African Journal of Biotechnology Vol. 10(66), pp. 14990-14998, 26 October, 2011
Available online at http://www.academicjournals.org/AJB
DOI: 10.5897/AJB10.1449
ISSN 1684–5315 © 2011 Academic Journals

Full Length Research Paper

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.

Ahou Rachel Koumi[1,3], Kouamé Mathias Koffi[2], Boua Celestin Atsé[3]* and Lucien Patrice Kouame[1]

[1]Université d'Abobo-Adjamé Abidjan, UFR Sciences et Technologies des Aliments 02 BP 801 Abidjan 02, Côte d'Ivoire.
[2]Université de Cocody Abidjan, UFR Biosciences 22 BP 582 Abidjan 22, Côte d'Ivoire.
[3]Centre de Recherches Océanologiques BPV 18 Abidjan, Côte d'Ivoire.

Accepted 19 September, 2011

The effects of substitution dietary fish protein by soybean protein on growth, survival, biochemical composition and mineral composition of juvenile *Heterobranchus longifilis*, *Sarotherodon melanotheron* and *Oreochromis niloticus* were evaluated. Three diets were formulated to be isonitrogenous (35% crude protein) by substituting fish meal for soybean meal at levels of 0 (FM), 25 (SBM25) and 50% (SBM50). Diets were fed to triplicate groups of each species at ratio of 5% body weight. At the end of the study period, final body weight (FBW), final body length (FBL), specific growth rate (SGR) and protein efficiency ratio (PER) decreased with an increasing dietary soybean protein level in *H. longifilis*. Survival rate (SR) was 1.5 times lower in juvenile catfish fed SBM50 (29.3%) than FM- and SBM25-fed fish (44%). *S. melanotheron* fed all three diets had no significant difference in FBW, FBL, SGR, SR, FCR, PER or production time. In *O. niloticus*, SR, FCR and PER were not affected by dietary protein substitution level. However, FBW, FBL and SGR increased with an increasing dietary soybean protein level. The production time generally showed a decline at lower protein substitution levels. The production cost was significantly lower in fish fed SBM50. Proximate composition analysis indicated that the carcass moisture in the three species and carcass protein content in *H. longifilis* and *O. niloticus* were not affected by dietary protein source. In *S. melanotheron*, carcass protein content showed a decline in fish fed SBM50. Carcass lipid, ash and gross energy levels in these species were also significantly affected by dietary protein sources. Carcass calcium and phosphorus concentrations in fish were significantly reduced with a high inclusion of dietary soybean meal. The results of this study indicated that fish meal can be replaced with soybean meal up to 50% level in diets for Tilapia *S. melanotheron* without adverse effects on growth, nutrient utilization or nitrogen balance.

Key words: Fish protein, soya protein, growth, feed efficiency, proximate composition, mineral composition.

INTRODUCTION

Nile tilapia *Oreochromis niloticus*, black-chinned tilapia *Sarotherodon melanotheron* and African catfish *Heterobranchus longifilis* are the major species used in intensive aquaculture in Ivory Coast because of their rapid growth, ready acceptance of artificial diets and resistance to disease (Atsé et al., 2009). Moreover, fish meal which is a primary protein source of the fish diets is the major constraint of the intensive aquaculture development. In fact, this feedstuff has a well balanced essential amino acid profile, essential fatty acids, digestible energy, vitamins, minerals and good palatability (El-Saidy and

*Corresponding author. E-mail: atse_boua_ celestin@ hotmail. com.

Gaber, 2003; Wu et al., 2004; Tacon and Metian, 2008). However, it is expensive, usually unavailable in developing countries and the use of fish meal in the aquaculture feeds causes phosphorus pollution (Phromkunthong and Udom, 2008; Cahu et al., 2009).

Currently, plant proteins such as soybean meal, linseed meal, sunflower meal and cottonseed meal are usually used to partially or totally replace fish meal in the fish diets. In these proteins, soybean meal has one of the most plant proteins used for substituting fish meal in the world (Yigit et al., 2010). This ingredient has high protein content, relatively well balanced amino acid profile, reasonable price and it is available in many countries (Kumar et al., 2010; Oso et al., 2011). However, nutrients composition such as protein ratio, amino acid content, lipid profile ratio, ash ratio and mineral content of fish meal and soybean meal are different. These differences in raw materials could influence growth, feed utilisation and fish carcass composition (Tomás et al., 2005). Moreover, there is a variation in the use of soybean for different fish species.

A number of studies on the utilization of soybean meal as a partial or complete replacement for fish meal in of teleost fish diets have been reported (Wu et al., 2004; Tocher et al., 2008; Kumar et al., 2010). For *H. longifilis* and *Sarotherodon melanotheron*, very few studies reported the substitution of fish protein by soya protein in diets. The incorporation of soya protein in fish diet could reduce the cost of diet and improve growth (Akinrotimi et al., 2007). The aim of this study was therefore to investigate the influence of partial or total substitution of fish protein by soya protein on growth and feed efficiency and carcass mineral composition of three West African aquaculture species.

