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Cost Benefits of Fermented Groundnut Shell Meal as Supplemented Feed in the Diets of *Clarias gariepinus* Fingerlings

*Sogbesan, O. A. and Ekundayo, T.M.
Department of Fisheries and Aquaculture, Modibbo Adama University of Technology Yola, PMB 2067, Yola, Nigeria,

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ABSTRACT
The cost benefits of fermented groundnut shell meal as supplemented feed in the diets of *Clarias gariepinus* (catfish) fingerlings were investigated using semi-flow through system in fish farm and laboratory over a period of 12 weeks. The improvement in the nutritional composition of groundnut shells was attempted through solid state fermentation. A comparative utilization of the fermented groundnut shells, and a control diet was studied using parameters like growth performance and nutrient utilization in addition to economic indicators to arrive at conclusion that isonitrogenous diets were produced using fermented groundnut shells which were compared to a control diet. The process of fermentation resulted in improvement in the crude protein value of groundnut shells and the reduction in the crude fibre composition. Probably as a result of the fermentation process, fingerlings fed diet 5 had a better food conversion ratio (FCR), protein efficiency ratio (PER), mean weight gain (MWG) and specific growth rate (SGR) than other fermented diets and the control. Similarly, Highest Net Profit, Profit Index and Benefit Cost Ratio of ₦475.76, ₦4.16, and ₦3.50 respectively were from diet 5. This study recommended diet 5 for optimum growth performance and economic benefit in sustainable aquaculture.

Key Words: Fermentation, Groundnut shell, Benefit Cost Ratio, Catfish

INTRODUCTION

Fish is generally accepted as protein source in diets of average Nigerians (Agbabiaka, 2010). Economically and nutritionally, fish is the cheapest source of animal protein and micro-nutrients for several millions of people as documented by Bene and Heck (2005). The growth and development of Aquaculture in sub-Saharan Africa, including Nigeria has been reported to be insignificant compared to those in Asia and Europe (Changadeya *et al*., 2003) because of non-availability of quality feed at economic prices hence the fish production cum supply has been in deficit of the demand.

In view of this, many studies have been conducted on the use of non-conventional feedstuffs such as roots and tubers, and plant by-products which can probably reduce feed cost and ultimately the production cost in fish farming in particular. For the purpose of nutritional and economic benefits, previous researchers have made attempts at increasing the use of non-conventional plant and animal materials such as maize-

*Corresponding Author email: sokayfish@gmail.com, Tel: +234(0)8050957768

cobs (Sogbesan *et al*., 2012), Mucuna (Sogbesan *et al*., 2012) to replace conventional feed ingredients like maize and fish meal in the fish feed ration (Baruah *et al*., 2003; Eyo, 2004).

Groundnut (*Arachis hypogea*) shell is a by-product of groundnut processing industry. Groundnut shell is a waste produced when the nut is being processed for consumption by breaking the shell open manually or mechanically. Groundnut shells are classified as low value agricultural wastes or agricultural by-products. However, new technology and innovation has converted groundnut hulls to a wide range of applications. Groundnut shells which are agricultural by-products are one of the most available biomass resources in the northern part of Nigeria. This unique renewable energy resource has a high potential to be an alternative for fish feed. The presence of lignin in these agrowastes limit their utilization by either herbivorous or omnivorous fish, hence there is a need to break this lignin barrier either by physical, chemical or/and biological treatments. The biological treatment of fibrous materials is not entirely new and the biotechnological techniques are gradually being introduced into the field of aquaculture nutrition/biotechnology nutrition throughout the globe. If the huge amount could be recycled or converted to useful feedstuff, the whole environment will be cleansed of pollution, thereby improving human health (Sogbesan *et al.,* 2012).

The development of fish production in the semi-intensive and intensive culture system is adversely affected by the current high cost of fish feed. It also accounts for a minimum of 60% of the total cost of fish production in Africa (Falaye, 1992; Jamu and Ayinla, 2003; Sogbesan, 2014), a major factor that determines the viability and profitability of fish farming enterprise. The major component in fish feed formulation is the fishmeal (that constitute about 50-70% by weight), which was to appear limited as a result of high cost, non-availability and competition from poultry and livestock sectors (Misra *et al*., 2003).

