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Effects of incorporation of shea caterpillar flour (*Cirina butyrospermi*) in the feed on the growth performance of tilapia *Oreochromis niloticus* (Linnaeus, 1758) raised in basin brazil strain

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Abstract

With the aim of seeking alternatives to the expensive use of fish meal in fish feed, a study was carried out on the incorporation of shea caterpillar meal (*Cirina butyrospermi)* into the diet of *Oreochromis niloticus*. Three diets with progressive incorporation rates of 15% (A15), 20% (A20) and 25% (A25) of *C. butyrospermi* meal were prepared from a local feed based on agricultural by-products and compared with a control diet (AT) without animal meal. Tilapia larvae with a mean initial weight of 4± 0.05 g were reared in duplicate basins at a stocking density of 100 fry per m3. The fish were fed 4 times a day with a ration of 5% of their total biomass from the start to the end of the experiment. After 90 days of rearing, the best feed conversion and final weight (1.50 ± 0.14; 37.10± 2.25 g, respectively) were obtained with diet A20, followed by diet A15 (1.62 ± 0.08; 35.20± 2.86 g) and A25 (1.74 ± 0.12; 33.03± 3.44 g). The lowest daily growth (0.33± 0.03 g/day) and the highest feed conversion index (1.99± 0.12) were recorded with the AT diet. At the end of the experiment, survival rates were greater than or equal to 92.86%. At the end of this study, shea caterpillar meal can be incorporated into tilapia feed and considered a good protein source.

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Introduction

To date, over 80% of global fish production depends on exogenous feed in the form of supplements to feed from the farming environment (FAO, 2018). Several investigations have been carried out in the field of feed, contributing to the rapid expansion and spectacular development of aquaculture worldwide (Kolditz, 2008; FAO, 2018). Against this backdrop, we are witnessing an intensification of fish farming, with widespread and significant use of artificial feeds (Gaye-Siessegger *et al.*, 2005). These high-performance feeds, which provide fish with a complete diet, are produced in developed countries. However, in developing countries, the difficulty lies in acquiring suitable exogenous feeds for feeding fish, especially at juvenile stages (Hung *et al.,* 2001; Coulibaly *et al.,* 2007; Pangni *et al.,* 2008).

These exogenous feeds are considered to be very expensive and, above all, difficult to access, which hampers the expansion of the fisheries sector (Barrows and Hardy, 2001).

The high cost of these feeds is most often due to the use of fishmeal as a protein source. Indeed, the extensive use of fishmeal in feeds is at the root of this high cost (Nguyen *et al.,* 2009; Hardy, 2010). These authors also point out that this input is becoming increasingly scarce and expensive, representing a major limiting factor to aquaculture developments. Faced with this situation, the use of adapted local feeds is necessary to maximize feed conversion efficiency and growth (Guzel and Arvas, 2011).

In Côte d'Ivoire, for example, *Oreochromis niloticus* production faces several obstacles. Among these obstacles are (i) the low nutritional quality of local feed (ii) the low availability of quality imported feed (iii) the cost of imported feed deemed high by stakeholders, and above all (iv) the lack of fry (MIRAH, 2014, PREPICO, 2019). Yet it has been reported by several authors (Richter *et al.,* 2003; Liebert and Portz, 2005; Zhao *et al.,* 2010) that in tilapia, combining several agricultural by-products with insect meal in feed formulas can reduce production costs while improving fish growth. However, in Côte d'Ivoire, there is a wide range of agricultural by-products that have already been tested in fish feeds (Nguyen *et al.*, 2009; Zhao *et al.,* 2010; Bamba *et al.,* 2018). These include cottonseed and soybean meal, and rice and wheat bran. These raw materials are found in abundant quantities in Côte d'Ivoire (Sangare *et al*., 2009; FAO, 2014). For all these aforementioned reasons, we chose to use compound feeds based on agricultural by-products and shea caterpillar *(C. butyrospermi*) meal in the diet of pond-reared fry. With this in mind, the general objective of this study was to test the use of shea caterpillar meal (*C. butyrospermi*) combined with local agricultural by-products in the diets of tilapia *Oreochromis niloticus* "Brazil strain" fry.