MATERIALS AND METHODS

Experimental diets

Three practical diets (isonitrogenous) on a crude protein of 35% were formulated with commercially available ingredients. Carcass fish meal (59.5% crude protein) was the tuna protein source in the control diet. The test diets were formulated by substituting fish meal for soybean meal (45.5% crude protein) at levels of 0 (FM), 25 (SBM25) and 50% (SBM50) replacement. Ingredients and chemical composition of the diets are presented in Table 1. To prepare the diets, practical ingredients were ground into small particle sizes (approximately 250 µM) in a Wiley mill. All dry ingredients were mixed together with 1% fish oil (FM) and soya oil (SBM25 and SBM50) in a food mixer for 15 min. Lysine and methionine at 0.5% and premix vitamin and mineral supplemented at 2% were added to the test diets. Thereafter tap water was blended into the mixture to attain a consistency appropriate passing through a meat grinder with 0.5 to 3 mm holes die. After pelleting, the diets were dried to moisture content of 80 to 100% and stored at -20°C until use. The diet containing fish meal (FM) as the main source of protein was considered as the reference diet. More also, the cost of each diet was determined by multiplying the contributions of each diet ingredient by their cost per kilogram and summing the values obtained for all the ingredients (Table 1).

Experimental procedure

Hatchery reared African catfish *H. longifilis* fingerlings with mean initial weight of 0.2 ± 0.0 g, black-chinned tilapia *S. melanotheron* juveniles (11.9 ± 0.4 g), and Nile tilapia *O. niloticus* juveniles (11.6 ± 4.2 g) were obtained from the Experimental Aquaculture Station of Layo (5°19′N, 4°19′W), Ivory Coast. Prior to the experiments, the fish were acclimatized two weeks into tanks and fed a commercial fish meal-based diet (35% crude protein) to satiation. Experimental fish were then randomly distributed into 9 identical 4 m^3 tanks for each growth experiment per fish species (40 fish per tank with three replicate tanks per treatment for *S. Melanotheron* and *O. niloticus* and 500 fish per tank for *H. longifilis*). Fish were fed a ratio of 5% body weight three times daily (08:00, 12:00 and 17:00 h). All fish in each tank were individually weighed at the start of the experiments, every month, and at the end of the experiments (180 days). At the end of the trials, ten fishes per tank were randomly withdrawn for analysis of fish carcass composition and calculation of nutrient retention rates.

Growth performance, feed efficiency and production parameters

All calculations were performed for each fish individually in each tank at the end of the trials as follows:

Specific growth rate = (ln final weight – ln initial weight) / number of days
Survival rate = (Final number of fish / initial number of fish) x 100
Feed conversion ratio = dry feed intake (g) / weight gain (g)
Feed efficiency ratio = [wet weight gain (g) / dry feed intake (g)] x 100
Protein efficiency ratio = weight gain (g) / protein intake (g)
Production time = Experimental period (days) / weight of fish produces (kg)
Production cost = Cost of feeding (CFA) / weight of fish produces (kg)

Carcass composition analysis

The proximate composition of diet ingredients, diets and fish carcass (whole body fish excluding viscera) were determined using the standard methods of the AOAC (2003) as follows: dry matter 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 in a Soxhlet system, ash by incineration in a muffle furnace at 550°C for 24 h, while nitrogen-free extract (NFE) was calculated by difference. The gross energy contents of the diets and the fish were calculated on the basis of their crude protein, lipid and carbohydrate contents using the equivalents of 22.2, 38.9 and 17.15 kJ g^{-1} respectively (Luquet and Moreau, 1989). Experimental diets and fish were analysed for mineral composition (calcium, phosphorus, potassium, sodium, magnesium, iron, zinc, manganese and copper), using microwave digestion and atomic absorption spectrophotometer (Varian SAA 110) air-acetylene flame (AOAC, 2003). All the samples were analyzed in triplicate and the mean of each value were taken. Proximate and mineral compositions of the experimental diets are given in Table 1.

Statistical analysis

All data collected were subjected to one-way analysis of variance(ANOVA) and the significance of the differences between means was tested using Duncan's multiple range test ($P < 0.05$). Statistical version 7.1 software (Statsoft, Tulsa, OK, USA) was used

Table 1. Ingredients (gkg^{-1}), proximate and mineral compositions (dry matter basis) of diets used in the experiment.

Ingredient	Experimental diet		
	FM	SBM25	SBM50
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 (%)[b]			
Moisture	10.8 ± 0.1	10.7 ± 0.1	10.5 ± 0.2
Crude protein	35.5 ± 0.5	35.6 ± 1.3	35.6 ± 0.9
Total nitrogen	5.7 ± 0.1	5.7 ± 0.2	5.7 ± 0.3
Crude fat	9.2 ± 9.2	8.3 ± 0.9	12.9 ± 1.0
Ash	12.1 ± 1.1	9.5 ± 0.6	7.4 ± 0.7
Crude fibre	8.4 ± 0.4	8.4 ± 0.2	8.8 ± 0.3
Carbohydrate content[c]	23.3 ± 0.3	27.5 ± 0.8	24.8 ± 0.6
Gross energy (kJ g $diet^{-1}$)[d]	15.5 ± 0.2	15.9 ± 0.7	17.2 ± 0.5
Cost (CFA kg^{-1})[e]	260	225	195
Mineral composition			
Calcium (g kg^{-1})	33.9 ± 2.0	18.7 ± 0.1	14.2 ± 1.5
Phosphor (g kg^{-1})	10.2 ± 0.3	7.4 ± 0.4	5.2 ± 1.1
Potassium (g kg^{-1})	6.5 ± 0.2	8.1 ± 0.4	12.3 ± 0.7
Sodium (g kg^{-1})	6.0 ± 0.3	6.2 ± 0.2	7.4 ± 0.6
Magnesium (g kg^{-1})	2.5 ± 0.3	2.7 ± 0.1	2.6 ± 0.1
Iron (mg kg^{-1})	371.3 ± 3.5	640.0 ± 17.3	970.0 ± 50.0
Zinc (mg kg^{-1})	243.0 ± 43.0	121.0 ± 9.0	133.3 ± 25.2
Manganese (mg kg^{-1})	81.0 ± 2.0	79.0 ± 2.5	82.0 ± 5.0
Copper (mg kg^{-1})	37.3 ± 2.6	36.3 ± 5.5	32.0 ± 8.0

