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Growth potential and body composition of the African catfish C*hrysichthys nigrodigitatus* (Lacépède, 1803) juveniles fed different locally available feed ingredients

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A B S T R A C T

Bagrid catfish *Chrysichthys nigrodigitatus* has a great aquaculture potential, excellent taste and high market value in the most countries of West Africa. However, it is lowly raised in these countries. Among the constraints to its low raising in Cote d'Ivoire, the unavailability of high-quality feeds adapted to the different growth stages was often reported. The aim of this study was to formulate quality feeds with locally available agro-industrial byproducts for juvenile's growth stage of *Chrysichthys nigrodigitatus* to improve the availability of adapted high quality feeds of this fish and its growth. Thus, locally agro-industrial by-products were selected based on their availability, cost and nutritional composition in the three fish farmed agro-ecological areas to formulate and produce three different isoproteic feeds (35 % crude protein) for juveniles *Chrysichthys nigrodigitatus*. Fish of mean initial weight 10.57 ± 3.88 g were fed with the three feeds produced in earthen ponds in triplicates groups per treatment. Feed consumption and fish growth (weight and length) were measured monthly. At the end of 120 days rearing, proximate and mineral compositions of the fish were determined. Final body weight and daily weight gain of fish fed varied respectively between 106.27±6.85 (G-35%) and 149.83±19.01g (SG2-35%), and 0.80±0.06 (G-35%) and 1.16±0.16 g/d (SG2-35%). Growth of *Chrysichthys nigrodigitatus* juveniles fed with isoprotéiques feeds varied with quality of locally raw material used for feeds production. Body moisture, ash, and gross energy were not influenced by feed used, but the least body protein content (18.41±0.67 %) and poorest body lipid content (0.99±0.14%) were observed in fish fed G-35 % and SG2-35% respectively. Feed SG2-35% at 0.53 USD/kg recorded the most growth and the best feed utilization ratio.

Keywords: *Chrysichthys nigrodigitatus*; Feedstuffs; Feeds; Growth; Fish farmed agro-ecological areas

1. Introduction

Bagrid catfish *Chrysichthys nigrodigitatus* has a great aquaculture potential, excellent taste and high market value in the most countries of West Africa (Hem and Nunez-Rodriguez 1995). However, it is lowly raised in these countries. In Cote d'Ivoire, the annual production of *Chrysichthys nigrodigitatus* continues to decline since 1990. It's was 300 tons in 1990, 20 tons in 2000 and in 2013 only 18 fish farmers (5.98%) reported on the total of 301 farmers in the national survey raised *Chrysichthys nigrodigitatus* (Hem and Nunez-Rodriguez, 1995; FAO, 2005; Koumi et al., 2016; Yao et al., 2017).

Among the constraints to its low raising in Cote d'Ivoire, the unavailability of high-quality feeds adapted to the different growth stages was often reported. Koumi et al. (2015) reported the absence of national industrial commercial feeds adapted to *C. nigrodigitatus* different growth stage and the high cost (1.02-2.13 USD/kg) of the imported industrial commercial catfish feeds not accessible for the majority of fish farmers. However, feeds are one of the major inputs in fish farming, it plays very vital role in aquaculture growth and expansion (Craig and Helfrich, 2002). The availability of high quality nutritionally balanced feeds in quantity is the most important factors that promote fish growth, health and determine the sustainability and profitability of aquaculture (Craig and Helfrich, 2002; Jamu and Ayinla, 2003; Gabriel et al., 2007). Otherwise, catfish nutrients requirements depending of growth stage were well documented. Thus, 30-40% crude protein, 6-10% lipid, 6-10% fiber and 6-10% Ash content were recommended for catfish feeds formulation (New, 1987; Guillaume et al., 1999; Lazard, 2007). Also, Adewolu and Benfey (2009) reported that diets containing at least 35% crude protein are suitable for rearing of *C. nigrodigitatus* juveniles for efficient growth and feed utilization. In addition, feeds formulation and accessibility depending highly to the availability of the requirement feedstuffs. Cote d'Ivoire has a lot of variety of raw materials usually used in the fish feeds formulation because of the high practice of agriculture and the high level of industrialization of country (MINAGRI, 2009; FAO, 2014). However, availability and cost of raw material using in fish feeds vary according to continent, countries, and region and within the same country depending to the climate, ecology and development level of areas.

Production of locally available low-cost feeds to improve fish growth and production require well knows of the availability and costs of feedstuffs in the principal fish production areas. As well, Yao et al. (2017) reported high concentration of fish farmers in the three agro-ecological areas: Guinean zone; Sudano-Guinean zone 1 and Sudano-Guinean zone 2 defined by MINESUDD (2014). This study proposes to formulate feeds at 35% crude protein, suitable for *C. nigrodigitatus* juveniles rearing from locally available agricultural raw materials in the three main fish production areas identified in Cote d'Ivoire. The aim is to offer to the fish farmers the locally high-quality low-cost feeds to contribute to the boost of *C. nigrodigitatus* raising in Cote d'Ivoire.

2. Material and methods

2.1. Selection of feeds ingredients

Feeds ingredients were chosen in the three fish farming agro-ecological areas in Cote d'Ivoire depending to their locally availability, cost and nutritional quality. There are Guinean zone (G), Soudano-Guinean zone 1(SG1) and Soudano-guinean zone 2 (SG2). Six (6) different raw materials were selected in these zones. There are imported fish meal 55 which content 55.30% crude protein at 1.04 USD/kg (Guinean area) and 1.21 USD/kg (Sudano-Guinean area 1 and 2); Locally fish meal with 42.67% of crude protein at 0.52 USD/ kg in the three concerned areas; Soybean meal at 45.0% protein content at 0.52 USD/kg (Guinean and Sudano-Guinean 1) and 0.729 USD/kg (Sudano-Guinean 2); Cotton seed oil cake with 35.72 % protein content at 0.417; 0.373 and 0.347 USD/ kg respectively in the Guinean, Sudano-Guinean zone 1 and Sudano-Guinean zone 2; Cashew nut oil cake with 38.90% lipid content at 0.347 USD/kg (Guinean zone and Sudano-Guinean zone 2) and not available in Sudano-Guinean zone 1; White rice bran with the 44.68% carbohydrate content at 1.04 USD/kg Guinean zone and 0.0521 USD/kg Sudano-Guinean zone 1 and not available in Sudano-Guinean zone 2.

