and 1300 mm spread over two rainy seasons and two dry seasons. Well-watered, the study environment has ten (10) kilometers which gives four (04) rivers and some backwaters, also crossed by the Ouémé River. The large number of wetlands and shallow waters is ideal for fish farming and the cultivation of vegetables. However, during the rainy season, increased turbidity due to the supply of sediment can reduce light penetration and limit the primary productivity of the basins. The local soils, mainly ferritic and rich in clay, facilitate water retention in fish ponds, while contributing to the enrichment of nutrients such as nitrogen and phosphorus, favorable to the development of phytoplankton, a natural food source for fish. In addition, the local biodiversity, composed of wetlands and tropical vegetation, can both enrich the aquatic ecosystem and pose challenges related to the presence of wild predators, such as fish-eating birds.

2.2 Experimental units

The test lasted 45 days and was carried out in four (04) fine mesh happa (2 mx 1 m). The tanks were installed in a pond with an area of 500 m². A total of 20 Oreochromis niloticus fry with an initial average weight of 10.41±0.5 g was loaded into each tank. The fry was obtained from the farm. Cricket flour was produced on the farm. Its production consisted of seeding the crickets in a system of plastic boxes equipped with cells, laying boxes, feeders and drinkers, with a diet based on soy flour and Moringa oleifera powder. Specific measures, such as the use of drain oil to prevent ant invasions, as well as strict feed management to avoid fungal infections, are implemented. This technique was observed at the Songhaï Center during an internship. The crickets after harvesting are fasted and frozen for ethical slaughter. They are then washed and dried in the sun. Once dehydrated, they are ground and sieved to obtain a homogeneous powder. The meal is stored in airtight containers to preserve its nutritional qualities. The powder produced was integrated into the formulation as a total replacement for fish meal at a rate of 100% (R100). A control diet containing only fish meal (R0) was also prepared. These two diets were manufactured locally. The test was repeated three times and the two treatments (R0 and R100) were randomly assigned to the happas, according to a randomized complete block experimental design. A weekly check was carried out every 7 days using a landing net. It consisted of fishing 50% of the fry from each tank, which were then weighed using a scale with a maximum capacity of 7 kg (precision of 0.01) to monitor the evolution of their weight during the test.

2.2.1 Food manufacturing

The manufactured feeds were formulated (Table 1) using an Excel spreadsheet that was used to calculate the proportions of crude protein (R0 = 31.69 %; R100 = 35.63 %) and metabolizable energy (R0 = 3126.2 kcal/kg; R100 = 2488.07 kcal/kg) in line with the nutritional requirements of the species studied. Local raw materials such as fish meal, soybean meal, cottonseed meal, corn flour, wheat bran, rice bran, palm oil, as well as nutritional additives such as table salt, L-Lysine HCL (98%) and DL-Methionine (99%) were purchased from a local feed mill.

Table 1. Food formulas of the different experimental diets

Raw materials	**Incorporation rate (%)**	
	R0	**R100**
Cricket flour	0	25
Fish meal	25	0
But	20	20
Wheat bran	6	6
Rice bran	9.5	9.5
Cottonseed cake	10	5
Soybean meal	20	20
Methionine DLL 99%	2	2
L-Lysine HCl 98%	2	2
Table salt	0.5	0.5
Palm oil	5	5
Total (%)	100	100
Crude protein (%)	31.69	35.63
Metabolizable energy (kcal/kg)	3126.2	2488.07

R0%: ration containing 0% cricket flour, R100% containing 100% cricket flour

About the manufacture of feed, the raw materials were ground in a corn mill, then they were weighed according to their incorporation rate in the feed. Red palm oil was added to the mixture. After adding the oil, the whole was homogenized by hand and water was then added gradually during mixing to a level of 25%. The mixture thus formulated was put into 3 mm granules using a granulator and then dried in the sun for 5 days.

