EFFECT OF FEEDS BASED AGRO-INDUSTRIALS BY-PRODUCTS ON GROWTH AND BODY COMPOSITION OF CLAROTEIDAE *Chrysichthys nigrodigitatus* (LACEPEDE, 1803) FRY REARED IN HAPPAS

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ABSTRACT

In this study, trials with agro-industrials by-products feeds were conducted on fry of African catfish Claroteidae *Chrysichthys nigrodigitatus*. The aim is to provide locally available feed for fry of Bagrid catfish *C. nigrodigitatus*. To satisfy the nutritional requirements of these fry, feeds have been formulated by agro-ecological areas with high fish activity. From the agro-industrial by-products accessibles and good nutritionals values, three feeds (G, SG1 and SG2) with 40% of crude protein were formulated and tested. During 60 days, fry with an initial average weight 4.05 ± 1.24 g for an initial average length 7.54 ± 0.73 cm were fed at 10% of body weight with these different feeds. These diets were tested on triplicate. After the feeding period, no significant difference ($p > 0.05$) was observed between the three diets tests on final length and survival rate. However, fish fed with G and SG2 diets recorded the best growth performance. In addition, the body biochemical composition of fry at the end of rearing showed that the fish fed with the feed SG1 presented a high amount of nutriments. Thus, feeds composition influenced the growth indices and the quality of fry at the end of rearing.

Keywords: Fry, Formulated diets, Agro-ecological areas, Growth performance, *Chrysichthys nigrodigitatus*.

RESUME

Dans cette étude, des essais avec des aliments à base de produits agro-industriels ont été menés sur des alevins de Chrysichthys nigrodigitatus. L'objectif est de produire des aliments localement disponibles pour les alevins de mâchoiron C. nigrodigitatus. Pour satisfaire les besoins nutritionnels de ces alevins, des aliments ont été formulés par zones agro-écologiques à forte activité piscicole. A partir de sous-produits agro-industriels accessibles et de bonnes valeurs nutritionnelles, trois aliments (G, SG1 et SG2) à 40 % de protéines brutes ont été formulés et testés. Pendant 60 jours, des alevins d'un poids moyen initial de 4,05 ± 1,24 g pour une longueur moyenne initiale de 7,54 ± 0,73 cm ont été nourris à 10 % de leur poids vif avec ces différents aliments. Ces régimes ont été testés en triple. Après la période d'alimentation, aucune différence significative (p > 0,05) n'a été observée entre les trois régimes tests sur la longueur finale et le taux de survie. Cependant, les poissons nourris avec les régimes G et SG2 ont enregistré les meilleures performances de croissance. De plus, la composition biochimique corporelle des alevins en fin d'élevage a montré que les poissons nourris avec l'aliment SG1 présentaient une quantité élevée de nutriments. Ainsi la composition des aliments influence les indices de croissance et la qualité des alevins en fin d'élevage.

***Mots clés :** Alevins, Aliments formulés, Zones agro-écologiques, Performances de croissance, Chrysichthys nigrodigitatus.*

INTRODUCTION

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In Côte d'Ivoire, aquaculture predominantly revolves around fish farming, focusing on various cultured species such as *Oreochromis niloticus, Heterobranchus longifilis, Clarias gariepinus*, and their hybrid counterparts, alongside *Chrysichthys nigrodigitatus*, *Labeo coubie*, and *Parachanna africana* (Yao *et al.*, 2017). Notably, prior investigations have disclosed that the cultivation of *C. nigrodigitatus*, commonly referred to as "mâchoiron," within a semi intensive system, accounts for a mere 9.62% across 301 Ivorian fish farms (Koumi *et al.*, 2016). This under performance in *C. nigrodigitatus* breeding can be attributed to various factors influencing the species' survival, growth, and production duration. A notable challenge hindering the advancement of fish farming is the scarcity of quality feed. The absence of tailored industrial feeds for distinct growth stages of "mâchoiron" further exacerbates this issue within the Ivorian market (Koumi *et al.,* 2016).

Adjanké (2011) emphasizes the importance of tailoring rearing practices to the specific needs of each fish species in aquaculture. Consequently, developing an appropriate diet for *C. nigrodigitatus* fry mandates a profound understanding of their nutritional requisites during this developmental stage. While nutritional requirements for "mâchoiron" fry remain relatively obscure, insights from catfish (*Heterobranchus longifilis*) can inform feed formulation, with recommended proportions including 40% protein, 10% lipid, less than 10% fiber, and between 8 and 10% ash, alongside 25% carbohydrates (New, 1987; Guillaume *et al.*, 1999; Robinson and Li, 2015).

