



# Comparative study of three locally available feeds on the growth and nutritional quality of *Oreochromis niloticus* juveniles

Ella Pélagic Larissa Kouadio<sup>1</sup>, Ahou Rachel Koumi<sup>2\*</sup>, Tia Jean Gonnety<sup>1</sup>, Boua Célestin Atsé<sup>2</sup>, Lucien Patrice Kouamé<sup>1</sup>

<sup>1</sup>Université Nangui Abrogoua UNA, UFR des Sciences et Technologies des Aliments STA, Abidjan, Côte d'Ivoire

<sup>2</sup>Département Aquaculture, Centre de Recherches Océanologiques CRO, Abidjan, Côte d'Ivoire

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## ABSTRACT

The aim of the present study was to evaluate the effects of three feeds formulated for three fish farming agroecological areas of Côte d'Ivoire on the growth and nutritional quality of *Oreochromis niloticus* juveniles. Feeds were formulated at 30% crude protein with locally-sourced raw materials available by area. The use of different ingredients at different levels for feeds formulation made variations in the nutritional compositions and costs of the three feeds produced. The average male weight of *O. niloticus* juveniles,  $26.89 \pm 2.98$ – $27.35 \pm 2.74$  g, was stocked at a density of 3 fish/m<sup>2</sup> and was hand fed at 5%–3% body weight two times daily, 6 days per week during 120 days in the triplicate earthen ponds. At the end of the feeding trial, daily weight gain values varied between  $1.12 \pm 0.08$  g/day and  $1.21 \pm 0.06$  g/day and survival rate ranged between  $99.44 \pm 0.00$  and 100%. No significant difference ( $p < 0.05$ ) was observed in the growth performance and feed efficiency parameters of juveniles *O. niloticus* feeding. An increase in crude lipid and gross energy was observed in whole body compositions of *O. niloticus* feeding with the highest dietary lipid levels. Low-cost locally adapted feeds produced for *O. niloticus* juveniles growth were competitive and proffer the opportunity to improve availability of local quality feeds in the fish farming areas of Côte d'Ivoire.

## 1. INTRODUCTION

Fish is a major source of protein, essential fatty acids and micronutrients [1–3]. It contributes to the production of diversified and healthy diets. Hence, during the recent year around the world, aquacultural and fish production gained high increase to supply the fish needs of the populations [4]. In Côte d'Ivoire, most of the fish farming production is dominated by Nile tilapia *Oreochromis niloticus* [5]. This fish has been raised in Côte d'Ivoire since the year 1940 for subsistence or commercial purposes; and the vast majority of fish farmers use the semi-intensive system in the earthen pond as rearing structures for *O. niloticus* production [5–8]. However, tilapia *O. niloticus* rearing on the majority of Côte d'Ivoire fish farms in a semi-intensive system meet various difficulties. Some of these problems are a long time (9–12 months) of merchant *O. niloticus* production; low weight (250–350 g) of fish farming tilapia, as well

as low yields (1,000–6,000 kg/ha/year), recorded on the majority of fish farms reported by several authors [9–12]. Otherwise, the origins of these difficulties on the tilapia rearing are reported to be the inaccessibility of high-quality commercial feeds to the majority of fish farmers localized in the high concentration of fish farmers' areas who are usually low-income farmers [5]. This situation results to the strong use of non-quality feed sellers' commercial feeds; farm-made feeds; agro-industrial byproducts and non-conventional feeds to feed fish; non-respect of the feeding and rearing practices, thereby inducing low production of fish farming [11,12].

However, feeds are one of the major inputs in aquacultural production and the use of quality fish feeds in recommended quantity is the most important factor that determines the profitability and the sustainability of fish farms [13,14]. In the semi-intensive fish farming system, the tilapia merchant weight of 700 g and production yields of 15–17 tones/ha/year can be achieved with good nutrition practices [11,15,16]. According to Gabriel et al. [14] and Koumi et al. [8], the production of low-cost locally composed fish feeds, which take into account the requirement of different species and stages of farmed fish made with locally available raw

\*Corresponding Author

Ahou Rachel Koumi, Centre de Recherches Océanologiques CRO,  
Département Aquaculture, Abidjan, Côte d'Ivoire.  
E-mail: [koumirachel@yahoo.fr](mailto:koumirachel@yahoo.fr)

materials with good processing methods, is the main challenge of fish farming. To try this solution, several authors tested with success the use of locally available ingredients in fish feeds [7,17–20].

In Côte d'Ivoire, the development of high-quality low-cost feeds for fish farmers has become a priority for many scientists. Previous works made by Bamba *et al.* [21,22] and Koumi *et al.* [23,24] on *O. niloticus* feeds, although based on local raw materials, were not specific to the areas of the high concentration of fish farmers. However, the different areas of fish farming practices in Côte d'Ivoire were well identified by [5] and availability and costs of raw materials vary by region and by area in the same country. In addition, the nutritional requirements of *O. niloticus* fingerlings are very well documented. The purpose of this study was to locally formulate low-cost quality feeds for *O. niloticus* juveniles in the three fish farming agroecological areas with accessible raw materials in each area to increase the availability of quality feeds for *O. niloticus* rearing in Côte d'Ivoire.

## 2. MATERIALS AND METHODS

### 2.1. Agroecological Areas and Fish Farming Agroecological Areas

According to MINESUDD [25], three agroecological areas (Guinean, Sudano-Guinean, and Sudanese) subdivided into four agroecological areas (Guinean, Sudano-Guinean I, Sudano-Guinean II, and Sudanese) were identified in Côte d'Ivoire depending on climate, type of vegetation, rainfall and annual precipitation levels, altitude and agricultural crops. Table 1 presents the localization of the four agroecological areas in Côte d'Ivoire. Of

the same, Figure 1 presents localization of fish farming practice in Côte d'Ivoire. Hence, Table 1 and Figure 1 show the practice of fish farming in Côte d'Ivoire only in the Guinean, Sudano-Guinean I, and Sudano-Guinean II areas in the South, West, Center, and East zones. Also, Yao *et al.* [5] reported a high concentration of fish farmers and/or high level of fish farming production in these three areas. In this study, feeds of *O. niloticus* juvenile stage were formulated and produced based on raw materials and feedstuffs accessible in Guinean, Sudano-Guinean I, and Sudano-Guinean II areas.

