Effects of incorporating cowpea flour and peanut meal into the diet of *Clarias gariepinus* fry(Burchell, 1822).

Abstract

Feed represents up to 70 % of production costs in fish farming, which limits the development of aquaculture in Africa. This study evaluated the effect of incorporating cowpea meal and groundnut cake into the diet of *Clarias gariepinus* fingerlings. Three quasi-isoprotein diets respectively A0, A1, and A2 were tested in triplicate during 56 days on *Clarias gariepinus* fingerlings with an average weight of 5.73 ± 0.04 g; 5.60 ± 0.03 g; 5.62 ± 0.08 g, at a density of 15 individuals per 67.5-liter tank. The results of the bromatological analyses of protein content showed moderate differences (32.72%, 36.71% and 35.11%) between diet A0, A1 and A2, respectively. The physicochemical parameters of the water remained stable (pH: 7.54 ± 0.1; temperature: 28 ± 0.87 °C; dissolved oxygen: 11.1 ± 0.1 mg/L), with no significant difference between treatments ($p > 0.05$). According to top digital trends, the best zootechnical performance indicators (specific growth rate of 2.76 ± 0.27%/day; feed conversion ratio of 1.78 ± 0.29; daily weight gain of 0.38 ± 0.07 g/day; and absolute weight gain of 21.38 ± 4.00 g)were obtained with diet A0. The highest survival rate was observed with diet A1 (82.22%). No significant difference was detected between diets ($p > 0.05$). These results indicate that cowpea meal and peanut meal can be used as partial local alternatives for fish meal in the diet of C. gariepinus fry.

Keywords: Aquaculture; *Clarias gariepinus* fry; diet; local by-products, Senegal

Introduction

Fish farming is considered one of the most important agricultural activities capable of ending nutritional deficiencies around the world and contributing to poverty reduction for millions of people in developing countries (Pèlèbè et al., 2020). For this aquaculture sector to thrive, in addition to developing an adequate workforce, it is necessary to research and optimize various production inputs, particularly fish feed.According to fish nutritionists,there are still significant gaps in knowledge about how to feed *Oreochromis niloticus* and *Clarias gariepinus* larvae and juveniles, two species produced in aquaculture, in order to achieve optimal growth and high survival rates (Gang et al., 2022). The quantity and quality of feed have been identified as critical factors for the growth performance of these fish larvae (Djissou et al., 2020).Unlike other farm animals, fish have diverse diets. *Clarias gariepinus* is an example of this due to its varied diet and resilience in unfavorable environments (El-Mezayen et al., 2024). Although it is an omnivorous fish species, *C. gariepinus* is one of the farmed species that requires a rich diet to ensure optimal growth. In aquaculture, feed accounts for more than 70% of the total production cost in so-called intensive farming systems (JICA and DPH, 2023). Almost all of the world's aquaculture production depends exclusively on industrial feed or a combination of industrial feed and primary production (FAO, 2014). To this end, studying the nutritional needs of fish has become a research priority in aquaculture. Scientific research on fish nutrition began long ago, with studies focusing more on the anatomy of the digestive tract, its functioning, and the feeding habits of fish in their natural environment (Burel, 2020). However, reducing the costs associated with feeding fish in controlled production is one of the priorities for researchers (Kumar et al., 2017). On the other hand, several researchers believe that fishmeal is the ideal component of feed due to its high content of high-quality protein. It is the main factor in the high cost of fish feed and accounts for 40 to 60% of the total protein in diets formulated specifically for catfish (Edéa, 2019). Thus, faced with fluctuations and high prices on the local market, researchers are turning to other plant or animal alternatives, such as raw materials typically of animal origin, for the formulation of feed for farmed fish (Médalle, 2013).However, the use of local raw materials is essential to stabilize the supply chain. It is therefore necessary to consider the use of less expensive and appropriate nutritionally satisfactory food sources to address the constraints of availability and high cost of feed, particularly for *Clarias gariepinus* fry. Several by-products, such as peanut and cottonseed meal, wheat and millet bran, cowpea and corn flour, could probably fill this gap, which is further damaging the fish farming sector and the *Clarias* fry sector in particular in Senegal. The objective of this study is to evaluate the effect of different levels of incorporation of these ingredients in quasi-isoprotein diets on the zootechnical performance of *Clarias gariepinus* fry. Specifically, the aim was to(1) characterize the nutritional composition of the raw materials used; (2) formulate three test diets; (3) compare growth and survival performance according to diet; and finally (4) propose an optimal level of incorporation.