Materials and methods

Rearing facilities and experimental fish

The experiment was carried out between March and May 2023 at the Nangui ABROGOUA University fish farm. The experimental set-up consisted of eight (8) rectangular concrete basins. The concrete basins (Fig. 1) had a usable water volume of 1 m3 (Length × Width × Height: 1.5 m × 1 m × 0.67 m). Trials were conducted in duplicate. The rearing tanks were supplied with SODECI water from a15 m settling tank3 via a PVC pipe system and a SMART suppressor. Before being used on the farms, the water is piped to the settling tank, where it remains for 72 hours (3 days) to allow the chlorine to dissolve.

Fig. 1. Livestock infrastructure

Experimental feeds

Four feeds were formulated on the basis of plant raw materials, with the addition of shea caterpillar larvae meal. The agricultural by-products used were purchased from local suppliers. A15%, A20%, A25% and AT feeds are composed of: A15% (cotton and soybean meal, rice flour, wheat bran, vitamin-mineral complexes at a rate of 15% of insect meal), A20% (cotton and soybean meal, rice flour, wheat bran and vitamin- mineral complexes at a rate of 20% of insect meal); A25% (cottonseed and soybean meal, rice flour, wheat bran and mineral vitamin complex at 25% insect meal) and AT (cottonseed and soybean meal, rice flour, wheat bran, mineral vitamin complex containing only insect meal). Caterpillar meal was used as a source of animal protein. Soy and cotton cakes were used as vegetable protein sources. Wheat bran, low- grade rice flour and vegetable oil were added as sources of carbohydrates and energy components. Shell flour, rich in calcium and phosphorus, is added as a source of minerals (Campbell, 1978; Rivière, 1978). Different combinations have been applied to test the impact of each of the proportions of caterpillar meal incorporation) on the nutritional quality of compound feeds (Azaza, 2005; Bamba *et al.*, 2018). Thus, four test feeds were developed (A15%, A20%; A25% and AT). In the present study, AT was used as the reference diet. This diet contained no caterpillar meal and 30% protein.

To manufacture the feeds (A15%, A20%, A25% and AT), the raw ingredients were ground (1.5 mm diameter) using a locally-made hammer mill and passed through a sieve made of 500-micron mesh screen (Siddiqui and Harbi, 1995; Bamba *et al.*, 2007). For each foodstuff, the ingredients were sieved, weighed and mixed by hand until a homogeneous powder was obtained. Vegetable oil and the vitaminized mineral complex were then added to the mix, which was blended by hand to obtain a homogeneous product. The manufactured feeds were packaged in plastic bags and sacks, and then stored on wooden pallets.

Preparation of shea caterpillar flour

C. butyrospermi caterpillars were hand-picked from shea trees in the PORO region (Korhogo) and then washed, pre-cooked at 100°C and dried in an oven at 65°C for 72 hours. The dried larvae were ground and stored for analysis and use in the formulation of fish diets (Fig. 2).

Fig. 2. A- Shea caterpillar (*Cirina butyrospermis*); B- *Cirina butyrospermis* flour

Breeding management and monitoring

Trials were conducted for 90 days. The experiments consisted of feeding the experimental feeds to tilapia *Oreochromis niloticus* "Brazil strain" fry with an average initial weight of 4 ± 0.05 g. The fry was counted and weighed for stocking. Fingerlings were counted and weighed for stocking. Different weighing was carried out to achieve the applied stocking density of 100 ind/m^3 i.e. 100 fry/bassins. These weights were then used to determine the overall average weight. This average weight was calculated to determine weight variability at the start of the trials. Three test feeds (A15, A20 and A25), and a local reference feed (AT) were fed to the different batches to be reared. The fish were randomly distributed in eight tanks, forming four duplicate treatments. Batches of fry with an average initial weight of 4 ± 0.05 g were fed daily at a ration rate of 5% of total biomass. Daily feed rations were served manually in four meals (9h, 11h 13h and 15h). Weight growth was monitored every ten days. These checks enabled the daily rations to be readjusted accordingly. At the end of the 90th day of rearing, 30 fry were taken from each pond and weighed individually (Bamba *et al.,* 2007) for statistical comparison. From these data, various zootechnical performance parameters were calculated. In addition, all tanks were emptied of their contents to assess survival rates.