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Table 1: Ingredients (gkg^{-1}), proximate and mineral composition (dry matter basis) and cost of *Chrysichthys nigrodigitatus* juveniles' feeds formulated at 35 % crude protein

Components	Formulated feeds		
	G -35 %	SG 1-35 %	SG 2-35 %
Ingredients (kg)			
Fish meal 55	25	25	
Fish meal 42			35
Cotton seed oil cake	15	20	15
White rice bran	15	30	
Cashew nut oil cake	20		15
Proximate analysis (%) [a]			
Moisture	7.05	8.20	7.20
Crude protein	35.22	35.66	35.44
Crude fibre	5.00	7.45	8.65
Crude fat	12.90	7.77	10.68
Ash	8.27	10.46	18.43
Carbohydrate content [b]	31.57	30.46	19.61
Gross energy (kJ/g) [c]	19.73	18.04	17.48
Mineral composition (mg/g)			
Calcium	6.32	5.85	12.63
Phosphorus	8.45	9.24	12.04
Magnesium	4.48	5.63	3.95
Manganese	0.18	0.01	0.08
Potassium	17.20	22.23	15.34
Sodium	6.16	4.82	2.08
Iron	1.39	0.97	1.36
Cost (USD/kg)	0.57	0.51	0.53

[a] Values represent the mean of three replicates. [b] Carbohydrate content = 100 – (% moisture + % protein + % fat + % fibre + % ash).
[c] Gross energy = (22.2 × protein + 38.9 × fat + 17.2 × Carbohydrate content).

Table 2: Water quality parameters recorded in the earthen ponds during the feeding trial according to the feed used

Parameters	Formulated feeds		
	G -35 %	SG 1-35 %	SG 2-35 %
Temperature (°C)	29.71 ± 0.58^{a}	29.81 ± 0.93^{a}	29.93 ± 0.83^{a}
pH	9.16 ± 0.66^{a}	9.28 ± 0.73^{a}	9.00 ± 0.83^{a}
Dissolved Oxygen (mg/L)	8.91 ± 0.37^{a}	9.59 ± 0.09^{a}	9.23 ± 0.18^{a}
Conductivity (µs/cm)	48.60 ± 6.24^{b}	32.17 ± 4.75^{a}	41.60 ± 3.41^{b}
TDS (mg/L)	25.67 ± 6.53^{b}	16.67 ± 1.63^{a}	25.14 ± 6.79^{b}
ORP (mV)	42.4 3 ± 29.55^{a}	63.95 ± 45.80^{a}	55.83 ± 48.00^{a}
Percentage of Dissolved Oxygen	116.55 ± 23.33^{a}	123.23 ± 14.44^{a}	122.52 ± 18.50^{a}
Salinity (‰)	0 ± 0^{a}	0 ± 0^{a}	0 ± 0^{a}

Values are presented as mean ± standard deviation. TDS: Total Dissolved Solids. ORP: Oxydo-Reduction Potential.
$^{a, b, c}$: Means with different superscript letters within a row are significantly different ($p < 0.05$).

Table 3: Growth performance and survival rate of *Chrysichthys nigrodigitatus* juveniles fed with feeds formulated with ingredients available in agro-ecological areas (G: Guinean; SG1: Sudano-Guinean 1; SG2: Soudano-Guinean 2) during 120 days in earthen ponds

Parameters	Formulated feeds		
	G-35 %	SG1-35 %	SG2-35 %
Initial body weight (g)	10.77 ± 3.90^{a}	10.75 ± 3.77^{a}	10.18 ± 3.98^{a}
Final body weight (g)	106.27 ± 6.85^{a}	143.33 ± 14.40^{b}	149.83 ± 19.01^{b}
Initial body length (cm)	10.57 ± 0.34^{a}	10.56 ± 0.33^{a}	10.57 ± 0.34^{a}
Final body length (cm)	22.87 ± 0.50^{a}	24.03 ± 1,05^{b}	24.77 ± 1.03^{b}
Body weight gain (g)	95.50 ± 6.85^{a}	132.58 ± 14.40^{b}	139.65 ± 19.01^{b}
Body lenght gain (cm)	12.30 ± 0.81^{a}	13.47 ± 0.78^{ab}	14.20 ± 0.75^{b}
Daily weight gain (g/d)	0.80 ± 0.06^{a}	1.10 ± 0.12^{b}	1.16 ± 0.16^{b}
Specific growth rate (%/ d)	1.91 ± 0.05^{a}	2.16 ± 0.08^{b}	2.24 ± 0.11^{b}
Survival rate (%)	99.16 ± 0.00^{a}	100.00 ± 0.00^{a}	99.47 ± 0.00^{a}

Values are means ± SD. Values in the same row with different superscript letters are significantly different ($p < 0.05$)

Table 4: Feed utilization of *Chrysichthys nigrodigitatus* juveniles fed with feeds formulated with ingredients available in agro-ecological areas (G: Guinean; SG1: Sudano-Guinean 1; SG2: Soudano-Guinean 2) during 120 days in earthen ponds

