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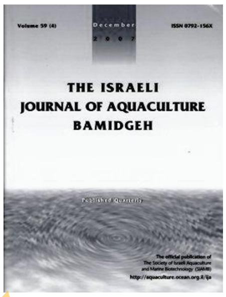

Effect of Differently Processed African Yam Beans (*Sphenostylis stenocarpa* Harms) on Performance of African Catfish (*Clarias gariepinus*) Juveniles

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Abstract

A 12-week feeding trial was conducted in 27-cm^3 circular plastic tanks (50 × 34 cm) to assess the performance of juvenile African catfish (*Clarias gariepinus*) fed diets containing African yam bean meals (*Sphenostylis stenocarpa*) processed by different techniques. Five 35% crude protein diets were formulated containing no yam bean meal (control) or 34% fishmeal and 66% yam bean meal. The yam bean meals were processed in four manners: (a) 'cooked', sun-dried, and ground, (b) 'toasted', cooled, and ground, (c) 'soaked', cooked, sun-dried, and ground, (d) soaked, 'dehulled', cooked, and ground. Each treatment was replicated thrice, each replicate contained 15 fish (3.97±0.03 g, 8.70±0.97 cm). Fish were fed thrice daily at 5% of their body weight per day. Fish fed the control diet perfomed better (p<0.05) than those fed the diets containing yam bean meal. Among the diets containing yam bean meal, the 'soaking' treatment produced the best results. In all diets, the packed cell volume, hemoglobin concentration, red blood cell count, white blood cell count, erythrocyte sedimentation rate, mean corpuscular volume, mean corpuscular hemoglobin, mean corpuscular hemoglobin concentration, lymphocytes, and neutrophils were within the ranges for healthy fish. Therefore, since the differences in fish performance between the control and the 'soaked' diet were less than with other yam bean diets, and because this diet was more cost-efficient than the control fishmeal diet, we conclude that soaked, cooked, and ground African yam beans can partially replace fishmeal in diets for African catfish without compromising growth or nutrient utilization.

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Introduction

African catfish (*Clarias gariepinus*) is a commonly cultured fish species in Nigeria and elsewhere. Traditionally, fishmeal has been the main protein source in balanced fish diets as it is rich in essential amino acids and minerals and highly digestible by fish. However, its use is limited by high cost and limited availability. Many oil seed meals have been used as partial or complete replacements for fishmeal in fish diets though most plant proteins contain one or more anti-nutritional factors (NRC, 1993). The African yam bean (*Sphenostylis stenocarpa*) is a non-oil, seed legume grown in Nigeria with a reported crude protein content of 22% (Aletor and Aladetimi, 1989) or 21-29% (Evans and Boulter, 1994). It is a cheap source of protein among poor populations in West Africa and is grown for its seeds and edible tubers (Klu et al., 2001). African yam beans are not known as a protein source in fish feeds even though it has a similar amino acid profile as soybeans (Akinmutimi et al., 2006). This study was conducted to assess the performance of *C. gariepinus* juveniles fed diets containing differently-processed African yam bean meals.

Materials and Methods

The study was carried out in fifteen 27 cm^3 circular plastic tanks (50 × 34 cm, water level 0.30 m). Water was replaced every three days and aerated using an air stone and an aerator pump (Lawson, 1995). Dissolved oxygen, water temperature, and pH were measured using a DO meter (Jenway 3015), a pH meter to an accuracy of 0.01, and a mercury-in-glass thermometer. Each treatment was replicated thrice with 15 fish per replicate (3.97±0.03 g, 8.70±0.97 cm standard length). Fish were acclimatized for one week before the study and fed at a daily rate of 5% of their body weight in three meals. Weights were recorded weekly and feeding rates were adjusted accordingly.

