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Effect of substitution of acha for maize on the growth and economic performance of *Oreochromis niloticus*

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Abstract

Growth and digestibility experiments were conducted to determine the effects of replacing maize with Acha (*Digitaria exilis*) at 0, 20, 40, 60, 80, 100 % for diets 1, 2, 3, 4, 5, 6 of *Oreochromis niloticus*. The digestibility experiment was conducted for 14 days in indoor glass tanks while the feeding trial was carried out for 63 days in outdoor concrete tanks. In both experiments, the fishes were fed at 4% body weight twice daily. Results indicated no significant difference ($p > 0.05$) in the apparent digestibility coefficient (ADC) for protein and energy in the diets. There were no significant differences ($p > 0.05$) in the survival (%), mean weight grain (MWG), specific growth rate (SGR) and food conversion ratio (FCR) of the fishes fed the diets. However, the fishes fed diets of 20, 40, 60, 80 and 100% of Acha had better ($p > 0.05$) MWG, SGR and FCR than the fishes fed the diet without Acha (control diet). Fishes fed the diets 1 - 6 had similar ($p > 0.05$) haematocrit values and there was no histopathological effects as a result of the dietary treatments. Economic analysis showed that fishes fed diets up to 100% replacement of Acha for maize had higher profit index than those fed the control diet. Consequently, complete replacement of maize with Acha in the diets of *O. niloticus* is recommended for best economic returns.

Key words: Acha, substitution, maize, *Oreochromis niloticus.*

Introduction

High costs of fish feed has been recognised as a major factor militating against rapid development of aquaculture in the developing countries. Jauncey and Ross [1] reported, that feed is the most expensive cost item in semi-intensive and intensive fish culture. Maize is a cereal commonly used as energy/carbohydrate in fish diets. As a dietary carbohydrate, it has the ability to reduce the oxidation of dietary protein for energy (protein-sparing) [2,3] which invariably minimises the quantity/costs of dietary protein. However, competition for its use in human foods and animal feeds limits the availability/quantity and hence increase in its price. This has necessitated research into non-conventional carbohydrate ingredients that will replace maize without compromising fish growth. To this end, the use of forest seeds in fish diets has strong economic justification. Acha (*Digitaria exilis*) is a forest seed/ grain usually abundant in Nigeria, under-utilized and cheaper than maize. Acha has similar crude protein content with maize. It has a higher methionine-cystine (met + cys) content than maize, and it is complementary to legumes with low methionine + cystine contents in tropical animal feeds[4]. It may be feasible to replace expensive conventional fish feedstuffs such as fish meal and maize with cheaper alternatives in order to reduce the cost of the feed. This study was conducted to evaluate the effects of replacing maize with Acha in the diets of Nile Tilapia (*Oreochnomis niloticus*) using growth and economic performance assessments.

Materials and Methods

Ingredients used in this study were purchased from Pfizer (livestock) feeds depot, Ibadan Nigeria, while Acha seeds were purchased from Jos central market, Nigeria. Acha seeds were sun-dried to a constant moisture content of 11.8%, before they were mechanically de-hulled and milled into fine powder. Phytin and tannin contents of the Acha meal (AM) were determined according to the methods of Sathe and Salunkhe [5]. The mineral content of AM was determined as described by Harris [6] (Table 1), while the proximate composition was determined according to the methods of AOAC [7]. Based on the proximate composition of the feedstuffs, six isoproteic (300g kg^{-1} crude protein) diets were formulated (Table 2). The control diet (diet 1) contained 35% of maize which was replaced with Acha meal in diets 2, 3, 4, 5 and 6 at 20, 40, 60, 80 and 100% respectively. The feedstuffs were milled, blended, moistened, pelleted, solar-dried at 30^0C between (1200 – 1600 h) for three days and stored in air-tight polyethylene bags at ambient temperature (28^0C). Proximate analysis of the diets and the fishes, (moisture, crude protein (N x 6.25), crude lipid, crude fibre and total ash) were conducted in triplicate according to AOAC methods [7]. Gross energy of the diets was determined in triplicate samples by combustion in an adiabatic bomb calorimeter. Groups of 20 fingerlings of *O. niloticus* (10.1 $\pm$ 0.03 g) having been acclimated for seven days were randomly stocked into 18 outdoor rectangular concrete tanks (1.8 x 1.8 x 1 m) containing 800 L of water for growth trials. Each of the diets was fed to the fishes in triplicate tanks at 4% body weight twice daily (900 – 1000 and 1500 – 1600 h) for 63 days. Fresh water was used to change the water in the experimental tanks once every 2 weeks. Total weight of fishes in each tank was taken bi-weekly to monitor growth responses and feed utilization. Mean weight grain (MWG), specific growth rate (SGR), protein efficiency ratio (PER) and food conversion ratio (FCR) were estimated from bi-weekly weight data [8].