### 2.2. Selection of Raw Materials and Feeds Formulation

The raw materials used in the formulation of feeds were selected based on their availability, market prices, and nutritional values by three fish farming agroecological areas. But for the same nutritional quality of several raw materials, availability and prices were the definitive selection criteria. So low-cost local fish meal at 42% of protein (0.52 USD/kg), copra (0.17 USD/kg), white rice bran (0.10 USD/kg), and soybean meal (0.70 USD/kg) were selected for Guinean area feed formulation; imported fish meal (1.21 USD/kg) with 55% of protein content, white rice bran (0.052 USD/kg) and soybean meal (0.64 USD/kg) were used for Sudano-Guinean area I; while local fish meal (0.52 USD/kg) content 42% protein, cottonseed oil cake (0.35 USD/kg), cornmeal (0.22 USD/kg), cashewnut oil cake (0.35 USD/kg), and soybean meal (0.73 USD/kg) were used for Sudano-Guinean area II feeds formulation (Table 2). Soybean meal available in the three agroecological areas and the two types of fish meals (42% and 55% of protein) were used as a protein source in feeds formulation (Table 3).

**Table 1:** Côte d'Ivoire agroecological areas [25].

Agroecological areas	Regions	Zones	Departments and subprefectures
Guinean	Agnéby-Tiassa, Grands-Ponts, La Mé Sud-Comoé Nawa, Haut Sassandra Loh Djiboua, Tonkpi, Guemon, San-Pedro, Gbôké	South and West of the country	Agboville, Tiassalé, Taabo, Sikensi, Rubino, Azaguié, Dabou, Grand-Lahou, Jacqueville, Adzopé, Akoupé, Alépé, Yakasse-Attobrou, Affery, Agou, Aboisso, Adiaké, Ayame, Grand-Bassam, Bonoua, Tiapoum, Maferé; San-Pedro, Tabou, Gbôklé, Sassandra, Fresco, Nawa, Soubéré, Buyo, Guéyo, Méagui, Daloa, Gonaté, Domangbeu, Issia, Nahio, Vavoua, Bazra-Nattis, Ketro-Bassam, Sétifla, Gadouan, Zaibo, Bediala, Boguhé, Zoukougbeu, Divo, Didoko, Gbagam, Lauzoua, Ogodou, Dairo-Didizo, Guitry, Lakota, Goudouko, Zikisso, Djidji, Man, Logoualé, Podiagouiné, Yapleu, Duekoué, Facobly, Kouibly, Totrodrou, Sémien, Danané, Daleu, Kouan-Houlé, Mahapleu, Bangolo, Zéo, Diéouzon, Zou, Biankouma, Santa, Zouan-Hounien, Banneu, Teapleu
Sudano-Guinean I	Gôh Marahoué Indenié-Djuablin, Moronou, N'zi, Guemon, Bafing, Cavally	South-Central of the country	Gagnoa, Guibéroua, Ouragahio, Gnagbodougnou, Dignago, Bayota, Doubé, Galebouo, Serihio, Oumé, Guepahouo, Tonla, Diégonéfla, Bouaflé, Sinfra, Zuénoula, Gohitafla, Bonon, Abengourou, Niablé et Agnibilékrou, Dimbokro, Bongouanou, Arrah, Tiémélékro, Kotobi, Guiglo, Zagné, Nizahon, Taï, Duékoué, Toulepleu, Bloulequin, Zéaglo, Touba, Koro, Ouaninou
Sudano-Guinean II	Gbeke, District de Yamoussoukro, Ifiou, Bounkani, Worodougou, Belier Gontougo	Central and East of Country	Bouaké, Béoumi, Dabakala, Katiola, Fronan, Niakaramandougou, Tafiré, Tortiya, Sakassou, Botro, Yamoussoukro, Toumodi, Kossou, Tiébissou, Yakpabo-Sakassou, Molonou, Lomokankro, Didiévi, Molonou-Blé, Prikro, Ouellé, M'Bahiakro, Daoukro, Bocanda, Bouna, Doropo, Nassian, Tehini, Bondoukou, Koun-Fao, Sandegue, Tanda, Transua, Séguéla, Massala, Maradiassa
Sudanese	Poro, Bagoué, Tchologo, Hambol, Folon, Kabadougou	North of Country	Korhogo, Sirasso, Niofoin, Boron, Kanoroba, Sinématiali, Boundiali, Ganaoni, Kasséré, Siempurgo, Kouto, Blességué, Gbon, Kolia, Sianhala, Ferkessédougou, Togonieré, Ouangolodougou, Tingréla, Kanakono, Folon, Minignan, Sokoro, Tienko, Kimbirila Nord, Kaniasso, Goulia, Mahandiana-Sokourani, Kabadougou, Samatiguila, Kimbirila Sud, Odienné, Samango, Gbéléban, Seydougou, Bougouso, Bako, Dioulatiédougou, Tiémé, Madinani, Fengolo, N'Goloblasso, Séguélon, Gbongaha

White rice bran was used as a major source of carbohydrate in the Guinean and Sudano-Guinean I areas, and cornmeal was used as carbohydrate source of feed in the Sudano-Guinean I. Three isonitrogenous 30% protein feeds were formulated using linear programming method to quantify the different raw materials by feed (Table 4). All feedstuffs were incorporated following the limit levels recommended for fish feeds. Then, for each formulation, dry feed ingredients were weighed, ground in fine flour, and mixed and mixes were pelleted in 2-mm diameter pellets. Feeds were produced in bimonthly frequency to cover the needs of fish

feeding. Samples of all the feeds produced were collected to the complete nutritional quality and analyzed according to [26,27].