I. Materials and methods

Location of the study area

The experiment was conducted at the experimental farm of Gaston Berger University in Saint-Louis, specifically in the Aquaculture Department laboratory. This site has facilities suitable for experimental fish farming and the manufacture of feed for experimental testing.

Experimental setup

The experiment was conducted over 56 days (June 19-August 14, 2025) in nine 90-liter plastic tanks filled to three-quarters capacity (Figure 1). The tanks were arranged in a completely randomized design with three experimental regimes (A0, A1, A2) in triplicate. Each basin was stocked with 15 *Clarias gariepinus*fry with an initial average weight of 5.73 ± 0.04 g, 5.60 ± 0.03 g, and 5.62 ± 0.08 g for A0, A1, and A2, respectively. The fry used in this experiment (Figure 2) came from artificial reproduction carried out in a local hatchery (farm 3A). The fish were acclimatized before the start of the trial. In the trial, sex was not taken into account, but rather the growth and survival parameters of the fry. The fry was fed three diets (A0, A1, and A2) with virtually identical protein content (35.69%, 35.06%, and 34.43%).

Figure 1: Experimental setup

Figure 2: *Clarias gariepinus fry*

Monitoring of physical and chemical parameters of the water

A landing net was used for control fishing and for retrieving dead individuals. Water quality (temperature, pH, and dissolved oxygen) was monitored regularly throughout the experiment using a *Hanna* pH meter and a digital pen-type oximeter. Porous stone aerators connected to an air compressor via hoses, at a rate of one aerator per basin, were used and operated continuously during the experimental period, except during growth control fishing. Hach colorimetric strips were also used to monitor nitrite and nitrate levels in the water. An electric scale was used to weigh the test feed and by-products during the growth control fishing operations.

Test diet preparation process and feeding frequency

Each diet was mixed manually to obtain a homogeneous mixture. A sieve was used to remove large particles and unwanted debris from the by-products. An electric mincer (Figure 3) was used to transform this homogeneous mixture into spaghetti-shaped feed, which was then cut into small pieces. The feed was spread out in laboratory compartments to prevent the loss of nutrients due to ultraviolet rays from the sun. Three diets were formulated based on peanut meal, cottonseed meal, wheat bran, millet, corn, fish meal, and cowpea meal.They were subjected to bromatological analyses to obtain data on their nutritional quality. The crude protein content of the raw materials used and their incorporation rates for each diet are shown in Table 1.These different incorporation rates or quantities enabled us to formulate three experimental diets (A0, A1, and A2) by varying the cowpea meal and peanut meal content by 0, 10, and 20%. The experimental diets were created using the algebraic Sum-Product (ΣPROD) method to obtain comparable diets that meet the nutritional requirements of *Clarias gariepinus* fry.The feed ration distributed to *Clarias gariepinus* fry was 8% of the biomass of each tank before the first two control catches and 5% of the biomass for the rest of the experiment. This variation in the rationing rate from 8% to 5% was due to recurrent deterioration in water quality and mortality recorded at the start of the trial. The feed ration was divided into two parts and distributed daily at 8 a.m. and 4 p.m.

Figure 3: Electric mincer

Table 1: Incorporation rates and crude protein contents of the by-products used and the formulated feeds

Ingredients	*Protein content (%)*	*Ingredient inclusion levels (%)*		
Corn meal	8.78	10	5	0
Fish meal	51.62	58	53	48
Cowpea meal	22.24	0	5	10
Peanut meal	25.54	0	5	10
Cottonseed meal	22.24	10	10	10
Millet bran	14.36	10	10	10
Wheat bran	15.16	8	8	8
Peanut oil	-	1	1	1
Fish oil	-	1	1	1
Yeast	-	1	1	1
Vitamin	-	1	1	1
Total values		**100**	**100**	**100**
Proteins		**35.69**	**35.06**	**34.43**
Lipids		**2.83**	**3.18**	**3.53**
Diets		**A0**	**A1**	**A2**

Evaluation of zootechnical parameters of *Clarias gariepinus* fry

Knowledge of the zootechnical parameters of fish makes it possible to evaluate the growthperformance, feed efficiency, and survival of fry in aquaculture.They were calculated as follows.