According to Olurin *et al*. (2006), maize is the major source of metabolisable energy in most compounded diets for *Clarias* species. This is because it is readily available and digestible. However, the increasing prohibitive cost of this commodity has necessitated the need to search for an alternative source of energy. The use of maize in fish feeds as a source of energy (carbohydrate) is becoming increasingly unjustified in economic terms (Tewe, 2004) because of the grossly increasing cost of maize due to high competition between human and livestocks. There is, therefore, the need to exploit cheaper energy sources to replace expensive cereals in fish feed formulation in order to relieve the food feed competition between man and animal and for profit maximization. The fermented groundnut shell meal is very appropriate for this purpose.

The need to solve the problems of feeding in aquaculture has been demonstrated through various researches in the utilization of agricultural wastes such as poultry offal (Fasakin, 2008), fermented shrimp head waste meal (Nwanna, 2003), maggot meal (Faturoti *et al*., 1995; Fasakin *et al*., 2004; Sogbesan, 2014) and water hyacinth meal (Sotolu, 2008) has been emphasized in the formulation of the least cost fish feed towards ensuring profitable fish business. Groundnut shell is an observed predominant waste from the processing of groundnut in Northern Nigeria. The abundance of groundnut shell as the alternative would therefore constitute a huge benefit for the sustainability of the aquaculture industry if properly harnessed. This study is therefore designed to investigate the cost benefit of utilizing fermented groundnut shell meal in the diets of *Clarias gariepinus* fingerlings.

MATERIALS AND METHODS

Experimental site

The experiment was carried out in the Teaching and Research Fish Farm, Department of Fisheries, Modibbo Adama University of Technology, Yola. The experimental set-up which is a semi - flow through system consisted of fifteen (15) circular plastic tanks. The semi-flow through the consist of inlet pipe through which water is supplied to the set-up, outlet pipe which regulate water inflow to the set-up, plastic bowls that serve as aquatic environment for the experimental fish fingerlings. The plastic tanks were cleaned, disinfected and allowed to dry for 24 hours, after which water was supplied to two-third of the size of the tank and were covered with 3mm mesh net to protect the fish from jumping out of the tanks.

32Collection and processing of fish feed ingredients

Five kilogram weight of groundnut shells used for this research was obtained from the groundnut processing firm in Yola metropolis, Adamawa State, Nigeria where the shells were indiscriminately dumped after removing the groundnut seed. Other ingredients were purchased from local market in Yola. The groundnut shells were pre-treated using hot air oven at 100°C until a constant weight was obtained for any dry matter. This was to obtain constant dryness and to prevent groundnut shells from being infected with fungi such as aflatoxin before solid state fermentation process.

Fermentation of groundnut shells

Solid state fermentation was carried out under laboratory condition. The oven dried groundnut shells were divided into six different treatments of solid state fermentation for a period of 0, 12, 24, and 48 hours in accordance with Sogbesan *et al.* (2012) where 100ml of distilled water and 10g of potash were added to 500g groundnut shells. The addition of potash is to serve as a softening agent and to serve as a buffer in order to create a suitable medium for the growth of fungi (FAO/WHO, 2011):

(a) **Control:** 500g of raw, cleaned dried groundnut shells were not subjected to solid state fermentation thereby serving as control**.**

(b) **Moistened without ash for 12 hours (S12):** 500g Groundnut shells were moistened with 100ml distilled water only and fermented for 12 hours under laboratory conditions.

(c) **Moistened with ash for 12 hours (SA12):** 500g Groundnut shells were moistened with 100ml distilled water and 10g of potash; fermented for 12 hours under laboratory conditions.

(d) **Moistened without ash for 24 hours (S24):** 500g Groundnut shells were moistened with 100ml distilled water only and fermented for 24 hours under laboratory conditions.

(e) **Moistened with ash for 24 hours (SA24):** 500g Groundnut shells were moistened with 100ml distilled water and 10g of potash; fermented for 24 hours under laboratory conditions.