MWG = mean final weight - mean initial weight
SGR = 10^2 (lnwt - lnw0)/t, where wt is the final weight of fish, w0, is the initial weight of fish, it is the culture period in days.
PER = weight gain / protein fed
FCR = feed fed/fish weight gain

At the beginning and end of feeding, six tilapia, randomly selected from the initial pool and each treatment group were homogenised,

Table 1. Mineral, proximate, amino acid and anti-nutrients composition of Acha meal.

Minerals and Anti nutrients		Proximate composition (g/100 g/DM)		Amino acid profile [1] (100 g/kg/DM)	
Minerals mg/g		Crude protein	10.34	Arginine	3.84
Iron (Fe)	60.96	Ether extract	11.65	Histidine	2.15
Copper (Cu)	ND	Crude fibre	0.17	Isoleucine	4.12
Manganese (Mn)	ND	Ash	1.10	Leucine	9.82
Zinc (Zn)	18.8.29	Moisture	11.83	Lysine	2.63
Lead (Pb)	ND			Methionine	5.70
Cadmium (Cd)	ND			Cystine	2.84
Magnesium (Mg)	199.36			Phenylalanine	5.20
Sodium (Na)	189.21			Tyrosine	3.62
Potassium (K)	417.86			Threonine	4.15
Calcium (Ca)	210.61			Tryptophan	1.43
Phosphorus (P)	800.31				
Anti-nutrients (g/kg)					
Phytin	1.14				
Tannin	0.01				

1 Source: Fagbenro et al.[4]

packed in air-tight polythene bags and stored in a deep freezer (-20^{0}C), prior to carcass analyses. At the end of the feeding trials, some haematological parameters were studied from fish from each tank. Five fishes were used from each triplicate groups. Three fish from each tank (9 fish/treatment) were removed, anesthetized using tricainemethane – sulfonate (MS 222, Sandoz). Blood samples were withdrawn from the caudal vein with heparinized syringes, put separately in 1ml heparinized tubes and immediately centrifuged at 5,000 rpm for 15 mins to remove red blood cells. The blood parameters, total erythrocyte count (TEC), pack cell volume (PCV) and red blood cells (RBC) were determined according to the methods of Svobodova et al. [9]. Fish samples from each treatment were fixed in 10% buffered formalin and routine histopathological examinations of the liver was carried out to observe any changes in the fish as a result of the dietary treatments. The liver was sectioned at a thickness of 5 mm using base-sledge microtome, stained with haematoxylin and eosin, and examined under a light microscope. Groups of 20 fingerlings of *Oreochromis niloticus* (12.0 $\pm$ 0.03 g) having been acclimated for seven days were randomly stocked into 18 indoor rectangular glass tanks (75 x 40 x 40 cm) containing 120 L of water. The tanks were supplied with fresh water (flow rate 1 L m^{-1}). Each of the diets was fed to the fishes in triplicate tanks at 4% body weight twice daily for 14 days, for digestibility studies. Faeces were collected from each of the tanks eight hours after each feeding. The faeces and diets were separately pooled and the proximate composition determined by methods of AOAC [7]. At the end of the experiment, feed samples and the dried faeces per sample/treatment were pooled and ashed. The ashes were digested by Acid Insoluble Ash (AIA) method (10). AIA% = 10^2 (weight of Ash-weight of AIA) / weight of Ash.

Apparent digestibility coefficient (ADC) was determined from the formular, ADC = 10^2 – (10^2 x (Af/At x Nt/Nf)
where, Af = AIA in feeds, At = AIA in faeces, Nf = Nutrient in feed and Nt = Nutrient in faeces.

Table 2. Ingredients and proximate composition of diets.