### 2.3. Fish and Feeding Trial

Juveniles males of tilapia *O. niloticus* were collected from a private fish farmer near Azaguié town (Latitude 5°–6 ° North; Longitude 4°–5° West) to constitute the three different groups of feeding trial. Three replicate earthen ponds were used by the feed formulated and feeding trial was performed on one fish farm located near Azaguié town, in Agboville Department localized in the south of

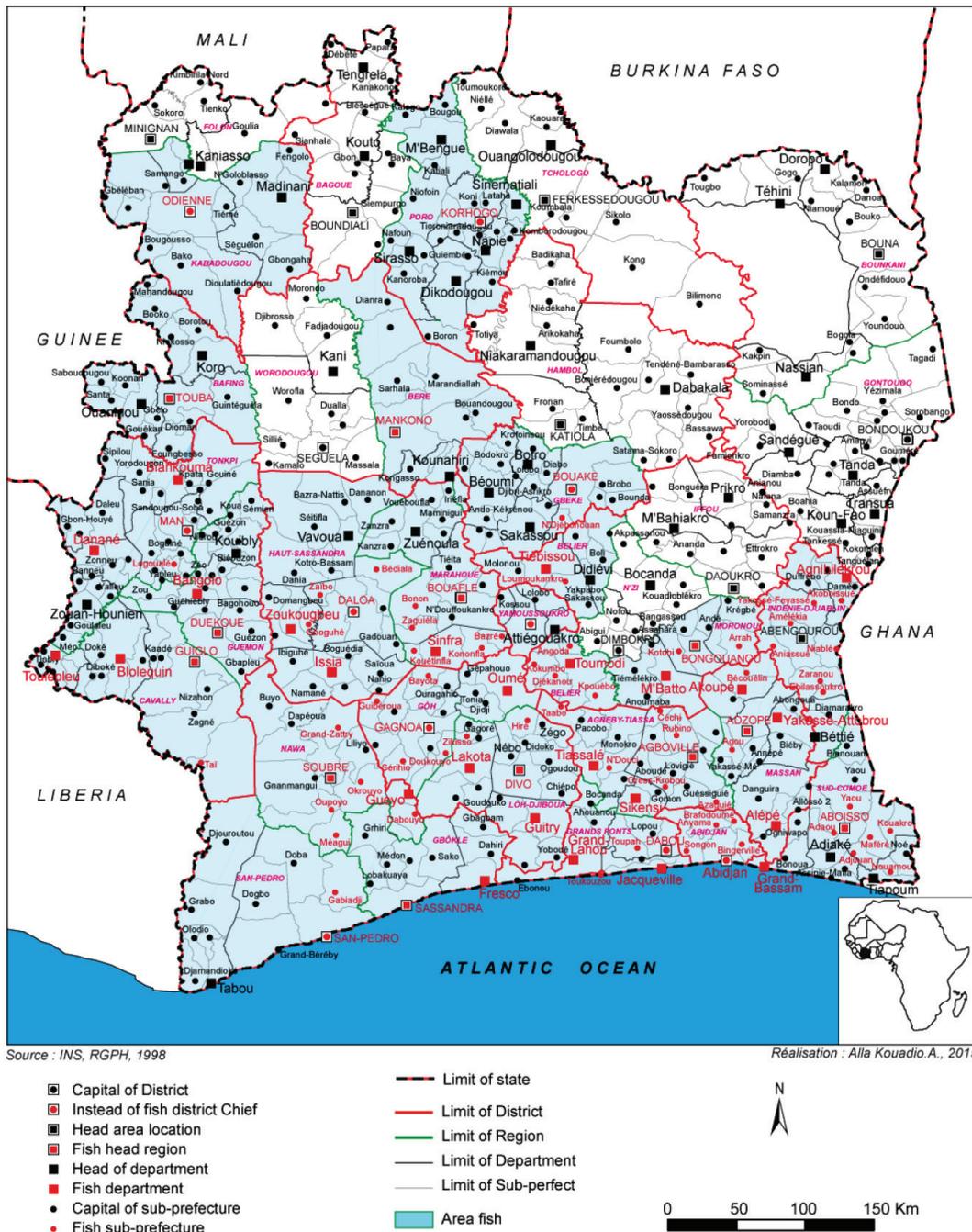


Figure 1: Districts, Regions, Departments, and Subprefectures of fish farming practice in Côte d'Ivoire according to Yao et al. [5].

Côte d'Ivoire to 40 km near Abidjan. Rearing was realized in the same conditions of fish farmers. Juveniles Nile tilapia *O. niloticus* of an average weight of  $26.89 \pm 2.98$ – $27.35 \pm 2.74$  g were stocked at a density of 3 fish per square-meter and were hand-fed at 3%–5% body weight two times daily at 09:00 and 17:00 hours 6 days per week during 120 days. Earthen ponds water temperature, pH, dissolved oxygen, Total Dissolved Solids (TDS), Potential redox (ORP), and conductivity were monitored throughout the feeding trial. These parameters were measured weekly using multiparameter HANNA type. Every month, a sample of 30% fish was collected by the pond, individually weighed and measured. Then the monthly fish biomass by the pond was calculated based on the fish mean weight and the number of fish death recorded during the month for adjusting the feeding ration. At the end of the feeding trial, fish of each pond were harvested, counted, and individually weighed and measured. Total quantity of feed used was calculated for each pond.

#### 2.4. Determination of Growth and Feed Efficiency Parameters

Growth and feed utilization parameters were calculated using the following formulas according to [28]:

Weight gain: WG (g)

$$WG(g) = \text{Final body weight of fish} - \text{Initial body weight of fish}$$

Length gain: LG (cm)

$$LG(cm) = \text{Final fish length} - \text{Initial fish length}$$

Daily Weight Gain: DWG (g/day)

$$DWG(g/day) = \frac{\text{Final weight of fish} - \text{Initial weight of fish}}{\text{Number of trial days}}$$

Daily Length Gain: DLG (cm/day)

$$DLG(cm) = \frac{\text{Final fish length} - \text{Initial fish length}}{\text{Number of trial days}}$$

Specific Growth Rate: SGR (%/day)

$$SGR(\%/day) = \frac{\ln(\text{Final weight of fish}) - \ln(\text{Initial weight of fish})}{\text{Number of trial days}} \times 100$$

Survival Rate: SR (%)

$$SR(\%) = \frac{\text{Final number of fish} - \text{Initial number of fish}}{\text{Initial number of fish}} \times 100$$

Feed Conversion Ratio: FCR

$$FCR = \frac{\text{Total weight of feed consumed by fish}}{\text{Wet fish biomass gain}}$$

Protein Efficiency Ratio: PER

$$PER = \frac{\text{Wet fish biomass gain}}{\text{Total dietary protein intake}}$$

**Table 2:** Variation of the market price of raw materials selected by agroecological area.

Raw materials	Price (USD/kg)*		
	Guinean Area	Sudano-Guinean area I	Sudano-Guinean area II
Fish meal (55)	1.11	1.21	1.21
Fish meal (42)	0.52	0.52	0.52
Soybean meal	0.70	0.64	0.73
Cottonseed oil cake	0.41	0.37	0.35
Cashewnut oil cake	0.35	-	0.35
Copra	0.17	0.27	0.22
White rice bran	0.10	0.052	-
Cornmeal	0.28	0.26	0.22

\* 1 USD = 578.54 FCFA based on February 2019 exchange data.