Water quality parameters

To monitor water quality in the basins, we took weekly readings of pH, dissolved oxygen and temperature in situ between 6 and 7 a.m. and 1 and 2 p.m. respectively. The calibrated measuring instruments were switched on, the various probes were immersed in the water and the desired function was selected to obtain the value of the parameter on the dial.

Determination of zootechnical performance parameters

Parameters for comparison between feed treatments were calculated according to the formulas presented in Table 1.

Table 1. Comparison parameter calculation methods

Parameters	Formulas
Weight gain (GM, g)	Final weight (g)- initial weight (g)
Daily weight gain (DWG, g/d)	final weight (g)- initial weight (g)/feeding time
Specific growth rate (SGR, %/day)	100 × [ln (final weight)- ln (initial weight)] /feeding time
Protein efficiency coefficient (CEP)	Fresh weight gain/protein intake
Nutrient quotient (Qan)	Quantity of dry feed distributed/fresh weight gain
Survival rate (%)	100 × final number of fish/initial number of fis

Statistical analysis

Statistical processing of the data for the various zootechnical parameters studied consisted of a hierarchical single-criteria analysis of variance (ANOVA1) using R software version 4.1.3. The objective of the ANOVA was to determine whether or not there was a statistically significant difference ($P<0.05$) between the parameters resulting from the different feed treatments used. For these comparisons, a significance level of 5% was used.

Results

Water quality

Data on water quality parameters in the rearing structures are presented in Table 2. Temperature was relatively high in all tanks, varying between 30.82 and 31.25°C throughout the experiment. Recorded dissolved oxygen values ranged from 8 to 8.89 mg/L. Mean pH values were 8.44 ± 1.16 (A15%); 8.63 ± 1.21 (A20%); 8.55 ± 1.37 (A25%) and 8.38 ± 1.68 (AT). Mean values for conductivity and total dissolved solids (TDS) were 259.62 (µS/cm) (A15%); 270.33 (µS/cm) (A20%); 246.41 (µS/cm) (A25%); 224.79 (µS/cm) (AT); 117.13 (mg/l); 120.29 (mg/l); 110.29 (mg/l) and 102.62 (mg/l) respectively. However, the analysis did not show a significant difference between feed treatments ($p > 0.05$) for the different parameters (temperature, dissolved oxygen and pH), but there was a significant difference between feed treatments ($p < 0.05$) for the different parameters conductivity and total dissolved solids (TDS).

Weight growth

Fig. 3 shows the evolution of the average weight of *O. niloticus* specimens fed the different feeds (A15%; A20%, A25% and AT) during 90 days of rearing. After the first growth control, the four batches clearly stand out and maintain this trend until the end of the experiment. The first batch is made up of fish fed with the 20% feed, followed by the other 25% and 15% feeds. Then comes the AT control feed. After 30 days, the average weight of fish fed the 20% feed remained stable until the end of rearing. On the other hand, fish fed the 25% and 15% feeds increased at about the same rate.

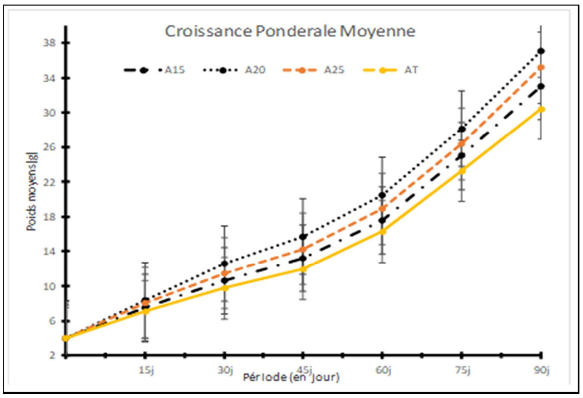

Fig. 3. Average weight growth of fish as a function of test feed

Zootechnical parameters

Results for growth parameters (mean final weight, mean daily weight gain, specific growth rate) and feed processing parameters (apparent feed conversion ratio, protein efficiency ratio and survival rate) are shown in Table 3.