(f) **Moistened without ash for 48 hours (S48):** 500g Groundnut shells were moistened with 100ml distilled water only and fermented for 48 hours under laboratory conditions.

(g) **Moistened with ash for 48 hours (SA48):** Groundnut shells were moistened with 100ml distilled water and 10g of potash; fermented for 48 hours under laboratory conditions.

Oven drying, grinding and sieving of solid state fermented groundnut shells

The solid state fermented groundnut shells were oven dried at the end of each fermentation time of 12 hours, 24 hours and 48 hours respectively at a temperature of 100°C for 12 hours. This was followed by grinding of the fermented groundnut shells using hammer miller to powder form. They were sieved and kept in sealed polythene bags until required.

Experimental diet formulation

The feed ingredients comprised of milled fermented groundnut shells, fish meal, groundnut cake, vitamin/mineral premix, cassava starch (binder), salt, palm oil, methionine, and lysine. The crude protein values of the groundnut shell meal derived from the proximate analysis were used to formulate feed at a crude protein level of 40.0% using the Pearson square method (Table 1). These ingredients were grounded, sieved and weighed into a bowl with the aid of a sensitive weighing balance. Five (5) diets, (Diet 1 (Control), Diet 2, Diet 3, Diet 4 and Diet 5) were formulated for *Clarias gariepinus* fingerlings.

Experimental diet preparation

The milled feed ingredients were weighed according to the formulated proportion and mixed in a bowl. Warm water was added to make the mixture moist forming homogenous dough. The resultant dough was extruded through pelleting machine into suitable size pellets. The pellets were collected and spread out in the sun for drying. The finished products (dried pelleted feed) were broken into smaller sizes, packaged and stored in cellophane bag till when they were used for 12 weeks feeding trials.

Table 1: Formulation and production cost of experimental diets

Ingredients (g/kg)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Fish Meal	30.00	30.00	30.00	30.00	30.00
Maize	30.00	0.00	0.00	0.00	0.00
Groundnut cake	34.00	34.00	34.00	34.00	34.00
Fermented Groundnut shell	0.00	30.00	30.00	30.00	30.00
Vitamin & Mineral Premixes	2.00	2.00	2.00	2.00	2.00
Starch	1.00	1.00	1.00	1.00	1.00
Salt	0.50	0.50	0.50	0.50	0.50
Palm-Oil	0.50	0.50	0.50	0.50	0.50
Methionine	1.00	1.00	1.00	1.00	1.00
Lysine	1.00	1.00	1.00	1.00	1.00
Total	100.00	100.00	100.00	100.00	100.00
Calculated Crude Protein (%)	40.02	40.02	40.02	40.02	40.02
Cost of production (₦/kg)	266.20	242.20	242.20	242.20	242.20
Calculated gross energy (kcal/100g)	12.07	12.07	12.07	12.07	12.07
Protein/Energy ratio	3.32	3.32	3.32	3.32	3.32

Keys: Control=Diet 1; Diet 2 (S12), Diet 3 (SA12), Diet 4 (SA24) and Diet 5 (SA48).

Experimental fish

One hundred and fifty fingerlings of *Clarias gariepinus* were obtained from Salihu farm in Yola and transported to the laboratory in 50 litre water storage can. They were held in circular plastic tanks for one week for acclimation. They were also randomly stocked at the rate of ten (10) fingerlings per plastic bowl in triplicate into 15 plastic bowls for growth trials. They were aerated with electric powered aerator.

Feeding rate and frequencies

Each of the diet was fed at 5% body weight twice daily (9:00-10:00 and 17:00-18:00) for 12 weeks and the quantity of feed was adjusted based on the new weight after 7 days.

Monitoring and sampling

Each bowl was monitored for survival rate. The length and weight of each fingerling in each tank were measured at the commencement and the end of the experiment. Subsequently, all the fingerlings were taken from each tank once a week and weighed to access the growth rates and the new weight were used to adjust feed rations. The total and average weight and length of fish in each tank were computed at the end of the experiment.

