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Effect of replacement of fish meal with broiler chicken viscera on growth, feed utilization and production of African catfish *Clarias gariepinus* (Burchell, 1822)

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Abstract
A 42-days experiment was conducted to evaluate the effect of dietary replacement of fish meal with chicken viscera meal on growth, feed utilization and production of *Clarias gariepinus*. Fish (initial weight 8.0 ± 0.4g) were hand-fed twice daily to apparent satiation with three isonitrogenous (43% crude protein) and isocalorics (20 KJ/g gross energy) diets containing three levels of chicken viscera, 0% (diet A_0), 30% (diet A_{30}) and 50% (diet A_{50}). The diet A_0 acted as a control diet. Experimental diets were compared to the commercial diet Coppens developed for Catfish. At the end of the experiment, survival rate was high, with value ranging from 94.3% to 97.5%. Fish fed viscera meal showed significantly lower total feed intake (range: 2117 – 2183 g) than that of fish fed coppens (5195 g) and viscera-free (5800 g). Final weight (range: 39 - 111g), specific growth rate (range: 3.8 – 6.3%/day), food conversion ratio (range: 1.1 – 1.4), protein efficiency ratio (range: 1.7 - 2.2) and annual production (range: 14.7 – 50.6 Kg/m^3/year) were significantly higher in fish fed coppens and A_0 (*$P<0.05$*). However, feed conversion ratio in fish fed chicken viscera is relatively low (1.4 ± 0.1), ensuring that this protein is as valuable for the experimental fish. Ultimately, the incorporation of the chicken viscera causes a reduction of 58% on financial expenses related to the fish production. Surely, these findings will have great emphasis in the field of promotion of C. *gariepinus* rearing in rural areas.

Keywords: African catfish, feeding, fishmeal, broiler chicken viscera, feed efficiency, growth

1. Introduction

Aquaculture industry has grown considerably in the world during the last fifty years, from a production of less than one million tons in the early 50s to 73.8 million tons in 2014 (FAO, 2016) [11]. This rapid development of aquaculture in the world depends largely on the availability of fish feed; which are traditionally based on fish meal as the main protein source (Hardy & Tacon, 2002) [22]. Fishmeal has traditionally been used as a major protein source because its balanced essential amino acids profile, fatty acids, vitamins and minerals (Tacon, 1993; Mambrini & Kaushik, 1995; Kaushik, 1998) [40, 30, 28]. However, the high cost, poor quality and the unavailability of this ingredient locally require research other alternative protein sources to replace fishmeal in fish feed especially *Clarias gariepinus.* The African catfish is one of the popular fish species in fresh water aquaculture due to its omnivorous feeding habits, air-breathing characteristics, rapid growth and good market potential. Moreover, this species has replaced the tilapia, as most fish produced in fish farms since 2004 in sub-Saharan Africa (FAO, 2012) [12].

One of the by-products resulting from poultry breeding is the broiler chicken viscera, which contain 35% crude protein, 13% crude fat and 6% ash (Nyina-Wamwiza *et al.*, 2007) [32]. Giri *et al.* (2000a) [15] have showed that dried chicken viscera can be incorporated up to 30% in the diet for juveniles of *Clarias batrachus* without affecting nutrients digestibility and can be used as a replacer of expensive fishmeal in the diet. Moreover, dried chicken viscera could be used as a complete and superior substitute of marine by-catch fishmeal without adversely affecting the performances in this species fingirlings (Giri *et al.*, 2010) [14]. According to Tabinda *et al.* (2013) [39], poultry by-product can replace fishmeal by 75 to 100% in diet for fingerlings *Cirrhinus mrigala* without using any additional amino acids as well as processing. Other studies have shown considerable success in partially or totally replacing fish meal with poultry by-products such as chicken viscera in diets for various fish species (Abdel-Warith *et al.*, 2001; Shapawi *et al.*, 2007; Yang *et al,* 2006; Rawles *et al.*, 2006; Tabinda & Butt, 2012) [1, 37, 43, 34, 38].