**Table 4:** Formulation (kg/100 kg) and costs of feeds produced for *O. niloticus* juveniles rearing by agroecological area (G = Guinean zone; Sudano-Guinean area I = SGI; Sudano-Guinean area II = SGII).

Parameters	Fish feeds		
	G-30%	SGI-30%	SGII-30%
Raw materials			
Fish meal (55)	-	20	-
Fish meal (42)	30	-	25
Copra	10	-	-
Cottonseed oil cake	-	-	20
Cornmeal	-	-	20
White rice bran	25	45	-
Cashewnut oil cake	-	-	10
Soybean meal	35	35	25
Total (kg)	100	100	100
Cost (USD/kg)	0.43	0.52	0.49

**Table 3:** Variation of proximate composition of raw materials selected by agroecological area.

	Fish meal (55)	Fish meal (42)	Soybean meal	Cottonseed oil cake	Cashewnut oil cake	Copra	White rice bran	Cornmeal
Moisture (%)	11.23 ± 21	8.92 ± 0.56	11.89 ± 0.50	9.66 ± 0.51	6.14 ± 0.51	8.63 ± 0.57	9.88 ± 0.22	12.68 ± 0.81
Crude protein (%)	55.30 ± 0.12	42.67 ± 1.00	44.56 ± 2.29	35.71 ± 0.73	19.87 ± 1.74	19.67 ± 0.57	11.95 ± 1.77	5.77 ± 0.37
Crude lipid (%)	9.05 ± 0.71	14.59 ± 0.88	1.74 ± 0.51	3.01 ± 0.10	38.90 ± 0.36	16.02 ± 0.64	14.27 ± 1.76	4.38 ± 0.37
Ash (%)	21.15 ± 0.98	29.17 ± 0.12	6.09 ± 0.16	5.93 ± 1.46	3.21 ± 0.18	5.73 ± 0.40	8.75 ± 1.05	1.87 ± 0.95
Crude fiber (%)	2.39 ± 0.61	4.84 ± 0.83	4.67 ± 0.40	24.58 ± 0.25	6.08 ± 0.32	34.58 ± 3.11	10.37 ± 0.28	2.91 ± 0.04
NFE <sup>1</sup> (%)	0.99 ± 0.46	0.51 ± 0.40	31.32 ± 3.27	21.10 ± 1.79	26.73 ± 1.23	15.13 ± 0.98	44.68 ± 2.67	71.97 ± 0.52
Calcium (mg/g)	57.90	65.37	3.48	1.10	0.17	1.23	0.97	0.23
Phosphorus (mg/g)	26.00	28.90	3.14	4.88	1.53	5.30	7.78	2.53

<sup>1</sup>Nitrogen Free Extract= 100 – (moisture + crude protein + crude lipid + crude fiber + ash).

## 2.5. Proximate Composition Analysis of Feeds and Fish

Proximate composition of fish and feeds was determined according to [26,27]. Dry matter (DM) was determined after drying the samples in an oven (80°C) until a constant mass. Crude protein was measured using Kjeldhal method ( $N\% \times 6.25$ ), Ash was measured by incineration at 550°C in a muffle furnace for 24 hours, and crude fat was determined using Soxhlet extraction with hexane as solvent. The gross energy content of feeds and fish samples were calculated based on energy equivalents of crude protein, crude fat, and total carbohydrates; 23.7, 39.5, and 17.2 kJ/g, respectively [29]. The mineral contents of the samples were determined by atomic absorption spectrophotometer. All analyses were made in triplicate for each sample.

## 2.6. Statistical Analysis

Statistical analysis of data collected was performed on STATISTICA 7.1 software. Data were expressed as means  $\pm$  standard deviation. One-way ANOVA analysis of variance was used to compare the values. Then, Duncan multiple range tests were used to compare differences among means. Differences were considered significant at  $p < 0.05$ .

## 3. RESULTS

### 3.1. Fish Feeds

Proximate and mineral composition of feeds produced for *O. niloticus* juveniles by agroecological area are shown in Table 5. All feeds were isoproteic at 30% protein level without any significant difference between feeds. However, significant differences were recorded at  $p < 0.05$  for all the other biochemical parameters (moisture, crude lipid, crude fiber, ash, carbohydrate, gross energy, and protein/energy) determined. The high values of moisture were recorded with feeds SGI-30% ( $8.50\% \pm 0.08\%$ ) and SGII-30% ( $8.10\% \pm 0.04\%$ ); feeds G-30% ( $5.35\% \pm 0.11\%$ ) and SGII-30% ( $5.00\% \pm 0.04\%$ ) presented the highest values of crude fiber; highest values of gross energy were recorded with feeds SGI-30% ( $18.35 \pm 0.04$  kJ/g) and SGII-30% ( $17.81 \pm 0.16$  kJ/g) when G-30% ( $17.73 \pm 0.09$  mg/kJ) and SGII-30% ( $17.32 \pm 0.09$  mg/kJ) showed the highest values of protein/energy ratio. Feed SGI-30% recorded significantly ( $p < 0.05$ ) highest values of crude lipid ( $11.02\% \pm 0.02\%$ ) and carbohydrate ( $35.24\% \pm 0.14\%$ ), followed by feed SGII-30% ( $10.20\% \pm 0.08\%$ ;  $32.62\% \pm 0.17\%$ ), while feed G-30% ( $9.93\% \pm 0.07\%$ ;  $29.22\% \pm 0.14\%$ ) recorded the lowest values of these two parameters. Inversely, feed G-30% presented significantly ( $p < 0.05$ ) highest values of ash ( $18.62\% \pm 0.09\%$ ), followed by SGII-30% ( $13.25\% \pm 0.10\%$ ), while feed SGII-30% recorded lowest values ( $10.62\% \pm 0.03\%$ ). Calcium and phosphorus values of the three feeds formulated ranged between 5.10 and 9.37 mg/g and 14.15 and 18.25 mg/g, respectively.