[a]Vitamin and mineral mixture; each 1 kg of mixture contains: 4800 I.U. Vit A, 2400 IU cholecalciferol (vit. D), 40 g 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), 150mg; 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] Carbohydrate content = 100 – (% moisture + % protein + % fat + % fibre + % ash). [d] Gross energy = (22.2 × protein + 38.9 × fat + 17.2 × Carbohydrate content). [e]Price in CFA pound: 100 CFA = 0.22 $ based on 2011 exchange prices in Ivory Coast.

for determining the level of significance and values are expressed as means ± standard deviation.

RESULTS

Growth performance, feed efficiency and production parameters

Mean final body weights (FBW), final body length (FBL), specific growth rate (SGR), survival rate (SR), feed conversion ratio (FCR), protein efficiency ratio (PER), production cost (PC) and production time (PT) of *H. longifilis, O. niloticus* and *S. melanotheron* fed different diets are shown in Table 2. Growth performance (FBW, FBL, SGR) and protein efficiency ratio (PER) of juvenile African catfish *H. longifilis* decreased with the increasing of the soybean meal incorporations in feed. We observed that SBM50-fed juvenile catfish had 1.5 times lower survival rate (29.3%) than FM-fed and SBM25-fed fish (44%). In contrast FCR, PC and PT of juvenile catfish fed with the SBM50 diet were significantly higher ($P<0.05$) than those of fish fed FM and SBM25. In this species, the mortality was higher for fish fed SBM50. In *S. melanotheron,* the substitution of dietary fish meal by soybean meal did not affect the growth performance and the feed efficiency parameters. Survival in this species was not significantly different ($P>0.05$) among the experimental groups, even through a slight increase was observed when dietary soybean meal increase.

On the other hand, inclusion of soybean meal up to 50% into Black-chinned tilapia diet resulted in a lower production cost ($P<0.05$) as compared to the FM and SBM25 diets (Table 2, $P<0.05$). In this species, production time (PT) was not significantly different ($P>0.05$) among the experimental groups. In Nile tilapia *O. niloticus*, there was no significant difference ($P>0.05$) among the survival rate (SR), FCR and PER between the dietary groups although fish fed diets SBM25 and SBM50 showed significantly ($P<0.05$) lower SGR values than that of FM diet (Table 2). FBW and FBL values of *O. niloticus* decreased with the increasing level of soybean meal in diet. The best FBW and FBL were observed in fish fed FM. Production time (PT) of *O. niloticus* increased with high level of soybean meal in diet. Fish fed FM and SBM25 diets resulted in significantly higher production cost (PC) than those fed SBM50 diet.

Carcass nutrient composition

Carcass proximate composition of *H. longifilis*, *O. Niloticus* and *S. melanotheron* at the end of the experiments is given in Table 3. No significant difference in carcass moisture content was observed between the three fish species fed with different dietary protein sources. The carcass crude protein content of *H. longifilis* and *O. niloticus* did not show any significant difference among the experimental groups. In contrast, *S. melanotheron* fed SBM50 had the significantly lowest values of carcass crude protein (54.2%) than those fed the FM and SBM25 (58.2%). *H. longifilis* fed SBM25 diet had the highest significant ($P<0.05$) values of carcass lipid (30.6%) and energy (25.2 kJg^{-1}) and lowest values of ash (8.2%). There was no significant difference between the carcass lipid contents and energy of both *S. melanotheron* and *O. niloticus* fed FM and SBM25, which were significantly lower than that of fish fed SBM50. For these two species of fish, ash carcass contents decreased in fish fed the diets with soybean meal inclusion unlike the carcass energy which increased with soybean protein high level in diet.

Mineral composition

At the end of the feeding trial, there was no significant difference between the carcass Ca^{2+} and P^{2-} contents of both *H. Longifilis* and *S. melanotheron* fed FM and SBM25 diets which were significantly higher than those of fish fed SBM50 diet (Table 4). For *O. niloticus*, carcass Ca^{2+} tended to decrease significantly as dietary soybean meal increased (Table 4). *H. longifilis* fed the FM and SBM25 diets had significantly higher values of carcass K^+ contents than those of fish fed the SBM50 diet (Table 4). The highest carcass Zn^{2+} values had been noted with *H. longifilis* fed the FM diet. In S. *melanotheron*, the carcass Mg^{2+} levels of fish fed SBM25 and SBM50 diets were higher than those of fish fed the control diet. Overall, the carcass Na^+, Fe^{2+}, Mn^{2+} and Cu^{2+} of fish species *H. longifilis*, *S. melanotheron* and *O. niloticus* did not show any significant difference among the experimental groups. The Mg^{2+} values of *H. longifilis* and *O. niloticus* also showed the similar tends (Table 4).