Water quality parameters

Water quality parameters records were taken twice a week before feeding, temperature at 7:00-8:00 with mercury-in-glass thermometer calibrated in degree centigrade (^{o}C). Dissolved oxygen was determined by using the Winkler's solution and pH with Digital pH meter (E251) model.

Biochemical analysis

One hundred grams of sample of each diet were analysed in the laboratory for proximate composition of the fish feed pellets. The proximate analysis was carried out for crude protein, crude fibre, crude lipid, ash and Nitrogen free extracts according to the Association of Official Analytical Chemist Methods (A.O.A.C., 2010).

Economic evaluation of experimental diets

The cost was based on the current prices of feed ingredients in Yola, Nigeria as at the time of purchase. The economic evaluation of the diets was done according to New Method (New, 1989):

Estimated Investment Cost Analysis (EICA) = cost of feeding (₦) – cost of fingerlings stocked

Profit Index (PI) = Value of fish (₦) /Cost of feeding (₦), Net profit = sales – expenditure

Benefit cost ratio = total sales at (₦) /total expenses (₦)

Statistical analysis

All the data were subjected to descriptive statistics, analysis of variance, correlation and regression and line graph representation. The mean values were compared at 5% significance level using Duncan Multiple Range Test Duncan (1955) with the aid of SPSS 16.0 for windows.

RESULTS

Table 1 presented the formulation and cost of production of the experimental diets at ₦262.00 for the diet 1 and ₦ 242.00 for other diets (2, 3, 4, and 5) and the feed ingredients in gram per kilogram consisting of fish meal, maize and fermented groundnut shells at 30% inclusion each; while the groundnut cake was 34% included in the ingredient make up. Other ingredients are vitamin premix (2%), starch (1%), salt and palm oil (0.5%), and methionine and lysine are 1% each.

The proximate composition and the gross energy in kilocalorie per kilogram of the experimental diet 1, died 2, died 3, diet 4 and diet 5 with their respective values are presented in Table 2. The highest dry matter of 88.03% was recorded in diet 5, while the lowest (86.80%) was in diet 2. There is no statistical difference in dry matter between the experimental diets 1, 2, 3, 4, and 5 at $p< 0.05$ level of significance. Similarly, the highest moisture content recorded was 13.20% in diet 2 and the lowest was 11.95% in diet 5 which was statistically significant to diet 2 and other diets. There was a significant difference among the diets in terms of crude protein at $p<0.05$. The highest crude protein of 43.41% was recorded for diet 5 while the least value of crude protein, 41.61% was recorded for diet 1. This gave a 96.31% improvement from the initial value of the control. The highest crude fibre of 3.31% was discovered in diet 1 while the least value 1.08% of crude fibre was recorded in diet 5. There was a 41.58 % reduction in fibre fraction. Diet 3 to diet 5 were not significantly different from each other, but were significantly different from diet 1 and diet 2. The lipid value also shows a level of significance from diet 1 to the other fermented diets 2, 3, 4, and 5. The highest value of 9.30% was recorded in diet 1 and the least value of 7.15% was from diet 5.

Table 2: Proximate and energy composition of the experimental diets

Proximate Composition (%)	Diet 1	Diet 2	Diet 3	Diet4	Diet 5	SEM
Moisture	9.11	9.20	9.25	9.30	9.97	0.25
Crude Protein	41.61	42.51	42.77	43.28	43.41	0.32
Ether Extract	9.30	8.51	7.20	7.22	7.15	0.44
Crude fibre	3.31	2.15	1.10	1.14	1.08	0.44
Ash	4.00	4.51	4.72	4.81	4.85	0.16
Dry matter	86.89	86.80	87.75	87.70	88.03	0.25
NFE	28.67	29.12	31.96	31.25	31.54	0.67
Calculated Gross Energy (kcal/100g)	1842.47	1840.25	1843.48	1844.10	1849.39	1.51
Digestible energy (kcal/100g)	1531.36	1529.51	1532.20	1532.71	1532.11	1.26

NB: Calculated gross energy = Protein X 23.6KJ/100g + Lipid X 39.5 KJ/100g + NFE X 17.2KJ/100g (Blaxter, 1989).

