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Comparative study of effects of locust meal (*Ornithachris turbida*) and caterpillar meal (*Cirina butyrospermi*) on the zootechnical parameters of tilapia (*Oreochromis niloticus*)

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Abstract
The purpose of this study was to compare two diets based on locust meal (*Ornithachris turbida*) and shea caterpillar (*Cirina butyrospermi*) on the growth performance of Nile tilapia. Three isoproteinic (35% crude protein) and isolipidic (13% crude lipid) diets were formulated. These diets are named R0 (Control diet), R25% caterpillar meal and R25% locust meal. Twenty (20) *O. niloticus* fingerlings with an average initial weight of 4.85 g were distributed in nine (9) 60 L fibreglass tanks. Fish were manually fed the treatment diets three times a day (08:00, 13:00 and 17:00) for 8 weeks. Feed intake was reduced every two weeks, from 10, 8, 6 and 4% of body weight. The results of this study showed that the highest values for growth such as final average weight (fAW), absolute average weight gain (AWG), relative average weight gain (rAWG), specific growth rate (SGR) and feed efficiencies such as lower feed conversion ratio (FCR) were obtained in fish fed the diet containing 25% caterpillar meal with respectively (16.95 g, 12.12 g, 250.83%, 2.24%/day and 1.06). However, these values did not differ statistically from those of the control and R25% cricket diets. Analysis of the flesh of fish fed the different treatment diets showed that protein levels were higher in fish fed the R0 control diet (72.32%), while lipid levels were higher in fish fed the R25% caterpillar diet (19.87%). Ash levels were highest in fish fed the R25% locust diet (20.88%). In view of these results, we can conclude that a 25% inclusion of caterpillar meal and locust meal did not affect negatively the growth of Nile tilapia *O. niloticus* fry.

Keywords: Cricket meal, caterpillar meal, *Oreochromis niloticus*, growth, survival rate

1. Introduction

The availability of quality animal protein is the main concern for a growing world population. The gradual decline in fish catches and the increased demand for feed for the aquaculture sector have led to a marked reduction in the availability of fishmeal and fish oil, and a rise in their price. The sustainability of these inputs is becoming problematic, and the search for high-performance alternative resources is imminent. Vegetables meals such as soybean and other terrestrial plants have been widely introduced into fish diets. Although rich in protein and lipids, many of these plant resources present anti-nutritional factors, high levels of saturated fatty acids, a deficiency in long-chain polyunsaturated fatty acids, and are in competition with the human consumption sector. The work has demonstrated the potential of using insects as a partial or total substitute for fish meal in fish diets, thanks to their high protein content and adequate amino acid profiles, with few deficiencies. Insects of the order Diptera appear to have the amino acid profile closest to that of fish, with those of Coleoptera and Orthoptera closer to the profile of soya (Bazoche and Poret, 2017) [1].

Currently, the use of insects as food is not in direct competition with food production. Insect meal can be an important source of essential amino acids such as methionine. These values are higher than those declared for other animal and vegetable meals. Insects are also good sources of lipids, fatty acids, and the quantities and types of fatty acids vary according to species, stage of development and type of feed (Nogales-Mérida *et al*., 2019) [2]. The Nile tilapia (*Oreochromis niloticus*) is a well-known African fish that feeds on vegetation and is herbivorous, but sometimes exhibits omnivorous feeding behavior. Nile tilapia is the most popular cultivated species in many countries (Akoll and Mwanja, 2012) [3]. Commercially, tilapia is the second most important group of wild-caught fish, after carp. Tilapia is a group of fish belonging to the species of the Cichlidae family. Tilapia is primarily a freshwater, biparental fish species. It is generally known as a mouth brooding aquatic fish species. The main objective of this study is to compare the effects of incorporating locust meal and caterpillar meal into the diets of Nile tilapia *Oreochromis niloticus.*

2 Methods

2.1 Feeds formulation

Three experimental diets (control), (25% cricket meal) and (25% caterpillar meal) were formulated using Diet-formulator software. The formulated diets are isoproteinic and isolipidic (Table 1).