Côte d'Ivoire boasts abundant food and industrial crops distributed across its regions, with previous studies identifying ample availability of agro-industrial by-products within major fish farming zones (Kimou *et al.*, 2016). These zones are delineated across three agro-ecological areas: the Guinean zone, Sudano-Guinean 1 zone, and Sudano-Guinean 2 zone (Yao *et al.*, 2017; FAO, 2010). Formulating feed entails considering the cost, availability, production, and profitability, contingent upon the raw materials employed, their quality, and incorporation rates. Thus, this study aims to characterize and select accessible raw materials within agro-ecological zones for formulating competitive and available feeds tailored for *C. nigrodigitatus* fry breeding. Additionally, the study assesses the efficacy of different formulated feeds and their impact on the growth and body biochemical composition of *C. nigrodigitatus* fry.

Ultimately, the findings will pave the way for proposing quality feeds formulated from locally available raw materials in Côte d'Ivoire, catering to the breeding requirements of *Chrysichthys nigrodigitatus* fry.

MATERIALS AND METHODS

CHOICE AND INGREDIENTS CHARACTERIZATION

A preliminary investigation was conducted to assess the raw materials accessible within different agro-ecological areas. Following an evaluation of the cost and nutritional value of these materials, only five were chosen for further analysis in this study. These include imported fish meal (with a fish meal content of 55), soybean meal, cashew nut oil cake, wheat bran, and white rice bran.

The table provided (Table 1) outlines the biochemical composition of all the ingredients utilized. Fish meal 55 and soybean meal emerge as the primary protein sources, boasting approximately 55% and 44% crude protein content, respectively.

These ingredients are easily obtainable in each of the three agro-ecological areas, although their prices differ. For instance, soybean meal and fish meal 55 range from 370 XOF /kg (in the Sudano-Guinean 1 zone) to 420 XOF/kg (in the Sudano-Guinean 2 zone), and between 600 XOF/kg (in the Guinean zone) and 700 XOF/kg (in both Sudano-Guinean zones), respectively. Cashew nut oil cake serves as the primary lipid source, containing approximately 39% lipid content. While this by-product is present in all three areas, its cost differs significantly. It's priced at 350 XOF/kg in the Sudano-Guinean 1 zone, whereas it ranges between 200 XOF/kg (in the Sudano-Guinean 2 zone) and 250 XOF/ kg (in the Guinean zone). Finally, white rice bran and wheat bran were selected for the feed formulation for their highest carbohydrate content and low cost. Wheat bran is available regardless of the area at an average price which varied between 115 XOF / kg and 135 XOF / kg. The white rice bran is only available in the Guinean (55 XOF / kg) and Sudano-Guinean 1 zone (70 XOF / kg). Therefore, considering both the cost and availability of each raw material, the formulation of the feed varied across different regions. The composition and quantity of ingredients differed from one feed to another. However, when the same ingredients were utilized, the quantities incorporated were influenced by the selling price of the respective agro-industrial by-product.

Table 1: Proximate composition (Mean ± S.D.) of selected ingredients (% dry matter) used in feed formulation.

Composition biochimique (Moyenne ± E.C.) des ingrédients sélectionnés (% de matière sèche) utilisés dans la formulation des aliments.

Ingredients	Protein (%)	Fiber (%)	Lipid (%)	Ash (%)	Carbonhydrates (%)
Fish meal 55	55.30±0.12	02.39±0.61	09.05±0.71	21.15±0.98	00.99±0.46
Soybean meal	44.56±2.29	04.67±0.40	01.74±0.51	06.09±0.16	31.32±3.27
Cashew nut oil cake	19.87±1.74	06.08±0.32	38.90±0.36	03.21±0.18	26.73±1.79
Wheat bran	15.97±0.93	20.32±0.35	04.64±0.03	05.12±0.02	43.27±1.61
White rice bran	11.95±1.77	10.37±0.28	14.27±1.76	08.75±1.05	44.68±2.67