### 3.2. Water Quality

Water quality parameters values in ponds during the feeding trial are presented in Table 6. No significant difference ( $p > 0.05$ ) was recorded between all the water physicochemical parameters values recorded. Temperature means values ranged between  $29.58 \pm 1.22$  (G-30%) and  $29.92 \pm 1.14^\circ\text{C}$  (SGI-30%), pH values

varied between  $8.92 \pm 0.88$  (G-30%) and  $9.62 \pm 0.74$  (SGII-30%), dissolved oxygen and % dissolved oxygen ranged, respectively, within  $8.05 \pm 1.07$  (SGI-30%)– $8.25 \pm 1.56$  mg/L (SGII-30%) and  $102.83 \pm 18.49$  (G-30%)– $102.83 \pm 18.49$  (SGI-30%). Conductivity varied between  $19.43 \pm 7.50$  and  $20.00 \pm 8.49$   $\mu\text{S}/\text{cm}$ , while ORP values fluctuated between  $47.6 \pm 8.29$  (SGII-30%) and  $54.94 \pm 6.46$  mV (SGI-30%). Water salinity values recorded in ponds were zero.

### 3.3. Fish Growth and Feed Efficiency

Growth of *O. niloticus* juveniles fed with the different feeds is shown in Figure 2. Similar growth evolution trends were observed with the three groups of fish fed. Also, there was no significant difference ( $p > 0.05$ ) in the monthly growth of the three groups of fish during the feeding trial. At the end of the growth trial, similar significant ( $p > 0.05$ ) results were observed with all the parameters of growth performance and feed efficiency of *O. niloticus* juveniles analyzed. No significant difference was observed ( $p > 0.05$ ) between all these parameters despite the differences observed between the means of values recorded (Table 7). Means weight gain values recorded for the three groups

**Table 5:** Proximate and mineral composition of feeds produced for *O. niloticus* juveniles rearing by agroecological area (G = Guinean area; Sudano-Guinean area I = SGI; Sudano-Guinean area II = SGII).

Parameters	Fish feeds		
	G-30%	SGI-30%	SGII-30%
Moisture (%)	6.70 $\pm$ 0.04 <sup>a</sup>	8.50 $\pm$ 0.08 <sup>b</sup>	8.10 $\pm$ 0.04 <sup>b</sup>
Crude protein (%)	30.19 $\pm$ 0.09 <sup>a</sup>	30.97 $\pm$ 0.03 <sup>a</sup>	30.84 $\pm$ 0.10 <sup>a</sup>
Crude lipid (%)	9.93 $\pm$ 0.07 <sup>a</sup>	11.02 $\pm$ 0.02 <sup>c</sup>	10.20 $\pm$ 0.08 <sup>b</sup>
Crude fiber (%)	5.35 $\pm$ 0.11 <sup>b</sup>	4.15 $\pm$ 0.04 <sup>a</sup>	5.00 $\pm$ 0.04 <sup>b</sup>
Ash (%)	18.62 $\pm$ 0.09 <sup>c</sup>	10.62 $\pm$ 0.03 <sup>a</sup>	13.25 $\pm$ 0.10 <sup>b</sup>
Carbohydrate (%)	29.22 $\pm$ 0.14 <sup>a</sup>	35.24 $\pm$ 0.14 <sup>c</sup>	32.62 $\pm$ 0.17 <sup>b</sup>
Gross energy (kJ/g)	17.02 $\pm$ 0.07 <sup>a</sup>	18.35 $\pm$ 0.04 <sup>b</sup>	17.81 $\pm$ 0.16 <sup>ab</sup>
Protein/energy (mg/kJ)	17.73 $\pm$ 0.09 <sup>b</sup>	16.61 $\pm$ 0.05 <sup>a</sup>	17.32 $\pm$ 0.09 <sup>ab</sup>
Calcium (mg/g)	9.37	5.10	8.86
Phosphorus (mg/g)	18.25	14.15	14.82

<sup>a, b, c</sup> alphabetical letters on the same line show a significant difference among treatments at  $p < 0.05$ .

**Table 6:** Physicochemical parameters values of the water in ponds during the feeding trial.

Parameters	Fish feeds		
	G-30%	SGI-30%	SGII-30%
Temperature ( $^\circ\text{C}$ )	29.58 $\pm$ 1.22 <sup>a</sup>	29.92 $\pm$ 1.14 <sup>a</sup>	29.79 $\pm$ 1.21 <sup>a</sup>
pH	8.92 $\pm$ 0.88 <sup>a</sup>	8.95 $\pm$ 0.86 <sup>a</sup>	9.62 $\pm$ 0.74 <sup>a</sup>
Dissolved oxygen (mg/L)	8.15 $\pm$ 0.64 <sup>a</sup>	8.05 $\pm$ 1.07 <sup>a</sup>	8.25 $\pm$ 1.56 <sup>a</sup>
% dissolved oxygen	106.19 $\pm$ 11.67 <sup>a</sup>	102.83 $\pm$ 18.49 <sup>a</sup>	106.02 $\pm$ 16.77 <sup>a</sup>
Conductivity ( $\mu\text{S}/\text{cm}$ )	19.43 $\pm$ 7.50 <sup>a</sup>	20.00 $\pm$ 6.07 <sup>a</sup>	20.00 $\pm$ 8.49 <sup>a</sup>
TDS (mg/L)	10.01 $\pm$ 3.83 <sup>a</sup>	10.50 $\pm$ 4.89 <sup>a</sup>	9.33 $\pm$ 3.01 <sup>a</sup>
ORP (mV)	51.51 $\pm$ 10.36 <sup>a</sup>	54.94 $\pm$ 6.46 <sup>a</sup>	47.6 $\pm$ 8.29 <sup>a</sup>
Salinity	0 <sup>a</sup>	0 <sup>a</sup>	0 <sup>a</sup>