Parameters	Formulated feeds		
	G-35 %	SG1 -35 %	SG2- 35 %
Quantity of feed used (kg)	365.04 ± 80.12[a]	574.49 ± 67.14[b]	470.96 ± 69.90[b]
Feed conversion ratio	2.60 ± 0.09[b]	2.46 ± 0.07[a]	2.32 ± 0.03[a]
Protein efficiency ratio	1.1 ± 0.08[a]	1.15 ± 0.13[a]	1.23 ± 0.17[a]

Values are means ± SD. Values in the same row with different superscript letters are significantly different ($p<0.05$)

Table 5: Proximate body composition of *Chrysichthys nigrodigitatus* fed the formulated feeds G-35%, SG1-35% and SG2-35% during 120 days of feeding (wet-weight basis)

Parameters	Formulated feeds		
	G-35 %	SG1-35%	SG2- 35%
Moisture (%)	78.82±0.11[a]	78.00±0.17[a]	78.75±0.29[a]
Lipid (%)	1.91±0.79[b]	1.18±0.13[ab]	0.99±0.14[a]
Ash (%)	0.99±0[a]	1.09±0.14[a]	0.90±0.13[a]
Gross energy (kJg^{-1})	5.12±0.4[a]	5.11±0.05[a]	4.87±0.06[a]

Values are means ± SD. Values in the same row with different superscript letters are significantly different ($p<0.05$).

There are used in *C. nigrodigitatus* juveniles feed formulation depending to their availability through year, and their cost by area and their richness in nutriment. So, cotton seed oil cake and soybean meal were chosen for all three different feeds formulation. Fish meal 42 was used only in the Sudano-Guinean zone 2 feed, white rice bran was used to feeds for Guinean and Sudano-Guinean zone 1 feeds formulation and cashew nut oil cake in Guinean and Sudano-Guinean zone 2 feeds.

2.2. Feeds formulation and production

Three isoproteic (35 % crude protein) practical diets adapted to *Chrysichthys nigrodigitatus* juveniles' nutritional requirements were formulated using linear programming method. One diet was formulated by fish farming agro-ecological area for the three selected zones. All raw materials selected by feed was quantified, weighted, ground to flour, mixed and presented in 2 mm diameter dried pellets size. All the three feeds were produced in the monthly frequency in the sufficient quantities to cover the needs of feeding trial. Feeds ingredients, proximate and mineral compositions and cost of different feeds were presented in Table1.

2.3. Experimental fish

Chrysichthys nigrodigitatus juveniles were collected in experimental farm of the Oceanological Research Center named Layo localized next to Dabou town (5°19'00'' north, 4°23'00'' West) in the South of the Côte d'Ivoire. Then fish were transported at the experiment farm localized at the entrance of Azaguié town (5°38'00'' north and 4°23'00'' west), in the South Eastern of Cote d'Ivoire at 43.8 km of the capital Abidjan. Fish were transferred to the experimental earthen ponds for acclimation for two weeks. During this period, fish were fed with a locally industrial commercial pellet feed at 30% protein (IVOGRAIN). Fish of mean initial weight 10.57 ± 3.88 g were stocked randomly at density of 3 fish/m^2 in earthen ponds sizes ranged between 306 to 396 m^2 in triplicates per treatment.

2.4. Feeding trial

The feeding trial was conducted for 120 days follow the recommended aquaculture practices. Fish were hand-fed twice a day (09:00, 17:00) at the rate of 7 % total biomass six days per week with the three formulated feeds in triplicate by treatment. Every day all fish dead were removed and recorded. Each week, water temperature, pH, dissolved oxygen concentration, conductivity, total dissolved solids, oxydo-reduction potential and salinity of each earthen pond were measured before the first feeding with a multi-parameter HANNA. Feeding rates were adjusted every month with the total biomass. Once month also, 30 % of fish by pond were randomly sampled and individually weighed and total length was measured. At the end of growth trial, the sample of 10 fish by feed treatment was immediately conserved at -20°C for fish proximate composition analysis.

2.5. Proximate composition analysis

The proximate composition of feed ingredients, diets and fish flesh were determined using the standard methods of the AOAC, (1990) as follows: moisture after drying in oven at 105°C for 24 h until constant weight, protein (N × 6.25) by the Kjeldahl method after acid digestion, lipids by hexane extraction with a Soxhlet system, ash by incineration in a muffle furnace at 550°C for 24 h, crude fibre by acid/base digestion. Carbohydrate content was calculated by subtracting from 100%, crude protein, crude fat, crude fibre, ash and moisture percent content by sample (Maynard et al., 1979). The gross energy contents of the diets and the fish were calculated on the basis of their crude protein, crude fat and carbohydrate contents using the equivalents of 22.2, 38.9 and 17.2 kJ g^{-1} respectively (Luquet and Moreau, 1989). The ratio of protein/energy (P/E) was calculated. Mineral composition (calcium, phosphorus, potassium, sodium, magnesium, iron and manganese) of feeds were analyzed using atomic absorption spectrophotometer (AOAC, 2003). All the samples were analyzed in triplicate.

2.6. Growth and feed utilization parameters

At the end of the feeding trial, growth and feed utilization parameters were calculated for each formulated diet as follows: body weight gain (g) = final body weight – initial body weight; body length gain (cm) = final body length – initial body length; daily weight gain (g/day) = (final body weight – initial body weight)/(number of day); specific growth rate (%/day) = [ln (final body weight) – ln (initial body weight)] / number of day×100; feed conversion ratio = total weight of feed consumed (g)/ biomass gain (g); protein efficiency ratio = weight gain (g)/ protein intake (g); survival rate (%) = (final number of fingerlings/ initial number of fingerlings) × 100 and quantity of feed used = ∑ feed quantity distributed by earthen pond.