DISCUSSION

The growth data of *H. longifilis* and *O. niloticus* were affected by both the nature and the levels of dietary protein source contrary to *S. melanotheron*. Maximizing the utilization of dietary protein for growth is related to both the dietary inclusion level of protein and the availability of non-protein energy sources, such as lipid and/or carbohydrate (Ergün et al., 2008). Inclusion of non-protein energy has been shown to spare dietary protein from catabolism to provide energy and enhance its utilization for growth (Ergün et al., 2008; Ghanawi et al., 2011). For *H. longifilis* feeds, utilisation parameters were also influenced by the dietary protein source. For this fish, fish meal could be the most important dietary protein sources because *H. longifilis* is both omnivorous and carnivorous, and hence needed the highest fish protein for growth. Moreover, the decreasing growth of *H. longifilis* and *O. niloticus* fed with soya protein diet could be due to the quantity and the quality of soybean meal

Table 2. Growth performance, feed utilization and production parameters of *Heterobranchus longifilis, Oreochromis niloticus* and *Sarotherodon melanotheron* fed with formulated diets.

Species	Parameter	Formulated diet			F-max	P
		FM	SBM25	SBM50		
Heterobranchus longifilis	Initial body Weight (g)	0.15 ± 0.01^{a}	0.15 ± 0.01^{a}	0.15 ± 0.01^{a}	-	-
	Final body Weight (g)	133.2 ± 52.7^{c}	74.6 ± 30.80^{b}	52.1 ± 25.6^{a}	98.94	0.000000
	Final body Length (g)	24.7 ± 3.2^{c}	20.7 ± 3.5^{b}	17.9 ± 3.2^{a}	88.243	0.000000
	Specific growth rate (%/j)	5.6 ± 0.3^{c}	5.2 ± 0.1 ^{b}	4.8 ± 0.4 ^{a}	5.294	0.047
	Survival rate (%)	43.9 ± 1.3^{b}	44.0 ± 6.0^{b}	29.3 ± 3.5^{a}	12.876	0.007
	Feed conversion ratio	1.0 ± 0.1^{a}	1.2 ± 0.0^{a}	1.6 ± 0.2^{b}	13.885	0.006
	Protein efficiency ratio	2.9 ± 0.2^{c}	2.4 ± 0.1^{b}	1.8 ± 0.3^{a}	19.934	0.002
	Production cost (CFA/kg)	258.3 ± 19.3^{a}	268.3 ± 6.6^{a}	302.4 ± 4.2^{b}	10.603	0.011
	Production time (days/kg)	13.9 ± 2.7^{a}	20.2 ± 3.3^{a}	86.5 ± 10.5^{b}	114.226	0.000017
Sarotherodon melanotheron	Initial body Weight (g)	11.9 ± 0.3^{a}	11.9 ± 0.5^{a}	11.9 ± 0.6^{a}	-	-
	Final body Weight (g)	133.8 ± 6.3^{a}	125.5 ± 10.6^{a}	124.3 ± 9.9^{a}	0.953	0.437
	Final body Length (g)	23.6 ± 1.0^{a}	23.2 ± 0.9^{a}	23.7 ± 0.4^{a}	0.7852	0.4592
	Specific growth rate (%/j)	1.3 ± 0.02^{a}	1.3 ± 0.03^{a}	1.3 ± 0.04^{a}	0.433	0.668
	Survival rate (%)	84.2 ± 9.5^{a}	87.5 ± 4.3^{a}	91.7 ± 1.4^{a}	1.9010	0.2294
	Feed conversion ratio	2.4 ± 0.7^{a}	2.9 ± 0.3^{a}	2.4 ± 0.3^{a}	1.484	0.299
	Protein efficiency ratio	1.3 ± 0.4^{a}	1.0 ± 0.1^{a}	1.2 ± 0.1^{a}	1.261	0.349
	Production cost (CFA/kg)	580.4 ± 24.1^{b}	643.1 ± 38.4^{b}	449.1 ± 33.6^{a}	27.68	0.0009
	Production time (days/kg)	43.5 ± 3.1^{a}	46.2 ± 4.3^{a}	43.9 ± 3.9^{a}	0.441	0.662
Oreochromis niloticus	Initial body Weight (g)	11.6 ± 4.2^{a}	11.6 ± 4.2^{a}	11.6 ± 4.2^{a}	-	-
	Final body Weight (g)	221.9 ± 50.4^{c}	169.7 ± 32.6^{b}	140.7 ± 30.3^{a}	43.98	0.000000
	Final body Length (g)	22.2 ± 1.6^{c}	20.4 ± 1.3^{b}	19.1 ± 1.4^{a}	43.9801	0.000000
	Specific growth rate (%/j)	1.6 ± 0.1^{b}	1.5 ± 0.04^{a}	1.4 ± 0.1^{a}	7.162	0.026
	Survival rate (%)	71.3 ± 12.2^{a}	76.0 ± 9.2^{a}	67.3 ± 6.4^{a}	0.4339	0,6668
	Feed conversion ratio	1.1 ± 0.2^{a}	1.2 ± 0.04^{a}	1.2 ± 0.1^{a}	1.207	0.363
	Protein efficiency ratio	2.7 ± 0.4^{a}	2.4 ± 0.1^{a}	2.3 ± 0.2^{a}	1.605	0.277
	Production cost (CFA/kg)	278.3 ± 46.2^{b}	270.9 ± 9.6^{b}	235.1 ± 25.8^{a}	54.275	0.0001
	Production time (days/kg)	26.0 ± 1.0^{a}	31.1 ± 0.8^{b}	43.1 ± 5.6^{c}	38.547	0.00038

*Values are means ± SD. Values in the same row with different superscripts are significantly different ($P < 0.05$)

used in the SBM25 and SBM50 diets.