<sup>a, b, c</sup> alphabetical letters on the same line show a significant difference among treatments at  $p < 0.05$ .

of *O. niloticus* fed with feeds produced varied between  $134.62 \pm 9.63$  (SGII-30%) and  $144.89 \pm 7.25$  g (G-30%) with daily weight gain oscillated between  $1.12 \pm 0.08$  (SGII-30%) and  $1.21 \pm 0.06$  g/day (G-30%). Survival rate recorded ranged between  $99.44 \pm 0.00$  (SGII-30%) and 100% (G-30%; SGI-30%). Feed conversion ratio values oscillated between  $2.85 \pm 0.14$  (G-30%) and  $2.88 \pm 0.21$  (SGII-30%) when protein efficiency ratio varied between  $1.13 \pm 0.08$  (SGII-30%) and  $1.17 \pm 0.08$  (G-30%).

### 3.4. Proximate Composition of Juveniles *O. niloticus*

Whole body composition data of juveniles *O. niloticus* fed with feeds produced by fish farming agroecological area during 4 months are shown in Table 8. No significant difference ( $p < 0.05$ ) was found between the crude protein and ash content of three fish groups. Protein content varied between  $19.83 \pm 1.0$  (SGI-30%) and  $20.78\% \pm 1.00\%$  (SGII-30%); and Ash values ranged between  $1.09 \pm 0.15$  (G-30%) and  $1.19\% \pm 0.01\%$  (SGI-30%). Significantly highest ( $p < 0.05$ ) values of fish moisture content was recorded with fish fed with feeds G-30% ( $77.35 \pm 0.42\%$ ) and SGI-30% ( $76.73\% \pm 0.64\%$ ), highest lipid content was observed with fish fed with feed SGII-30% ( $2.62\% \pm 0.17\%$ ), followed by those of fish fed with feed SGI-30% ( $1.85\% \pm 0.06\%$ ), and fish fed with feed G-30% ( $0.96\% \pm 0.13\%$ ) presented the lowest values. The same trend was observed with fish gross energy values recorded which were highest from fish fed with feed SGII-30% ( $5.96 \pm 0.23$ ) and lowest from fish fed with feed G-30% ( $5.18 \pm 0.06$ ).

## 4. DISCUSSION

All fish feeds produced were isoproteic at 30% protein level, but the difference between the compositions of feeds formulated depending on the availability, the cost, and the nutritional

values of raw material used by area induced variations in feeds proximate composition. Using the fish meal, 42% protein at 30% in fish feed G-30% consequently influenced this feed moisture and carbohydrate levels and increased its ash, calcium, and phosphorus level compared to the other two feeds. High level of ash in fish meal used in feeds formulation influences the ash and mineral levels of the feed [29]. However, an excess of minerals and ash in fish feeds compared to the requirement value ( $<10$ ) could be well released into the water by fish and should not affect the uptake of the other nutrient of feeds as reported by [29,30]. Also, high level of white rice bran incorporated in feed SGI-30% and the use of cashewnut oil cake in feed SGII-30%, both rich in the lipid at, respectively, 10.37% and 38.90%, consequently increased the levels of these feeds in lipid, carbohydrate, and gross energy compared to feeds G-30%. However, all feeds produced follow the needs of 30%–35% protein, 6%–10% lipid, inferior to 8%–10% fiber, and the minimum of 25% carbohydrate required for good growth of this stage (10–35 g) of *O. niloticus* juveniles reported by [31]. Also, the difference in price and quantity from the ingredients used for the three feeds formulated affected their cost. The lowest cost of feed recorded by feed G-30% could be due to the incorporating of 30% level of the low-cost local fish meal at 42% of protein, the good accessibility of copra, white rice bran and soybean meal in Guinean area, and its high level of industrialization compared to the two other areas.

Nonetheless, the costs of these three formulated feeds of *O. niloticus* juveniles' nutritional requirement that was adapted ranged between 0.43 and 0.52 USD/kg and were low compared to the costs of imported industrial commercial feeds (1.04–2.16 USD/kg) and were almost similar to industrial national commercial feeds (0.42–0.51 USD/kg) and the maximum costs of feeds sellers'

