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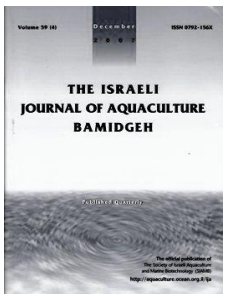

Growth Performance and Nutrient Utilization of African Mud Catfish (*Clarias gariepinus*) Fingerlings fed Different Levels of Fermented Pigeon Pea (*Cajanus cajan*) meal

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Key words: fermentation, *Cajanus cajan*, soybean, growth, nutrient utilization, *Clarias gariepinus*

Abstract

The suitability of fermented pigeon pea meal as a protein ingredient in diets for *Clarias gariepinus* fingerlings was evaluated. A strain of *Rhizopus oligoporus* was used to ferment the meal for six days at 37°C. Five isonitrogenous (30% crude protein) and isoenergetic (16.45 MJ/kg) diets were formulated in which fermented meal was used to replace soybean meal at five inclusion levels (0%, 25%, 50%, 75%, 100%). Diets were fed to triplicate groups of *C. gariepinus* fingerlings for 70 days. Crude protein content (22.6%-27.0%), total sugar, calcium, and phosphorus increased while lipids, carbohydrate, crude fiber, and antinutritional factors decreased in catfish fed increasing levels of pigeon pea meal. The group fed the 100% diet had significantly ($p<0.05$) better growth, which declined as the inclusion level declined. The apparent digestibility coefficients protein and dry increased with the inclusion level. No histopathological changes were observed in the liver. The highest crude protein content in catfish tissues was obtained in the group that received the highest inclusion level. The study shows that fermented pigeon pea meal can replace soybean meal in practical feeds for *C. gariepinus* without compromising growth performance or nutrient utilization.

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Introduction

The high cost of fish feed resulting from the expanding fish culture industry in Nigeria is a major concern to fish farmers, especially those in the small scale fish production sector which is the fastest growing sector and contributes about 70% to domestic production (Raufu et al., 2009). Soybean meal in its variously processed forms is one of the best protein sources in many fish diets (Lovell, 1988). Soybean meal has a relatively high crude protein content and a well-balanced essential amino acids profile. It is widely used to replace or supplement fishmeal in fish feeds (Lovell, 1988). In some studies, soybean meal produced reasonable feed utilization and growth performance ratios. In others, growth tended to drop in fish fed diets with soybean meal replacing or supplementing fishmeal (Forde-Skjaevik et al*.,* 2006). Reasons include the activity of antinutritional factors such as protease (trypsin) inhibitor in crude or inadequately heat-processed soybean meal (Lovell, 1988) and the suboptimal amino acid balance of soybean meal.

The inclusion of soybean in practical fish rations is further constrained by the rising price of soybeans due to competing demand for livestock feeds and human nutrition. In addition, soybean production has declined due to reduced planting areas and late season dryness (IITA, 1990). Therefore, it is important to evaluate the nutritive value of other inexpensive under-utilized plant protein sources such as sunflower seeds (*Leucaena leucocephala*), castor oilseed, pigeon pea (*Cajanus cajan* L. Millsp.), and by-products (Adewolu et al., 2010).

Pigeon pea is one of the oldest food crops and ranks fifth in importance among edible legumes of the world. It grows well in tropical and subtropical latitudes and is widely grown on over 4 million hectares in over 14 countries (Phatak et al., 1993). Pigeon pea has potential for inclusion in fish diets (Obasa et al., 2006). Fermented foods have advantages such as improved keeping quality and flavor, and additional desirable nutrients not present in the original product (Steinkraus, 1983). Typically, fermentation does not extensively alter amino acids in cereals and legumes, and it often makes protein more available. Fermentation of legumes destroys undesirable beany flavors, inactivates trypsin inhibitor, and eliminates flatulence factors (Hesseltine and Wang, 1980). Crude fiber that prevents optimal digestibility and nutrient release are reduced to utilizable sugars during fermentation. In many cases, microorganisms produce tasty nutritious food and require less energy than conventional processing.

The objective of this study was to assess the effect of fermentation on the proximate composition of pigeon pea and evaluate its potential to supplement or replace soybean meal in diets for African catfish (*Clarias gariepinus* Burchell 1822) fingerlings.