Table 2. Water quality parameters for different diets

Parameters	Food treatments			
	A15%	A20%	A25%	AT
Dissolved oxygen (mg/L)	8.89 ±0.65[a]	8.37 ±0.03[a]	8.60±0.31[a]	8.35 ± 0.5[a]
Temperature (°C)	31.12 ± 1.41[a]	30.82 ±2.15[a]	31.14 ±1.5[a]	31.25±1.42[a]
Ph	8.44 ± 1.16[a]	8.63 ± 1.21[a]	8.55 ± 1.37[a]	8.38 ± 1.68[a]
COND (µS/cm)	259.62 ± 26.05[b]	270.33± 27.60[b]	246.41±32[ab]	224.79±40.67[a]
TDS (mg/l)	117.13±10.33[bc]	120.29±11.41[c]	110.29±13[ab]	102.62±15.h89[a]

Table 3. Zootechnical parameters of *Oreochromis niloticus* fed on four test diets

Parameters	Food treatments			
	A15%	A20%	A25%	AT
Initial weight: Pmi (g)	4.00± 0.05[a]	4.00 ±0.05[a]	4.00± 0.05[a]	4.00 ± 0.05[a]
Final weight: Pmf (g)	35.20±2.86[bc]	37.10± 2.25[c]	33.03±3.44[ab]	30.50 ± 2.58[a]
Weight gain: GP (g)	31.20± 2.86[bc]	33.30 ± 2.25[c]	29.11 ± 3.44[ab]	26.50 ± 2.58[a]
Daily weight gain: GPj (g/d)	0.40 ± 0.036[bc]	0.42 ± 0.092[c]	0.37± 0.044[ab]	0.33± 0.033[a]
Nutrient quotient (NQ)	1.62 ± 0.08[ab]	1.50 ± 0.14[a]	1.74 ±0.12[b]	1.99±0.12[c]
Specific growth rate: TCS (%/day)	2.52 ±0.09[b]	2.63± 0.18[c]	2.47 ±0.17[b]	2.35 ± 0.10[a]
Survival rate: Ts (%)	91.87 ± 1.87[b]	93.75 ± 1.25[a]	90.62 ± 0.62[b]	91.87 ± 1.87[b]

Survival rates (Ts) were 90.62 ± 0.62; 91.87 ± 1.87, 91.87 ± 1.87 and 93.75 ± 1.25 respectively for feed A25, AT, A15, and A20. After 90 days of rearing, mean final weights were 30.50 ± 2.58 g; 35.20±2.86 g; 33.03±3.44 g and 37.10±7.25 g, respectively for feed AT, A15, A25 and A20. In the same order, mean daily weight gain (GPJ) values for AT, A15, A20 and A25 feeds were 0.33±0.033 g/d; 0.37±0.044g/d; 0.40 ± 0.036 g/d and 0.42 ± 0.092g/d respectively. Calculated specific growth rates (SGR) ranged from 2.35 ± 0.10 %/d (AT) to 2.63± 0.18 %/d (A20). There was no significant difference between the A15, A20 and AT diets. However, these three diets performed significantly better ($P<0.05$) than AT.

Discussion

In the present study, all water quality parameters were within the acceptable range as recommended for tropical aquaculture (Balarin and Haller, 1982). Overall, the mean values of the water quality parameters were similar for all feed treatments. In other words, the various water quality parameters studied (temperature, dissolved oxygen, pH) did not differ significantly (ANOVA 1; $p > 0.05$) from one pond to another and from one feed treatment to another, whereas there was a significant difference between feed treatments ($p < 0.05$) for the various parameter conductivity and Total Dissolved Solids (TDS).