EXPERIMENTAL DIETS

Three isoproteic feeds (40% crude protein) were formulated based on the nutritional value of the selected raw materials and the nutritional requirements of *Chrysichthys nigrodigitatus* fry. These diets were prepared using the linear programming method outlined by Koumi (2010). The ingredients were weighed according to the specified formula, finely ground, and then mixed thoroughly. The resulting mixture was sun-dried, bagged, labeled, and stored in a designated area for the experimental trials. The formulation, proximate composition and cost of the experimental feeds are shown in Table 2. The feed from Guinean zone (G) and Sudano-Guinean 2 zone (SG2) contain the same ingredients. Fish meal 55 and soybean meal were incorporated at identical rates of 35%. The cashew nut oil cake has been added to a quantity of 20% in the feed (SG2). Inversely, wheat bran has been less incorporated into the feed of this zone. Unlike these two types of experimental feeds which contain four ingredients, the SG1 feed contains only fish meal 55, soybean meal and white rice bran. The incorporation rates of these various ingredients are respectively 50%, 20% and 30%.

Table 2: Ingredients, proximate and mineral composition and cost of the experimental diets.

Ingrédients, compositions biochimique et minérale et coût des régimes expérimentaux.

Ingredient (g/100g)	Diets		
	G	SG1	SG2
Fish meal 55	35	50	35
Soybean meal	35	20	35
Cashew nut oil cake	15	-	20
Wheat bran	15	-	10
White rice bran	-	30	-
Total	100	100	100
Proximate analysis[a]			
Moisture (%)	08.20	07.40	06.80
Crude protein (%)	40.45	40.25	40.69
Crude fiber (%)	05.95	07.15	05.65
Lipid (%)	09.56	07.82	10.35
Ash (%)	06.87	11.75	06.47
Carbonhydrate content (%)[b]	28.97	25.64	30.04
Gross energy ($Kj.g^{-1}$)[c]	19.37	18.27	19.87
Protein/energy ($mg.kJ^{-1}$)	20.88	22.04	20.48
Mineral composition ($mg.g^{-1}$)			
Calcium	08.86	09.63	07.60
Phosphor	04.40	10.36	03.39
Magnesium	00.60	05.64	05.29
Manganese	00.02	00.35	00.05
Potassium	02.54	10.37	13.39
Sodium	00.35	09.55	05.88
Iron	00.25	06.15	01.04
Cost ($XOF.kg^{-1}$)	390	385	400

a Values represent the mean of three replicates. b Carbonhydrate content = 100 - (% moisture + % protein + % fat + % fiber + % ash). c Gross energy = (23.7 × protein + 39.5 × fat + 17.2 × Carbonhydrate content).

FISH AND EXPERIMENTAL DESIGN

The experiment was conducted between July and September 2016. *Chrysichthys nigrodigitatus* fry used for the feeding trials were captured from Adjin lagoon in Côte d'Ivoire. A total of 1872 fish, with an initial average weight of 4.05 ± 1.24g and an initial average length of 7.54 ± 0.73 cm, were utilized for the experimental trials at the Azaguié fish farm (located at 5°38'00'' North, 4°05'00'' West) in Côte d'Ivoire. Before beginning of the feeding test, fishes were acclimated to experimental condition for 14 days. During the acclimation period, the fry was fed with a commercially available feed provided by a specialized distributor of aquaculture products (IVOGRAIN). At the end of this period, fishes were equally distributed in three dietary treatment groups (G, SG1 and SG2) in a completely randomized design. Fishes were reared in happas of 9 ± 0 m3 of volume, set in ponds. All these happas were fed by water from a water table. The stocking density was set at 17 fish per cubic meter. The fry were fed daily, with the feed amounting to 10% of their body weight. The feeds were portioned into three meals as the fish were fed three times a day, at 09:00 AM, 01:00 PM, and 5:00 PM hours. The amount of feed was adjusted every 15 days basing on the total weight of the fish calculated from the mean weights.

During the sixty-day rearing period, the physico-chemical parameters of the water were recorded weekly using a HANNA multi-parameter device. This device measured temperature, pH, salinity, dissolved oxygen, total dissolved solids (TDS), and Oxydo-Reduction Potential (ORP) for each pond. In addition, all the dead fish found in each happas were noted and removed. Similarly, every two weeks, control fisheries were conducted to readjust the new biomass. During this procedure, a sample of fish from each treatment was individually weighed and measured. The happas were washed to remove any undigested food particles and feces, ensuring proper water flow. At the conclusion of the experiment, a sample of 60 fish from each happas was individually measured and weighed. Then a sample of ten fish per happas was randomly removed for analysis of proximate body composition.