Table 2: Method for calculating data obtained on zootechnical parameters

Zootechnical parameters	Formula for calculating parameters
Survival rate (SR)	$= \frac{\text{Final number of fish}}{\text{Initial number of fish}} \times 100$
Daily weight gain (DWG)	$= \frac{\text{Final average weight} - \text{Initial average weight}}{\text{Rearing period in days}}$
Absolute weight gain (AWG)	= Average final weight – Average initial weight
Specific growth rate (SGR)	$= \frac{\ln(\text{Final weight}) - \ln(\text{Initial weight})}{\text{Duration}} \times 100$
Feed conversion ratio (FCR)	$= \frac{\text{Amount of feed distributed}}{\text{Biomass Produced}}$

Analysis and Processing of Experimental Data

The data generated in this study were entered using Microsoft Excel software. They were subjected to a one-way analysis of variance (ANOVA) using R software version 4.5.2 via the RStudio interface. Where a significant difference was observed with ANOVA, Tukey's multiple comparison test was applied at a probability threshold of 5%. When the data did not meet the assumptions of normality and homogeneity of variances, a nonparametric analysis using the Kruskal-Wallis test was applied.

I. Results and Discussion

Physicochemical parameters of water

The mean values and standard deviations of the physicochemical parameters of the water are presented in Table 3 below. The Shapiro-Wilk test performed between regimes A0, A1, and A2 shows that there is a distribution deviation ($p < 0.05$) for pH ($p < 0.003$ and 0.00) and temperature ($p < 0.00$), respectively. With regard to dissolved oxygen, the distribution is normal ($p > 0.05$) for regime A0 ($p > 0.515$), while regimes A1 and A2 do not meet the conditions of normality.However,Leven's test for homogeneity of variances shows that there is no significant difference (p-value > 0.05) between the variances of the different regimes for pH, temperature, and dissolved oxygen (0.3293, 0.9739, 0.7434).

The scope of application of the test comparing the means of the variances between diets, in this case ANOVA, is not valid. The Kruskal-Wallis test is applied to verify whether or not there is significance between the means of the different diets. In this sense, the analyses carried out specify that the degrees of significance of pH, temperature, and dissolved oxygen are above the 5% probability threshold. In other words, the physicochemical parameters remained stable during the experiment. No significant differences were observed between the treatments ($p > 0.05$).

Table 3: Mean values and standard deviations of physicochemical parameters

Parameters	Feed A0	Feed A1	Feed A2
Temperature (°C)	28.8^{a} ± 0.87	28.8^{a} ± 0.87	28.7^{a} ± 0.89
Dissolved oxygen (mg/l)	11.2^{b} ± 2.16	11.0^{b} ± 2.28	11.1^{b} ± 2.30
pH	7.53^{c} ± 0.14	7.54^{c} ± 0.13	7.55^{c} ± 0.13

Theoretical and analytical comparison of regimes

The protein and lipid content of foods estimated using the theoretical sum-product method (Sum-PROD) shows a variation compared to the results of bromatological analyses of formulated foods. Diet A0 shows the largest difference between the theoretical and analytical values for protein content (35.69% vs. 32.72%), but also shows the smallest difference for lipids (2.83% vs. 2.15%). However, feeds A1 and A2 show relatively small differences for crude protein (35.06% vs. 36.71%) and (34.43% vs. 35.11%), respectively. Furthermore, their lipid values vary slightly, with a difference of approximately 1.38 for food A1 (3.18% vs. 1.80%) and a similar variation for food A2 (3.53% vs. 1.85%).

Nutritional composition of *Clarias gariepinus* fry flesh

Analysis of the nutritional composition of *Clarias gariepinus* fry flesh carried out at the beginning and end of the experiments reveals variations in protein and amino acid profiles (Table 4). Initially, the crude protein content found in the flesh of the fry was between 58 and 63%. These values are similar to those obtained in the flesh of fry fed with feed A0. However, analysis of the flesh of fry fed with feeds A1 or A2 showed protein values of 63 and 68%. As for amino acid profiles, the flesh of fry fed with feed A0, A1, or A2 showed values that were generally higher than those observed in the flesh of fry in their initial state. However, in terms of the cumulative numerical value of the amino acids identified, feed A0 (627.9 g) had thehighest value, followed by A1 (620.8 g) and A2 (619.5 g) with similar values. Essential amino acids, particularly methionine and lysine, have higher numerical values in the flesh of the fry tested compared to the values obtained in the flesh in its initial state.

