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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

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Abstract: A feeding trial was carried out in concrete tank to examine complete and partial replacement of the fish protein with soya protein in practical feeds of African catfish *Heterobranchus longifilis*. Three diets containing 35% crude protein replacing 0% (FD), 50% (MD) and 100% (SD) of the fish protein with similarpercentage of soya protein were formulated. Soya protein diets were supplementing with 0.5% of methionine and lysine. After 4 months of feedings at 5% body weight, the best growth was achieved with fish fed FD. Growth parameters such as Final Body Weight (FBW), Body Weight Gain (BWG) and Specific Growth Rate (SGR) decreased with the increase dietary soya protein. Similarly, the feed and protein utilization parameters decreased significantly with increasing soya protein substitution in diet. The highest number of the extreme fish size was obtained with the fish fed MD. Cannibalism was observed during the first two months of experiment and was higher in fish fed SD. Fish fed MD showed higher values of carcass lipid content while higher values of carcass ash content were obtained with fish fed SD.

Key words: Cannibalism, growth, *Heterobranchus longifilis,* protein, proximate composition, soybean meal

INTRODUCTION

The catfish *Heterobranchus longifilis* is one of the most suitable species for aquaculture in West Africa (Legendre, 1989; Otémé *et al*., 1996). Biological and ecological characteristics such as omnivorous feeding habit, good acceptance of commercial pellet diet, resistance to disease, pollution and tolerance to low dissolved oxygen make *H. longifilis* an excellent candidate for aquaculture (Micha, 1973; Bard *et al*., 1976; Legendre, 1983). In add, this fish commands high market value in West Africa, because of its good flavour and ability to grow of large size (Legendre, 1983, 1989). In spite, of these advantages, one of the major reasons given for the low production of the catfish larvae and juveniles is the high mortality rate due to cannibalism.

Fish meal which serves as the main protein sources of the fish feed because of its high quality protein content, is not only very expensive but also usually unavailable (Keembiyehetty and Gatline, 1997) particularly in developing countries. Efforts to replace fishmeal with vegetable protein from more sustainable sources have been embarked upon by various authours (El-Sayed, 1990; Shiau *et al*., 1990; Watanabe *et al*., 1993; Robinson and Li, 1994). Since, the current focus of nutrition studies is the reduction and the possible elimination of fish meal and fish oil from practical diets (Craig, 2004).

Soybean has one of the most promising plant proteins for substituting fish meal worldwide (Adewumi, 2006). Soya is widely cultivated and soybean meal have high protein content with a well balanced amino acids profiles, constant composition, reasonable price (Storebakken *et al*., 2000) and it can be used for the fish feeding. This incorporation of soya protein in fish diet could reduce the cost of diets and improve growth (Rumsey, 1993). However, considerable variations exist in the ability of different fish species to utilize soybean protein. Concerning carnivorous catfish, many studies have shown successful in replacing fish meal with soybean meal in diet. For example carnivorous blue catfish *Ictalurus furtacus* grow well on diets with 70% of crude protein from soybean meal (Webster *et al*., 1992). Robinson and Li (1994) also reported that soybean meal could be used to completely replace fish meal in catfish

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feed. Based on these results soya protein could be one suitable alternative protein of catfish feed.

Alternatively, the changing of the protein source in the diets could reduce the cannibalism in the young fish culture entraining to the reduction of fish mortality. This aspect of carnivorous fish has not been studied. Therefore, the objective of this study was to evaluate the effect of a partial or complete substitution of dietary fish protein with soya protein on growth performance, cannibalism rate, economic value and carcass composition of African catfish *H. longifilis* fingerlings.

MATERIALS AND METHODS

Experimental diets: Three experimental diets were formulated to be isonitrogenous in terms of crude protein (35%). The proximate composition of these diets was given in Table 1. Fish meal protein was replaced by soya protein on the basis of crude protein as follows: fish diet (FD) = 0% soya protein replaced fish protein; mixture diet (MD) = 50% soya protein replaced fish protein; soya diet (SD) = 100% soya protein replaced fish protein in diet. To balance of lysine and methionine, 0.5% from each amino acid was added of soya protein diets and 2% premix vitamin and mineral supplemented each diet formulated. The energy values were calculated using the gross energy values for the macro nutrients (Luquet and Moreau, 1989).