GROWTH PERFORMANCE AND FEED EFFICIENCY

After sixty days of rearing, the fish were individually measured for total length and weight taken. Based on the collected data, the following growth indices and feed utilization parameters were calculated for each experimental diet at the end of the feeding trial: weight gain, daily weight gain, length gain, daily length gain, specific growth ratio, survival rate, apparent consumption index, and protein efficiency ratio. The indices were calculated as follows:

- Weight gain (WG) (g) = final weight - initial weight;
- Daily weight gain (DWG) (g/ day) = final weight - initial weight / number of day;
- Length gain (LG) (cm) = final length - initial length;
- Daily length gain (DLG) (cm/ day) = final length - initial length/ number of day;
- Specific growth ratio (SGR) (%/day) = (Ln (final weight) - Ln (initial weight) /number of day) X 100;
- Survival rate (SR) (%) = (final number of fish / initial number of fish) X 100;
- Apparent consumption index (ACI)= total weight of feed consumed (g)/ biomass gain (g) ;
- Protein efficiency ratio (PER) = weight gain (g)/ protein intake.

PROXIMATE COMPOSITION

The proximate composition of the ingredients, diets, and whole-body fish was analyzed in accordance with AOAC (1990) standards. Moisture was determined after oven drying (105 °C) for 24 h.

Crude protein was determined using micro-kjeldahl method, N% × 6.25 (N :   ); ash was measured by incineration at 550 °C in a muffle funace for 24 h. Crude lipid by Soxlhet extraction with hexane according to AFNOR, (1986). Crude fiber by acid digestion followed by ashing the residue at 105 °C in muffle funace for 24h. Carbonhydrate content was calculated by taking the sum of values for crude protein, crude lipid, crude fiber, ash and moisture, and subtracting this from 100. The gross energy of the diet and fish were calculated on the basis of their crude protein, total fat and carbonhydrate contents using the energy equivalents of 23.7, 39.5 and 17.2 kJ/g respectively (Guillaume *et al.*, 1999). The ratio protein to energy (P/E). Experimental diets were analyzed for mineral composition (calcium, potassium, sodium, magnesium, iron and manganese), using atomic absorption spectrophotometer (AOAC, 1990) and phosphor according Taussky and Shorr (1953) methods. All the samples were analyzed in triplicate and the mean of each value were taken. Chemical and mineral composition is presented in table 2.

STATISTICAL ANALYSIS

The results were analyzed using a one-way analysis of variance (ANOVA) through the Statistica 7.1 software package. Data are presented as mean ± standard deviation (SD). Duncan multiple range tests were employed to compare differences between treatment means at a significance level of $p < 0.05$.

RESULTS

WATER QUALITY

The physico-chemical parameter values obtained indicate that the water temperature ranged from 27.83 to 29.32 °C, with a mean of 28.71 ± 0.64 °C. The pH values varied from 8.26 to 10.53, with a mean of 9.11 ± 1.00. Dissolved oxygen levels ranged from 7.77 to 9.90 mg/L, with a mean of 8.59 ± 0.91 mg/L. The values of conductivity varied between 26.00 and 32.00 µs/ cm with a mean of 29.75± 2.63 µs/ cm. Salinity had a range of 0.00 - 0.01 ‰ with a mean of 0.00 ± 0.01 ‰. The mean values of TDS (Total Dissolved Solids) and ORP (Oxydo-Reduction Potential) were respectively 14.75 ± 1.26 mg/L and 87.40 ± 22.85 mV.

GROWTH DATA

Figure 1 illustrates the monthly variation in the mean weight (a) and mean total length (b) of fry fed with the formulated feed over the course of two months, housed in happas. The variation in average final weight of fry after the first month

(M1) has the same evolutionary trend as that recorded at the end of the second month (M2) for the three treatments (Figure 1a). After the first month of feeding, feed SG2 produced the largest fish ($p < 0.05$). However, after 2 months, the best weight growth was obtained with feed G (00.17±0.02 g/day) and SG2 (00.20±0.03 g/day) . Thus, both feeds are conducive to enhanced weight growth of the fry. Figure 1b indicates that, overall, the size growth curves exhibited a similar pattern during months 1 and 2. Irrespective of the feed distributed, the sizes of the fry remained consistent ($p > 0.05$).