2.7. Statistical analysis

All data collected were analyzed using ANOVA one-way analysis of variance. Results were presented as mean ± SE (Standard Error). Duncan multiple range tests were used to compare differences among treatments means which were considered significant at $p < 0.05$. The analyses were performed using Statistical version 7.1 software.

3. Results

3.1. Water quality

The means values of water quality parameters recorded in the earthen ponds during the feeding trial were presented in Table 2. Temperature, pH, dissolved oxygen, ORP, percentage of dissolved oxygen and salinity were not significantly ($p> 0.05$) influenced by the quality of feeds used. These values were as follows (mean ± SE): temperature, 29.71 ± 0.58 - 29.93 ± 0.83 °C, pH varied between 9.00 ± 0.83 and 9.28 ± 0.73, dissolved oxygen between 8.91 ± 1.37 and 9.59 ± 0.49 mg/L, ORP between 42.43 ± 29.55 and 63.95 ± 45.80 mV and percentage of dissolved oxygen between 116.55 ± 23.33 and 123.23 ± 14.44 %. When, the water salinity values were 0‰. Inversely, the significantly high values ($p < 0.05$) of conductivity (32.17 ± 4.75 - 48.6 ± 6.24 µs/cm) and TDS (16.67 ± 1.63 - 25.14 ± 6.79 mg/L) were recorded with the water in ponds which fish were fed to feeds G-35 % and SG2-35 % compared to ponds where fish were fed with feed SG1-35 %.

3.2. Growth performance and survival

The effect of the three formulated feeds on the growth and survival of *Chrysichthys nigrodigitatus* juveniles rearing in the earthen ponds is shown in Figure 1 and Table 3. *C. nigrodigitatus* accepted all the three feeds formulated and the weights of all fish were increased continually during the 120 days of feeding (Figure 1). However, fish growth rates were affected significantly by feed used. The highest growth rates were achieved in the fish fed SG2-35% following by those fed with SG1-35%, fish fed G-35% recorded the lowest growth rate. At the end of feeding period, final body weight and final body length (cm) of fish ranged

between 106.27 ± 6.85-149.83 ± 19.01g and 22.87 ± 0.50-24.77 ± 1.03 cm respectively. Fish fed SG2-35% and SG1-35% achieved a significantly highest ($p < 0.05$) final mean body weight, final body length, body weight gain, body length gain, daily weight gain and Specific growth rate than those of fish fed G-35% feed. However, fish fed with SG2-35% and SG1-35% growth performance parameters did not record any significant difference ($p > 0.05$). Fish survival rate varied between 99.16 ± 0 (G-35 %) and 100 ± 0 % (SG1-35 %). Fish survival rate were not significantly ($p > 0.05$) affected by feed used.

3.3. Feed utilization of Chrysichthys nigrodigitatus juveniles

Feeds utilization parameters of *Chrysichthys nigrodigitatus* juveniles fed with formulated feeds in earthen pond for 120 days are shown in Table 4. Quantities of feeds used by pond were varied between 365.04 ± 80.12 (G-35%) and 574.49 ± 67.14 kg (SG1-35%) and feed conversion ratio ranged between 2.32 ± 0.03 (SG2-35%) and 2.60 ± 0.09 (G-35 %). Quantities of feed used, and feed conversion ratio were affected significantly ($p<0.05$) by feed used. Also, irregular variations were observed in monthly values of feed conversion ratio (FCR) recorded by treatment (Figure 2). Values of FCR recorded from fish fed G-35% feed increased monthly with the highest value of the last month of feeding period. Contrary to the fish fed with SG1-35% which presents highest values of FCR the third month of the growth. Monthly values of FCR were affected significantly by feed used. The best FCR values were recorded by SG2-35% feed the months one and two, when fish fed G-35% recorded the best FCR values the third month and those of fish fed with SG1 recorded the best values of FCR the fourth month of growth trial. At the end of growth trial, fish fed with SG2-35 % and SG1-35% achieved the better feed conversion ratio values than those of fish fed feed G-35%.

Final values of protein efficiency ratio (PER) ranged between 1.1 ± 0.08 (G-35 %) and 1.23 ± 0.17 (SG2-35%) without significant ($p>0.05$) variation depending of feed used (Table 4) despite monthly significant variations recorded in Figure 3. Monthly PER values variation showed a decrease of PER of fish fed SG1-35% and SG2-35% with the lowest values recorded the last month of growth trial, contrary to the fish fed SG-35% which presented the lowest values of PER the third month. The monthly highest values of PER were recorded by the fish fed SG2-35% during the first month of growth trial when, the lowest values were recorded by fish fed G-35% feed the fourth month of feeding.

3.4. Proximate body composition of Chrysichthys nigrodigitatus

The proximate body composition of fish recorded at the end of the 120 day of feeding trial has been shown in the Table 5. Fish body constituents such as moisture, Ash and gross energy were not significantly ($p > 0.05$) influenced by feeds used contrary to the body crude protein and lipid values. Fish fed SG1-35% and SG2-35% exhibited the highest contents of crude protein (19.60 ± 0.04%; 18.88 ± 0.01% respectively) and the lowest total lipid (1.18 ± 0.13%; 0.99 ± 0.14%). Highest values of lipid were recorded by fish fed G-35% (1.91 ± 0.79 %).