Table 4: Amino acid profiles in g/kg of flesh from *Clarias gariepinus* fry

Amino acids	FI	A0	A1	A2
Lysine	46.1	51.9	51.3	51.2
Methionine	17.0	19.1	18.9	18.9
Cysteine	5.5	6.1	6.1	6.1
Threonine	25.5	28.7	28.3	28.3
Tryptophane	6.7	7.5	7.4	7.4
Leucine	44.2	49.8	49.3	49.1
Isoleucine	25.5	28.7	28.3	28.3
Arginine	35.8	40.3	39.8	39.7
Valine	29.7	33.4	33.1	33.0
Histidine	15.8	17.7	17.5	17.5
Phenylalanine	23.6	26.6	26.3	26.3
Tyrosine	18.8	21.2	20.9	20.9
Alanine	38.2	43.0	42.5	42.4
Aspartic acid	56.4	63.5	62.8	62.6
Glutamic acid	78.8	88.7	87.7	87.5
Glycine	39.4	44.4	43.9	43.8
Proline	26.7	30.0	29.7	29.6
Serine	24.2	27.3	27.0	26.9
Total	557.9	627.9	620.8	619.5

FI: Initial flour; A0: Feed 0; A1: Feed 1; A2: Feed 2.

Growth dynamics of *Clarias gariepinus* fry

Control catches of *Clarias gariepinus* fry fed diets A0, A1, and A2 show a gradual increase in their average weight throughout the experiment (Figure 4). Furthermore, this weight gain in fish following the test diets shows that diet A0 presented the highest weight increase at 27 g, followed by diet A1 at approximately 24 g and diet A2 at 20 g. However, the error bars indicate moderate variability within diets.

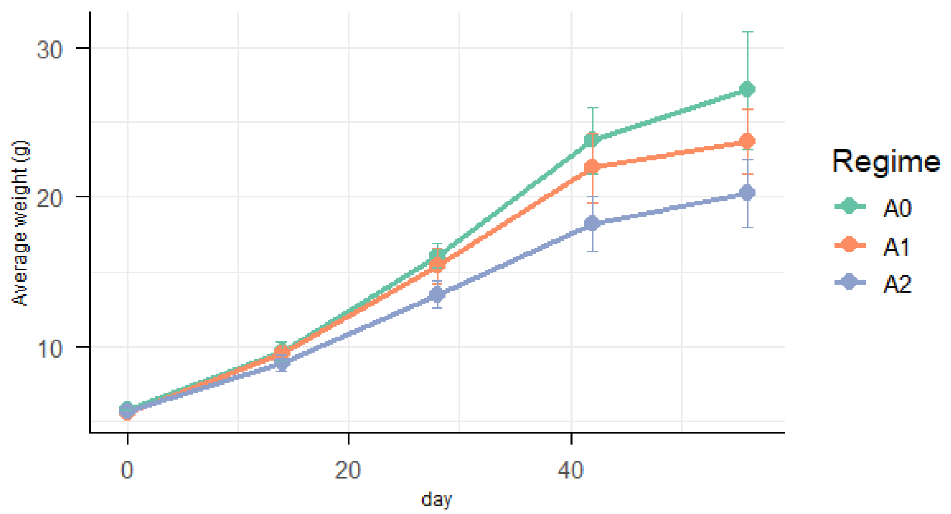


Figure 4: Growth dynamics of average weight according to diet

Growth and Feed Efficiency Parameters

The zootechnical performance results for *Clarias gariepinus* fry fed the three experimental diets (A0, A1, and A2) are shown as means ± standard deviation in Table 5, and others are illustrated in Figures 5 and 6. The data obtained on initial (Pmi) and final (Pmf) average weights are also shown, with no significant differences between the diets tested.

Daily weight gain (DWG) ranged from 0.26 to 0.38 g/day between diets, with higher values in fry fed diet A0 (0.38 ± 0.07 g/day) followed by those fed diet A1 (0.32 ± 0.04 g/day) and diet A2 (0.26 ± 0.04). No significant differences were observed between the diets tested (p-value > 0.05).

Absolute weight gain (AWG) also followed the same trend as GPQ, with values of 21.38 ± 4.00 g for diet A0, 18.09 ± 2.14 for diet A1, and 14.62 ± 2.22 g for diet A2, with a p-value >5%.