African yam beans were processed using four methods: (a) cooking at 121°C for 30 min in a pressure cooker (Qlink model no.9000), sun-drying, grinding into fine powder ('cooked'), (b) toasting at 80°C for 3 h, cooling, grinding ('toasted'), (c) soaking 24 h, replacing water and soaking for an additional 6 h, cooking 30 min at 121°C, sun-drying, grinding into powder ('soaked'), (d) soaking 6 h, manually removing seed coats, cooking 30 min at 121°C, grinding into powder ('dehulled'), all of which resulted in considerable ($p<0.05$) reduction of the anti-nutritional factors (Table 1). Feed ingredients were mixed together to formulate 35% crude protein diets (Table 2). The diets were treated separately, extruded through a ¼ mm die mincer of a Hobart A-200T pelleting machine to form noodle-like strands, dried, and mechanically broken into suitable sizes for the fish. The control diet contained 72.32% fishmeal and no African yam bean.

Hematological analyses were carried out before and after the experiment using the methods of Blaxhall and Daisley (1973), Dacie and Lewis (1975), and Jain (1986). Fish were evaluated as follows: wt gain = final body wt - initial body wt; wt gain (%) = 100 (final body wt - initial body wt)/initial body wt; increase in standard length (cm) = $L_2 - L_1$, where L_2 = final standard length and L_1 = initial standard length; specific growth rate (SGR) = 100 ($\log_e$ final body wt - $\log_e$ initial body wt)/time (days); metabolic growth rate = (final wt - initial wt)$^{0.75}$, where 0.75 = constant metabolic mass (Dabrowski et al., 1986); feed conversion ratio (FCR) = dry wt of feed fed (g)/fish wt gain (g); protein

Table 1. Proximate composition of differently-processed yam bean meal and fishmeal (%).

						Anti-nutritional factor		
Ingredient	*Moisture*	*Crude protein*	*Ether extract*	*Ash*	*Nitrogen free extract*	*Thio-glucoside (%)*	*Trypsin inhibitor (Tiu/mg protein)*	*Hemaglutinin (Hu/mg protein)*
Raw	9.30±0.02^f	28.78±0.06^a	8.40±0.00^e	3.42±0.02^a	50.10±0.05^c	2.63±0.00^c	10.40±0.01^d	1.50±0.02^c
Cooked	5.69±0.05^d	32.41±0.02^c	5.48±0.06^b	4.42±0.01^c	52.00±0.06^e	0.53±0.02^b	0.00±0.00^a	0.00±0.00^a
Toasted	5.41±0.00^c	31.18±0.04^b	3.78±0.01^a	4.23±0.03^b	55.40±0.04^f	0.36±0.02^b	0.23±0.02^c	0.12±0.02^b
Soaked & cooked	3.85±0.01^a	40.16±0.09^e	6.38±0.02^d	5.51±0.04^e	44.10±0.08^b	0.47±0.02^a	0.12±0.01^b	0.06±0.01^{ab}
Dehulled & cooked	5.89±0.01^e	33.31±0.01^d	5.68±0.03^c	4.62±0.02^d	50.50±0.04^d	0.38±0.01^a	0.24±0.01^c	0.10±0.02^b
Fishmeal	4.69±0.02^b	65.01±0.05^f	10.29±0.07^f	19.73±0.08^f	0.28±0.21^a	-	-	-

Table 2. Gross and proximate compositions of experimental diets (%).

	Diet				
	Control	*Cooked*	*Toasted*	*Soaked*	*Dehulled*
Ingredient					
Fishmeal	72.32	24.11	24.11	24.11	24.11
Cooked yam bean meal	-	48.21	-	-	-
Toasted yam bean meal	-	-	48.21	-	-
Soaked & cooked yam bean meal	-	-	-	48.21	-
Dehulled & cooked yam bean meal	-	-	-	-	48.21
Wheat	9.84	9.84	9.84	9.84	9.84
Maize	9.84	9.84	9.84	9.84	9.84
Vitamin premix	2	2	2	2	2
Mineral premix	2	2	2	2	2
Starch	1	1	1	1	1
Vegetable oil	3	3	3	3	3
Proximate composition					
Moisture	6.84±0.02^{a}	8.27±0.04^{c}	8.79±0.03^{e}	8.55±0.02^{d}	7.86±0.08^{b}
Crude protein	36.63±0.04^{d}	35.60±0.01^{a}	35.92±0.02^{b}	35.93±0.05^{b}	35.87±0.01^{b}
Ether extract	14.48±0.01^{d}	10.99±0.03^{b}	10.53±0.04^{a}	11.48±0.08^{c}	11.46±0.75^{c}
Ash	22.09±0.02^{e}	9.41±0.05^{a}	11.56±0.02^{b}	12.14±0.01^{c}	13.28±0.02^{d}
Nitrogen free extract	19.96±0.75^{a}	35.73±0.08^{e}	33.20±0.03^{d}	31.90±0.02^{c}	31.53±0.01^{b}