The cost of each diet was determined by multiplying the respective contributions of each ingredient by their respective cost per kilogram and summing the values thus obtained for all the ingredients. The experimental diets were dried, broken into suitable sizes and stored at 20°C until use.

Table 1: Formulation and proximate composition of the experimental diets

	Diets		
	FD	MD	SD
Ingredients (g kg^{-1})			
Corn flour	100	100	100
Fish meal	380	190	-
Soybean meal	-	248	500
Wheat bran	340	222	120
Cottonseed meal	150	200	240
Fish oil	10	5	-
Soya oil	-	5	10
Lysine	-	5	5
Methionine	-	5	5
Vitamin and mineral premix[a]	20	20	20
Total	1000	1000	1000
Proximate analysis (% on dry matter basis)[b]			
Moisture	10.8	10.7	10.5
Crude protein	35.5	35.6	35.6
Total nitrogen	5.7	5.7	5.7
Crude fat	9.2	8.3	12.9
Ash	12.1	9.5	7.4
Crude fibre	8.4	8.4	8.8
Nitrogen-free extract[c]	23.3	27.5	24.8
Gross energy (kJg diet^{-1})[d]	15.5	15.9	17.2
Cost (CFA kg^{-1})[e]	260	225	195

[a]Vitamin and mineral mixture each 1-kg of mixture contains: 4800 I.U. Vit A, 2400 IU cholecalciferol (vit. D), 40g Vit E, 8 g Vit K, 4.0 g Vit B_{12} , 4.0 g Vit B2, 6 g Vit B6, 4.0 g pantothenic acid, 8.0 g nicotinic acid, 400 mg folic acid, 20 mg Biotin, 200 mg Choline, 4 g Copper, 0.4 g Iodine, 12 g Iron, 22 g Manganese, 22 g Zinc, 0.04 g Selenium. Folic acid, 1.2 mg; niacin, 12 mg; D-calcium pantothenate , 26 mg; pyridoxine HCL, 6 mg; riboflavin, 7.2 mg; thiamine HCL, 1.2 mg; sodium chloride (NaCL, 39% Na, 61% Cl), 3077 mg; ferrous sulphate ($FeSO_4 7H_2O$, 20% Fe), 65 mg; manganese sulphate ($MnSO_4$, 36% Mn), 89 mg; zinc sulphate ($ZnSO_4.7H_2O$, 40% Zn), 150 mg; copper sulphate ($CuSO_4.5H_2O$, 25% Cu), 28 mg; potassium iodide (KI, 24% K, 76% I), 11 mg: Celite AW521 (acid-washed diatomaceous earth moisture-silica), 1000 mg; [b]Values represent the mean of three replicates; [c]Nitrogen-free extract = 100–(% moisture + % protein + % fat + % fibre + % ash); [d]Gross energy = (22.2 × protein + 38.9 × fat + 17.2× nitrogen-free extract); [e]Price in CFA pound: 100 CFA = 0.15 $ based on 2006 exchange prices in Ivory Coast

Experimental procedure: *Heterobranchus longifilis* fingerlings were obtained by using the procedure of artificial reproduction established by Legendre (1986). The larvae have been reared in the requisites structures and fed consequently with *Atemia salina* based diet during 35 days. After this period, fish initial weight 0.15±0.01 g were counted and stocked at density of 500 fish per tank (125 fish m^{-3}). Three replicate tanks were constituted for each diet and fish were fed at ration of 5% fresh weight according to Hem *et al.* (1994) three times a day (08:00, 12:00 and 17:00 h).

Every day, dead fish of each tank were removed and counted. A distinction was drawn between cannibalism and natural death. Missing fish were presumed to have succumbed to a complete cannibalism (Hecht and Appelbaum, 1988). Natural death was determined by the presence of complete fish floating in the tank (Haylor, 1991). Monthly samplings were carried out for assessment of growth, condition factor and general health of fish. For this purpose, 30 fish of each tank from each replicate were sampled, measured and weighed and the feeding rate was adjusted. The extreme high sizes of fish were also collected in each group, counted and removed of the other fish of homogeneous size. At the end of the experiment (120 days), survival fish were collected and counted from each tank. Thus individual body weight was recorded and 10 fish were removed from each replicate to chemical composition determination.