Soy meal contains anti-nutritional compounds that influence feed intake, growth and protein retention (Storebakken et al., 2000). Replacement of fish meal with soybean meal up to 50% in Nile tilapia *O. niloticus* and African catfish *H. longifilis* feed lowered growth, primarily by lowering protein efficiency ratio (PER) and secondary increasing feed conversion ratio (FCR). In contrast, soybean meal levels of 25% or more have little or no effect on Black-chinned tilapia *S. melanotheron* growth performances. Replacement of fish meal with soybean meal at levels between 20 and 50% in the diet has variable effects on growth, depending on the study (Refstie et al., 2000). This variance is perhaps associated with the specific requirement, the synthesis ability or the enzymatic equipment of fish. Thus, studies involving partial or total replacement of fish meal with soybean meal in diets for different fish species are difficult to compare. The higher growth performance exhibited by *H. longifilis* fed fish diet was in agreement with Toko et al. (2008), who obtained higher growth performance with same species fed fish meal diet in comparison with ones fed soybean diet. In addition, Borgeson et al. (2006) had reported that substituting fish protein with plant protein at higher levels of dietary protein reduces the growth for *O. niloticus*. The lowest values of FCR (FCR <2) associated to the best values of PER (PER>2) of fish fed diets with decreasing soybean meal inclusion resulted in a highest growth in *H. longifilis* and *O. niloticus*. In addition, there was a general decrease in FCR and increase in PER for fish fed FM diet compared to the SBM feed-fish. Such observation may be related to the fact that FCR decreases, while PER increases with increased feeding rate and growth (Chakraborty et al., 2011).

In *S. melanotheron,* feeding trials revealed that the sources and the levels of dietary protein appeared to be

Table 3. Carcass composition of *Heterobranchus longifilis*, *Oreochromis niloticus* and *Sarotherodon melanotheron* fed with formulated diets*(dry matter basis).

Species	Parameter	Formulated diet			F-max	P
		FM	SBM25	SBM50		
Heterobranchus longifilis	Moisture (%)	75.7 ± 0.8^a	74.9 ± 0.7^a	75.2 ± 0.7^a	0.827	0.482
	Crude protein (%)	59.8 ± 0.5^a	59.9 ± 0.5^a	59.9 ± 0.5^a	0.017	0.983
	Lipid (%)	25.1 ± 0.8^a	30.6 ± 0.3^b	24.1 ± 0.4^a	129.245	0.000012
	Ash (%)	11.0 ± 0.4^b	8.2 ± 0.2^a	12.2 ± 0.7^c	59.817	0.0001
	Gross energy (kJg^{-1})	23.1 ± 0.3^a	25.2 ± 0.2^b	22.7 ± 0.1^a	131.565	0.00001
Sarotherodon melanotheron	Moisture (%)	70.1 ± 4.3^a	70.1 ± 1.5^a	67.3 ± 0.8^a	1.171	0.372
	Crude protein (%)	58.2 ± 0.4^b	58.2 ± 0.3^b	54.2 ± 2.2^a	9.022	0.016
	Lipid (%)	16.9 ± 0.7^a	16.7 ± 1.2^a	23.2 ± 0.2^b	65.631	0.00008
	Ash (%)	20.0 ± 0.5^c	18.3 ± 1.1^b	16.5 ± 0.1^a	17.985	0.003
	Gross energy (kJg^{-1})	19.5 ± 0.3^a	19.4 ± 0.5^a	21.1 ± 0.6^b	12.619	0.007
Oreochromis niloticus	Moisture (%)	69.6 ± 1.4^a	69.1 ± 0.1^a	69.1 ± 0.3^a	0.3826	0.698
	Crude protein (%)	63.1 ± 0.03^a	63.0 ± 0.1^a	62.6 ± 0.5^a	2.407	0.171
	Lipid (%)	19.7 ± 0.2^a	20.5 ± 0.5^a	26.6 ± 0.6^b	180.367	0.000004
	Ash (%)	17.7 ± 0.6^c	15.3 ± 0.5^b	13.0 ± 0.01^a	88.539	0.00004
	Gross energy (kJg^{-1})	21.5 ± 0.3^a	22.0 ± 0.2^a	23.8 ± 0.6^b	105.750	0.000021

*Values are means ± SD. Values in the same row with different superscripts are significantly different ($P < 0.05$).

relatively unimportant for the growth. A similar result was observed by Goda et al. (2007) who observed comparable growth and feed utilization in tilapia *Sarotherodon galilaeus* fed soybean meal diet with those fish meal based diet. Since *S. melanotheron* is an herbivorous fish (Koné and Teugels, 2003), it could have the enzymatic equipment to use nutrient and energy provided by soybean meal.

More also, in the present study, the moisture content of fish carcass did not vary with experimental diets. On the contrary, protein, lipid, ash and energy were significantly influenced by the dietary protein source. Our results show a significant increase in *S. melanotheron* and *O. niloticus* carcass lipid contents with higher levels of soybean meal in diets. The rising lipid values obtained with tilapia fish fed SBM50 diet may be due to the highest lipid content (12.9%) observed in SBM50 diet. *A* similar result for carcass fat is reported by Abdelghany (2003) in *O. niloticus* and Goda et al. (2007) in *S. galilaeus*. The high fat and energy retention values in this group, clearly suggest that there were rising lipogenesis with high levels of fish meal replacements as reported by Kaushik et al. (2004) in European sea bass. In addition, Costanzo et al. (2011) showed dietary protein levels and sources as the major factors responsible for the species lipogenesis and lipid retention. In *H. longifilis* carcass, the changes of lipid, ash and energy levels did not reflect those of diets used in contrast with *S. melanotheron* and *O. niloticus*. These fish had a significant decrease in ash carcass with high levels of fish meal replacement. Normally, the ash content of good quality fishmeal averages between 17 and 25%, more ash indicates a higher mineral content, especially calcium, phosphorus, and magnesium (Costanzo et al., 2011).