2.2.2 Fish Feeding

O. niloticus fry were fed twice daily (10 A.M. and 5 P.M.). The feeding rate was set at 6% of the total biomass [17] throughout the experiment. The mean weight of the fry was measured on the scale at the beginning of the trial and then every 7 days. The number of fry surviving at the end of the trial was counted.

2.3 Zootechnical Parameters

The following zootechnical parameters were determined:

- Average Daily Gain:

[ADG = (Bf – Bi)/dt]

Bi: Initial biomass, Bf: Final biomass, dt: duration of the experiment

- Specific Growth Rate:

[SGR (%/d) = 100*(ln Wf – ln Wi)/dt]

Wi: Initial weight, Wf: Final weight, dt: duration of the experiment

- Consumption index:

[CI = Qi / (Bf- Bi)] where Qi: quantity of food ingested.

- Survival rate:

SR (%) = 100*Nf/Ni] where Ni: Initial number of fish and Nf: Final number of fish.

2.4 Data Processing and Analysis

The collected data were analyzed using IBM SPSS Statistic 26.0 software. The Shapiro-Wilk test was used to verify the normality of the distribution of data on zootechnical performances. The equality of variances was tested using the Bartlett test. When these conditions were met, the Student T test was used to assess the existence of significant differences between the mean values of zootechnical performances of fry according to the different feed rations (R0 and R100). The data were presented as Mean +/- standard error.

3. RESULTS AND DISCUSSION

3.1 RESULTS

3.1.1 Effect of feed on zootechnical performance of Tilapia fry (*O. niloticus*)

3.1.1.1 Average Daily Gain (ADG)

Figure 1 shows the evolution of the Average Daily Gain (ADG) of fry according to the feeding regimes. The average daily gain of fry varied from 0.09 g/d to 0.17 g/d. The fry fed with the R100 diet have a higher ADG than that of R0.

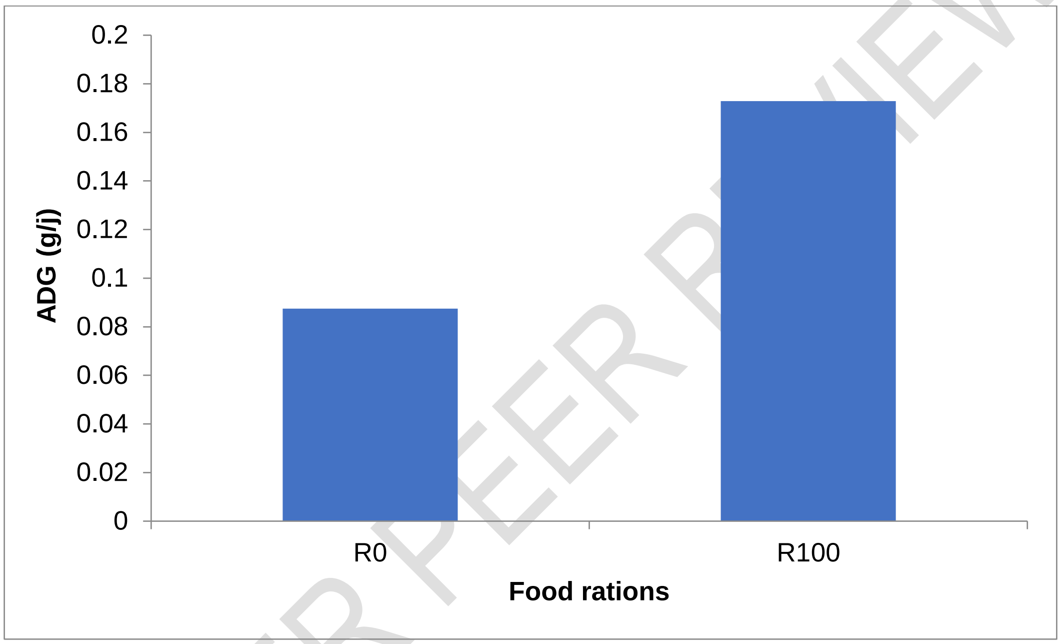

Fig. 1. Evolution of Average Daily Gain according to the experimental diets.