The survival rate, growth performance and nutrient utilization were evaluated as follows: Cannibalism Rate (CR) = (number of fish missing/initial number of fish) ×100; Mortality rate (MR) = (number of dead fish/initial number of fish) ×100; Survival Rate (SR) = (final number of fish/initial number of fish) × 100; Body Weight Gain (BWG) = [(final body weight–initial body weight)/initial weight] × 100; Specific Growth Rate (SGR) = (ln final body weight-ln initial body weight)/number of day; Feed Conversion Ratio (FCR) = dry feed intake (g)/wet weight gain (g); Protein Efficiency Ratio (PER) = weight gain (g)/protein intake (g); Daily Lipid Gain (DLG) = retained lipid (g)/biomass gain (kg)/rearing period. The cost benefit analyses of the diets were performed according to El-Sayed (1990).

Water quality: During the experiment, water temperature, dissolved oxygen and pH were recorded daily in each tank. Water temperature and dissolved oxygen were measured using an Oxy meter model WTW OXI 330 and pH by using ph-meter model WTW pH 90. Water quality, nitrate-nitrogen, nitrite-nitrogen and phosphorus were recorded at weekly intervals using a spectrometric method (Aminot and Chaussepied, 1983).

Biochemical analysis: The approximate compositions of the experimental diets and the fish carcasses were determined by the standard methods of AOAC (1995). Moisture content of each sample was determined through a hot-air oven set at 105°C for 24 h and ash was measured by incineration at 550°C in a muffle furnace for 24 h. Crude protein (Nitrogen × 6.25) was determined using micro-Kjeldahl method; crude fat was extracted (hexane extraction) by using the Soxhlet method and crude fibre was quantified by acid digestion followed by ashing the dry residue at 550°C in muffle furnace for 4 h. The gross energy contents of the diets and fish were calculated on the basis of their crude protein, total fat and carbohydrate contents using the equivalents of 22.2, 38.9 and 17.15 kjg^{-1}, respectively (Luquet and Moreau, 1989).

Statistical analysis: Percentage and ratio values were transformed to arcsine values and data of weight to logarithm values prior to analyse. Growth data (weight) and fish carcass composition were analysed by using one way Analysis of Variance (ANOVA). Turkey's HSD ranking test was used to compare the differences among weight means. Duncan multiple ranking tests were used to compare the differences among others means. The treatment effects were considered to be significant at ($p<0.05$).

RESULTS

Water quality: The recorded minimum and maximum values of water quality parameters during the experimental period were: water temperature, 28.9-29.1°C; water pH from 6.8-7.0; Dissolved Oxygen from 4.3-4.4 mgL^{-1}; Nitrate-N, 0.24-0.26 mgL^{-1}; Nitrite-N, 0.05-0.06 mgL^{-1}; phosphate-D, 0.35-0.40 mgL^{-1}. All the water quality parameters were within the acceptable range for African catfish *H. Longifilis* (Boyd and Tucker, 1998).

Growth performance: At the end of the experiment, growth parameters such as FBW and BWG decreased with increasing dietary soya protein (Table 2). Significant highest values ($p<0.05$) of these parameters were obtained with fish fed FD followed by those fed MD and SD. In contrast SGR was not influenced by the protein source of diet. Mortalities in all groups were observed only during the first 2 months. At the end of experiment, survival rate decreased significantly ($p<0.05$) with the total substitution of fish protein by soya one (Table 2). The highest values ($p<0.05$) of cannibalism and mortality rates was observed with SD. Contrary, fish fed FD and MD diets recorded the highest values of survival rate. The number of the extreme high fish sizes was higher ($p<0.05$) with fish fed MD followed by those fed FD and SD (Fig. 1). The cost and time of production data indicated that the total substitution entrained significantly ($p<0.05$) a greater highest values of cost and time of fish kilogram produce (Table 2).

Feed utilization: The FCR was influenced by the diets ($p<0.05$); it's was lower ($p<0.05$) for fish fed FD and MD, while the highest values was obtained with those fed SD (Table 2). The highest values ($p<0.05$) of protein efficiency ratio were recorded with fish fed FD followed by fish fed MD and SD. Significantly, higher values ($p<0.05$) of DLG was obtained with fish fed MD followed by fish fed FD and SD (Table 2).