Mean water quality parameters were presented in Table 3. The temperature was 28.50±0.05 as the lowest, and 29.10±0.05 as the highest. Diet 1, 2, 3, 4, and 5 were not statistically different from each other, while diet 2, 3, and 4 is also not different from each other, but diet 5 is statistically different to diet 2, 3, and 4 respectively. The pH of 7.30±0.05 was the highest from diet 5 and diet 1 recorded the lowest pH of 7.08±0.00. All these diets were statistically different from each other across the row. Dissolved oxygen of 6.43±0.02 was the highest from diet 1 and diet 4 recorded 6.20±0.00 as the lowest value. Diets 1, 2, and 3 were not different from each other, but were statistically different to diet 4 and diet 5, while diet 4 and 5 were not different from each other at p<0.05.

Table 3: Mean (±SEM) water quality parameters of the during the experiment

Composition	Diet 1 (Control)	Diet 2 S12	Diet 3 SA12	Diet 4 SA24	Diet 5 SA48	SEM
Temp. (°C)	28.50[a]±0.05	29.10[ab] ±0.05	29.02 [ab] ±0.02	29.00 [ab] ±0.05	28.70 [ac] ±0.05	0.11
pH	7.08[a]±0.00	7.20 [a] ±0.00	7.13 [a] ±0.01	7.15 [a] ±0.00	7.30 [a] ±0.05	0.04
DO (mg/l)	6.43[a]±0.02	6.39[a] ±0.00	6.38[a] ±0.01	6.20[b] ±0.00	6.30[b] ±0.02	0.04

Means with the same superscript along the same row are not statistically different from each other and vice versa at p<0.05.
Keys: SEM = Standard Error of Mean

The growth performance and feed utilization of *Clarias gariepinus* fingerlings fed with fermented groundnut shell diets is presented in Table 4. It was revealed that *Clarias gariepinus* responded positively to all the diets since an increase in weights was recorded as shown in Table 4. The highest mean weight gain (MWG) of 5.87g; specific growth rate (SGR) (0.51%/day), metabolic growth rate (18.10), and protein efficiency ratio (PER) (0.56) were recorded in diet 5 and the lowest MWG of 3.84g, SGR (0.38%/day), MBR (13.37), and lowest PER of 0.36 was from diet 4. The best feed conversion ratio (FCR) of 0.43 was recorded in diet 5. All the parameters studied were significantly different (p<0.05) among each other and the control diet (died 1). Figure 1 presented the growth pattern recorded during the course of this study and it showed a linear growth pattern among the fingerlings fed fermented groundnut shell diets and the control diet. The survival rate recorded falls within 80-93% and there were statistical differences between the diets.

Table 4: Growth parameters, feed utilization indices of *Clarias gariepinus* fingerlings fed with fermented groundnut shell diets

Parameter	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	SEM
Initial mean weight (g)	3.50	3.52	3.65	3.60	3.50	0.03
Final mean weight (g)	8.46	8.10	9.00	7.44	9.37	0.37
Mean weight gain (g/fish)	4.96±0.02[a]	4.58±0.05[ab]	5.35±0.04[ac]	3.84±0.02[ad]	5.87±0.01[a]	0.34
Relative growth rate (%/fish)	141.75[ab]	130.11[ab]	146.58[ab]	106.67[c]	167.71[a]	10.03
Metabolic growth rate	17.42[a]	15.99[ab]	16.72[ab]	13.37[c]	18.10[a]	0.82
Specific growth rate (%/day)	0.50±0.00[a]	0.46±0.01[b]	0.47±0.01[b]	0.38±0.02[a]	0.51±0.00[ab]	0.02
Mean feed intake (g)	2.56±0.01[a]	2.60±0.01[ac]	2.53±0.00[ad]	2.54±0.01[ad]	2.51±0.01[bd]	0.02
Feed conversion rate (FCR)	0.52±0.01[a]	0.57±0.01[a]	0.47±0.01[bc]	0.66±0.01[ac]	0.43±0.01[bd]	0.04
Survival (%)	87	83	90	87	89	2.19
Protein intake	10.75	10.92	10.63	10.67	10.54	0.06
Protein efficiency ratio (PER)	0.46±0.02[a]	0.42±0.01[ac]	0.50±0.01[ac]	0.36±0.02[bc]	0.56±0.02[ac]	0.03
Protein rating	4.95	4.59	5.32	3.84	5.90	0.35
Condition factor (k)	2.17[b]	2.54[b]	1.86[c]	3.63[a]	1.55[c]	0.36