Materials and Methods

Experimental system. The experiment was carried out in 15 fish hapa nets (1 x 0.5 x 0.5 m) suspended from bamboo poles in an outdoor concrete cistern (5 x 3 x 1.5 m) at the College of Environmental Resources Management (COLEREM) in the University of Agriculture, Abeokuta, Nigeria (UNAAB). The hapas were suspended to 75% of their volume with a Kuralon twine (no. 15), tied to carefully-arranged bamboo poles. The concrete tank was filled to about 75% of its volume and continually supplied with fallowed tap water (chlorinated water collected in a container and left unused for some time to allow the chlorine to escape) introduced in a shower to enhance aeration, sustain an optimal environment, and preclude primary productivity. African catfish fingerlings (1.5±0.24 g) of the improved Dutch strain were obtained from Iki Fish Farm Obantoko, Abeokuta, Nigeria, 20 days prior to the commencement of the feeding trial. The fingerlings were acclimatized for 15 days in a concrete tank in the Department of Aquaculture and Fisheries Management, UNAAB, maintained on a basal diet (25% crude protein).

Feed preparation. All feed ingredients were purchased from UNAAB Agro Allied Industry Ltd. Kotopo, except the pigeon pea (*Cajanus cajan*), which was purchased from Oja-Odan market, Yewa North, Ogun State. The pigeon peas were dehulled, milled, sieved, and autoclaved at 126°C and 15 psi (1.05 kp/cm^2) for 11 min, after which distilled water was added until a paste is formed. The pigeon pea paste was fermented

with *Rhizopus oligosporus* at the rate of 10^6 at 37°C in an incubator for six days, sundried, and milled in a locally fabricated hammer mill into powdery form. The biochemical composition of the ingredients was chemically analyzed and used to formulate five isonitrogenous (30% crude protein) and isoenergetic (16.45 MJ/kg) diets in which soybean was progressively replaced by fermented pigeon pea meal at 25%, 50%, 75%, and 100% inclusion levels. A control feed contained no fermented pigeon pea meal. The feeds were thoroughly mixed and pelletized into 2-mm diameter using an HV 6 Moulinex pelletizing machine. The pellets were sun dried and stored in a refrigerator in tagged polythene bags.

Experimental procedure. The fingerlings were starved for 24 h prior to the start of the feeding trial, then weighed individually and randomly distributed at a stocking rate of 10 fish per hapa. The cistern flow-through system was regulated. Each of the five treatments was randomly assigned to triplicate groups of *C. gariepinus* fingerlings. Fish were fed at 5% body weight twice daily for 10 weeks at 8:00-9:00 and 16:00-17:00. Fish from each hapa were batch-weighed weekly with an electronic balance (Mettler BD 601) and daily feed allowances were adjusted accordingly. Fish were starved on weighing day to reduce stress-induced feed regurgitation. Hapa nets were thoroughly cleaned of debris and plankton during the short interval of weighing. Five fish were collected at the start of the experiment and from each of the three replicates of each dietary treatment at the end of the experiment, and sacrificed for carcass analysis (AOAC, 1990).

Chemical analyses. The proximate compositions of feed ingredients, experimental diets, and fish carcasses (initial and final) were analyzed as follows: crude protein (N x 6.25) by Kjeldahl methods, crude lipid by extraction with petroleum ether in a Soxhlet apparatus, ash content at 450°C in a Gallenkamp Muffle Furnace, and crude fiber as loss on ignition of dried lipid-free residues after acid-alkaline digestion (trichloroacetic acid method). Moisture was determined after oven-drying in a Gallenkamp oven (BS 250 size 2) at 105°C to a constant weight (AOAC, 1990). Total free sugar was determined as described by Dubios et al. (1956), total tannin as described by Graham (1992), and phytate as described by Wheeler and Ferrel (1971). The amino acid profile was determined after digestion in 6N HCl for 22 h at 110°C in a Technicon TSM-1 Model DNA 0209. Tryptophan was determined as described by Matheson (1974) and phosphorus by the phosphor-vandomolybdate method. Feces were collected daily during the last three weeks of the feeding trial, pooled according to treatment, dried, and stored in tagged cellophane bags for analysis. Chromium III oxide contents of the diets and fecal materials were determined as described by Schurch et al. (1950). Gross energy was calculated according to Jobling (1983), based on an estimated 23.65 MJ/kg for protein, 40 MJ/kg for lipids, and 16.8 MJ/kg for carbohydrates.