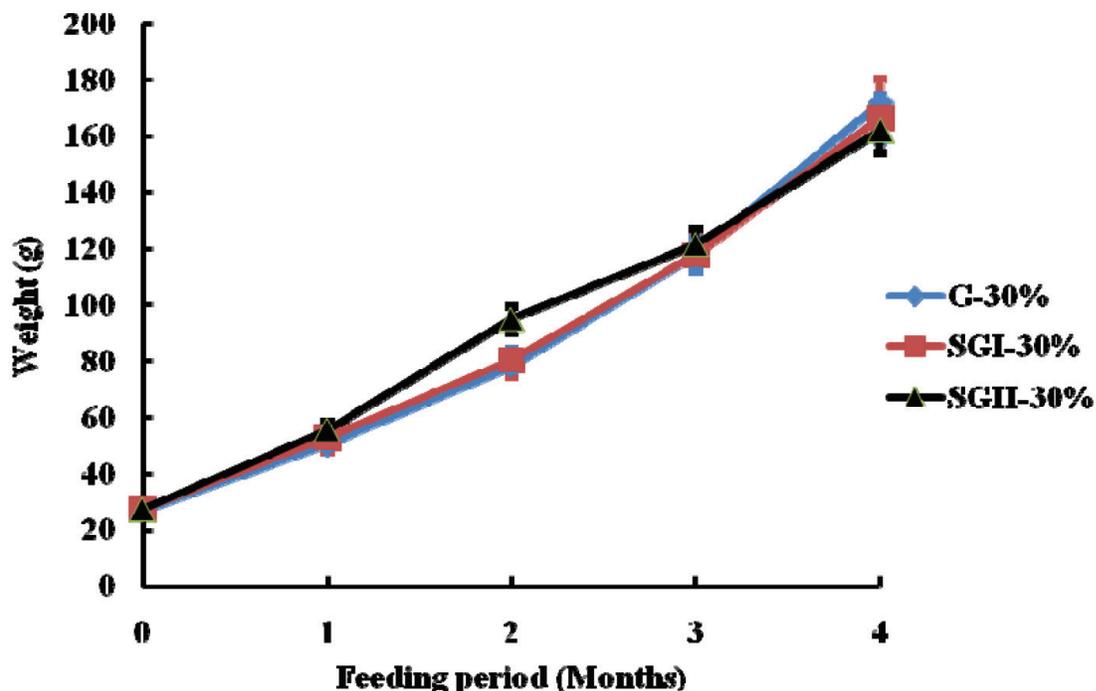


Figure 2: Growth evolution of *O. niloticus* juveniles fed with feeds produced by fish farming agroecological area (Guinean zone; Sudano-Guinean area I = SGI; Sudano-Guinean area II) during 4 months.

commercial feeds (0.52 USD/kg) and fish farmers' feeds (0.47 USD/kg) met in Côte d'Ivoire [11]. So the costs of the three feeds proposed calculated from retail prices of raw materials selling on the market and/or by the feeds sellers' feeds could be affordable for fish farmers in these three areas. Furthermore, the three simple composed feeds at 30% protein level had high nutritional quality than the feed sellers' commercial feeds, the majority of fish farmers' feeds and the agro-industrial byproduct used as fish feeds analyzed by [11]. Hence, the three feeds produced in this study offer the opportunity to improve availability and use of quality feeds for *O. niloticus* juveniles in the fish farming agroecological areas.

During the feeding trial, the water temperature of all the ponds ranged between  $29.58 \pm 1.22$  and  $29.92 \pm 1.14$ °C and was revolved around 30°C reported as the optimal temperature of *Tilapia Oreochromis niloticus* rearing [32]. This resulted in advantage during the trial because the temperature is a control factor which plays a major role in fish metabolic regulation and can influence fish behavior and growth [33]. For high growth conditions of *Tilapia O. niloticus* in earthen ponds, [34] recommended a dissolved oxygen level ranged between 5 and 23 mg/l. In this study, dissolved oxygen

values in ponds ( $8.05 \pm 1.07$ – $8.25 \pm 1.56$  mg/l) were within these reported values and show good oxygenation conditions of rearing ponds. Also, according to El-Sayed [35], *O. niloticus* can survive successfully and tolerate pH values recorded in these ponds ( $8.92 \pm 0.88$ – $9.62 \pm 0.74$ ) which oscillated between recommended values ranged between 4 and 11. Otherwise, according to Abowei [36], natural waters have conductivity ranged between 20 and 1500 us/cm. Conductivity values ( $19.43 \pm 7.50$ – $20.00 \pm 8.49$  µs/cm) recorded in all pond waters influenced by the levels of total solids dissolved levels ( $9.33 \pm 3.01$ – $10.50 \pm 4.89$ ) were within the conductivity values of natural waters (20–1500 us/cm). Similarly, the total solids dissolved values recorded in pond waters were under to the limit recommended at 500 mg/l [37]. In view of these comparisons, the degradation activities of organic matter and the mineral discharges from three feeds used by fish did not influence negatively the physicochemical characteristics of the water in the earthen ponds. In fact, all water physicochemical parameters data recorded showed the good growth conditions of *O. niloticus* juveniles during the feeding trial.

Growths of the three groups of *O. niloticus* juveniles fed with the feeds formulated were similar despite the significant difference observed in some nutritional parameters (moisture, lipid, fiber, ash, carbohydrate, gross energy, and protein/energy) of feeds. Also, values of feeds efficiency recorded during the feeding trial were not influenced by the quality of feeds, and, the survival rates at the end of the feeding trial were high (99.44% and 100%). These results proffer the opportunity to use low-cost local fish meal rich in ash as a protein source in juveniles *O. niloticus* feeds formulations. Likewise, cashewnut oil cake can be used as a lipid source and an additional protein and carbohydrate source in *O. niloticus* local quality feeds formulations. Similar growth results show also the opportunity of fish farmers to use the simply composed 30% protein fish feed with only three ingredients (SGI-30%) as high-quality feed for *O. niloticus* juveniles rearing.

Daily weight gain values recorded from *O. niloticus* fed with the formulated feeds (G-30%, SGI-30%, and SGII-30%), which ranged between  $1.12 \pm 0.08$  and  $1.21 \pm 0.06$  g/day, were higher than those obtained ( $0.35 \pm 0.01$ g/d) by Oumer [38] with *O. niloticus* juveniles fed with 30% protein content feed in concrete ponds and further higher than those (0.89 g/d) of Opiyo *et al.* [39] recorded with the same fish fed in earthen ponds with 32.7% protein level of feed. Also, the daily weight gain values recorded with the feeds proposed in this study were higher than  $0.86 \pm 0.20$  g/j reported by Sumagaysay-Chavoso [40] and were almost equal to the value of 1.5 g/d reported as reference growth value in intensive rearing system of *O. niloticus* juveniles by FAO [41]. In the same trend, specific growth rate values recorded in this study ( $1.48 \pm 0.05$ – $1.54 \pm 0.03$  %/d) were in the same order as those of  $1.17 \pm 0.06$ – $1.49 \pm 0.02$  %/d reported by Abarike *et al.* [42] from *O. niloticus* fed with 30% protein in out-door hapas, and higher than  $1.01 \pm 0.02$  and  $1.25 \pm 0.02$  %/d recorded from the same fish by Opiyo *et al.* [39] with a commercial 32.7% protein level feed in earthen pond rearing during 6 months.

Concerning the efficiency of the feeds used, feed conversion ratio values recorded with fish fed with feeds produced varied between  $2.85 \pm 0.14$  and  $2.88 \pm 0.21$  and were similar to those (2.83–2.87)

**Table 7:** Mean values of growth performance and feed efficiency parameters of juveniles *O. niloticus* fed with the feeds produced by fish farming agroecological area (Guinean zone; Sudano-Guinean area I = SGI; Sudano-Guinean area II) during 4 months.