Carcass composition: No significant differences were observed in the carcass moisture and protein content of the fish fed with different diets (Table 3). Contrary, fish ash and lipid contents were significantly influenced by

Table 2: Growth performance and nutrient utilization of *Heterobranchus longifilis* fed with experimental diets

	Diets		
Parameters*	FD	MD	SD
IBW (g)	0.15±0.01	0.15±0.01	0.15±0.01
FBW (g)	134.4±51.7^c	73.6±27.5^b	52.1±25.6^a
CR (%)	52.1±1.7^a	52.0±6.0^a	63.3±4.2^b
MR (%)	4.0±0.4^a	4.0±0.9^a	7.33±1.5^b
SR (%)	43.9±1.3^b	44.0±6.0^b	29.3±3.5^a
BWG (%)	86221.9±30805.6^b	48652.7±5310.2^a	35484.6±14299.3^a
SGR (%/j)	5.6±0.3	5.2±0.1	4.8±0.4
FCR	1.0±0.07^a	1.2±0.0^a	1.6±0 .2^b
PER	2.9±0.2^c	2.4±0.1^b	1.8±0.3^a
DLG (g kg^{-1} days)	2.1±0.1^a	2.6±0.0^b	2.0±0.0^a
PC (F.CFA)	258.2±19.3^a	268.3±6.6^a	302.4±4.2^b
PT (days kg^{-1})	14.0±2.7^a	20.2±3.3^a	86.5±10.5^b

*Values are means±SD. Values in the same row with the same superscripts are not significantly different (p = 0.05). IBW = Initial body weight; FBW = Final body weight; CR = Cannibalism rate; MR = Mortality rate; SR = Survival rate BWG = Body weight gain; SGR = Specific growth rate; FCR = Feed conversion ratio; PER = Protein efficiency ratio; DLG = Daily lipid gain; PC= Cost per fish kg produced; PT= Time per fish kg produced; [#] Price in CFA pound: 100 CFA = 0.15 $ based on 2006 exchange prices in Ivory Coast

Table 3: Final composition of *Heterobranchus longifilis* fed with experimental diets (% on dry matter basis)

	Diets		
Parameters*	FD	MD	SD
Moisture	75.7±0.8	74.9±0.7	75.2±0.7
Ash	11.0±0.4[b]	8.2±0.2[a]	12.2±0.7[c]
Crude protein	59.8±0.5	59.9±0.5	59.9±0.5
Crude fat	25.1±0.8[a]	30.6±0.4[b]	24.1±0.4[a]
Gross energy (kJg^{-1} diet)	23.7±0.2[b]	25.4±0.1[c]	23.3±0.1[a]

*Values are mean±SD of triplicate analysis. Values in the same row with the same superscripts are not significantly different (p≥0.05)

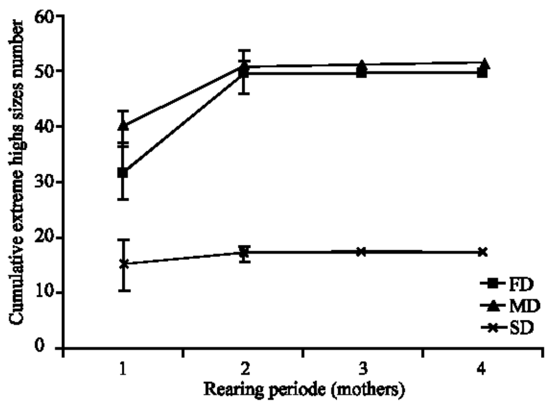

Fig. 1: Cumulative extreme highs sizes number of *Heterobranchus longifilis* fed with experimental diets. Values are means of triplicate groups. FD = Fish diet; MD = Mixture diet; SD = Soya diet

the diets (p<0.05). The highest values (p<0.05) of fish ash content were observed in fish fed SD; the lowest values were obtained with those fed MD. The body lipid content was higher (p<0.05) with fish fed MD followed by FD and SD. The similar trend was observed in carcass energy content of fish (Table 3).