The temperature values recorded during this experiment are comparable to those obtained by (Sarr *et al.*, 2013) with intervals of (24 - 35 °C). According to (Ndour *et al.*, 2011), the optimum temperature for *O. niloticus* growth is between 26-30°C. The average values for temperature and pH remained within the limits favorable to good growth of this species, as a result of the constant renewal of the water. As for Total Dissolved Solids (TDS) and conductivity, mean values ranged from 120.29 (mg/l) to 102.62 (mg/l) (270.33 (µS/cm) 224.79 (µS/cm)) these values are lower than those obtained by Houndonougbo *et al.* (2017) who obtained mean values (516.35(µS/cm); 524.91(µS/cm) for conductivity then (346(mg/l a 355(mg/l)) for Total Dissolved Solids (TDS). Survival rates were acceptable, ranging from 90% (A25) to 93% (A20). Similar survival rates in Nile tilapia have been reported in other studies. These include survival values between 92.85 and 93.33% (Silue *et al.*, 2024) and (89.7% - 93.5%) (Bamba *et al.*, 2014). The present results are satisfactory, compared with those obtained (85 and 98%) (Bamba *et al.*, 2008) and (95.5% to 97.5%) (Diabagate *et al.*, 2024) with *O. niloticus* fed on local by-product feeds. Dead fish were generally observed one to three days after the fish were loaded into the structures. This suggests that the mortality observed was probably the result of handling stress during loading.

In general, the control feed containing no caterpillar meal provided fish with lower zootechnical performance than the local feeds containing caterpillar meal. Among the three local feeds containing caterpillar meal, feed A20 containing 20% caterpillar meal provided fish with higher zootechnical performance ($p < 0.05$; ANOVA) than fish fed feed A25 and A15 containing 25% and 15%. These results highlight both the effects of the inputs used and the proportions of caterpillar meal used on the nutritional quality and performance of the experimental diets.

Growth parameters are also acceptable with the incorporation of shea caterpillar flour (*Cirina butyrospermis*). The specific growth rate (SGR) results obtained in our study are lower than those of Azaza *et al.* (2018); who had recorded a value ranging from 5.11 to 5.97%/d but higher than those of (Coulibaly *et al.*,2021; Dibala *et al.*, 2018) who obtained SGRs ranging from 0.01 to 0.05%/d and from 0.83 to 0.90%/d respectively. The daily growth rates (DGR) recorded in this study (0.33 to 0.42 g/d) are lower than those of (Fanda, 2012) who reported a rate of 0.24 g/d as well as (Dibala *et al.*, 2018) or (Coulibaly *et al.*, 2021) who recorded 1.36 g/d in Burkina Faso and 0.74 to 1.61 g/d in Burkina Faso respectively in a happas rearing cycle placed in a 4 acres pond with masoned side walls and supplied with borehole water. On the other hand, the consumption index (CI) or nutrient quotient (NQ) is lower, ranging from 1.50 to 1.99, than that of Dibala *et al.* (2018) who had an NQ of 2.7, as well as that of (Parrel *et al.*, 1986) who had a CI ranging from 2.5 to 3.05, but similar to that of Coulibaly *et al.* (2021) (1.41 to 2.57). The best CIs were obtained with shea caterpillar meal.

The results show that the growth performance of batches fed with the AT control feed is lower than that of the three experimental feeds (A15, A20, A25). This difference in zootechnical performance could be explained by the low protein content of the AT control feed, and therefore the low protein intake of the fish fed with this AT feed. The difference in performance observed between the test feeds (A15%, A20% A25%) and the control (AT) could be linked to the incorporation of *C. butyrospermi* meal in these feeds. The test foods would be richer in nutrients than AT. In other words, the A15% A20% and A25% feeds would be more digestible and easily assimilated by the fish. Indeed (Köprücü and Özdemir, 2005) indicate that the digestibility of a feed depends on the nature of the ingredients used. The results obtained corroborate those of work carried out on cobia by (Zhao *et al.*, 2007).

Conclusion

This study evaluated the effects of incorporating shea caterpillar meal (*C. butyrospemis*) into the diet of *Oreochromis nilotuicus* fry for 90 days. The quality of the rearing environment, zootechnical performance and nutritional values were evaluated during the experiment. Results showed that a 15% to 25% incorporation level of shea caterpillar flour (*C. butyrospemis*) improved growth performance. The observed performance shows that the flour could be used as a protein source in the feed of *Oreochromis niloticus* "brazil strain" fry.

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