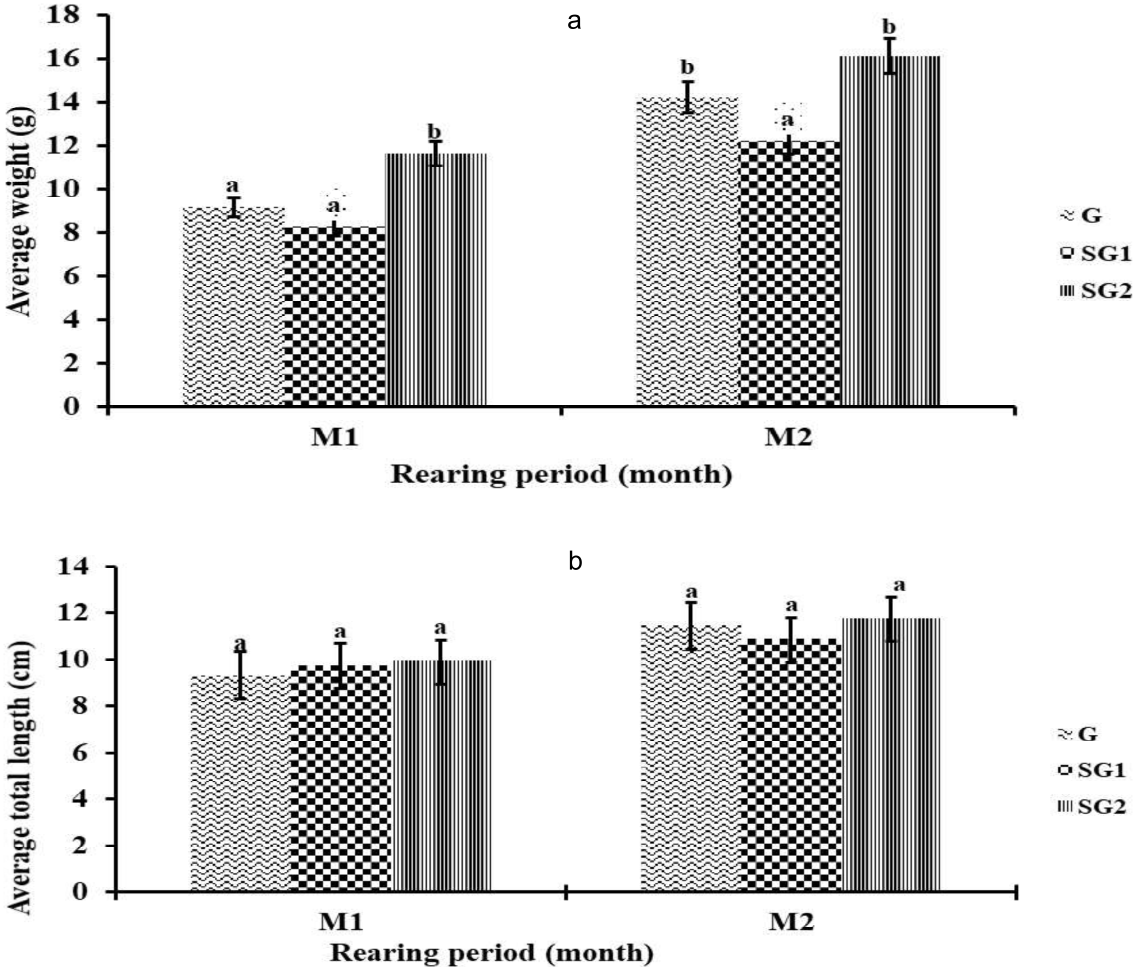

Figure 1: Monthly evolution of the average weight (a) and average total length (b) of the fry of *Chrysichthys nigrodigitatus* fed with feeds formulated at 40 % protein by agro-ecological zone for 60 days in happas.

Evolution mensuelle de la masse moyenne (a) et de la longueur totale moyenne (b) des alevins de Chrysichthys nigrodigitatus nourris avec des aliments formulés à 40 % de protéines par zone agro-écologique pendant 60 jours en happas.

G: Guinean; SG1: Sudano-Guinean 1; SG2: Sudano-Guinean 2

a, b, c: alphabetic letters during the same rearing period show a significant difference among the treatments at the threshold of $\alpha = 0.05$.