NB: Values with same superscript along row are statistically not different to each other and vice versa

The economic evaluation (Table 5) indicated that the highest benefit cost ratio (BCR) (7.89±0.02), net profit (NP) (₦1, 309.76±0.03) and profit index (PI) (9.36±0.03) were obtained from diet 5 while the lowest BCR, NP and PI of 6.11±0.03, ₦973. 56±0.03 and 7.26±0.03 respectively were obtained from diet 4. However, lowest Estimated Investment Cost (EIC) of ₦190. 24±0.01 was from diet 5 while the highest EIC value of ₦ 210.07±0.01 was recorded for diet 1. The BCR of diet 3 and 5 were not statistically different from each other, but they are statistically different from diets 1, 2 and 4. This is similar to the results obtained for NP, but diet 4 were statistically different to each other diets ($p<0.05$). The PI value of diet 1, 2 and 4 were not significant, but they were significantly different to diets 3 and 5. Table 6 presented the paired correlation of the performance indices of *Clarias gariepinus* fed experimental diets. Feed conversion ratio (FCR) was negatively correlated to SGR, PER, NP, BCR, and PI except incidence cost which was positively correlated.

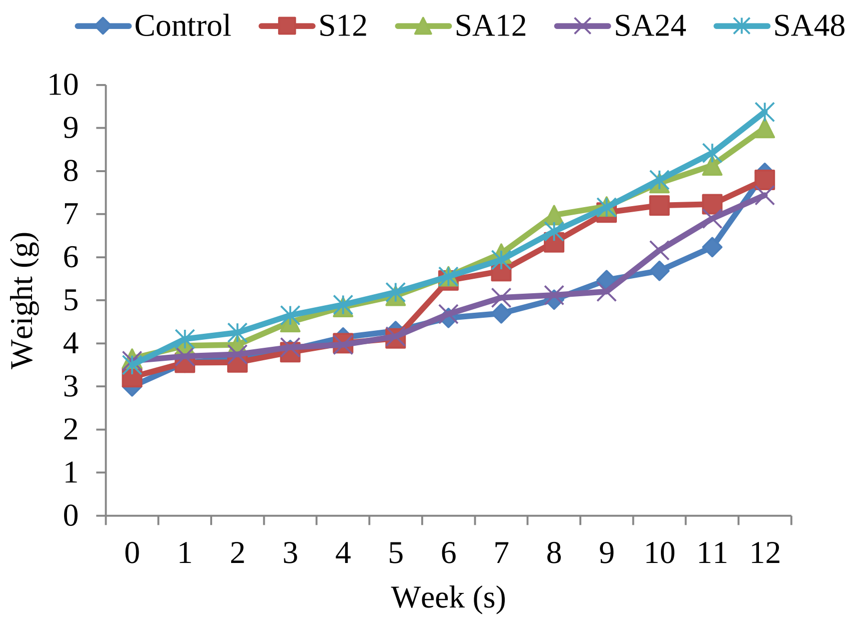

Figure 1: Weekly growth pattern of *Clarias gariepinus* fed with fermented groundnut shell diet for 12 weeks

Table 5: Economic performance of the fermented groundnut shell diets (₦)