Data analysis. Growth performance and feed utilization were statistically analyzed by one-way Analysis of Variance (ANOVA) and differences between means were tested for significance (p = 0.05) using Duncan's Multiple Range Test. Weight gain, specific growth rate (SGR), feed conversion ratio (FCR), protein efficiency ratio (PER), protein productive value (PPV), and apparent digestibility of dry matter, protein, and lipid were calculated using standard formula (Castell and Tiews, 1980). Essential physico-chemical parameters of the culture system were monitored twice weekly. Water temperature (27.7-30°C) was determined with a mercury-in-glass thermometer, dissolved oxygen (4.4-5.30 mg/l) and pH (6.86-7.62) with an Electric Jenway pH meter, NH_3 (0.13-0.35 mg/l) and alkalinity (149-162 mg/l) by the titrimetric determination of total alkalinity.

Results

Fermentation resulted in increased crude protein and decreased lipid, crude fiber, and the nutritional stress factors, tannin, phytic acid and antitrypsin (Table 1). There were no significant differences between raw and fermented meals, but the fermented meal had a measurably superior amino acid profile than the raw (Table 2). Diets with high inclusion levels of fermented pigeon pea meal met the amino acid requirements of *C. gariepinus*; those of the control and lower inclusion levels of fermented meal showed less conformity, especially in lysine, methionine, and phenylalanine (Table 3).

Table 1. Chemical composition (% dry matter) of feedstuffs.

	Crude protein	*Crude lipid*	*Crude fiber*	*Ash*	*NFE*
Fishmeal	68	4.11	-	4	14.8
Soybean meal	42	18	5	4.6	26.5
Ground nut cake	45	8.8	4.6	13.8	30.21
Corn	10	5.5	26.5	1.4	76.6
Pigeon pea meal					
Raw	22.6	4.6	5.22	3.8	63.7
Fermented	27	1.6	1	2.6	66.1

Table 2. Amino acid profiles (g/16 g N) and antinutritional factors in raw and fermented pigeon pea meal.

	Raw	*Fermented*
Arginine	4.38	5.79
Histidine	1.23	1.95
Isoleucine	2.19	3.88
Leucine	2.39	6.65
Threonine	1.82	2.96
Tyrosine	2.39	3.01
Methionine	0.87	1.18
Phenylalanine	4.19	4.28
Tryptophan	0.85	0.93
Valine	4.26	3.65
Lysine	3.47	5.34
Non-essential		
Aspartic acid	12.59	10.01
Serine	2.98	2.90
Glutamic acid	19.46	16.89
Proline	2.99	2.07
Glycine	3.08	4.09
Alanine	0.95	1.96
Cystine	1.04	1.07
Free sugar (g/100 g)	5.97	9.65
Minerals		
Phosphorus (g/kg)	2.76	4.15
Calcium (g/kg)	1.22	1.65
Zinc (mg/kg)	30.42	38.42
Tannin	6.84	1.21
Phytate	5.2	ND
Trypsin inhibitor (TIU/mg)	26.25	2.14

Table 3. Formulation, chemical composition, and essential amino acids of experimental diets.

	Fermented pigeon pea meal (%)					*African catfish require-ments*[1]
	Control	*25*	*50*	*75*	*100*	
Ingredient (g/kg)						
Fishmeal	100	100	100	100	100	
GNC	100	100	100	100	100	
Soybean meal	348.5	296	227.6	134.4	-	
Fermented pigeon pea meal	-	98.7	227.6	403.0	656.0	
Corn	406.5	360.3	299.8	217.6	99.0	
Lysine	10	10	10	10	10	
Methionine	10	10	10	10	10	
Vit/Min premix[2]	15	15	15	15	15	
Vegetable oil	5	5	5	5	5	
Chromium III oxide	5	5	5	5	5	
Chemical composition (%)						
Dry matter	83.21	88.41	89.25	81.22	85.45	
Crude protein	30.94	31.03	30.45	30.02	29.95	
Crude lipid	5.60	5.34	5.50	5.25	5.65	
Crude fiber	4.76	4.46	4.09	3.48	3.06	
Ash	7.42	7.88	8.14	7.20	7.25	
Gross energy (MJ/kg)	16.15	16.90	16.99	15.71	16.50	
Essential amino acid (% of total protein)						
Arg	3.62	4.88	4.52	4.77	5.85	4.30
Hist	0.88	1.02	1.23	1.43	1.73	1.50
Isoleu	2.38	2.44	2.55	2.74	3.05	2.60
Leu	5.31	7.43	7.60	7.55	7.76	3.50
Lys	4.63	4.28	5.25	5.65	5.78	5.00
Met	2.23	2.25	2.66	2.73	3.02	2.30
Pheny	5.56	5.76	5.47	5.68	5.89	5.00
Theo	4.05	3.64	4.42	4.89	5.43	2.00
Tryp	1.01	1.05	1.03	1.22	1.07	0.50
Val	5.43	5.53	5.61	5.16	5.30	0.50