GROWTH PERFORMANCE AND SURVIVAL RATE

The growth and survival parameters for fry fed experiments feeds are shown in table 3. In general, these parameters at the end the feeding trials were influenced ($p < 0.05$) by the experimental feeds. Final body weight of fry fed with G diet (14.23 ± 1.71 d) and SG2 diet (16.12 ± 1.84 d) ware not different. But these final body weight ware significantly higher ($p < 0.05$) than those of fish fed with SG1 diet (12.20 ± 1.89 d). Nevertheless, no significant difference ($p > 0.05$) was observed in final body length and daily length gain among the three treatments. Similarly, the survival rate of fish did not vary significantly ($p > 0.05$) across the treatments. The values ranged between 99.04 ± 0 % (G) and 100% (SG1 and SG2). But, the fry fed both G and SG2 fed obtained at the end trials, values of daily weight gain and specific growth ratio significantly identical ($p > 0.05$) and highest than the values of daily weight gain (0.14 ± 0.01 g/j) and specific growth ratio (1.87 ± 0.16 %/j) recorded in fish fed with SG1 feed.

FEED UTILIZATION

The feed utilization parameters (Table 3) were significantly influenced by the experimental diets. Specifically, the apparent consumption index (ACI) recorded with diet SG2 (2.99 ± 0.05) was significantly lower ($p < 0.05$) than with diet SG1 (3.95 ± 0.03) and diet G (3.26 ± 0.76). Furthermore, the highest significant value of protein efficiency ratio (PER) (0.82 ± 0.01) was observed in fish fed SG2, while the lowest values (0.63 ± 0.01) were recorded in fry fed diet SG1.

Table 3: Growth performance, feed utilization and survival rate of *Chrysichthys nigrodigitatusfry* fed with the formulated diets.

Performances de croissance, utilisation des aliments et taux de survie des alevins de Chrysichthys nigrodigitatus nourris avec les régimes formulés.

Parameters	Diets		
	G	SG1	SG2
Initial body weight (g)	04.08±1.14^{a}	03.95±1.30^{a}	04.12±1.27^{a}
Final body weight (g)	14.23±1.71^{b}	12.20±1.89^{a}	16.12±1.84^{b}
Initial body length (cm)	08.00±1.00^{a}	07.33±0.58^{a}	07.30±0.61^{a}
Final body length(cm)	11.45±1.07^{a}	10.88±0.70^{a}	11.77±1.01^{a}
Daily weight gain (g/day)	00.17±0.02^{b}	00.14±0.01^{a}	00.20±0.03^{b}
Daily length gain (cm/day)	00.06±0.03^{a}	00.06±0.02^{a}	00.07±0.01^{a}
Specific growth rate (%/ day)	02.04±0.15^{b}	01.87±0.16^{a}	02.24±0.11^{b}
Apparent consumption index	03.26±0.76^{b}	03.95±0.03^{b}	02.99±0.05^{a}
Protein efficiency ratio	00.79±0.19^{b}	00.63±0.01^{a}	00.82±0.01^{b}
Survival ratio (%)	99,04±0.00^{a}	100±0.00^{a}	100±0.00^{a}

Values are means ± SD. G: feed of Guinean zone; SG1: feed of Sudano-Guinean 1 zone; SG2: feed of Sudano.

-Guinean 2 zone. Values in the same row with different superscript letters are significantly different ($p < 0.05$).

PROXIMATE COMPOSITION OF FRY

The whole-body composition of Chrysichthys nigrodigitatus fry at the conclusion of the experiments is provided in Table 4. The results indicated that the body biochemical composition of the fish was influenced by the formulated feeds. The body moisture content varied among the diets and was significantly higher ($p < 0.05$) in fish fed with feed G (72.34 ± 0.38%) followed by feed SG2 (70.20 ± 0.36%). The lowest body moisture value was obtained in fry fed SG1 diet (68.78 ± 0.44%).The inverse trend was recorded with crude protein content. Highest values of crude protein content were recorded in fish fed with feed SG1 (18.08 ±0.02 %), followed feed SG2 (17.87 ± 0.01 %). Fish of treatment with feed G obtained the lower values of crude protein (17.69 ± 0.03%) and crude lipid (7.62 ± 0.66%) content than fish fed with feeds SG1and SG2.No significant difference ($p < 0.05$) was observed in ash contents between fry fed with feeds G (1.89 ± 0.42%) and SG2(1.79 ± 0.56%). Fish fed with these feeds had significantly lower ash content compared to SG1.The lowest ($p > 0.05$) gross energy was recorded in fry fed with feed G (7.20 ± 0.27 %) than those fed with feeds SG1 (8.55 ± 0.59 %) and SG2 (8.89 ± 0.03 %).