Table 1: Composition of the different diets

Ingredients	R0 (control)	R 25% Caterpillar	R 25% Cricket
Fish meal	30	22.5	22.5
Caterpillar meal	0	7.5	0
Cricket meal	0	0	7.5
Peanut cake meal	20	20	20
Rice polish meal	7	7	7
Wheat bran	7	7	7
Corn flour	7	7	7
Brewery waste meal	15	15	15
Yeast (g)	4	4	4
Sterculia gum (g)	3	3	3
Oil (A+V) (ml)	5	5	5
Vitamins	1	1	1
Minerals	1	1	1
Total (g)	100	100	100
Protein rate (%)	35.7	35.6	35.5
Lipid rate (%)	12.9	13.2	13

2.2 Feed processing

The experimental diet formula is presented in Table 1. We formulated three isoproteinic diets, each containing 35% crude protein (CP), to replace 25% fish meal with 25% caterpillar meal (*Cirina butyrospermi*) and 25% cricket meal: 0% insect meal as control diet, 25% caterpillar meal and 25% cricket meal. Fish oil and peanut oil at a ratio 1:1 were used as lipid sources. Locally sourced caterpillars (*Cirina butyrospermi*) and crickets (*Ornithachris turbida* cavroisi) were ground and powdered. Ingredients obtained from the local market were initially ground into small particles using a hammer mill, then passed through a 250 µm mesh sieve. The quantities of the various ingredients, first solid, then liquid, were quantified according to Table 1 and mixed together to obtain a homogeneous mixture. Next, distilled water (approx. 30% of dry weight) was added to the mixture to convert it into a malleable paste. This paste was then extruded through a 3.0 mm diameter die to produce pellets. The granules were dried in a dry-air oven at 60 °C, then packaged in plastic bags.

2.3 Culture conditions

The study was carried out at Pr Omar Thiom Thiaw aquaculture station of the university institute of fisheries and Aquaculture (IUPA), located opposite the university library at 14°41'04.9 "N 17°27'42.7" W. The Nile tilapia fry used came from breeding carried out at the fish farm. A total of 180 fry were placed in 9 x 60 L tanks at a density of 20 individuals/tank. Prior to the experiment, the Nile tilapia fry were acclimatized for a week and fed twice a day during this period. After the acclimatization phase, R0 was considered the control group, R2 (25% cricket meal), R2 (25% caterpillar meal) The fish were fed three times a day (08:00, 13:00 and 17:00) with R0 (control), R2 (25% cricket meal) and R3 (25% caterpillar meal) diets at 10%, 8%, 6% and 4% of their body weight. Physico-chemical parameters (temperature, pH and O2) were taken twice a day before feeding using a multi-parameter device, and feed and faeces remains were siphoned off. The experiment lasted 60 days, after which biometry was carried out every two weeks to determine zootechnical parameters and adjust the feeding rate.

2.4 Zootechnics parameters

Various zootechnical parameters and indices were calculated to assess fish growth and feed utilization efficiency:

- Absolute average weight gain (g) = Final weight (g) - Initial weight (g)
- Relative average weight gain (%) = [(Final weight (g) - Initial weight (g))] * 100/ Initial weight (g).
- Specific Growth Rate (RGS) (% /day) = [ln (Final Weight) - ln (Initial Weight)] * 100 / Experiment duration (days).
- Feed Conversion Rate (FCR) = Quantity of feed distributed / Average absolute weight gain.
- Survival rate (%) = Final number of fish x 100 / Initial number of fish

2.5 Statistical analysis

A one-way analysis of variance (ANOVA) was performed to examine differences in final mean weight (FMW), weight gain (AMWG), percentage weight gain (RMWG), specific growth rate (SGR) and feed conversion ratio (FCR) between the three diets. When a significant difference was observed, Duncan's test was used to compare differences between treatments. Significance was set at $p<0.05$, and all statistical analyses were performed using SAS software (V9.3, SAS Institute, Cary, NC, USA).