4. Discussion

During feeding trial, similar values of temperature, pH, dissolved oxygen, ORP, percentage of dissolved oxygen and salinity recorded in the ponds independently to the feed used could reflect the characteristics of the water source which supplies the ponds. Water source was cold with the temperature ranged between 29.71 ± 0.58 and 29.93 ± 0.83 during four months of the trial, alkaline (pH = 9.00 ± 0.83 - 9.28 ± 0.73), well aerated (8.91 ± 0.37 - 9.59 ± 0.09) and exempted to salt (0%). Also, values recorded of these parameters were within the recommended range for fish culture (Boyd, 1990; Lawson, 1995). According to Delince (1992) and Bhatnagar and Devi (2013), 30-35°C is tolerable to fish and desirable temperature for pond water fishery for getting high yield was 20-30°C. According to Boyd (1990) for good pond production dissolved oxygen should be above 5.0 mg/l but more than 10 mg/l could provide stress of fish. Also, according to Santhosh and Singh (2007) the suitable pH range for fish culture is between 6.7 and 9.5 and ideally, an aquaculture pond should have a pH between 6.5 and 9 (Bhatnagar et al., 2004). Ponds water quality reflects a good water renewal of the ponds, a good fish density in ponds, and the acceptance of feeds distributed by fish. However, according to Lanoiselee (1984) and Boyd (1995) the quality and the degradation activities of organic matter and the mineral discharges from feeds used influences the physicochemical characteristics of farmed water. This could explain the high values of water conductivity and TDS in ponds were fish were fed with feeds G-35 % and SG 2-35 %. Also, discharge of any element depends on fish growth and level of respective nutriment of feeds. However, natural waters have conductivity of 20 – 1500 us/cm (Abowei, 2010). Conductivity values (32.17 ± 4.75 - 48.60 ± 6.24 µs/cm) recorded in all ponds water influenced by levels of TSD were within the natural water's conductivity.

In this study, variation of ingredients quality and quantities in isopreic feeds (35 % crude protein) depending for their accessibility by area influenced feed utilization and efficiency, fish growth, and fish proximate body composition in crude protein and lipid. High growth recorded by fish fed diets SG2-35 and SG1-35 % must be due to the proximate compositions of these feeds. In fact, all three formulated feeds had 35% crude protein, but differences were found in carbohydrate content, gross energy and protein/energy ratio. Feeds SG 2-35 % and SG 1-35 % with the lowest level of feed gross energy and highest level of feed protein/energy ratio recorded the best growth parameters values. Results must be indicated the importance of feed gross energy and protein/energy ratio level for *C. nigrodigitatus* juvenile's growth. Similar trend was reported by Akian et al. (2008) from the same specie juveniles and by Atsé et al. (2008) from *H. longifilis* fingerlings both fed isoproteic 35% protein feeds with gross 15.9 kJ/g energy compared to 17,2 kJ/g gross energy level. So, low growth observed in fish fed with G-35% which contains 12.90% crude fat may be related to the inability of most fish to digest and use the excess energy provided in lipids as reported by Kaushik and Medale (1994) and Wang et al. (2005). In add, the best fish growth recorded with SG 2-35% despite the use of the local fish meal at 42.00% protein, rich in the Ash which consequently increase the level of this feed Ash to 18.43% represents an opportunity to use the locally low cost (0.52 USD/ kg) available fish meal in the *C. nigrodigitatus* juveniles' diets. In fact, catfish need 6-10% feed Ash content, but the excess of minerals in the fish feeds is well released into the water by fish (Guillaume et al., 1999; Pouomogne et al., 1997). In this case, excess of Ash in feeds SG 2-35 % not negatively affected fish growth. Consequently, feed formulated with 35% locally fish meal, 15% cotton seed oil cake, 15% cashew nut oil cake and 35% soybean meal to the Sudano-Guinean 2 area recorded the best growth from *C. nigrodigitatus* juveniles. This composition seems to present the better nutritional balance for *C. nigrodigitatus* juveniles. Also, the best FCR (2.32 ± 0.03) and PER (1.23 ± 0.17) values recorded from fish fed

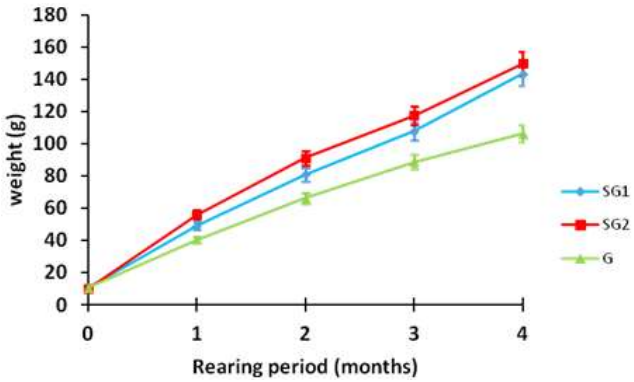

Figure 1. Monthly growth evolution of *Chrysichthys nigrodigitatus* juveniles Fed with feeds formulated with ingredients available in agro-ecological areas (G: Guinean; SG1: Sudano-Guinean 1; SG2: Soudano-Guinean 2) during 120 days in earthen ponds.

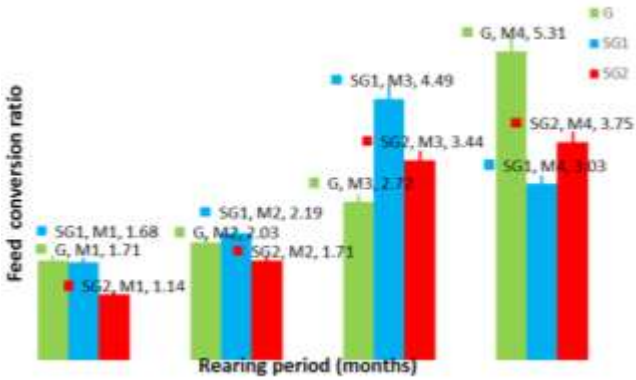

Figure 2. Monthly variation of feed conversion ratio of *Chrysichthys nigrodigitatus* juveniles fed with feeds formulated with ingredients available in agro-ecological areas (G: Guinean; SG1: Sudano-Guinean 1; SG2: Sudano-Guinean 2) during 120 days in earthen ponds.