Ingredients (g /100 g and DM)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Fish meal (65 % Cp)	15.0	15.0	15.0	15.0	15.0	15.0
Soybean meal (45.5% Cp)	45.0	45.0	45.0	45.0	45.0	45.0
Yello maize	30.0	24.0	18.0	12.0	6.00	0.00
Acha (*Digitaria exilis*)	0.00	6.00	12.0	18.0	24.0	30.0
Carboxymethyl cellulose	2.00	2.00	2.0	2.00	2.00	2.00
Cod liver oil	6.00	6.00	6.0	6.00	6.00	6.00
Vitamin mineral premix [1]	2.00	2.00	2.00	2.00	2.00	2.00
Proximate composition (g/100 g/DM)						
Crude protein	30.5	30.8	31.2	31.5	31.8	32.3
Ether extract	11.6	11.8	11.8	11.9	11.9	12.0
Crude fibre	1.01	1.24	1.29	1.39	1.41	1.46
Ash	3.17	3.24	3.31	3.42	4.18	4.43
Gross Energy (kcal/g/DM)	471.6	475.0	471.9	471.9	469.0	468.6
Protein-Energy Ratio (P/E)(mg/Protein/Cal/ GE)	64.7	64.9	66.0	60.7	67.8	69.0

1. (gkg^{-1}: vitamin A, 400000 IU; vitamin D3, 40000 IU; vitamin, 3000mg;
vitamin K3, 200mg; vitamin Bi, 400mg; vitamin B2, 600mg; vitamin B12, 1mg;
vitamin C, 10000mg; nicotinic acid, 260mg, panthotenic acid, 1000mg; folic acid 80mg;
biotin, 1mg; choline chlorid, 12000 mg; manganese, 1333 mg; iron, 2667 mg; zinc, 1600 mg; copper, 27 mg; iodine, 21 mg; cobalt, 3 mg; selenium, 1mg)

Table 3. Growth and Nutrient Utilization of *O. niloticus* fed Acha diets for 63 days.

Parameters	Diets/treatments					
	1	2	3	4	5	6
Initial mean weight (g)	10.3 ±0.02	10.1±0.01	10.4 ±0.03	10.2±0.02	10.3±0.01	10.3±0.01
Final mean weight (g)	20.6 ±0.85	20.5±0.86	20.8 ±0.84	20.7± 0.82	20.5±0.85	20.7±0.81
Mean weight gain (g)	10.3±0.10	10.4±0.12	10.4±0.10	10.5±0.12	10.2±0.11	10.4±0.12
Survival (%)	86.0±0.51	85.0±0.53	86.0±0.51	86.0±0.52	86.0±0.54	85.0±0.52
SGR	1.11±0.01	1.12±0.02	1.12±0.03	1.12±0.01	1.11±0.01	1.12±0.02
FCR	2.67±0.08	2.65±0.06	2.62±0.07	2.56±0.05	2.74±0.06	2.79±0.08
PER	5.76±0.14	5.79±0.13	5.67±0.12	5.74±0.14	5.51±0.11	5.45±0.13
ADC protein	83.6±0.82	84.0±0.83	85.7±0.80	85.1±0.83	85.0±0.81	84.0±0.82
ADC energy	87.1±0.80	87.3±0.79	89.2±0.81	88.5±0.80	88.0±0.82	87.5±0.81

The one way analysis of variance (ANOVA) and Duncan's multiple-range tests[11] were used to compare differences between diet treatment means (p = 0.05)
Economic analysis were calculated using profit index (PI) and incidence of cost (IC) models[12],
PI = value of fish / cost of feed
IC = cost of feed / kg of fish produced.

Results and Discussion

The mineral composition of Acha is presented in Table 1. The results showed the three most abundant minerals as phosphorous (0.80 g/kg), potassium (0.42 g/kg) and calcium (0.21 g/kg). The major anti-nutrients (Table 1) found in Acha were phytin 1.14 gkg, and tannin 0.01 g/kg. These values are insignificant and could not have posed any nutritional problems. The proximate composition of Acha (Table 1) showed crude protein content of 10.3%, and low values of crude fibre and ash contents as 0.17 and 1.10 respectively. This protein value is similar to crude protein level in maize (10%). This dietary lipid of 11.7% obtained in Acha is within the acceptance range recommended by Teshima and Kanazawa [13] for optimum production of tilapia. The gross composition of the experimental diets, and the proximate composition are presented in Table 2. The lipid content of the experimental diets, ranged between 11.6 and 12.0 and increased progressively from diets 1–6. Teshima and Kanazawa [13] found that an increase in the dietary lipid content from 4 to 12% could increase the protein efficiency ratio and weight gain in tilapia. The values obtained from the present study are within this recommended ranges. The fibre contents of the diets varied progressively as 1.01, 1.24, 1.29, 1.34, 1.41 and 1.46%, for diets 1, 2, 3, 4, 5 and 6 respectively. These low values indicate good quality of the diets and support the suitability of the diets for tilapia culture. The gross energy of the diets also ranged between 468.6 and 475.0 kcal/g, with mean protein – energy (P/E) ratio of 66.4. This value of P/E is lower than the mean value of P/E (80.1) reported by Nwanna and Daramola [14] from feeding tilapia with shrimp waste diets. This discrepancy could be attributed to higher gross enrgy values in the Acha based diets than in the shrimp waste diets. Apparent digestibility coefficient (ADC) of nutrients is used to evaluate the acceptance/utilization of feeds by fishes [15,16]. The ADC protein and energy values obtained from the present study are high (Table 3) and ranged between 83.6 and 85.9, and 87.1 and 89.2 respectively. There were no significant differences ($p > 0.05$) in the ADC protein and ADC energy of the fishes fed the six diets, indicating that the diets were equally digested. However, ADC protein and ADC energy from all the fishes fed Acha diets were higher than those obtained from fishes fed maize diet. This observatioin is in line with Fagbenro et al [4] who reported ADC protein for tilapia fishes fed maize diets as 80.2 and 75.0 respectively. Also the mean values of ADC protein (84.8) and ADC energy (87.9) from the present study compare favourably with the mean values of ADC protein (86.0) and ADC energy (85.7) reported by Nwanna and Daramola [14] for *O.niloticus* fed shrimp head waste diets.