[1] Uys (1989)

[2] Radar Vitamin Premix (g/100 g diet): vitamin A palmitate 1000 IU; cholecalciferol (D) 1000 IU; α-tocopherol acetate (E) 1.1 mg; menadione (K) 0.02 mg; thiamine B1 0.63 mg; riboflavin (B2) 0.5 mg; pantothenic acid 1.0 mg; pyridoxine (B6) 0.15 mg; cyanocobalamine (B12) 0.001 mg; nicotinic acid 3.0 mg; folic acid 0.1 mg; choline 31.3 mg; ascorbic acid (C) 0.1 mg; ferrous sulphate 0.05 mg; copper sulphate 0.25 mg; manganese sulphate 6.00 mg; cobalt chloride 0.5 mg; zinc sulphate 5.0 mg; sodium selenite 0.02 mg.

All feeds were accepted at the start of the feeding trial but feed intake was significantly higher in fish that received diets with higher levels of fermented meal. There were no signs of disease. Survival ranged 60-90% and was not affected by the level of fermented meal, Mortality was non-differential and could have been due to handling.

The mean final weight was significantly higher than the initial weight in all treatments (Table 4). The final weight of the fingerlings fed the 100% replacement diet was significantly higher than of those fed the control, 25%, and 50% diets. All food efficiency factors were best in fish fed the 100% diet, but survival was significantly lower than in fish fed the diets containing a lower amount of fermented meal. There was an increase in carcass protein and lipid in all treatments over the initial contents. The highest carcass protein (33.3%) and lipid (51.6%) gains were recorded in the group fed the 100% diet. Carcass moisture measurably decreased as the inclusion level increased.

Table 4. Growth performance, feed utilization, and carcass composition of *Clarias gariepinus* fed diets containing different amounts of fermented pigeon pea meal for 70 days.

		Fermented pigeon pea meal (%)			
	Control	*25*	*50*	*75*	*100*
Initial body wt (g)	1.31±0.02^{a}	1.32±0.17^{a}	1.35±0.06^{a}	1.39±0.03^{a}	1.22±0.22^{a}
Final body wt (g)	7.65±0.04^{ab}	6.46±0.06^{c}	7.11±0.19b^{c}	8.40±0.41^{a}	8.55±0.31^{a}
Wt gain (g)	6.34±0.02^{bc}	5.39±0.14^{d}	5.76±0.13^{cd}	7.01±0.38^{ab}	7.33±0.27^{a}
SGR (%/day)[1]	2.52± 0.08^{ab}	2.44±0.10^{ab}	2.37±0.03^{b}	2.57±0.04^{ab}	2.87±0.15^{a}
Feed intake (g)	9.49±0.03^{b}	10.09±0.24^{ab}	10.81±0.21^{a}	10.35±0.46^{ab}	10.34±0.37^{ab}
Protein intake (g)	2.85±0.12^{b}	3.03±0.09^{ab}	3.24±0.01^{ab}	3.41±0.17^{a}	3.40±0.14^{a}
FCR[2]	1.50±0.01^{b}	1.88±0.10^{a}	1.88±0.01^{a}	1.48±0.02^{b}	1.41±0.01^{b}
PER[3]	2.22±0.12^{a}	1.78±0.06^{b}	1.78±0.04^{b}	2.06±0.01^{a}	2.16±0.12^{a}
Survival %	60.00±2.00^{c}	90.00±6.00^{a}	87.00±2.00^{ab}	77.00±1.00^{ab}	73.00±5.00^{bc}
ADC[4] dry matter	64.74±0.55^{d}	71.86±0.60^{c}	73.92±0.64^{b}	76.56±0.68^{a}	76.70±0.22^{a}
ADC[4] protein	76.45±0.81^{c}	76.79±1.07^{c}	80.67±1.75^{bc}	84.64±1.22^{ab}	85.30±0.68^{a}
ADC[4] lipid	84.23±1.12^{a}	85.02±2.02^{a}	79.31±04^{ab}	73.44±1.35^{b}	75.09±1.56^{b}
PPV(%)	29.88±0.29^{b}	28.07±0.63^{b}	29.96±1.54^{b}	32.81±1.06^{b}	39.10±2.32^{a}
Carcass composition (%)					
Initial	*Control*	*25*	*50*	*75*	*100*
Moisture 78.61	75.85±2.81^{a}	75.40±1.45^{a}	74.75±0.68^{a}	72.11±2.45^{b}	71.08±1.27^{b}
Crude protein 13.44	15.90±0.30	16.23±0.98	15.55±0.57	17.45±0.57	17.92±0.56
Lipid 5.29	5.70±0.09^{bc}	6.16±0.27^{bc}	7.10±0.55^{a}	7.21±0.34^{b}	8.02±0.81^{a}
Ash 2.66	2.55±0.76^{b}	2.21±0.11^{b}	2.49±0.03^{a}	2.58±0.03^{a}	2.42±0.36^{a}