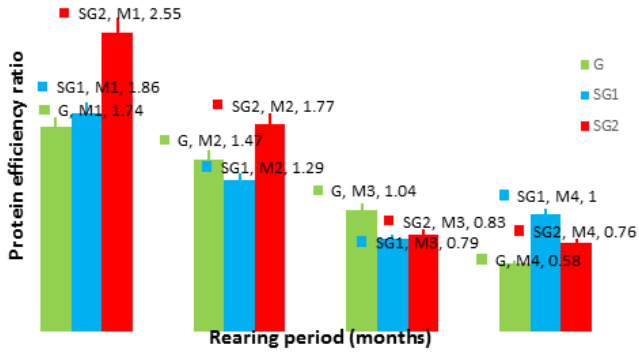

Figure 3. Monthly variation of protein efficiency ratio of *Chrysichthys nigrodigitatus* juveniles fed with feeds formulated with ingredients available in agro-ecological areas (G: Guinean; SG1: Sudano-Guinean 1; SG2: Sudano-Guinean 2) during 120 days in earthen ponds.

SG2-35% treatment show that this feed was more digestible and more effectively used by fish than the other feeds during all the feeding trial. This feed has a good nutritional profile to reduce the time of *C. nigrodigitatus* growth to attend market size. However, considering the absence of a significant difference between growth performance parameters values, FCR and PER of fish fed both SG 1-35 % and SG 2-35 % we can deduct the similar competence of these two feeds. The monthly increase of highest values of feed conversion ratio and the decrease of protein efficiency ratio from fish fed feed G-35% were consequently results to the low growth performance of these fish. The monthly decline of feed efficiency by these fish can be explained by several biological mechanisms. These mechanisms occur at different physiological levels, including decreased feed intake and disruption of energy metabolism related to the fish age (Panserat et al., 2009; Geurden et al., 2013, Saravanan et al., 2013). However, all the three composed feeds formulated with locally available raw material by area recorded the better values of *C. nigrodigitatus* daily weight gain (0.80 ± 0.06 - 1.16 ± 0.16 g/d) and survival rate (99 -100%) than Affoumou et al. (2014) when juveniles of *C. nigrodigitatus* were fed at 35% crude protein feed in tank, enclosure and fresh and brackish water pond with survival rate ranged between 68 ± 0.21 and 70± 0.25% and daily weight gain varied between 0.75 ± 0.61 and 0.76 ± 0.65 g/d. Also, our values of daily weight gain were better than those reported by Avit and Luquet (1993) with *Chrysichthys nigrodigitatus* juveniles fed with 35% crude proteins in cage-enclosure varying between 0.61 and 0.73 g/d. As well, 0.72 g/d and 0.88 g/d daily weight gain recorded respectively by Van Ospal and Coton (1981), and Hem (1982) with feeds contain 40 and 50% crude protein in lagoon enclosure suggest that the use of the three formulated feeds at 35% crude protein by fish farmers in fresh water earthen pond will improve at the low cost *C. nigrodigitatus* juveniles growth, yield, and survival compared to existing previous data.

At the end of feeding trial, the highest values of *Chrysichthys nigrodigitatus* fed feed G-35 % could be result of high level of lipid deposition in fish fed due to the high level of lipid content of this feed (Abbass, 2007). This accumulation of dietary lipids in the body tissues of *C. nigrodigitatus* is contrary to that observed from catfish *H. longifilis* and *C. gariepinus* and similar to those observed from Cichlidae *O. niloticus* and *S. melanotheron* fed high level of lipid in feed reported by Abdelghany (2003), Goda et al. (2007) and Koumi et al. (2011). Inversely, fish fed SG1-35% and SG2- 35% recorded the highest protein content. However, at the end of feeding trial, *Chrysichthys nigrodigitatus* proximate body composition recorded of moisture = 78.00 ± 0.17 - 78.82 ± 0.11 %; crude protein = 18.41 ± 0.67 - 19.60 ± 0.04 %; lipid = 0.99 ± 0.14 - 1.91 ± 0.79 % and Ash = 0.90 ± 0.13 - 1.09 ± 0.14 % were almost similar of those reported (moisture = 75.50 – 77.67; crude protein = 17.50 – 20.90; lipid = 0.90 – 1.20; Ash = 1.10 -1.3) by Igbinosun and Talabi (1982). These values of fish body proximate composition were characteristics of this specie, but the few variations observed could be assigned to the changes in nutriments composition of different feeds used which influence fish quality (Jamu and Ayinla, 2003).

5. Conclusion

The use of the low cost three formulated feeds by agro-ecological areas based on the locally available feed ingredients by fish farmers will improve *Chrysichthys nigrodigitatus* juvenile's growth, survival and yield. However, the most competitive feed which provide the best fish growth with the highest fish protein and lowest fish lipid content was feed SG2-35% formulated for Soudano-guinean zone 2 area.

Author contributions

All authors contributed to conception and realization of the work. All the authors have contributed to the paper redaction and given their approval to the final version of the manuscript.

Compliance with ethical standards

The research described herein was performed on locally available feedstuffs and catfish *Chrysichthys nigrodigitatus* (Lacépède, 1803) juveniles. This study was conducted in strict accordance with the guidelines of the Ethical on the care and use of animals for scientific research.

Conflict of interests

The authors have not declared any conflict of interests.

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References

Abbass, F.E., 2007. Effect of dietary oil sources and levels on growth, feed utilization and whole body chemical composition of Common Carp, *Cyprinus carpio* L. Fingerlings. J. Fish. Aquat. Sci. 2, 140-148.