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3.1.1.2 Specific Growth Rate (SGR)

Figure 2 shows the evolution of the Specific Growth Rate (SGR) of fry according to the different experimental diets. The specific growth rate of fry varied from 0.74 %/d to 1.29 %/d. Fry fed with the R100 diet had a higher SGR than fry fed with the R0 diet.

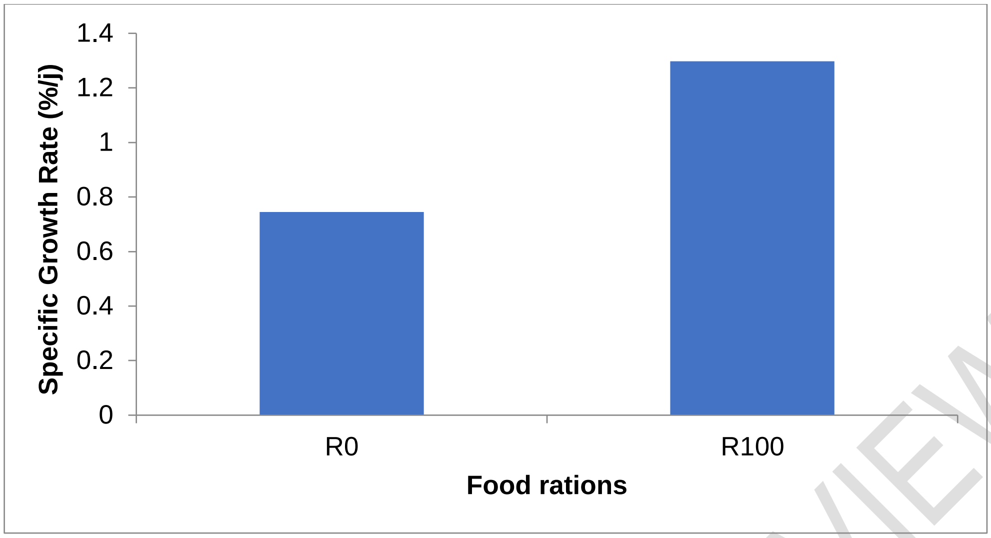

Fig. 2. Evolution of the specific growth rate of fry according to the experimental diets.

3.1.1.3 Consumption index (CI)

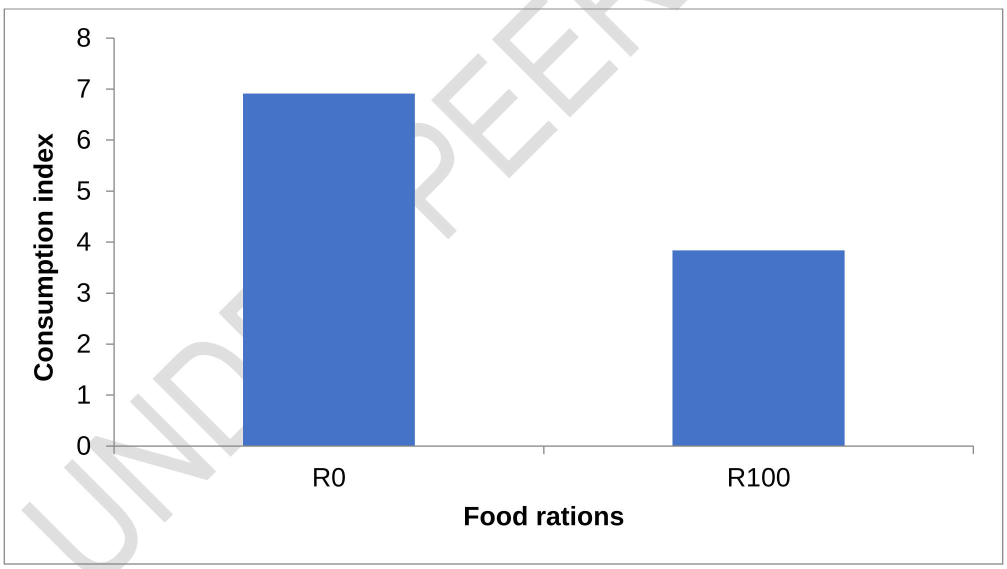

Fig. 3. Evolution of the consumption index (CI) of fry according to the experimental diets.