Parameters	Fish feeds		
	G-30%	SGI-30%	SGII-30%
Growth			
Initial body weight (g)	26.89 ± 2.98 <sup>a</sup>	27.32 ± 2.89 <sup>a</sup>	27.35 ± 2.74 <sup>a</sup>
Final body weight (g)	171.78 ± 7.25 <sup>a</sup>	166.33 ± 11.31 <sup>a</sup>	161.97 ± 9.63 <sup>a</sup>
Weight gain (g)	144.89 ± 7.25 <sup>a</sup>	139.01 ± 11.31 <sup>a</sup>	134.62 ± 9.63 <sup>a</sup>
Initial body length (cm)	10.67 ± 0.29 <sup>a</sup>	10.5 ± 0.5 <sup>a</sup>	10.50 ± 0.50 <sup>a</sup>
Final body length (cm)	20.93 ± 0.48 <sup>a</sup>	20.36 ± 0.57 <sup>a</sup>	20.76 ± 0.48 <sup>a</sup>
Length gain (cm)	10.26 ± 0.56 <sup>a</sup>	9.86 ± 0.93 <sup>a</sup>	10.26 ± 0.98 <sup>a</sup>
Daily weight gain (g/day)	1.21 ± 0.06 <sup>a</sup>	1.16 ± 0.09 <sup>a</sup>	1.12 ± 0.08 <sup>a</sup>
Daily length gain (cm/day)	0.09 ± 0.01 <sup>a</sup>	0.08 ± 0.01 <sup>a</sup>	0.09 ± 0.01 <sup>a</sup>
Specific growth rate (%/day)	1.54 ± 0.03 <sup>a</sup>	1.50 ± 0.06 <sup>a</sup>	1.48 ± 0.05 <sup>a</sup>
Survival rate (%)	100	100	99.44 ± 0.00 <sup>a</sup>
Feed efficiency			
Feed conversion ratio	2.85 ± 0.14 <sup>a</sup>	2.87 ± 0.23 <sup>a</sup>	2.88 ± 0.21 <sup>a</sup>
Protein efficiency ratio	1.17 ± 0.08 <sup>a</sup>	1.13 ± 0.09 <sup>a</sup>	1.13 ± 0.08 <sup>a</sup>

<sup>a,b,c</sup>alphabetical letters on the same line show a significant difference among treatments at  $p < 0.05$ .

**Table 8:** Whole body composition of *O. niloticus* juveniles fed with feeds produced by fish farming agroecological area (Guinean zone; Sudano-Guinean area I = SGI; Sudano-Guinean area II) during 4 months.

Parameters	Fish feeds		
	G-30%	SGI-30%	SGII-30%
Moisture (%)	77.35 ± 0.42 <sup>b</sup>	76.73 ± 0.64 <sup>ab</sup>	75.57 ± 1.11 <sup>a</sup>
Crude protein (%)	20.26 ± 1.13 <sup>a</sup>	19.83 ± 1.10 <sup>a</sup>	20.78 ± 1.05 <sup>a</sup>
Crude lipid (%)	0.96 ± 0.13 <sup>a</sup>	1.85 ± 0.06 <sup>b</sup>	2.62 ± 0.17 <sup>c</sup>
Ash (%)	1.09 ± 0.15 <sup>a</sup>	1.19 ± 0.01 <sup>a</sup>	1.10 ± 0.13 <sup>a</sup>
Gross energy (kJ/g)	5.18 ± 0.06 <sup>a</sup>	5.43 ± 0.02 <sup>b</sup>	5.96 ± 0.23 <sup>c</sup>

<sup>a,b,c</sup>alphabetical letters on the same line show a significant difference among treatments at  $p < 0.05$ .

recorded by Ghozlan *et al.* [43,44] with juvenile *O. niloticus* fed with floating industrial commercial feed at 25% crude protein supplemented in vitamin and mineral premix during 6 months in the earthen ponds. Otherwise, feed conversion ratio (FCR) is an important indicator of the quality of fish feed, also, low FCR indicates better utilization of the fish feed [45]. Hence, the feeds conversion ratio values that recorded ( $2.85 \pm 0.14$ – $2.88 \pm 0.21$ ) lower or equal to 3 indicate the good use of all feeds by fish.

Compared results of daily weight gain, survival rate, specific growth rate, and feed conversion ratio with the previous research data show the competitiveness of these three feeds formulated at 30% protein level adapted to the *O. niloticus* juveniles rearing in the earthen ponds. These results could be due to the fact that these three feeds formulated at 30% protein proposed at low cost with the accessible raw materials in the three agroecological fish farming areas met well the essential nutritional needs for *O. niloticus* growth at this stage [29,31,46]. Results show the possibility of fish farmers in these areas to make simple composed feeds adapted to the growth of *O. niloticus* juveniles to improve growth and to reduce the time of merchant fish production. Results present also an opportunity to improve the availability of competitive quality fish feeds in the high concentration of fish farmers' areas in Côte d'Ivoire.

Whole body protein composition of fish fed was not influenced by the quality of feed used. This result must be due to the fact that at *O. niloticus*, whole body protein composition is not affected by the proximate composition of feeds when feeds used are the same protein content [24,47]. The increase of crude lipid and gross energy from *O. niloticus* species with high levels of dietary lipid observed, it's already well documented [25,48,49]. In fact, *O. niloticus* is unable to use dietary lipid and energy to improve feed efficiency and fish growth as observed from some catfish, so it accumulates dietary lipid in its carcass [50,51]. The similar ash levels recorded in whole body composition of *O. niloticus* independently to the feed used confirms the releasing of the excess of minerals and ash to feed G-30% into the water by fish.

## 5. CONCLUSION

The three composed feeds based on the available feedstuffs in three agroecological areas in Côte d'Ivoire were competitive to improve *Oreochromis niloticus* juveniles growth. Variation of raw materials used influenced biochemical composition of feeds formulated, but *O. niloticus* used these feeds for similar growth performance, feed utilization, and whole body protein content. These feeds proffer the opportunity to improve the availability of low-cost local quality feeds for *O. niloticus* juveniles rearing in the high concentration areas of fish farmers in Côte d'Ivoire.

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