Results of the growth trials using the six diets showed no significant variations ($P > 0.05$) in MWG, SGR, FCR and PER (Table 3). However, all the fishes fed diets that contained Acha did better ($p > 0.05$) than the fishes fed the control diet (Diet 1). This is a good indication that Acha can completely replace maize in the diets of *O. niloticus*. The SGR obtained from the present study (1.12) is similar to 1.50 reported by Pouomogne and Mbonagblang [17]. Also the mean value of FCR (2.67) obtained compares favourably with the value of 2.31 reported by Nwanna and Bolarinwa [18]. The data on carcass analysis after the experiment (Table 4) indicated no significant differences in protein and lipid deposition. However, fishes fed diet 4 had the highest protein deposition followed by fishes fed diet, 3, 5, 2, 6, 1 in that order.

Table 4. Carcass analysis and blood parameters of the test fishes.

	Crude protein	Ether extract	Ash	TEC (million/μl)[1]	PCV (%)[2]	RBC (10^4m^3)[3]
Initial	36.3	6.25	4.16	2.80	28.0	179.0
Diet 1	50.5	8.61	6.08	2.80	28.0	179.0
Diet 2	52.0	10.9	8.15	2.70	29.0	180.0
Diet 3	54.5	11.4	6.19	2.90	28.0	179.0
Diet 4	55.3	12.2	6.12	3.00	29.0	180.0
Diet 5	53.8	11.4	6.21	3.00	30.0	179.0
Diet 6	51.0	9.93	6.14	3.00	29.0	180.0

1. TEC = Total Erythrocyte Count
2. PCV = Pack Cell Volume
3. RBC = Red Blood Cell

Table 5. Economic Evaluation.

Parameters	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Cost of feed (US$ / kg)	0.80	0.80	0.79	0.79	0.78	0.78
Fish produced , kg	0.35	0.35	0.35	0.36	0.35	0.35
Value of fish (US$3 / kg)	1.05	1.05	1.05	1.08	1.05	1.05
Incidence of cost (IC)	2.29	2.29	2.57	2.19	2.23	2.23
Profit Index (PI)	1.31	1.31	1.33	1.38	1.35	1.35

NB: Exchange rate is fixed at N100: US $1
Price of 1kg of fish is fixed at US $3
Period of study: January – March, 2001

The use of haematological techniques in fish culture is growing in importance for toxicological research, environmental monitoring and fish health conditions[19]. Sampath [20] noted that studies in fish blood lies in the possibility that the blood will reveal conditions within the body of the fish long before there is any outward manifestation of disease. Results of the haematological parameters from the present study (Table 4) indicated no significant variations ($p > 0.05$) in the total erythrocyte count (TEC), red blood cells (RBC) and pack cell volume (PCV) of the fishes fed Acha diets compared with fishes fed the control diet. The mean value of PCV (28.7%) obtained from the present study compare favourably with the mean value of PCV (32.1%) reported by Abdelghany [21] for *O. niloticus* fed diets with different methionine-cystine levels.

The economics of feed production indicated that the costs of the diets were minimised by replacing maize with Acha (Table 5). The incidence of cost decreased continuously from diet 1 to diet 6, while the profit index (PI) increased from diet 1 to diet 6. Though there was no significant differences in PI, the progressive increase from diet 1 to diet 6 is a good indication that the profit margin will increase significantly with increase in the volume of diets used. The trend of the results showed that though Acha can replace maize up to 100%, in the production of *O.niloticus*, 60% replacemnt has the best prospects based on nutrient digestibility, nutrient utilization, carcass yield and economic benefits.

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