efficiency ratio (PER) = wet body wt gain (g)/crude protein fed; protein productive value (PPV) = 100(final fish body protein - initial body protein)/crude protein intake; survival (%) = 100(initial no. fish stocked - mortality)/initial no. fish stocked; condition factor (K) = $100W/L^3$, where W = wt of fish (g) and L = standard length (cm); and protein intake = (feed intake × percent protein in diet)/100.

African yam meals, experimental diets, and fish carcasses were analyzed for proximate composition before and after the experiment using the methods of the AOAC (1990). One-way analysis of variance (ANOVA) was used to test for differences in growth performance and nutrient utilization of fish. Correlation and regression analyses were used to investigate the relationship between the weight and length of the fish.

Results

Water quality parameters are given in Table 3 and were within recommended limits for warmwater fishes (Boyd, 1981). Weight gain, feed utilization factors, and some hematological parameters differed between treatments (Table 4). Linear equations and

Table 3. Mean water temperature (°C), dissolved oxygen (DO; mg/l), and pH in tanks with African catfish juveniles fed diets containing differently-processed African yam bean meals.

		Week					
Diet	*Parameter*	2	4	6	8	10	12
Control	Temperature	25.03±0.45	25.20±0.16	25.70±0.00	26.02±0.05	26.00±0.01	26.03±0.00
	DO	6.48±0.01	6.60±0.03	6.58±0.01	6.60±0.02	6.60±0.00	6.70±0.05
	pH	6.88±0.01	6.90±0.06	6.93±0.07	7.20±0.05	7.10±0.03	7.20±0.02
Cooked	Temperature	24.27±0.38	25.17±0.00	25.80±0.003	26.00±0.00	26.05±0.01	26.00±0.02
	DO	6.48±0.03	6.50±0.08	6.48±0.02	6.51±0.02	6.55±0.05	6.51±0.03
	pH	6.80±0.02	6.90±0.02	6.95±0.08	6.95±0.01	7.10±0.02	7.10±0.01
Toasted	Temperature	24.03±0.05	24.53±0.75	25.20±0.01	25.70±0.01	25.70±0.03	25.90±0.01
	DO	6.55±0.02	6.39±0.04	6.70±0.01	6.46±0.02	6.47±0.02	6.47±0.01
	pH	6.84±0.01	6.78±0.01	6.90±0.03	6.90±0.08	6.95±0.05	7.02±0.01
Soaked	Temperature	25.10±0.08	25.27±0.12	25.10±0.04	25.80±0.01	26.00±0.02	26.01±0.01
	DO	6.56±0.05	6.61±0.01	6,70±0.50	6.50±0.02	6.52±0.01	6.55±0.02
	pH	6.84±0.03	6.90±0.01	6.95±0.05	6.95±0.00	7.10±0.02	7.10±0.21
Dehulled	Temperature	24.90±0.08	25.10±0.08	24.90±0.00	25.70±0.01	25.80±0.01	25.80±0.02
	DO	6.82±0.01	6.59±0.02	6.82±0.04	6.48±0.02	6.49±0.01	6.49±0.02
	pH	6.87±0.03	6.89±0.01	6.95±0.05	7.00±0.08	7.01±0.01	7.00±0.03

coefficients of determination are given in Table 5. The costs of producing one kilogram of diet and one kilogram of fish are presented in Table 6.

Table 4. Growth performance, nutrient utilization, hematological parameters, and plasma biochemistry of *Clarias gariepinus* fed diets with processed African yam bean meals for 12 weeks.