Because of the high nutritional value of broiler chicken viscera, it is estimated that the inclusion of these ingredient in diet for *C. gariepinus* would be beneficial. The aim of this work was to evaluate the effect of replacing fish meal by broiler chicken viscera in diet on growth performance, feed utilization and production of African catfish.

Materials and Methods

Experimental facilities and fish

The experiment was conducted in an indoor recirculation system, the system contained 12 tanks (diameter: 120 cm, water volume: 900 L). During the experiment, water temperature ranged from 27.5 to 28.5 °C (mean 28.03 ± 0.3 °C), dissolved oxygen was 6.23 ± 0.2 mgL^{-1} and pH= 6.3 ± 0.1. These parameters were daily measured in each tank throughout the experimental period using oxy thermometer WTW Oxi 197 and pHmeter WTW pH324 respectively. Water in all tanks was renewed continuously (2 L/min). To prevent fish from jumping out, tanks were covered at 50% with a perforated wooden plank. Juvenile of *C. gariepinus* were bought from the Research and Incubation Aquaculture Center of Benin (Abomey-Calavi, Benin). They were shipped to the experimental station located at the University of Abomey-Calavi, Benin, and put in circular tank. Before conducting the experiment, fish were acclimatized for one week, so as to adjust them to the rearing conditions. While acclimatization, the fish were fed with a fish meal protein based diet (30% crude protein) other than the experimental diets. At the end of the acclimation period, fish were weighed and were then started on the respective experimental diets. Each tank was randomly assigned to the dietary treatments. Fifty-three fish with an average weight of 8.0 ± 0.4 g were graded and transferred to each tank. All dietary treatments were tested in triplicate groups of tanks. The fish were weighed biweekly to control they growth. The experiment was undertaken for a total period of 6 weeks.

Ingredients, diet and feeding

The fishmeal used in the formulation of experimental diets is *Sardinella aurita* meal. *S. aurita* is purchased at Dantokpa market and dried in the sun for three days before being processed into meal. Broiler chicken viscera were collected from the S^{T} Michel market places of Cotonou, Benin, just after dressing and have been cleaned, crushed and stored frozen (+4 °C) until used. The beef blood was collected in the slaughterhouse. The other feed ingredients, soybean meal, corn bran and oil palm were obtained in the market. The formulation and proximate composition of the experimental diets are given in Table 1.

Four isonitrogenous and isoenergetic test diets namely A_0, A_{30} and A_{50}, were formulated on a dry weight basis to contain 43% crude protein and 20kJ/g gross energy. Diets were formulated to be representative of typically commercial diet used for African catfish and contains about 80% in animal protein, as recommended by Degani *et al.* (1989) [6] and Ali (2001) [3]. Fish were hand-fed to apparent satiation twice daily at 09:00 and 17:00 hours. Care was taken to stop feeding as soon as the fish stopped eating.

Each ingredient was grounded, weighed and mixed. Prior, viscera were weighed and cooked on a low heat. Experimental diets were made by adding appropriate volumes of water to ingredients. The resulting paste was transformed into spaghetti 2mm with the aid of food blender (Century Blender 8231D). After sun drying at a temperature of 28-35 °C for about three days, the spaghetti were manually broken and converted into pellets. The pellets were stored at +4 °C until use.

Table 1: Formulation (%), proximate composition (%) and energy content (KJ/g) of the diets used in the experiment

Ingredients	Diets			
	Coppens**	A_0	A_{30}	A_{50}
Fish meal		30	15	0
Beef blood meal		23	23	23
Corn bran		30	20	10
Soybean meal		15	10	15
Chicken viscera meal		0	30	50
Palm oil		2	2	2
Proximate composition and energy content				
Dry matter (%)		90.0	88.3	88.2
Crude protein (%)		43.0	42.8	42.6
Crude lipid (%)		10.8	12.0	14.0
Carbohydrates (%)		27.0	32.4	33.7
Gross energy* (KJ/g)		19.0	20.0	20.8

*Calculated using the factors of 23.7 KJg^{-1}, 39.5 KJg^{-1} and 17.2 KJg^{-1} protein, fat and carbohydrate respectively (Guillaume *et al*., 1999) [19]

**Crude protein: 43% ; Crude fat: 13% ; crude fibre: 3.0%; Ash: 6.7% ; Vitamine A 15000 IU/Kg ; Vitamine D3 2000 IU/Kg ; Vitamine E 200 mg/Kg; Vitamine C 150 mg/Kg; Phosphorus: 0.9%; Calcium 0.9%; Sodium 0.2%; Preservatives E280 ; Antioxidants E324, E321. Composition: soya dehulled, extracted, and toasted, wheat; rape seed, extracted; pea protein; maize gluten; premix. Produced by Coppens International bv, PO Box 534, 5700 AM Helmond, Holland.