DISCUSSION

The substitution of animal protein with plant protein meals is a common practice in aquaculture (Akiyama, 1988). However, adding high percentages of plant products in fish diets can reduce palatability and acceptability and delay growth of fish (Watanabe *et al*., 1993). The higher growth performance exhibited by *H. longifilis* fed fish diet was in agreement with Adewumi (2006), who obtained higher growth performance with adult *C. gariepinus* fed fish meal based diets compared to ones fed soybean based diets. In contrary, Goda *et al*. (2007) observed a higher growth of *C. gariepinus* fed diets containing 75 and 100% soybean meal. For the fingerlings *H. longifilis*, the origin of dietary protein could be the one of the most important factors largely affecting growth; the need of fish protein for growth is probably higher. Fish meal remains an important protein component in diets because of its well-balanced amino acid profile, essential fatty acids, digestible energy, vitamins and minerals (Tacon, 1993; Abdelghany, 2003). The decrease of fish growth in group fed soya protein suggests a low utilization of soya protein that may be explained by reducing digestibility of the soybean meal ingredient in some aquatic species (Shiau *et al*., 1990; Webster *et al*., 1992). In fact, soybean meal can contain active anti metabolites that had been incompletely heat-processed, such as saponines (Wolf and Thomas, 1970; Garcia-Ulloa, 1998); trypsin inhibitors (Kakade *et al*., 1970; Ayet *et al*., 1996), indigestible carbohydrates and several compounds that may disturb the digestive process in fingerling fish (Storebakken *et al*., 2000). For ever evaluation of different types of soybean product derived from extraction technique should be carried out. Samocha *et al*. (2004) and El-Sayed (2006) reported that the co-extrusion of feed ingredients is considered as a reasonable option to improve the nutritional quality of soybean when it is used as a replacement ingredient in fish diets. However, Adewumi (2006) after autoclaving soybean meal during 25 minu at 116°C (pressure 1.2 kg Cm^{-2}) was obtained similar growth performance of *Clarias gariepinus* fed with fish meal and soybean based diets. Lowers growth performances recorded in fish fed soya protein diets could reveal an inadequate heat treatment used for producing soybean meal and finding an adequate heat treatment of soybean meal by favouring starch digestibility and reducing anti nutrients factors.

The good values of FCR (1.0-1.6) obtained in all fish groups could reflect the best quality and palatability of the diets formulated. The highest PER obtained in fish fed FD could means that in *H. Longifilis*, diets formulated with fish protein has higher quality and palatability than these formulated with soya protein.

Several studies showed that cannibalistic behaviour is intensified by increasing size difference (Hseu, 2002; Smith and Reay, 1991), suitable feeding practice (Fukuhara, 1989; Watanabe *et al*., 1996), inter individual contacts, competition of food and stress (Haylor, 1992; Barcellos *et al*., 2004). The highest cannibalism and mortality rates observed with SD have consequently reduced survival rate in this group. This result would demonstrate that soya protein diet can not cover sufficiently the nutritional need of this species. So the substitution of fish protein had directly increase fish mortality and cannibalism. However, cannibalism rates obtained in all diets would be due to raising competitiveness which gave higher fish (extremes high fish sizes) than others. Therefore, these higher fish preferred to eat the small other fish. In fish fed SD, lower number of the extreme high fish sizes was obtained, but in this group, high mortality was observed. However, the extreme high fish sizes were observed only during the first two months in all experiment diets. During this period, some fish often are reluctant to accept the feed, fail to eat and became weak and vulnerable as observed in the catfish *C. gariepinus* (Baras and Almeida, 2001). In added, fish may prefer to prey on other fish, which may decrease once the first adjust to reading on the diets provided. This could be also the cause of mortality. After this period, the sizes were homogenised, so the cannibalism were disappeared and the mortality was reduced consequently. The proximate composition such as moisture and protein of carcass were similar in all diets. Higher values of carcass lipid were obtained in fish fed MD contrary to the higher values of dietary lipid which were given by SD. The higher values of carcass ash were obtained also in fish fed SD contrary to the high dietary ash which was given by FD. In other studies, Goda ***et al.*** (2007) reported that catfish *C. gariepinus* fed 100% soybean meal recorded higher lipid and gross energy contents compared with the fish meal based diet.

CONCLUSION

The reduction of fish growth and the increase of cannibalism rate obtained with soya protein diets suggest a low utilization of soya protein in *H. longifilis* fingerlings. In add, supplementing soya protein based diet entrains diminution of diet cost but increase the cost and time of kg fish produced. Therefore, it is matter of urgency that used adequate heat treatment of soybean meal by favouring starch digestibility and reducing anti nutrients factors. However, better characterization of these ingredients, digestible amino acid composition and fine-tuning of the diet formulation is required to obtain levels of performance matching those of high fish meal diets.

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REFERENCES

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

Adewumi, A.A., 2006. The growth and gonadal maturation of the African catfish, *Clarias gariepinus* (Burchell) broodstock fed differently heated soybean-based diets. Aquacu. Nutr., 12: 267-274.