2.6 Biochemical composition of fish flesh: At the end of the experiment, fish sampled per tank from each diet were analyzed at the ENSA bromatology laboratory in Thiès, Senegal. The standard methods described by the Association of Official Analytical Chemists (AOAC, 1995) [4] were used to perform these analyses. Samples were dried at a constant temperature of 105 °C to determine moisture content. Crude protein (Calculated as total nitrogen multiplied by 6.25) was determined using the micro-kieldahl method (kjeltec system 1002 distillation unit from Tecator in Hoeganes, Sweden). Crude fat content was determined by the Soxhlet method, and ash content was determined by subjecting samples to incineration in a bellows furnace at 550 °C for 6 hour.

3. Results and discussion
3.1 Results
3.1.1 Physical and chemical parameters
The follow-up of physico-chemical parameters during the experiment (Table 2) showed that the mean temperature was 26 °C. Table 2 also shows that pH varied from 7.77 to 7.85 and dissolved oxygen from 2.27 to 3.84 mg/l.

Table 2: Average values for temperature, pH and dissolved oxygen

Diet	Temperature (°C)	pH	Oxygen (mg/l)
Control	26.6	7.77	3.84
R25% Caterpillar	26.7	7.82	2.27
R25% Cricket	26.7	7.85	3.2

3.1.2 Growth parameters: The results of zootechnical parameters such as absolute mean weight (AMWG), mean relative weight gain (RMWG), specific growth rate (SGR), feed conversion rate (FCR) and survival rate (SR) were determined for each diet and recorded in Table 3.

Table 3: Fish zootechnical parameters.

Paramètres	Control	R25% caterpillar	R25% cricket
IW (g)	4.85[a]	4.83[a]	4.85[a]
FW (g)	15.50 ± 1.04[a]	16.95±1.25[a]	16.21±0.20[a]
AMWG (g)	10.65 ± 1.05[a]	12.12±1.26[a]	11.36±0.20[a]
RMWG (%)	220.33 ± 21.94[a]	250.83±26.33[a]	234.83±4.66[a]
SGR (%/d)	2.08 ± 0.12[a]	2.24±0.13[a]	2.17±0.03[a]
FCR	1.12 ± 0.05[a]	1.06±0.09[a]	1.10±0.01[a]
SR (%)	93.33 ± 11.55[a]	97.77±3.97[a]	100±00 [a]

IW= initial weight; FW= final weight; AMWG= absolute mean weight gain; RMWG= relative mean weight gain; SGR= specific growth rate; FCR= feed conversion rate; SR= survival rate.
Letters a in superscript indicate that there is no statistically significant difference ($p>0.05$).
Fish fed the 25% caterpillar meal diet recorded higher growth values (mean final weight, weight gain and specific growth rate) than fish fed the control diet and those fed the R25% cricket meal diet. However, no significant statistical differences were observed between diets.
In terms of FCR, the R25% caterpillar diet recorded the lowest value (1.06), meaning that it outperformed the other two diets, but showed no significant difference to them.
Overall, survival rates ranged from 93.33 to 100%.

3.1.3 Biochemical composition of flesh
Fish flesh samples were analyzed and processed at the ENSA laboratory in Thiès, Senegal. The results are shown in Table 4.

Table 4: Flesh analysis results.