Data are mean values±standard error

Means in a same row with different superscripts significantly differ (p>0.05)

[1] Specific growth rate = ($\ln_{\text{final wt}}$) - $\ln_{\text{initial wt}}$)/days of feeding x 100

[2] Feed conversion ratio = feed intake/fish wt gain

[3] Protein efficiency ratio = fish wt gain/protein intake

[4] Apparent digestibility coefficient = 100 x [1 - (% dietary Cr_2O_3/% fecal Cr_2O_3 x fecal nutrient/% dietary nutrient)]

[5] Protein productive value = (final fish body protein - initial body protein)/crude protein intake x 100

Discussion

Optimal water quality was maintained by frequently changing the water through the flow-through system; this also guaranteed that metabolic products did not accumulate.

Fermentation of *C. cajan* resulted in a measurable increase in crude protein and decreases in crude lipid, crude fiber, and antinutritional factors. There was also an elevation in phosphorus, calcium, and zinc. This agrees with studies of the effect of *R. oligosporus* fermentation on proximate composition and antinutritional factors of plant-based ingredients (Yigzaw et al., 2004). The increase in phosphorus could have been due to the breakdown of phytic acid (myo-inositol 1,2,3,5/46, hexakisphosphate) during fermentation (Porres et al., 2003). Phytic acid is the major (>80%) phosphorus storage compound in legumes (Baruah et al., 2004). Its breakdown therefore could cause the release of stored phosphorus. The consequent increase in phosphorus may have boosted feed performance. Inclusion of phosphorus can meet the methionine demand in feeds (El Sayed et al., 2000). *Rhizopus oligosporus* can reduce complex carbohydrates to simpler digestible sugar, possibly accounting for the higher level of total sugar in fermented *C. cajan* (Ferket et al., 2002). Proximate composition was improved by bacterial synthesis, in agreement with Steinkraus (1983) who reported that the nutritive value of legumes was improved by fermentation. Fermentation of pigeon pea by *R. oligosporus* has a number of beneficial effects: increased protein content, improved amino acid profile quality (lysine and methionine), and better digestibility of the meal (Yigzaw et al., 2004). Fermentation can also increase vitamin levels and mineral bioavailability and reduce toxic substances such as enzyme inhibitors, hemaglutinnins (lectin), phytates, polyphenols, flatulence factors, cyanogenic compounds, saponins, anti-vitamins, and allergens (Hesseltine and Wang, 1980).

The fingerlings consumed all the diets but feed intake was higher in groups that received diets with high levels of pigeon pea, perhaps because of the presence of low molecular weight metabolites such as free amino acids (FAA) which act as feed attractants in fish rations. FAA are often associated with fermentation (Erbas et al., 2005). The lower feed intake in the groups fed the control and 25% diets could be due to

poor palatability resulting from residual antinutritional factors such as tannin and non-starch polysaccharide (NSP). Soluble NSP can be deleterious to the growth performance of young fish (Leenhouwers et al., 2009).