Evaluation of the profitability

The evaluation of profitability has taken into account the price of feed ingredients and fingerlings during the experimental period, the price of marketable and unprocessed fresh fish on the national market (US$ 2.50), the depreciation of construction cost of the tank over 20 years and the number of hours and days of labor for tank and site management, routine weight control, broiler chicken viscera and diets processing (assuming that one man-day of 8 hours labor is US$ 3.33) (Abou, 2007) [2]. The variable costs included total feed cost, fish cost, feeding cost, tank management cost, weigh control and harvest costs. The depreciation cost of experimental tanks was generated to fixed costs. The estimated cost of the different experimental diets is presented in Table 2.

Table 2: Feed formulation, cost of ingredients and experimental diets

Diets		Coppens	A_0	A_1	A_2
Ingredients (%)	**US$ kg^{-1}**				
Fish meal	1.17		30	15	0
Beef blood meal	0.21		23	23	23
Corn bran	0.25		30	20	10
Soybean oil cake	0.66		15	10	15
Chicken viscera	0.11		0	30	50
Oil palm	1.33		2	2	2
Total			100	100	100
Cost of one kg of feed (based on ingredient cost)	US$ Kg^{-1}		0.60	0.42	0.25
Labor cost	US$ Kg^{-1}		0.13	0.13	0.13
Cost of feed	US$ Kg^{-1}	2.00	0.72	0.55	0.38

Statistical analysis

All data were subjected to one way analysis of variance to determine significance between means using SPSS Software version 20.0. Duncan's multiple range test (Duncan, 1955) [7] was used to compare differences among means. Before analyses, homogeneity of variance was checked using the "Hartley test" (Dagnelie, 1975) [5]. Differences were considered significant when $p<0.05$.

Results

The average values of physico-chemical parameters measured are 28.03 ± 0.3 °C for the temperature, 6.23 ± 0.2 mgL^{-1} for dissolved oxygen and 6.3 ± 0.1 for pH.

The amount of feed intake by fish fed diets A_0 and Coppens was significantly higher ($P<0.05$) than that obtained with fish fed diets A_{30} and A_{50}. Survival rates values ranged from 94 to 97.5%, with no significant difference ($P>0.05$).

Final body weight was significantly ($P<0.05$) influenced by the dietary treatments. The lower value (39.1 ± 3.6g) was observed in fish fed diet containing chicken viscera and the higher (111.0 ± 5.7g) in fish fed Coppens diet. The specific growth rate evaluated vary between 3.8 and 6.3% per day, significantly decreasing with fish fed broiler chicken viscera ($P<0.05$).

The feed conversion ratio with fish fed chicken viscera diets were significantly higher than those fed A_0 and Coppens, values ranging from 1.1 to 1.4 ($P<0.05$). Protein efficiency ratio of different diets tested varies between 1.7 and 2.3. The protein efficiency ratio decreased significantly in diets A_{30} and A_{50}. The highest annual production was obtained with fish fed the Coppens and A_0, values ranging from 14.7 to 50.6 Kg/m³/year.

Table 3: Growth, feed utilization and annual production of African catfish fed in concrete tanks with diets containing increasing level of chicken viscera for 42 days. Data are mean ± S.D[1] of three replicates.