Table 4: Whole body composition of *Chrysichthys nigrodigitatusfry* fed different formulated diets (% wet matter).

Composition biochimique des alevins entiers de Chrysichthys nigrodigitatus nourris avec les différents aliments formulés (% de matière humide).

Composition	Diets		
	G	SG1	SG2
Moisture (%)	72.34±0.38[c]	68.78±0.44[a]	70.20±0.36[b]
Crude protein (%)	17.69±0.03[a]	18.08±0.02[c]	17.87±0.01[b]
Crude lipid (%)	07.62±0.66[a]	10.80±1.49[b]	11.80±0.06[b]
Ash (%)	01.89±0.42[a]	02.39±0.58[b]	01.79±0.56[a]
Gross energy (kJ/g)	07.20±0.27[a]	08.55±0.59[b]	08.89±0.03[b]

Values are means ± SD. G: feed of Guinean zone; SG1: feed of Sudano-Guinean 1 zone; SG2: feed of Sudano-Guinean 2 zone. Values in the same row with different superscript letters are significantly different ($p < 0.05$).

DISCUSSION

The physicochemical parameters of the water in the happas are favorable for the development of *Chrysichthys nigrodigitatus* fry. This conclusion is supported by the fact that each physicochemical parameter falls within the aquaculture ranges recommended by Boyd and Tucker (1998). These conditions likely create an optimal environment for the fry's growth and well-being, contributing to their overall development and survival.

The high survival rate observed at the end of the rearing period indicates that the feeds provided adequate nutrition without posing significant health risks to the fry. This suggests that the formulated feeds did not negatively impact fry survival in the hapas, corroborating findings by Azim *et al.* (2002). Moreover, the observed differences in growth performance among the various feeds underscore the critical role of feed formulation and composition in influencing fish growth and development. Although the feeds are isoproteic, they differ in fiber, fat, ash, carbonhydrate, and gross energy content. The high protein level in the SG1 feed offers greater digestibility for the fish, yet growth was still low with this feed. This indicates that protein alone is insufficient for optimal growth; a combination of lipids, carbohydrates, and vitamins is necessary. This underscores the essential role of lipids in the diet of Siluriformes, including *Chrysichthys nigrodigitatus.* These nutrients help spare dietary protein from catabolism to meet growth requirements (Kerdchuen, 1992; Babobala and Apata, 2006). Furthermore, fats serve as a concentrated energy source that facilitates the absorption of fat-soluble vitamins and promotes increased food intake, thereby stimulating fish growth (Robinson *et al.*, 2006).

The lowest daily weight gain recorded with the SG1 diet corresponds to the low final weight of the fish on this diet. The ingredient composition of the SG1 feed could explain this poor growth performance. Nevertheless, the daily weight gain observed in this study is comparable to or exceeds the values reported by Hem *et al.* (1994), who conducted their experiment in a lagoon cage-enclosure using a feed with 40% protein. This difference in growth could be attributed, on one hand, to the variation in rearing structures (happas instead of cage-enclosure) and, on the other hand, to the difference in rearing environments (lagoon instead of pond). Therefore, both the rearing structure and the culture environment can significantly influence the growth performance of *C. nigrodigitatus* fry (Montchowui *et al.*, 2012).The specific growth rate is directly proportional to the daily weight gain. The values for this growth parameter in the study varied significantly, likely due to differences in the quality of the test feeds.

The zootechnical results at the end of the feeding tests reveal growth variations attributable to the nutritional differences in the feeds. Each raw material used in formulating the experimental feeds has intrinsic qualities that impart specific nutritional properties to these feeds (Ossey *et al.*, 2012). The disparity in growth performance between the feeds could be primarily due to the different incorporation rates of cashew nut oil cake, a high-lipid agro-industrial by-product, which was used extensively in the SG2 feed. The high lipid content in SG2 results from the substantial amount of cashew nut oil cake included in its formulation. Unlike feed G and

SG2, the use of feed SG1 resulted in fish of smaller weight. These low growths are due on the one hand to the low levels of lipids and on the other hand to the high rate of fiber contained in this feed compared to the other two (N'Zué *et al.,* 2022). However, fibers accelerate gastro intestinal transit. This induces a low digestive efficiency of enzymes and consequently a decrease in the absorption of nutrients (Médale *et al*., 2013). According to these authors, fiber can also reduce the bioavailability of nutrients.