Akiyama, D., 1988. Soyabean meal utilization by marine Shrimp. AOAC World Congress on Vegetable Protein Utilization in Human Food and Animal Feedstuffs, Am. Soya bean Asso. Singapore, pp: 27.

Aminot, A. and M. Chaussepied, 1983. Manuel des analyses chimiques en milieu marin. Centre National pour l'Exploitation des Océans (CNEXO), Jouve Paris, pp: 395.

AOAC (Association of analytical chemists), 1995. Official methods of analysis. 16th Edn. Association of Analytical Chemists, Arlington, Virginia, USA.

Ayet, G., M. Muzquiz, C. Burbano, L. M. Robredo, C. Cuadrado and K.R. Price, 1996. Determinations of saponins in the main legumes cultivated in Spain. Food Sci. Technol., 2: 95-100.

Baras, E. and A.F. D'Almeida, 2001. Size heterogeneity prevails over kinship in shaping cannibalism among larvae of sharptooth catfish *Clarias gariepinus.* Aquatic Living Res., 14: 251-256.

Barcellos, L.J.G., L.C. Kreutz, M.R. Quevedo, I. Fioreze, L. Cericato, M. Soso, A.B. Fagundes, J. Conrad, R.K. Baldissera, A. Bruschi and F. Ritter, 2004. Nursery rearing of *Rhamdia quelen* (Quoy and Gaimard) in cages: Cage type, stocking density and stress response to confinement. Aquacul., 232: 383-394.

Bard, J., P. De Kimpe and P. Lessent, 1976. Nouveaux poissons et nouvelles méthodes d'élevage en Afrique. FAO/CIFA Technical Paper Proceedings, Symposium on Aquaculture in Africa. Accra, Ghana, pp: 365-372.

Boyd, C.E. and C.S. Tucker, 1998. Water Quality and Pond Soil Analysis for Aquaculture. Alabama Agricultural Experiment Station. Alabama, USA., pp: 0700.

Craig, S.R., 2004. Organic agricultural feed. Aqua Feeds: Formulation and beyond, 1: 11-13.

El-Sayed, A.M., 1990. Long term evaluation of cottonseed meal as a protein source for Nile tilapia *Oreochromis niloticus* (L). Aquacul., 84: 315-320.

El-Sayed, A.M., 2006. Tilapia Culture. CABI Publishers. Wallingford, UK.

Fukuhara, O., 1989. A review of the culture of grouper in Japan. Bull. Nansei Region Fish. Res. Lab., 22: 47-57.

Garcia-Ulloa, G.M., 1998. Uso de harinas derivadas de subproductos agrícolas para la producción de biomasa del *Branquiopodo artemia* franciscana, Kellog, 1906. PhD Thesis, Universidad de colima, mexico, pp: 140.

Goda, A.M., E.R. El-Haroun and M.A. Kabir Chowdhury, 2007. Effect of totally or partially replacing fish meal by alternative protein sources on growth of African catfish *Clarias gariepinus* (Burchell, 1822) reared in concrete tanks. Aquacul. Res., 38: 179-287.

Haylor, G.S., 1991. Controlled hatchery production of *Clarias gariepinus* (Burchell, 1822): Growth and survival of fry at high stocking density. Aquatic Fish. Manag., 22: 405-422.

Haylor, G.S., 1992. Controlled hatchery production of *Clarias gariepinus* (Burchell, 1822): Growth and survival of fry at high stocking density. Aquatic Fish. Manage., 23: 303-314.

Hecht, T. and A. Appelbaum, 1988. Observations on intraspecific aggression and coeval sibling cannibalism by larval and juvenile *Clarias gariepinus* (Clariidae: Pisces) under controlled conditions. J. Zool., 214: 21-44.

Hem, S., M. Legendre, L. Trébaol, Cissé A., Z. Otémé and Y. Moreau, 1994. L'aquaculture, In: Dufour, P., J.R. Durand and S.G. Zadi (Eds.). Environnement and Ressources Aquatiques de Côte d'Ivoire. 2-Les milieux Saumâtres: L'Exemple de la Lagune Ebrié), pp: 455-505.

Hseu, J.R., 2002. Effects of size difference and stocking density on cannibalism rate of juvenile grouper *Epinephelus coioides.* Fish. Sci., 68: 1384-1386.

Kakade, M.L., D.H. Swenson and I.E. Liener, 1970. Note on the determination of chymotrypsin and chymotripsin inhibitor activity using casein. Anal. Biochem., 33: 255-258.