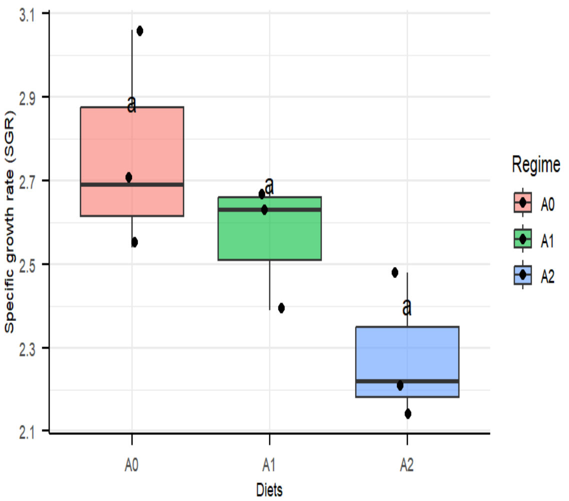
The specific growth rate (SGR) of diet A0 (2.76 ± 0.27 g/day) shows a decrease in numerical value compared to diet A2 (2.28 ± 0.18 g/day) without any significance (p-value > 0.05). With regard to the feed conversion ratio (FCR), the values recorded are low for diets A0 (1.78 ± 0.29) and A1 (1.81 ± 0.03) compared to those for diet A2, which is 2.09 ± 0.24. However, these variations are not statistically significant.

As with the survival rate (SR), no significant difference was observed between the diets, with values ranging from 73.33% to 82.22% despite high variability between repetitions of the same diet.

Table 5: Zootechnical performance of *Clarias gariepinus* fry

Parameters	Regime A0	Regime A1	Regime A2
IAW	5.73 ± 0.04	5.60 ± 0.03	5.62 ± 0.05
FAV	27.11 ± 3.97	23.69 ± 2.17	20.24 ± 2.28
DWG	$0.38^{a} \pm 0.07$	$0.32^{a} \pm 0.04$	$0.26^{a} \pm 0.04$
AWG	$21.38^{b} \pm 4.00$	$18.09^{b} \pm 2.14$	$14.62^{b} \pm 2.22$
SGR	$2.76^{c} \pm 0.27$	$2.57^{c} \pm 0.16$	$2.28^{c} \pm 0.18$
FCR	$1.78^{d} \pm 0.29$	$1.81^{d} \pm 0.03$	$2.09^{d} \pm 0.24$
SR	$77.78^{ab} \pm 16.78$	$82.22^{ab} \pm 19.25$	$73.33^{ab} \pm 24.04$

Numbers with the same superscript letter do not differ significantly.



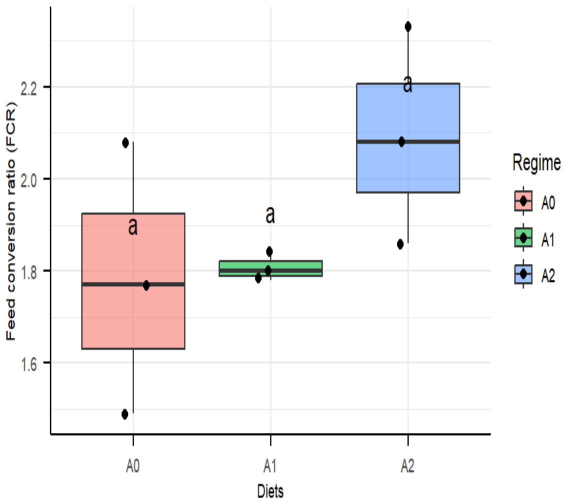


Figure 5: TCS as a function of speed

Figure 6: TCA as a function of speed

Discussion

Physicochemical parameters of water

Fish, particularly *C. gariepinus*, can tolerate a wide range of temperatures,but these must remain within the optimal survival limits for the species. They are known as cold-blooded species because their body temperature depends on the temperature of their breeding environment (Ogunji et al., 2017). The results show that during 56 days of testing, the average temperatures recorded between diets varied between 28.7°C ± 0.89 and 28.8°C ± 0.87. These results are consistent with those of Coppens (2015), who estimates that the optimal temperature range for *Clarias gariepinus* fry is between 26 and 30°C.

In terms of hydrogen potential (pH), the average values ranged between 7.53 ± 0.14 and 7.55 ± 0.13, with a slight deviation in standard deviations. These values are close to pH neutrality, and no significant differences were observed in the tests previously conducted. These pH values are within the optimal growth range for *Clarias gariepinus* fry, which, according to Uzoka et al. (2015), ranges from 6.5 to 8. However, for dissolved oxygen, as with the parameters mentioned above, there is a slight variation between the regimes. These results remain within the optimal tolerance limits for *Clarias gariepinus* fry (≥ 3 mg/liter) and are consistent with those reported by Mélard (1999). Furthermore, no significant differences were observed between the diets for this parameter. In view of the results on water quality, the preference criteria of *Clarias gariepinus* fry were met. Thus, our results on the physicochemical parameters of the water do not negatively affect the growth and survival of *Clarias gariepinus* fry subjected to the different diets tested.