Abdelghany, A.E., 2003. Partial and complete replacement of fish meal with gambusia meal in diets for red tilapia *Oreochromis niloticus* x *O. mossambicus*. Aquacult. Nutr. 9, 145-154.

Abowei, J.F.N., 2010. Salinity, dissolved oxygen, pH and surface water temperature conditions in Nkoro River, Niger Delta, Nigeria. Adv. J. Food Sci. Technol. 2 (1), 16-21.

Adewolu, A.M., Benfey, J.T., 2009. Growth, nutrient utilization and body composition of juvenile bagrid catfish, *Chrysichthys nigrodigitatus* (Actinopterygii: Siluriformes: Claroteidae), fed different dietary crude protein levels. Acta. Ichthyol. Piscat., 39 (2), 95–101. DOI: 10.3750/AIP2009.39.2.03.

Affourmou, K., Nobah, C.S.K., Alla, Y.L., 2014. Aquacultural potential of Silver Catfish *Chrysichthys nigrodigitatus* (Lacepede, 1803) bred in fresh and brakish water in three rearing systems: Enclosures, cement tanks and earth ponds. Adv. Biores., 5 (2), 165-171. DOI: 10.15515/abr.0976-4585.5.2.165171.

Akian, D.D., Atsé, B.C., Pangni, K., Koumi, A.R., Zobi, I.C., 2008. Effect of replacement of fish meal by soybean meal in diet on growth performance and feed utilization in *Chrysichthys nigrodigitatus* (Claroteidae) juveniles reared in lagoon enclosures. J. Ivoir. Oceanol. Limnol, V (1&2): 1-9.

A.O.A.C., 1990. Official Methods of Analysis. Association of Official Analytical Chemists, Washington.

A.O.A.C., 2003. Official Methods of Analysis Revised 17th ed. Association of Analytical Communities, Gaithersburg.

Avit, J-B.L.F., Luquet, P. 1993. Essais d'utilisation de ''nourrisseur à la demande ''pour l'alimentation de *Chrysichthys nigrodigitatus* en cage-enclos. J. Ivoir. Oceanol. Limnol, 2 (2), 1-7.

Bhatnagar, A., Devi, P. 2013. Water quality guidelines for the management of pond fish culture. Int. J. Environ. Sci. Technol., 3(6), 1980 - 2009.

Bhatnagar, A., Jana, S.N., Garg, S.K., Patra, B.C., Singh, G., Barman, U.K., 2004. Water quality management in aquaculture, in: CCS Haryana Agricultural (Ed.), Course manual of summer school on development of sustainable aquaculture technology in fresh and saline waters. CCS, Hisar, India, pp. 203- 210.

Craig, S., Helfrich, L.A., 2009. Understanding fish nutrition: Feeds and feeding. A reviewed: Coop. Ext. Serv. Publicat. 1-4., 240-256.

Boyd, C.E., 1990. Water quality in ponds for aquaculture, Auburn University Press, Birmingham.

Boyd, C.E., 1995. Bottom soils, sediment, and pond aquaculture, Chapman and Hall, New York.

Delince, G., 1992. The ecology of the fish pond ecosystem, Kluwer Acadmic Publisers, London.

F.A.O., 2005. Les productions en ressources halieutiques de la Côte d'Ivoire. Aperçu général du secteur national d'aquaculture-Côte d'Ivoire, FAO. Consulté le 18-12-2007.
http://www.fao.org/fi/website/MultiQueryAction.do.

F.A.O., 2014. Résidus agricoles et sous-produits agro-industriels en Afrique de l'Ouest; Etat des lieux et perspectives pour l'élevage, FAO, Rome, Italie.

Gabriel, U.U., Akinrotim, I.O.A., Bekibele, D.O., Onunkwo, D.N., Anyanwu, P.E., 2007. Locally produced fish feed: potentials for aquaculture development in sub-Saharan Africa. Afr. J. Agric. Res., 2, 287-295.

Geurden, I., Borchert, P., Balasubramanian, M.N., Schrama, J.W., Dupont-Nivet, M., Quillet, E., Kaushik, S.J., Panserat, S., Médale, F. 2013. The positive impact of the early- feeding of a plant-based diet on its future acceptance and utilisation in rainbow trout. PLos One 8(12), e 83162. doi: 10.1371/journal.pone.0083162.

Goda, A.M., Wafa, M.E., El-Haroun, E.R., Kabir Chowdhury, M.A., 2007. Growth performance and feed utilization of Nile tilapia *Oreochromis niloticus* (Linnaeus 1758) and tilapia galilae *Sarotherodon galilaeus* (Linnaeus 1758) fingerlings fed plant protein-based diets. Aquac. Res., 38, 827-837.

Guillaume, J., Kaushik, S., Bergot, P., Metailler, R., 1999. Nutrition et alimentation des poissons et crustacés, INRA, Paris.

Hem, S., 1982. L'aquaculture en enclos : adaptation en milieu lagunaire ivoirien. Aquaculture, 27, 261-272.

Hem, S., Nuñez Rodriguez, J., 1995. L'aquaculture du mâchoiron (*Chrysichthys nigrodigitatus* Lacépède, 1803) en Côte d'Ivoire : Un exemple de recherche pour le développement, in : Agnèse, J.F (Ed.), Atelier Biodiversité et aquaculture en Afrique. CRO/ UE/ ORSTM, Abidjan, Cote d'Ivoire, pp. 21-23.

Igbinosun, J.E, Talabi, S.O., 1983. Studies on the nutrition of brackish water catfish - *Chrysichthys nigrodigitatus*, in: 2nd Annual Conference of the Fisheries Society of Nigeria, Preliminary investigations on the probable use of vegetable oil in catfish feeds, FISON, Calabar, Nigeria, pp. 135-143.