Keembiyehetty, C.N. and D.M. Gatlin, 1997. Performance of sunshine bass fed soybean-meal based diets supplemented with different methionine compounds. Prog. Fish. Cult., 59: 25-30.

Legendre, M., 1983. Examen préliminaire des potentialités d'un silure Africain *Hetebranchus longifilis* (Valenciennes, 1840) pour l'aquaculture en milieu lagunaire. Document Scientifique. Centre de Recherches Océanographiques d'Abidjan, 14: 97-107.

Legendre, M., 1986. Seasonal changes in sexual maturity and fecundity and HCG-induced breeding of the catfish, *Heterobranchus longifilis* Val. (Clariidae), reared in Ebrié Lagoon (Ivory Coast). Aquacul., 55: 201-213.

Legendre, M., 1989. Enquête préliminaire sur la consommation du silure *Hetebranchus longifilis* en Côte d'Ivoire. Archives scientifiques, Centre de Recherches Océanographiques d' Abidjan, 12: 1-12.

Luquet, P. and Y. Moreau, 1989. Energy-protein management by some warmwater finfishes, In: Actes du Colloque N°9. AQUA COP, Advances in tropical aquaculture, Tahiti, Ifremer, pp: 751-755.

Micha, J.C., 1973. Etude des populations piscicoles de l'Ubangui et tentatives de sélection and D'adaptation de quelques espèces à l'étang de pisciculture. C.T.F.T., Division de Recherches en Pisciculture, Paris, France, pp: 110.

Otémé, Z.J., S. Hem and M. Legendre, 1996. Nouvelles espèces de poissons-chats pour le développement de la pisciculture Africaine, In: M. Legendre and J.P. Proteau (Eds.). The biology and culture of Catfishes, Aquatic Living Res., 9: 207-217.

Robinson, E.H. and M.H. Li, 1994. Use of plant proteins in catfish feeds. Replacement of soybean meal with cottonseed meal and replacement of fish meal with soybean meal and cotton seed meal. J. Wold Aquacul. Soc., 25: 271-276.

Rumsey, G.L., 1993. Fish meal and alternative sources of protein. Fish., 18: 14-19.

Samocha, M.S., D.A. Davis, I.P. Saoud and K. De Bault, 2004. Substitution of fish meal by co-extruded soybean poultry by-product meal in practical diets for the pacific white shrimp, *Litopenaeus vannamei.* Aquacul., 231: 197-203.

Shiau, S.Y., S.F. Lin, S.L. Yu, A.L. Lin and Ch.Ch. Kwok, 1990. Defatted and full fat Soya bean meal as partial replacements for fish meal in tilapia (*Oreochromis niloticus* x *O.aureus*) diets at low protein level. Aquacul., 86: 401-407.

Smith C. and P. Reay, 1991. Cannibalism in teleost fish. Rev. Fish. Biol., 1: 41-64.

Storebakken, T., S. Refstie and B. Ruyter, 2000. Soy products as fat and protein sources in fish feed for intensive aquaculture, In: Drackley, J.K. (Eds.). Soy in Anim. Nutr. Fed. Anim. Sci. Soc. Savoy, IL, USA., pp: 127-170.

Tacon, A.G.J., 1993. Feed ingredients for Warmwater Fish: Fish Meal and Other Processed Feedstuffs. FAO Fish Circ. No. 856, FAO Rome, Italy.

Watanabe, T., J. Pongmaneerat, S. Satoh and T. Takeuchi, 1993. Replacement of fish meal by alternative protein sources in rainbow trout diets. Nippon Suisan Gakkaishi, 59: 1573-1579.

Watanabe, W.O., S.C. Ellis, E.P. Ellis and V.G. Lopez, 1996. Evaluation of first-feeding regimens for larval Nassau grouper *Epinephelus striatus* and preliminary, pilot-scale culture through metamorphosis. J. Aquacul. Soc., 27: 323-331.

Webster, C.D., J.H. Tidwell, L.S. Goodgame, D.H. Yancey and L. Mackey, 1992. Use of soyabean meal and distillers grains with solubles as partial or total replacement of fish meal in diets for channel catfish, *Ictalurus punctatus*. Aquacul., 106: 301-309.

Wolf, W.J. and B.W. Thomas, 1970. Thin layer and anion exchange chromatography of soyabean saponin. J. Am. Oil Chem. Soc., 47: 86-90.