	Diet				
	Control	*Cooked*	*Toasted*	*Soaked*	*Dehulled*
Initial body wt (g)	3.98±0.02	3.97±0.03	3.98±0.03	3.97±0.03	3.98±0.03
Final body wt (g)	11.89±0.03^{a}	10.91±0.08^{c}	9.46±0.03^{e}	11.19±0.09^{b}	10.57±0.10^{d}
Body wt gain (g)	7.91±0.00^{a}	6.94±0.05^{c}	5.48±0.00^{e}	7.22±0.06^{b}	6.59±0.07^{d}
Body wt gain (%)	199.01±2.23^{a}	175.15±3.82^{c}	137.99±2.06^{e}	182.19±1.93^{b}	165.92±4.72^{d}
Initial length (cm)	8.70±0.97	8.70±0.97	8.70±0.97	8.70±0.97	8.70±0.97
Final length (cm)	13.13±0.21	12.88±0.31	12.61±0.54	13.05±0.30	12.56±0.15
Length increment (cm)	4.43±0.59	4.18±0.64	3.91±0.76	4.35±0.64	3.86±0.56
Specific growth rate	0.57±0.01^{a}	0.52±0.01^{cd}	0.45±0.01^{e}	0.54±0.02^{b}	0.51±0.01^{d}
Metabolic growth rate	14.85±0.08^{a}	13.89±0.16^{c}	12.15±0.11^{e}	14.19±0.08^{bc}	13.49±0.21^{d}
Feed conversion ratio	4.71±0.03^{d}	5.04±0.05^{bc}	5.48±0.01^{a}	4.95±0.06^{c}	5.28±0.18^{a}
Protein efficiency ratio	0.23±0.02^{a}	0.20±0.01^{cd}	0.16±0.00^{e}	0.21±0.01^{bc}	0.19±0.02^{d}
Protein productive value (%)	21.42±0.07^{a}	18.80±0.10^{b}	16.50±0.85^{d}	20.35±0.05^{a}	16.76±1.00^{cd}
Protein intake (g)	135.04±1.25^{a}	127.43±0.26^{d}	116.41±1.25^{e}	130.36±0.33^{b}	127.53±1.03^{cd}
Survival rate (%)	100	100	93.33	100	100
Condition factor (K)					
Initial	0.61±0.00	0.60±0.00	0.61±0.00	0.60±0.00	0.61±0.00
Final	0.53±0.03	0.51±0.04	0.48±0.06	0.51±0.03	0.53±0.001
Difference	-0.08±0.02	-0.09±0.02	-0.13±0.03	-0.09±0.02	-0.08±0.00
Plasma biochemistry					
Total protein	1.58±0.13	1.33±0.19	1.33±0.05	1.40±0.08	1.40±0.36
Albumin	0.62±0.07	0.53±0.12	0.53±0.05	0.53±0.05	0.57±0.09
Globulin	0.96±0.08	0.80±0.08	0.80±0.08	0.86±0.05	0.83±0.26