Figure 3 provides information on the Consumption Index evolution (CI) according to the feeding regimes. The consumption index varied from 3.84 to 6.91. The best CI was obtained with the fry that received the R100 diet (3.84).

Consumption index of experimental feeds and zootechnical performances of *Orechromis niloticus* fry

The results in Table 2 indicate that R100 treatment significantly improved zootechnical performances compared to R0. The Average Daily Gain (0.17 +/- 0.03 g/d vs. 0.09 +/- 0.01 g/d) and specific growth rate (1.30 +/- 0.15 %/d vs. 0.75 +/- 0.08 %/d) all have *P*-value less than 0.05, indicating a statistically significant difference between the two treatments. In contrast, no significant difference was observed for Consumption Index (3.85 +/- 0.99 vs. 6.91 +/- 0.86; *P*-value > 0.05), although R100 shows a better trend. The survival rate was 100% at both treatments.

Table 2. T-test of different zootechnical parameters

Zootechnical performances	R0 (M +/- SD)	R100 (M +/- SD)	*P*-value
Average Daily Gain (g/d)	0.09 +/- 0.01	0.17 +/- 0.03*	$P < 0.05$
Specific Growth Rate (%/d)	0.75 +/- 0.08	1.30 +/- 0.15*	$P < 0.05$
Consumption Index	6.91 +/- 0.86	3.85 +/- 0.99	$P > 0.05$

Values marked * are significant at the threshold of α = 0.05

3.2 DISCUSSION

3.2.1 Experimental feed consumption index and zootechnical performance of *Orechromis niloticus* fry

Growth performance and feed utilization efficiency in *Oreochromis niloticus* can be influenced by various environmental factors, such as water quality parameters, including temperature, pH, nitrogen waste, and dissolved oxygen concentration. These parameters are likely to affect the results of our study, by altering the growth and nutritional conditions of the fish [2,18]. The significant difference observed between the zootechnical parameters of *Oreochromis niloticus* fry fed with R0 and R100 diets can be attributed to the quality and nutritional composition of the diets [18,19]. The R100 diet, in particular, appears to contain a better source of essential nutrients such as high-quality proteins, amino acids, and lipids, which are crucial for fry development, compared to the R0 diet [2,20]. The growth performance observed in this study is consistent with the results obtained by Cadena-Cadena et al. (2023) and Mohd et al. (2022), who also reported significant growth in *Oreochromis niloticus* fed a diet containing grasshopper meal. These authors found greater weight gains in the experimental groups compared to the control groups, attributing these results to the high-quality protein content and digestibility of the alternative ingredients. Regarding the feed efficiency, both studies did not find any significant difference between diets, suggesting that feed efficiency remains stable regardless of the type of protein used.
Furthermore, the study by Mohd Taufek et al. (2016), conducted on catfish, confirmed the absence of significant differences between the diets tested, indicating that the substitution of traditional proteins by alternative sources does not necessarily compromise zootechnical performance. These observations reinforce the idea that the incorporation of unconventional ingredients, such as insects, can offer a sustainable solution to meet the nutritional needs of fish while maintaining growth and feeding efficiency similar to traditional diets.

4. CONCLUSION

This study highlighted the importance of incorporating cricket meal into the diet of *Oreochromis niloticus* fry as a sustainable alternative to fishmeal. The results obtained show that fry fed with the protein-rich R100 diet recorded superior zootechnical performances in terms of average weight, average daily gain and specific growth rate compared to those fed with the control R0 diet. These results indicate that the cricket meal-based diet is more efficiently valorized by the fry. Thus, insects represent a viable protein source for aquaculture, contributing to food security while reducing pressure on marine resources. However, to strengthen these results, additional studies over longer periods and under varied conditions are needed.

Disclaimer

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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