Parameters	Control	R25% Caterpillar	R25% Cricket
Ash (% DM)	18.19± 0.47[a]	16.10±0.40[b]	17.32±0.64[ab]
Crude Protein (%DM)	71.94±1.61[a]	71.27±0.26[a]	70.11±1.26[a]
Crude Fat (% DM)	18.56±0.66[b]	19.92±0.65[ab]	20.84±0.17[a]

DM= Dry matter

After analysis of the fish flesh, crude protein content ranged from 70.11 to 71.94%, with the highest value observed in the control diet and the lowest in R25% cricket. Lipid levels ranged from 18.54 to 20.84%. Lipid levels were highest in fish fed the R25% cricket meal diet which showed a significant difference from those fed the control diet. Fish fed the 25% Caterpillar diet had the highest ash levels and those fed the control diet the lowest, respectively (18.19 to 16.10%) and a significant difference was observed between these two diets.

3.2 Discussion
3.2.1 Physic and chemical parameters
The mean temperatures obtained during the study in the different diets ranged from 26.6 °C to 26.7 °C. These results are within the range obtained by Ndour and al. (2011) [5] who stated that the optimum temperature for *O. niloticus* growth is between 26±4.0 °C. The results are also within the range found by Balarin and Hatton (1979) [6] who stated that the thermal tolerance range observed in the laboratory is wider (7 to 41 °C) for good growth of Nile tilapia. pH values ranged from 7.77 to 7.88, showing little variation with time. These results are comparable to those obtained by Bahnasawy and al. (2009) [7], who obtained good growth in *O. niloticus* with a pH of 7.0±2.0. Dissolved oxygen values recorded ranged from 2.27 to 3.84 mg/l. These results are similar to those of Malcom and al. (2000) [8], who stated that tilapia can withstand oxygen levels of 3 mg/L. In terms of these results, physico-chemical parameters do not appear to be a limiting factor for fish growth.

3.2.2 Growth, feed efficiency and survival parameters
The present study showed positive effects of insect meal on the growth performance, feed efficiency and survival rate of *O. niloticus* fry, even though no significant statistical differences were observed between diets. Insect meal is a good source of protein, minerals and vitamins, similar to fish meal. It is also rich in essential amino acids, particularly lysine, methionine and leucine, and contains no anti-nutritional factors (Baiano, 2020) [9].
The highest growth parameters (FMW, AMWG, RMWG and SGR) were obtained with the R25% caterpillar diet with respectively (16.95±1.25 g; 12.12±1.26 g; 250.83±26.33% and 2.24±0.13% /day) followed by the R25% cricket diets and the control.
These values are higher than those of Obassa and al. (2012) [10] who obtained a better AMWG equal to 4.43 g with an incorporation of 25% Grasshopper flour in the diet of African catfish. These results are also greater than those of Ndione and al. (2022b) [11] who obtained a AMWG of 1.87g with diet D2 containing 25% caterpillar meal in the Nile tilapia feed.
The highest RMWG (250.83%) obtained with diet R25% caterpillar is lower than the value obtained by Obassa *et al.* (2012) [10] whose best RMWG was 337.91% with 25% grasshopper meal on African catfish and that of Ndione and al. (2022b) [11] who obtained a RMWG of 836.1% with diet D2 containing 25% caterpillar meal on Nile tilapia.
In the present study, the specific growth rate varied between 2.08 and 2.24%/d. The highest SGR value was obtained with the R25% caterpillar diet (2.24%/d), followed by the R25% cricket diet at 2.17%/d. This value obtained with the R25% caterpillar diet (2.24%/d) is lower than that of Ndione and al. (2022b) [11], who obtained a SGR of 3.9%/d with Diet D2 and also lower than that of Ndione and al.(2022a) [12] whose best

SGR (2.67%/d) was obtained with Diet R2 containing 25% cricket meal in his study on the growth of Nile tilapia. The lowest feed conversion rate (FCR) was obtained with the R25% caterpillar diet with a value of 1.06, followed by the R25% cricket diet with 1.10. The results obtained are good, in comparison with those observed by Ndione and al. (2022b) [11] on the growth performance, feed utilization and body composition of Nile Tilapia, *Oreochromis niloticus*, who found a FCR of 1.36 with diet D2 (containing 25% caterpillar meal) and those of Ndione and al. (2022a) [12] who found a FCR of 1.80 with diet R2 (Containing 25% cricket meal).