Parameters	Diet			
	Coppens	A_0	A_{30}	A_{50}
Initial individual weight (g)	8.0±0.04	8.0±0.3	8.0±0.4	8.0±0.4
Final individual weight (g)	111.0±5.7^a	109.6±3.3^a	39.1±3.6^b	39.0±2.3^b
Feed intake (g)	5195±360^a	5800±200^b	2117±375^c	2183±76^c
SGR[2] (%/day)	6.3±0.1^a	6.2±0.1^a	3.8±0.2^b	3.8±0.1^b
PER[3]	2.2±0.1^a	2.1±0.0^a	1.7±0.2^b	1.7±0.1^b
FCR[4]	1.1±0.1^a	1.1±0.0^a	1.4±0.1^b	1.4±0.1^b
Survival[5] (%)	94.4±5.6	97.5±2.2	95.0±2.2	94.3±0.0
Production[6] (Kg/m³/year)	47.1±5.9^a	50.6±1.1^a	14.9±2.2^b	14.7±0.1^b

1. In each line, means with no letters or with the same letters as superscripts are not significantly different ($P > 0.05$).
2. Specific growth rate (SGR) = [(ln final weight – ln initial weight)/days] × 100
3. Protein Efficiency Ratio (PER) = Body weight gain (g)/ protein intake (g)
4. Feed Conversion Ratio (FCR) = Feed supplied (g)/ Body weight gained (g)
5. Survival (%) = 100 *(number of survivors per tank) (initial number per tank) $^{-1}$
6. Production ($kg\ m^{-3}\ year^{-1}$) = Yield x 365 / rearing time (days) with Yield ($kg\ m^{-3}$) = $(Bf – Bi) / V$ where Bf and Bi are final and initial biomass respectively and V, the tank volume (m^3)

Table 4: Summary of cost benefit analysis of African catfish rearing

Diets	Coppens	A_0	A_{30}	A_{50}
Parameters				
Cost of feed used for production of one kilogram of fish* (US$ Kg^{-1})	2.20	0.81	0.76	0.53
Cost of expenses related to the production of one kilogram of fish (US$ Kg^{-1})	0.27	0.27	0.27	0.27
Total cost of production of one kilogram of fish (US$ Kg^{-1})	2.47	1.08	1.03	0.79

* Cost of feed used for production of one kilogram of fish = Feed Conversion Ratio × Cost of feed per kilogram

Discussion

Clarias gariepinus can support temperature as low as 6 °C and as high as 50 °C (Babiker, 1984) [4]. However, a temperature of 28-30 °C is considered optimal for the growth of this species (Goddard, 1996) [18]. The water temperature recorded in this study is optimal for the growth of *C. gariepinus*. Similarly, dissolved oxygen levels and pH recorded during the experiment were not a limiting factor for its growth. Indeed, this species can live in low oxygen conditions water for a long time (Teugels, 1986) [41] and tolerate a wide range of adverse environmental conditions (Légendre & Proteau, 1996) [29].