The results collected in fish fed with feed SG2 reveal that this feed was the best appreciated and the most digestible of the three feeds formulated. The difference in apparent consumption index observed particularly between feeds G and SG2 which, however, have the same ingredients, could be located at the level of the incorporation rate of wheat bran (Francis *et al*., 2001). According to Jabir *et al.* (2012), the results of ACI and PER are generally related to nutrient digestibility. Thus, The wheat bran is a cereal by-product rich in anti-nutritional substances; in particular tannins and phytates. However, phytates, during the digestion of fish, bind to minerals (calcium, zinc and iron) thus preventing their absorption by the intestinal mucosa (Azaza *et al*., 2006). However, minerals are essential elements involved in the formation of the skeleton and the maintenance of the acid-base balance. In addition, the low Protein efficiency ratio of diet SG1 could be explained by the decrease in the digestibility of the proteins contained in this feed. Indeed, the anti-nutritional factors present in by-products such as wheat bran, by the action of phytic acid, form a complex with phosphorus and proteins and make them unavailable (Pointillart, 1994; Vielma *et al*., 2002). These anti-nutritional substances can act indirectly through oligosaccharides, tannins, and glucosinolates, whose metabolites affect appetite, disrupt the synthesis of thyroid hormones, and impair the digestive capacity of fish (Pham *et al*., 2007). Similar to fibers, many anti-nutritional substances found in plant materials interfere with nutrient digestion, resulting in reduced feed digestibility (Storebakken *et al*., 2000; Krogdahl *et al.,* 2010).. Therefore, the growth results observed with the feed SG2 shows that when formulating feeds for the fry of *Chrysichthys nigrodigitatus*, an incorporation rate of 10% of wheat bran in the feed at 40% protein will be effectively used by fish for their growth. According to Azaza *et al.* (2006), the effectiveness of a feed depends not only on its chemical composition and palatability, but also on its ability to be digested and absorbed through the intestinal mucosa.

In this study, the body biochemical composition of fry was significantly influenced by the biochemical composition of the formulated feeds. The results show that the fish fed the SG1 feed had the highest dry matter content and therefore wealthy in nutrients. Conversely, fish fed with feed G are less rich in nutrients. In general, regardless of the feed formulated, the biochemical composition of fish indicates high amounts of lipids. These high rates are said to be due to the fact that the analyzes were carried out on whole fish. In fish, the liver, flesh and viscera are sites of lipid storage (Henderson and Tocher, 1987; Sheridan, 1994). The high lipid levels observed in fish fed with SG2 can be attributed to the relatively high lipid content in the SG2 feed. According to Fauconneau *et al.* (1990), Watanabe (1982), and Cowey (1993), although lipids offer several benefits, their increased presence in the diet can lead to fatty deposits in fish tissues, particularly in the muscle, liver, and adipose tissue, often associated with a decrease in water content. The nutritional analysis of the fish sampled at the end of the rearing period indicates that the SG2 feed produced fish rich in both proteins and lipids.

CONCLUSION

After two months of breeding in happas, it appears that diets based on agro-industrial by products with 40% protein did not have any negative effects on the survival and growth of the fry of *Chrysichthys nigrodigitatus*. Survival rates varied between 99.04% and 100%. Fish fed with the SG2 and G diets showed excellent growth. However, the SG2 feed was used best for growth among the three. Following a two-month breeding period in hapas, it is evident that diets comprising 40% protein from agro-industrial by products did not adversely affect the survival and growth of *Chrysichthys nigrodigitatus* fry. Survival rates ranged from 99.04% to 100%. Fish fed with diets SG2 and G exhibited robust growth; however, SG2 outperformed the other formulated feeds in terms of growth. Thus, formulating feeds with 35% imported fish meal, 35% soybean meal, 20% cashew nut oil cake, and 10% wheat bran appears to be an efficient method for producing juveniles averaging 16 grams in two months. The results also revealed significant effects on body moisture, protein, fat, ash, and gross energy content. The results indicated that body moisture, protein content, fat content, ash content and gross energy of fish were all influenced by diets. The fish obtained presented very good nutritional quality.

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