Theoretical and analytical characteristics of diets

The theoretical and analytical variations underlie a decrease in the practical composition for diet A0, unlike A1 and A2, where they are ascending. According to Jacquot et al. (1994), this instability in protein content between the theoretical method and bromatological analysis could be due to climatic effects, soil structure or composition, and/or the location where local by-products are grown. Furthermore, the differences are consistent with practical expectations.

The theoretical composition tables for diets are only typical guidelines and may be acceptable up to ± 15% for crude protein (Lacroix, 2004).

Nutritional profiles of meats

Diets can influence the nutritional quality of fish flesh. Fry fed diet A0 had the highest levels of essential amino acids. In contrast, diets A1 and A2 had comparable levels that were higher than the initial bromatological values. The results show that essential amino acids such as lysine, arginine, and methionine are more important in the final analyses, with values very close to, but higher than, the initial numerical composition of the flesh. According to Oellermann and Hecht (2000), these amino acids constitute the most important nutritional requirements for *Clarias gariepinus*. Thus, our results confirm those of Sourabie (2019), who estimates that amino acids decrease with the increase in the incorporation rate of plant matter in diets.

Growth and Feed Efficiency Parameters

The data on growth and feed efficiency (Table 5) indicate that the best trends in numerical values were observed in fry fed with diet A0. The results obtained for TCS (2.76 ± 0.27%/day) are compared with those of Djekota (2023), who obtained a TCS of around

2.04%/day with a formula containing 50% protein and 25% lipids. In terms of absolute weight gain, diet A0 showed the best numerical trend with 21.38 g, although there was no significant difference between diets A1 and A2. As for fry survival, diet A1 shows the best trend with a survival rate of 82.22%, followed by diets A0 and A2 with 77.78% and 73.33%, respectively. Our results are slightly higher than those of Phanindra et al. (2017), who reported survival rates for catfish in integrated farming systems of 68.75% and 73.33%. The results of the study show that the formulas applied are statistically comparable.

With regard to feed conversion ratio (FCR), the values observed indicate satisfactory efficiency for the three diets tested. Although diet A2 (2.09 ± 0.24 g) shows the highest FCR value compared to diets A1 (1.81 ± 0.03 g) and A0 (1.78 ± 0.29 g), this variation is not statistically significant ($P > 0.05$).However, it is accepted that an ACP close to unity reflects better utilization of the feed in biomass. To this end, diet A0, which did not substitute fish meal with cowpea meal and peanut meal, demonstrated better numerical efficiency. Thus, the absence of significant differences between the levels of incorporation (0, 5, and 10%) of these ingredients confirms that partially replacing fish meal with plant-based protein sources (cowpea meal and peanut meal) does not significantly alter feed efficiency. Our results corroborate those of Ly et al. (2016), who state that fish meal can be replaced by soybean meal in up to 51% of the diet of *Lates niloticus*. In addition, the work of Diallo (2015) shows that replacing up to 25% of fish meal with cottonseed meal or sesame meal does not affect the growth of *Clarias gariepinus* fingerlings. However, the results of previous studies on feed formulation have shown that, apart from the composition of the formulated feed, the methods of distribution can significantly influence feed efficiency and the survival of farmed animals (Atsé et al., 2013). The results of the study show that an incorporation rate of up to 10% of cowpea meal and peanut meal remains nutritionally satisfactory and in no way compromises the feed efficiency of the diets tested.Furthermore, the buoyancy of the test diets, palatability, and low vegetable meal content compared to animal meal, particularly fish meal, are among the major constraints of the study that may be the subject of further research.

Conclusion

This study demonstrates that incorporating peanut meal and cowpea flour into the feed of *Clarias gariepinus* fry does not significantly alter their growth performance, feed efficiency, or survival.

The results indicate that these ingredients can be used as partial substitutes for fish meal in quasi-isoprotein diets.

The use of local by-products in fish farming is a promising strategy for reducing production costs and improving the sustainability of aquaculture in West Africa.
Further studies are recommended to optimize incorporation levels and analyze economic profitability.

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