Survival rates in the different treatments of the present study were good, and no significant differences were observed between diets. Survival rates of *O. niloticus* fry fed the different diets ranged from 93.33 to 100%. These values are comparable to those of Muin and al. (2017) [13], who obtained 100% in all diets. The survival rates obtained in the present study are higher than those of Musoni and al. (2023) [14], who found survival rates ranging from 85 to 92.5% in Nile tilapia juveniles fed different inclusion levels (0%, 25%, 50% and 75%) of black soldier fly meal.

These good performances recorded by the diets tested compared with the control would be due to a substitution rate of 25% caterpillar meal and 25% locust meal. Abikikannda (2012) [15]; Emehinaiye (2012) [16] asserted that locust (*Locusta migratoria*) meal could replace fish meal by up to 25% in isoproteinic diets for Nile tilapia fry with no negative effect on nutrient digestibility, growth performance and hematological parameters.

3.2.3 Biochemical composition of fish flesh

Analysis of the biochemical composition of fish fed the diets showed little variation in crude protein, lipid and ash content between the different diets.

Dietary protein plays an important role in the supply of amino acids for body protein biosynthesis essential for fish growth. In the present study, it was observed that crude protein (CP) content was higher in fry fed with control diet (71.94%) and R25% caterpillar (71.27%). Similarly, the protein level obtained in the R25% locust diet was higher than the value (66.11% of the R2 diet) obtained by Ndione (2022a) [12] on the partial or total substitution of fish meal by locust meal on the growth performance and feed efficiency of Nile tilapia fry.

Lipids are highly digestible and an important source of concentrated energy, playing several roles in fish growth and development.

The present study showed that the lipid content of the flesh of fish fed the different diets ranged from 18.56% (control diet) to 20.84% (25% locust diet). This value is lower than that obtained by Ndione *et al* (2022a) [12] (29.66%) in tilapia fry fed an R2 diet in their study on the partial or total substitution of fishmeal by locust meal on the growth, feed efficiency and biochemical composition of the flesh of Nile tilapia fry. This progressive decrease in protein levels and increase in lipid levels in fish flesh at the diets level could be explained by the sparing effect in tilapia. The sparing effect has been reported in tilapia at 12 and 18% crude lipid content (Da Silva *et al*., 1991) [17]. Mohammadi *et al*. (2017) [18] stated that protein content can be reduced without negative effect on growth if energy intake is provided by non-protein resources. In the present study, the lipid-sparing effect was observed.

4. Conclusion

Feed represent one of the most important aspects of the aquaculture industry as it contributes to the growth, survival and welfare of farmed fish. Thus, the sustainability of the aquaculture industry depends on reducing feed costs while improving or not affecting the survival rate, growth performance and welfare of farmed fish.

The present study investigated the effects of partially replacing expensive fishmeal with cricket and shea caterpillar meal feeds on the rearing of Nile tilapia fingerlings. The results showed that feeding Nile tilapia fry the R25% caterpillar meal diet improved growth performance even though it did not differ significantly from the other two diets. These results confirm most studies that recommend insect meal replacement rates of less than 30%. However, the use of insects to replace fishmeal in the feed of farmed fish poses certain problems. One of these concerns the nutritional values of insects, which vary according to species and stage of development. In addition to experimental or pilot studies on feeding trials, the viability of scaling up insect production to an economically viable scale, capable of supplying insect meals in industrial quantities (i.e. a total of more than 5,000 tonnes per year), needs to be examined. This involves developing low-cost insect meals and designing specific infrastructures, such as the automation of insect cultivation systems, to reduce labour and energy costs. To compete with traditional protein sources, insect meals must offer advantages in terms of nutritional value and price, as well as year-round availability and consistent quality.

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