Hematological parameters						
	Before	*Control*	*Cooked*	*Toasted*	*Soaked*	*Dehulled*
Packed cell volume (%)	19.60±0.49	14.33±1.89^{cde}	13.67±1.23^{de}	13.00±0.82^{e}	15.00±5.72^{bcde}	22.34±1.70^{a}
Hemoglobin (g/dl)	6.08±0.15	4.77±0.21^{e}	5.67±0.47^{ab}	5.13±0.09^{bc}	6.07±0.74^{ab}	6.77±0.55^{a}
Red blood cells (10^{12}/l)	6.60±0.37	4.77±0.61	4.61±0.24	4.09±0.01	4.92±1.78	6.81±0.16
White blood cells (10^{12}/l)	5.32±1.07	3.90±0.65^{bcd}	3.27±0.49^{d}	3.34±0.27^{cd}	4.06±0.52^{abcd}	5.07±0.50^{a}
Erythrocyte sedimentation rate (mm/h)	1.66±0.68	1.13±0.40	0.93±0.09	1.46±0.17	1.80±1.07	1.23±0.54
Mean cell volume (Fl)	31.40±4.03	33.00±4.24	36.00±3.56	31.67±1.70	30.00±0.82	35.67±2.36
Mean cell hemoglobin (Pg)	5.40±3.01	8.00±3.56	12.67±0.94	12.33±0.47	14.00±4.32	8.67±1.89
Cell hemoglobin concentration (%)	30.60±1.02	36.67±0.94	44.00±4.32	39.33±2.62	45.33±4.38	30.00±0.01
Lymphocytes (%)	67.20±3.31	62.00±1.79	54.67±1.25	51.33±0.08	52.00±5.74	53.33±6.02
Neutrophils (%)	32.80±3.31	38.00±1.79	45.33±1.25	48.33±0.53	48.00±5.75	46.67±06.02
Proximate composition of fish						
Moisture	10.39	8.28±1.47^{b}	8.64±1.17^{b}	7.21±0.67^{b}	7.18±1.49^{b}	3.65±1.94^{a}
Crude protein	22.10	45.64±1.43^{d}	42.18±1.19^{b}	39.88±1.88^{a}	44.03±1.02^{c}	40.14±0.18^{a}
Crude fat	18.56	28.18±1.02^{d}	32.69±0.39^{e}	26.75±4.00^{a}	27.27±2.90^{a}	24.76±1.19^{a}
Ash	16.35	16.67±0.65^{d}	12.69±1.14^{b}	14.45±0.84c	7.40±3.81^{a}	13.49±0.08^{b}
Nitrogen free extract	32.60	1.23±1.14^{a}	3.80±0.97^{b}	11.80±1.85^{c}	14.12±2.31^{d}	17.96±1.52^{e}

Means followed by different superscripts significantly differ based on posthoc analysis using ANOVA (p = 0.05).

Table 5. Linear equations and coefficients of determination (r) relating dependent variables to independent variables (Y = length, X = weight).

	Diet				
	Control	*Cooked*	*Toasted*	*Soaked*	*Dehulled*
Prediction equation (Y =)	7.49+0.52X	7.19+0.53X	7.19+0.58X	7.24+0.54X	7.37+0.52X
r	0.9647	0.9760	0.9573	0.9857	0.9848
r^2	0.9331	0.9527	0.9164	0.9715	0.9698

Table 6. Economic analysis of using differently-processed African yam bean meals to replace fishmeal in diets for *Clarias gariepinus* juveniles, in Nigerian naira and US dollars.

Component	*Control*	*Cooked*	*Toasted*	*Soaked*	*Dehulled*
Fishmeal	97.63	32.55	32.55	32.55	32.55
Cooked meal	-	58.21			
Toasted meal	-	-	50.50	-	-
Soaked & cooked meal	-	-	-	63.21	-
Dehulled & cooked meal	-	-	-	-	64.41
Wheat offal	2.28	2.28	2.28	2.28	2.28
Maize	3.42	3.42	3.42	3.42	3.42
Vitamin/mineral premix	4.00	4.00	4.00	4.00	4.00
Starch	0.05	0.05	0.05	0.05	0.05
Vegetable oil	8.10	8.10	8.10	8.10	8.10
Cost/kg feed (Naira)	115.48	108.61	100.90	113.61	114.81
Cost/kg feed (US)	$0.77	$0.72	$0.67	$0.76	$0.77
Cost/kg flesh gain (Naira)	119.40	112.75	105.36	117.57	118.73
Cost/kg flesh gain (US)	$0.80	$0.75	$0.78	$0.78	$0.79

Discussion

In our study, the protein content of raw African yam bean was higher than values recorded by Aletor and Aladetimi (1989) and Okigbo (1973), perhaps due to differences in environment and culture practices such as the kind of fertilizer used. Body protein levels increased in all fish, indicating that all diets supported fish growth. Nevertheless, differences show that the whole body proximate composition was influenced by the method of processing the yam bean.

Anti-nutritional factors were lower in all the processed yam bean meals than in raw yam beans. Similar reductions have been reported when other legume seeds were similarly treated (Siddhuraju et al., 1996; Alonso et al., 2000). The reduction of trypsin inhibitor activity may be due to the heat labile nature of trypsin inhibitor (Siddhuraju et al., 1996). Other anti-nutritional factors in African yam bean include tannins, hydrocyanic acid (HCN), saponin, and phytin (Akinmutimi et al., 2006).