Although the initial average weight is the same in all treatments, fish fed the control diets Coppens and A_0, have the highest final weight and the best specific growth rate compared to those of fish fed 30% and 50% broiler viscera. These results are similar to those obtained by Giri *et al.* (2000b) [16] in *C. batrachus* fed a diet containing 30% of dried broiler viscera. The specific growth rate obtained in fish fed A_{30} is higher than those obtained by Nyina-Wamwiza *et al.* (2007) [32] with 18% of broiler chicken viscera in diets of *C. gariepinus* and Gumus & Aydin (2013) [20] in *Cyprinus carpio* fry fed with diet containing chicken viscera. The improvement of specific growth rate obtained here in this experiment can be explained by the fact that fish are fed to satiation. The decreasing in growth of fish fed with diets A_{30} and A_{50} could be explained by the low feed intake observed in the latter. Thus, the low palatability can be improved by using food attractants (Papatryphon & Sorares, 2000) [33]. Indeed, in *Morone saxatilis*, these authors showed that plant feedstuff based diet supplemented with neutral amino acid L-alanine and L-serine particularly increases feed intake in this species. Moreover, methionine and lysine requirements in catfish are respectively about 2.3 and 5.1% (Imam, 2012) [26]. Requirements in these amino acids for *C. gariepinus* have been determined by Fagbenro *et al.* (1998a) [9] and Fagbenro *et al.* (1998b) [10], and are 3.2% and 5.7% of the total protein, respectively, based on semi-purified diets. According to Hu *et al.* (2008a) [25], methionine and lysine are present in small amounts in the chicken viscera (1.43 and 3.51% respectively). This could justify the low growth achieved in fish fed diets based broiler chicken viscera. Indeed, Ronyai *et al.* (2002) [36] and Fagbenro (2004) [8] have reported that the deficit in one or more amino acids limit protein synthesis and affects growth of fish. However, the use of beef blood meal can correct the lysine deficiency because its richness in that amino acid (Hertrampf & Piedad-Pascual, 2000) [23]. Better results have been obtained in that way when using blood meal for balancing the lysine content in substitution of fishmeal by poultry by-products (including broiler chicken viscera) used alone or in combination with other ingredients of animal origin (Milliamena 2002; Guo *et al.,* 2007) [31, 21]. However, the methionine deficit remains. Although poultry by-products such as broiler chicken viscera have been shown to be nutritionally adequate sources of protein for many fish species (Fowler, 1991; Robaina *et al,*, 1997; Abdel-Warith *et al.,* 2001; Wang *et al.,* 2006) [13, 35, 1, 42], they were deficient in essential amino acid that limit they use as substitutes for fishmeal (Glencross *et al.,* 2007) [17]. Therefore, it will be benefit to adjust the level of essential amino acids in chicken viscera by supplementation. Hu *et al.* (2008b) [25] have provide 0.49% lysine and 0.14% methionine as supplementation in diets containing chicken viscera with better growth performance in *Carassius auratus gibelio*. Similar trends of results was obtained by Rawles *et al.* (2006) [34] in the hybrid *Morone chrysops* X *Morone saxatilis* fed a broiler viscera diet supplemented with methionine (0.63%) and lysine (1.55%).

Throughout the experiment, fish showed no pathological signs and mortality rates are low, indicating that fish were reared in good conditions. The mortality recorded could be therefore attributed to fish manipulation during the experiment.

The feed conversion ratio with diets based broiler chicken viscera are better than those obtained by Giri *et al.* (2000a) [15] in *C. batrachus* fed a diet containing 30% dried chicken viscera. Similarly, the feed conversion rate obtained in this experiment is relatively lower than those reported by Tabinda *et al.* (2013) [39] who fully substitute fish meal with chicken intestines in juvenile *Cirrhinus mrigala*. On the other hand, Nyina-Wamwiza *et al.* (2007) [32] have obtained a lower feed conversion ratio (0.86 ± 0.04) in *C. gariepinus* using 18% of the chicken intestines meal, fish oil and sunflower. Similar observations were made by Shapawi *et al.* (2007) [37] in grouper *Cromileptes altivelis* fed poultry by-products-based-diets.

The protein efficiency ratio obtained with diets based viscera at the end of this experience are superior to 1.2 obtained by Giri *et al.* (2000a) [15] in *C. batrachus,* but lower than 2.7 obtained by Nyina-Wamwiza (2007) [32] with diet containing of 18% of chicken viscera meal.

Highest production was determined in fish fed control diet A_0 and the lowest in fish fed diet A_{50}. The production with diets based broiler chicken viscera are better than those obtained by Imorou Toko (2007) in *C. gariepinus* fed commercial diet for catfish containing 40% crude protein at 24 fish/m^3 stocking density in pond. Low yield and annual production obtained in fish fed diets based broiler chicken viscera could be explained by the decrease in feed intake observed in the latter. Indeed, despite the low growth observed in fish fed with diets containing broiler chicken viscera (A_{30} and A_{50}), feed conversion ratio obtained is relatively low and the protein efficiency ratio is acceptable. This shows that the fish have recovered well the little food they have ingested. The results of the economic analysis are satisfactory. These results show a significant reduction in the cost of experimental diets versus Coppens returning overpriced local farmers. As shown in Table 4, a reduction on the cost production of one kilogram of fish is about 58% by using broiler chicken viscera based diet compared to the commercial feed Coppens.

Conclusion

The results from this study would indicate that chicken viscera are an acceptable ingredient for the partial replacement of fish meal protein in practical diets for juvenile African catfish. Chicken viscera can be used in diet formulations for this species up to 50% replacement of fish meal.

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