Calcium and phosphorus constitute the majority of the ash found in fishmeal associated with the bone fraction (Sugiura et al., 2000). Ca and P were highly available and retained for the three species *H. longifilis*, *S. melanotheron* and *O. niloticus* fed with fish meal diet. Unlike the phosphorus in plants, phosphorus in fishmeal is in a form highly available to most animals (Tocher et al., 2008). Phosphorus is a nutritionally important mineral due to its requirement for growth, bone mineralization, and energy metabolism (Lall, 2002). Reduced growth was the main P deficiency sign observed in most fish species (Phromkunthong and Udom, 2008). However, the results of carcass mineral composition showed that Ca and P concentrations in *H. longifilis*, *S. melanotheron* and *O. niloticus* carcass were considerably reduced with high inclusion of dietary SBM. This could be due to the low levels of these minerals in soybean meal based diets. In fact, Ca and P are the dominant inorganic components in the whole fish and about 90% of Ca and 80% of P are found in the bones (Hertrampf and Piedad-Pascual, 2000). Thus, fish meal Ca and P contents are more important than those of soybean meal. The phosphorus in plants is not as readily available to fish because it is primarily in the organic form known as phytic acid (Lall, 2002). Moreover, phytic acid readily chelates di- and trivalent cations such as calcium and zinc, thus reducing the availability of these minerals (Watanabe et al., 1997; Yigit et al., 2010).

Table 4. Carcass mineral composition (dry matter basis) of *Heterobranchus longifilis*, *Oreochromis niloticus* and *Sarotherodon melanotheron* fed with formulated diets*.

Species	Parameter	Formulated diet FM	SBM25	SBM50	F-max	P
Heterobranchus longifilis	Calcium (g kg^{-1})	19.2 ± 0.8^{b}	18.7 ± 0.7^{b}	12.4 ± 0.4^{a}	89.388	0.000034
	Phosphor (g kg^{-1})	19.7 ± 0.4^{b}	19.1 ± 0.5^{b}	12.5 ± 0.9^{a}	56.2985	0.000129
	Magnesium (g kg^{-1})	18.9 ± 0.5^{a}	18.6 ± 0.4^{a}	18.7 ± 0.4^{a}	0.4935	0.6332
	Potassium (g kg^{-1})	2.2 ± 0.3^{a}	2.0 ± 0.2^{a}	5.3 ± 0.2^{b}	143.2990	0.000009
	Sodium (g kg^{-1})	1.2 ± 0.2^{a}	1.1 ± 0.1^{a}	1.1 ± 0.1^{a}	0.1041	0.9028
	Iron (mg kg^{-1})	701.1 ± 18.3^{a}	706.1 ± 10.0^{a}	706.3 ± 9.1^{a}	0.1552	0.0012
	Zinc (mg kg^{-1})	121.0 ± 6.2^{b}	92.5 ± 5.7^{a}	88.9 ± 6.2^{a}	25.5470	0.0012
	Manganese (mg kg^{-1})	17.8 ± 8.5^{a}	18.5 ± 8.5^{a}	18.2 ± 8.9^{a}	0.0050	0.995
	Copper (mg kg^{-1})	113.3 ± 13.3^{a}	103.3 ± 6.8^{a}	107.4 ± 4.7^{a}	0.9318	0.4442
Sarotherodon melanotheron	Calcium (g kg^{-1})	18.4 ± 0.0^{b}	18.4 ± 0.1^{b}	16.2 ± 0,0^{a}	2439.244	0.0000
	Phosphor (g kg^{-1})	17.3 ± 0.3^{b}	17.3 ± 0.4^{b}	14.2 ± 0.1^{a}	150.337	0.000007
	Magnesium (g kg^{-1})	10.6 ± 0.1^{a}	12.4 ± 0.5^{b}	12.6 ± 0.6^{b}	18.310	0.0028
	Potassium (g kg^{-1})	3.4 ± 0.1^{a}	3.2 ± 0.5^{a}	3.3 ± 0.6^{a}	0.801	0.491
	Sodium (g kg^{-1})	11.0 ± 0,1^{a}	11.0 ± 0.2^{a}	11.0 ± 0.0^{a}	0.042	0.9596
	Iron (mg kg^{-1})	556.3 ± 14.8^{a}	524.3 ± 56.6^{a}	540.3 ± 43.0^{a}	0.437	0.665
	Zinc (mg kg^{-1})	61.9 ± 2.2^{a}	64.3 ± 5.9^{a}	62.0 ± 2.7^{a}	0.358	0.713
	Manganese (mg kg^{-1})	8.4 ± 0.6^{a}	8.0 ± 1.0^{a}	8.7 ± 0.6^{a}	0.596	0.5804
	Copper (mg kg^{-1})	363.3 ± 32.2^{a}	370.0 ± 45.6^{a}	366.7 ± 57.7^{a}	0.016	0.9842
Oreochromis niloticus	Calcium	18.3 ± 0.6^{c}	15.2 ± 0.2^{b}	7.5 ± 0.5^{a}	505.4501	0.000000
	Phosphor	17.2 ± 0.2^{b}	12.7 ± 0.8^{a}	12.3 ± 0.2^{a}	102.8548	0.000023
	Magnesium	11.4 ± 0.4^{a}	11.2 ± 0.5^{a}	11.1 ± 0,3^{a}	0.0899	0.9152
	Potassium	3.1 ± 0.1^{a}	2.9 ± 0.1^{a}	3.1 ± 0.0^{a}	2.415	0.1700
	Sodium	1.1 ± 0.2^{a}	1.0 ± 0.1^{a}	1.2 ± 0.2^{a}	0.0029	0.9971
	Iron	600.3 ± 51.4^{a}	570.7 ± 50.3^{a}	580.3 ± 45.4^{a}	0.2807	0.7647
	Zinc	83.0 ± 5.4^{a}	82.3 ± 7.6^{a}	78.0 ± 2.1^{a}	0.2835	0.7627
	Manganese	13.9 ± 4.1^{a}	19.3 ± 5.0^{a}	17.3 ± 3.1^{a}	1.3030	0.3389
	Copper	216.7 ± 33.1^{a}	201.7 ± 63.9^{a}	207.9 ± 26.9^{a}	0.0867	0.918