At the end of the experiment, there were significant differences in growth performance and nutrient utilization between the control group and those fed the pigeon meal diets. The group fed the 100% diet had the highest weight gain (7.33 g), significantly superior to the control, while the group that received the 25% diet had the poorest weight gain (5.29 g). Other growth and nutrient utilization parameters followed an earier trend as when a fermented product was fed to fish (Bairagi et al., 2004). Weight gain, SGR, and PER were significantly higher in groups fed higher pigeon pea levels, possibly because of their higher feed intake and digestibility. Digestibility was directly related to inclusion level, probably because of the reduction in crude fiber, tannin, phytates, and trypsin inhibitors in the fermented pigeon pea meal. Antinutritional factors markedly reduce nutrient utilization (Bairagi et al., 2004) and, together with crude fiber, are reduced by *R. oligosporus* (Yigzaw et al., 2004). Reduction of these factors could have facilitated better digestion and improved nutrient utilization. Also, the increased total free sugar after fermentation could have increased the digestibility of the pigeon pea meal. Elevation of total free sugar with mannose is a growth promoter and energy source (Ferket et al., 2002).

The amino acid profiles of the 75% and 100% diets were similar and higher than the amino acid requirements of *C. gariepinus* fingerling (Uys, 1989). The amino acid profiles of the control, 25%, and 50% diets were marginally similar with lower levels of methionine and lysine, the major limiting amino acids in plant-based diets (Apata and Ologhobo, 1994). This could be responsible for the growth performances.

Soybean is one of the most nutritious dietary protein sources of plant origin (Lovell, 1988) and improves growth performance (Obasa et al., 2006). The soybean meal used in this study was hydrothermally treated to reduce or remove heat labile antinutritional principles such as protease inhibitor and cause carbohydrate gelatinization that can enhance enzymatic hydrolysis of starch. While this could be positive, gelatinization during cooling can result in enzyme-resistant starch due to recrystallization by stronger intra molecular hydrogen bonding (Biliaaderis, 1991). The poor performance of the group fed the soybean-based control diet could have been due to the effect of heat on the bioavailabity of nutrients (Venktesh and Parkash, 1993). Thermal treatment can reduce the solubility of nutrients through the formation of protein complexes with polyphenols, carbohydrates, and general denaturation of protein. The combination of these factors may be partly responsible for the comparatively low digestibility of the control diet.

The levels of trypsin inhibitor and phytates in our soybean meal were lower than those observed to affect the growth performance of *C. gariepinus* (Nwanna et al., 2006). Thus, the relatively inferior performance of the control group could have been due to heat resistant principles inherent in soybean. Soybean contains an estimated 20-30% NSP (Forde-Skjaevik et al., 2006). The soluble part of this fraction could increase digesta viscosity, reducing nutrient absorption and mixing enzymes with digesta. The levels of trypsin and phytates in soybean are well below the tolerance of *C. gariepinus,* thus, NSP could be a major antinutritional factor, especially in young fish as used in this feeding trial. Soluble NSP is more deleterious to growth performance in young fish (Leenhouwers et al., 2009). The ADC for protein, dry matter, and lipid progressively increased with the pigeon pea meal inclusion level, similar to growth in carp fed fermented *Leucaena leucocephala* (Bairagi et al., 2004). Fermentation results in increased lysine and methionine contents (Yigzaw et al., 2004), amino acids that are particularly limiting in legume grains (Apata and Ologhobo, 1994). The improved amino acid profile of fermented pigeon pea meal could have been responsible for the better diet utilization. PPV was highest in the 100% group, suggesting that the amino acid profile was superior and more available to the fish.

Final protein and lipid carcass contents were significantly higher than initial values in all treatments. Protein and lipid values were directly proportional to the inclusion levels of the pigeon pea meal while moisture was inversely related to lipid. The highest carcass

ash was in the control group. These results are similar to those of earlier studies in which fermented legumes were fed to fish (Bairagi et al., 2004).

In conclusion, this study revealed the superior performance of 100% replacement of soybean meal with fermented pigeon pea meal and that fermented pigeon pea meal can be used as a source of dietary protein to replace full fat soybean in practical diets for *C. gariepinus* fingerlings. The use of fermented pigeon pea meal in feed formulations instead of soybean meal can bring about a reduction in price of fish products to levels affordable by a majority of consumers. Such replacement would reduce competition between man and animals for soybeans as a feed ingredient, with a consequent reduction in the market price of fish. The process of fermentation can be easily adopted by rural small-scale fish farmers who could extend the method to other non-conventional resources of plant origin.

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