Jamu, D.M., Ayinla, O.A., 2003. Potentiel for the development of Aquaculture in Africa. N. A. G. A., 26, 9-13.

JICA (Agence Japonaise de Coopération Internationale) 2016. Projet de relance de la production piscicole continentale en république de Côte d'Ivoire : Rapport de l'étude d'état des lieux. JICA, OAFIC CO., LTD. INTEM consulting, Abidjan.

Kaushik, S.I., Médale, F., 1994. Energy requirements, utilization and dietary supply to salmonids. Aquaculture, 124, 81-97.
Atsé, B.C., Koumi, A.R., Kouamé, P., 2008. Growth and cannibalism of the African catfish *Heterobranchus longifilis* fingerlings (Valenciennes, 1840) fed isoproteic diets with partial or total substitution of fish protein with soya protein. J. Fish. Int., 3(3), 68-74.
Koumi, A.R., Koffi, K.M., Atsé, B.C., Kouamé, L.P. 2011. Growth, feed efficiency and carcass mineral composition of *Heterobranchus longifilis*, *Oreochromis niloticus* and *Sarotherodon melanotheron* juveniles fed different dietary levels of soybean meal-based diets. Afr. J. Biotechnol. 10(66), 14990-14998. DOI: 10.5897/ajb10.1449.ISSN 1684–5315.
Koumi, A.R., Kimou, B.N, Atsé, B.C, Ouattara, I.N, Kouamé, L.P., 2015. Fish feeds used in Côte d'Ivoire: Nature, quality, use and productivity. Asian J. Agr. Food Sci., 3(2), 225-236.
Koumi, A.R., Kimou, B.N., Ouattara, I.N, Koffi, K.M., Atsé, B.C., Kouamé, L.P., 2016. Les aliments utilisés en pisciculture semi-intensive en Côte d'Ivoire et leur productivité. Tropicultura, 34 (3), 286-299.
Lanoiselee, B., 1984. Fertilisation organique en aquaculture : Utilisation du lisier de porc pour l'alevinage de poissons d'étang. Thèse de Doctorat, Institut National Agronomique de Paris-Grignon, France.
Lawson, T.B., 1995. Fundamentals of aquacultural engineering, Chapman & Hall, New York.
Lazard, J., 2007. Aquaculture et espèce introduites : exemple de la domestication ex situ des tilapias. Cah. Agric. 16(2), 123-124.
Luquet, P., Moreau, Y., 1989. Energy-protein management by some warm water fin fishes. Actes du Collogue 9, AQUACOP, IFREMER, France.
Maynard, L., Loosili, J., Hintz, H., 1979. Animal Nutrition. 7th ed. Mc Graw Hill, New York.
M.I.N.A.G.R.I., (Ministère de l'Agriculture). 2009. Rapport national sur l'état des ressources phytogénétiques pour l'alimentation et l'agriculture. MINAGRI, Abidjan.
M.I.N.E.S.U.D.D., (Ministère de l'Environnement de la Salubrité Urbaine et du Développement Durable). 2014. Communication-pays : L'agriculture intelligente face au climat en Côte d'Ivoire : Etat des lieux et besoins d'appui pour mieux intégrer l'agriculture intelligente face au climat (AIC) dans le programme national d'investissement agricole *(PNIA)*.
MINESUDD, Abidjan, Côte d'Ivoire.New, M.B., 1987. Feed and feeding of fish and shrimp. A manual on the preparation and presentation of compound feeds for shrimp and fish in aquaculture. ADCP/REP.
Panserat, S., Hortopan, G.A., Plagnes-juan, E., 2009. Differential gene expression fter total replacement of dietary fish meal and fish oil by plant products in rainbow trout (*Oncorhynchus mykiss*) liver. Aquaculture, 294, 123-131. Doi: 10.1016/j.aquaculture.2009.05.013.
Pouomogne V., 1994. L'alimentation du Tilapia *Oreochromis niloticus* en étang. Evaluation du potentiel de quelques sous-produits agro-alimentaire et modalités d'apport des aliments. Thèse de Doctorat en Halieutique, Ecole National Supérieure d'Agronomie, Rennes, France.
Pouomogn, V., Takam, G., Pouemegne, J., 1997. A preliminary evaluation of cacao husks in practical diets for juvenile Nile tilapia (*Oreochromis niloticus*). Aquaculture, 156 (3-4), 211-219.
Santhosh, B, Singh, N.P., 2007. Guidelines for water quality management for fish cultre in Tripura. ICAR Research Complex for NEH Region, Tripura.
Saravanan,S., Geurden, I., Figueiredo-Silva, C., Kaushik, S., Verreth, J., Schrama, JW., 2013. Voluntary feed intake in rainbow trout is regulated by diet-induced differences in oxygen use. J. Nutr.143, 781-787. Doi: 10.3945/jn.112.173062.
Yao, A.H. Koumi, A.R., Atsé, B.C., Kouamélan, E.P., 2017. Etat des connaissanes sur la pisciculture en Côte d'Ivoire. Agronom. Afr. 29 (3), 227 - 244.
Van Opstl, Y., Coton, P., 1981. Efficacité comparée de différentes formules alientaires sur la croissance en élevage de *Chrysichthys walkeri* et *C. nigrodigitatus*. Doc. Scientif. du Centre de Recherches Océanologiques, 12 (1), 79-89.
Wang, Y., Liu, Y.J., Tian, L.X., Du, Z.Y., Wang, J.T., Wang, S., Xiao, W.P. 2005.Effects of dietary carbohydrate level on growth and body composition of juvenile tilapia, *Oreochromis niloticus* x *Oreochromis aureus*. Aquacult. Res. 36, 1408-1413.