*Values are means ± SD. Values in the same row with different superscripts are significantly different ($P < 0.05$). FM = Fish meal; SBM = soybean meal.

In contrast, the high carcass levels of K in *H. longifilis* and Mg in *S. melanotheron* fed soybean meal diets suggest high retention of these minerals by fish. The minerals are responsible for skeletal formation, maintenance of colloidal systems, regulation of acid-base equilibrium and for biologically important compounds such as hormones and enzymes (Watanabe et al., 1997). Deficiency signs in mineral include reduced growth, biochemical, structural and functional pathologies and skeletal deformities and quantitative requirements have been determined for several fish species (Lall, 2002). In the present study, no pathology of mineral deficiency was observed. A slight increase in the survival rate was observed in *S. melanotheron* when the dietary inclusion level of soybean meal increased to 50%, however, these differences were not significant.

In *H. longifilis*, the results of survival showed that mortality increases around of 30% when the inclusion of soybean meal increased up 50% in the diet. The highest mortality rate observed with fish fed SBM50 due to the intensifying cannibalistic behavior have consequently reduced survival rate in this group. Our results suggest that the cannibalistic component might become important when soybean protein increased in the diet of African catfish. This result demonstrates that soybean meal diet up to 50% cannot cover sufficiently the nutritional need of *H. longifilis*.

In this study, the production cost of *H. longifilis* was higher in fish fed up to 50% soybean meal as compared to the lower soybean protein content diets in which no difference was observed. The production time in fish fed SBM50 was also 6.2 and 4.3 times greater compared to fish fed FM and SBM25 diets, respectively. On the other hand, addition of soybean meal to fish diet up to 50% decreased production cost in both *S. melanotheron and O. niloticus*, even though an increasing production time could be observed as the fish meal replacement levels rose in the later species. Inclusion of soybean meal into African catfish diets resulted in a lower economical efficiency as compared to the control diet. The soybean meal diet (SBM50) prices is nearly 75% of the fish meal diet (FM), so the result of production cost shows that the use of soybean meal has reduced feed cost and increase profits in *S. melanotheron* and *O. niloticus*. Minimizing the feed cost could be achieved through the use of untraditional cheaper feed ingredients. In aquaculture, feeding of fish has been acknowledged to generally contribute to the major cost incurred during the production cycle (Abu et al., 2010).In conclusion, this study showed that replacement of fish protein by soya protein in diet (35% crude protein) reduces the growth of *H. longifilis* and *O. niloticus* contrary to *S. melanotheron*. Therefore, results indicate that the lower ash and higher lipid contents of *O. niloticus* and *S. melanotheron* fish carcass were associated with soya protein diets. Furthermore, substitution of fish meal by soya meal up to 50% in the diet reduces the Ca and P carcass contents in the three species fish studied.

The aquaculture industry must continue to seek out alternative sources of high-quality plant and animal-based protein ingredients for their feedstuffs.

ACKNOWLEDEGMENTS

The authors thank the staff of Biochemistry and Foods Sciences Laboratory (LaBSA) University of Cocody (Ivory Coast) for their assistance in chemical analyses. Furthermore, the authors express their sincere thanks to the staff of Layo Aquaculture Station, for their contribution in conducting growth trials and samplings. This study is a part of the Oceanology Research Centre project and was financed by the Ivorian Government.

REFERENCES

Abdelghany AE (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.

Abu OMG, Sanni LO, Erondu ES, Akinrotimi OA (2010). Economic viability of replacing maize with whole cassava root meal in the diet of hybrid cat-fish. Agric. J. 5: 1-5.

Akinrotimi OA, Gabriel UU, Owhouda NK, Onunkwo DN, Opara JY, Anyanwu PE, Cliffe PT (2007). Formulating an environmentally friendly fish feed for sustainable aquaculture development in Nigeria. Agric.J. 2: 606-612.

AOAC (Association of Official Analytical Chemist) (2003). Official methods of analysis. 17th ed. Washington DC, USA.

Atsé BC, Konan KJ, Alla YL, Pangni K (2009). Effect of rearing density and feeding regimes on growth and survival of African catfish, *Heterobranchus longifilis* (Valenciennes, 1840) larvae in a closed recirculating aquaculture system. J. Appl. Aquacult. 21: 183-195.

Borgeson TL, Racz VJ, Wilkie DC, White LJ, Drew MD (2006). Effect of replacing fishmeal and oil with simple or complex mixtures of vegetable ingredients in diets fed to Nile tilapia (*Oreochromis niloticus*). Aquacult. Nutr. 12:141-149.