There was a general increase in weight, length, and protein intake as the processing of the yam beans increased. The control diet produced the highest length gain while the dehulling treatment produced the lowest, in agreement with the suggestion that dehulling of African yam beans may lower its nutritional quality by reducing Cu, Zn, Co, Na, Mg, Mn, and Fe which are concentrated in the hulls (Adeyeye and Agesin, 2007). These minerals are important for normal growth and serve as cofactors in several metabolic reactions of animals including fish. A reduction of any of them from the diet will negatively affect growth. Apart from weight gain, length increment is an indicator of growth in fish. There were significant differences in weight gain but not in length increment. The better performance of fish fed the control diet compared to the yam bean diets is attributed to its high content of fishmeal which has a better amino acid profile and greater biological value than yam beans. Fish use protein from fish more efficiently than protein from plant sources and fishmeal supplies a higher proportion of digestible energy within the total digestibility of diets (Lovell, 1981).

Among the yam bean diets, the soaked and cooked meal produced the best body weight gain, specific and metabolic growth rates, feed conversion ratio, protein efficiency ratio, protein productive value, and protein intake. The closeness in value of the protein efficiency ratio, specific growth rate, and metabolic growth rate to the values of the control show that soaked and cooked African yam bean meal could replace 66% of the fishmeal in diets for *C. gariepinus* juveniles without significant growth and nutrient utilization compromises. Considering the costs, fishmeal can be partially replaced by soaked and cooked African yam bean with no adverse effect on the cost of growth.

The survival rate of most treatments was 100% but survival in the toasted treatment was only 93.33%. Also in terms of biological parameters, the toasted yam beans produced the lowest values, which could be due to the presence of thioglucosides. Anti-nutritional factors such as trypsin inhibitor, thioglucosides, and hemaglutinin in African yam beans can reduce protein digestibility, thereby reducing the nutritive value in relation to the availability of amino acids and growth performance (Aletor and Aladetimi, 1989).

In comparison to the other methods, soaking before cooking of African yam beans improved growth performance and feed utilization of *C. gariepinus* but not to the level of performance obtained with the fishmeal diet. The reduced growth might be related to the non-starch polysaccharide content and low protein solubility of African yam beans. However, the robustness and general well being of the fish fed the yam bean diets are expressed by the condition factor (K), which did not significantly differ from the control.

All hematological parameters fell within the ranges recommended for healthy fish (Anderson et al., 1996). Examination of the fish before and after the experiment revealed they were in good condition and free from disease and infection. However, decreases in several hematological and biochemical parameters could be attributed to stress encountered during sampling, capture, and handling procedures which may have increased catecholamine secretion and produced hemoconcentration. They may also have been due to a change in the dietary protein intake during the experiment (Peter et al., 1991). Parameters such as red blood cells, packed cell volume, hemoglobin, and plasma protein respond to stress, parasitic infection, and changes in the dietary protein intake (Harms et al., 1996). The decreases in blood parameters could also have been caused by anti-nutritional factors still present in low quantities in the African yam bean diets.

The reduced leucocyte count of the fish may be attributed to a systemic derangement indicative of stress to which the fish were unable to adapt (Alkahem, 1994). Similar low leucocyte counts in the blood of fish exposed to pollutants were attributed to a reduction of lymphocytes (Alkahem et al., 1998). There were also decreases in total protein, albumin, and globulin. Reduced protein levels are attributed to stress-mediated mobilization of proteins to fulfill the increased energy demand of fish coping with detrimental conditions imposed by a toxicant (Alkahem et al., 1998).

In conclusion, the results of this study indicate that the African yam bean (*Sphenostylis stenocarpa*) can be used to partially substitute fishmeal. Its use in diets for *Clarias gariepinus* could boost aquaculture production and should therefore be further investigated. Further studies need to be carried out to confirm the advantages of soaking and cooking African yam bean over other processing methods.

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