Cahu C, Gisbert E, Villeneuve LAN, Morais S, Hamza N, Wold PA, Infante JLZ (2009). Influence of dietary phospholipids on early ontogenesis of fish. Aquacult. Res. 40(9): 989-999.

Chakroborty SB, Mazumbar D, Chatterji U, Banerjee S (2011). Growth of mixed-sex and monosex Nile tilapia in different culture systems. Turk. J. Fish. Aquat. Sci. 11: 133-140.

Costanzo M, Palmegiano GB, Caruso G, Gai F, Daprà F, Maricchiolo G, Micale V, Genovese L (2011). Alternative dietary sources in feeding of blackspot sea bream *Pagellus bogaraveo* (Brunnich, 1768). Open Mar. Biol. J. 5: 12-23.

El-Saidy DMS, Gaber MMA (2003). Replacement of fish meal with a mixture of different plant protein sources in juvenile Nile tilapia (*Oreochromis niloticus* (L.) diets. Aquacult. Res. 34: 1119-1127.

Ergün S, Yigit M, Türker A, Harmantepe B (2008). Partial replacement of fish meal by defatted soybean meal in diets for black sea turbot (*Psetta maeotica)*: Growth and nutrient utilization in winter. Isra. J. Aquacult-Bamid. 60: 175-182.

Ghanawi J, Roy L, Davis DA, Saoud IP (2011). Effects of dietary lipid levels on growth performance of marbled spinefoot rabbitfish *Siganus rivulatus*. Aquaculture, 310: 395- 400.

Goda AM, Wafa ME, El-Haroun ER, Kabir Chowdhury MA (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. Aquacult. Res. 38: 827-837.

Hertrampf JW, Piedad-Pascual F (2000). Handbook on ingredients for aquaculture feeds. Kluwer Academic Publishers. Netherland, p. 573.

Kaushik SJ, Covès D, Dutto G, Blanc D (2004). Almost total replacement of fish meal by plant sources in the diet of a marine teleost the European Sea bass, *Dicentrarchus labrax*. Aquaculture, 230: 391-404.

Koné T, Teugels GG (2003). Food habits of brackish water tilapia *Sarotherodon melanotheron* in reverie and lacustrine environments of a West African coastal basin. Hydrobiology, 490: 75-85.

Kumar v, Akinleye AO, Makkar HPS, Angulo-Escalante MA, Becker K (2010). Growth performance and metabolic efficiency in Nile tilapia (*Oreochromis niloticus* L.) fed on a diet containing *Jatropha platyphylla* kernel meal as a protein source. J. Anim. Physiol. Anim. Nutr. DOI: 10.111/j. 1439-0396.2010.01118.x.

Lall SP (2002). The minerals, In: Halver JE, Hardy RW (Eds.), Fish Nutrition, 3rd ed. Academic Press, San Diego. pp. 259–308.

Luquet P, Moreau Y (1989). Energy-protein management by some warm water fin fishes. Actes du Collogue 9, AQUACOP, IFREMER, France, pp 751-755.

Oso JA, Idowu EO, Agoi OF (2011). Growth response of *Clarias gariepinus* fingerlings fed *Parkia biglobosa* diet as protein source. Indian J. Sci. Technol. 4(2): 82-84.

Phromkunthong W, Udom U (2008). Available phosphorus requirement of sex-reversed tilapia fed all-plant diets. Songklanakarin J. Sci. Technol. 30(1): 7-16.

Refstie E, Korsøen ØJ, Storebakken T, Baeverfjord G, Lein I, Roem AJ (2000). Differing nutritional responses to dietary soybean meal in rainbow trout *Oncorhynchus mykiss* and Atlantic salmon *Salmo salar*. Aquaculture, 190: 49-63.

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

Sugiura SH, Babbih JK, Dong FM, Hardy RW (2000). Utilization of fish and animal by-product meals in low-pollution feeds for rainbow trout *Oncorhynchus mykiss* (Walbaum). Aquacult. Res. 31:385-593.

Tacon AGJ, Metian M (2008). Global overview on the use of fish meal and fish oil in industrially compounded aqua feeds: Trends and future prospects. Aquaculture, 285: 146-158.

Tocher DR, Bendisken EA, Campbell PJ, Bell JG (2008). The role of phospholipids in nutrition and metabolism of teleost fish. Aquaculture, 280: 21-34.

Toko II, Fiogbe ED, Kestemont P (2008). Growth, feed efficiency and body mineral composition of juvenile vundu catfish *Heterobranchus* *longifilis* (Valenciennes 1840) in relation to various dietary levels of soybean or cottonseed meals. Aquacult. Nutr. 14: 193-203.

Tomás A, De La Gándara F, Garcia-Gomez A, Pérez L, Jover M (2005). Utilization of soybean meal as an alternative protein source in the Mediterranean yellowtail, *Seriola dumerili*. Aquacult. Nutr. 11: 333-340.

Watanabe T, Kiron V, Satoh S (1997). Trace minerals in fish nutrition. Aquaculture, 151: 185-207.

Wu GS, Chung YM, Lin WY, Chen HH (2004). Effect of substituting de-hulled or fermented soybean meal for fish meal in diets on growth of hybrid tilapia, *Oreochromis niloticus* x *O. aureus*. J. Fish. Soc. 30: 291-297.

Yigit M, Ergün S, Türker A, Harmantepe B, Erteken A (2010). Evaluation of Soybean Meal as a Protein Source and Its Effect on Black Sea Turbot (*Psetta maeotica*) Juveniles. J. Marine Sci. Technol. 18(5): 682- 688.