Ingredients	**Diet 1 (Control)**	**Diet 2 (S12)**	**Diet 3 (SA12)**	**Diet 4 (SA24)**	**Diet 5 (SA48)**	**SEM**
Initial Cost of fish (₦)	30.00	30.00	30.00	30.00	30.00	0.00
Kg of fish produced	2.21 ±0. 00[a]	2.02 ±0. 00[a]	2.43 ±0. 00[a]	1.94 ±0. 0[bc]	2.50 ±0. 00[ac]	0.19
Estimated Investment Cost (EIC)	210.07 ±0. 01[a]	190.57 ±0. 02[b]	190.37 ±0. 02[c]	190.44 ±0. 0[c]	190.24 ±0. 01[d]	35.38
Value of fish @ ₦600/kg	1326.00 ±0. 04[a]	1212.00 ±0.03[a]	1458.00 ±0.03[ab]	1164.00 ±0.02[ac]	1500.00 ±0.02[a]	112.45
Net Profit (NP) (₦)	1115.93±0.02[a]	1021.43±0.02[a]	1267.63±0.03[ab]	973.56±0.03[ac]	1309.76±0.03[a]	79.13
Incidence of cost (IC) (₦/kg)	81.45±0.04[a]	79.49±0.02[a]	65.99±0.04[bc]	82.70±2.00[ac]	64.10±0.06[cd]	288.22
Profit index (PI)	7.36±0.03[a]	7.55±0.03[a]	9.09±0.00[ab]	7.26±0.03[ac]	9.36±0.03[a]	0.70
Benefit cost ratio (BCR)	6.31±0.03[a]	6.36 ±0.03[a]	7.66±0.02[ab]	6.11±0.03[ac]	7.89±0.02[a]	0.59

NB: Values with same superscript are statistically not different to each other along the same row SEM = Standard Error of Mean

Table 6: Paired correlation of the performance indices of *Clarias gariepinus* fed the experimental diets

	FCR	**SGR**	**PER**	**NP**	**BCR**	**PI**	**IC**
FCR	1						
SGR	-0.89106	1					
PER	-0.98785	0.857735	1				
NP	-0.48737	0.079918	0.552911	1			
BCR	-0.48628	0.076275	0.553138	0.999796	1		
PI	-0.39863	-0.00857	0.468025	0.994117	0.993175	1	
IC	0.820453	-0.91393	-0.74654	-0.10727	-0.09701	-0.03839	1

DISCUSSION

The aim of every fish farmer is to make profit at the end of the cultural season. Since the cost of feed has been one of the major constraints to the development of aquaculture sector; provision of an alternative ingredient that will be able to reduce certain percentage of the cost incurred by feeding overhead cost should be embraced. The reduction in cost of production of the experimental diets from ₦ 266.20 in diet 1(control) to ₦ 242.20 in fermented experimental diets (diet 2, 3, 4 and 5) is an indication of the cost effectiveness of using groundnut shells as non-conventional feedstuff in fish feed formulation (Table 1). This is similar to the report that non-conventional feed resources (NCFRs) are very cheap by products or wastes from agriculture, farm-made feeds and processing industries (Sogbesan, 2014).

It was found that the moisture content of the experimental diets including control was below 12%, and this corresponds with the theoretical range of moisture content in all low moisture food (Bradley, 1994). All the diets, however, did not exceed 75%, and based on Crickenberger and Carawan (1996) which stated that a feed sample that does not exceed 75% moisture content are suitable to be utilized as foodstuffs for animals. Therefore fermented groundnut shell diets can be classified as low moisture, biological material; hence it is safe from biological spoilage and possible aflatoxin production by mould (Table 2). Generally, crude protein (CP) of fermented groundnut shell diets increased significantly ($p<0.05$) at fermentation time 12, 24, and 48 hours. This is due to the action of some fungi. This is in accordance with the work of Joseph (2012) who used *Pleurotus ostreatus* to treat rice straw and groundnut shell. The highest crude protein recorded from diet 5 showed the improvement of the nutritive value of the experimental diet through solid state fermentation. This corresponds with the work of Lateef *et al*. (2008) who studied the effect of solid state fermentation of some agro-wastes with the fungus *Rhizopus stolonifer* and the protein contents of the substrates increased significantly by up to 94.8%. Similarly, Yang *et al*. (1986) also reported an increase in crude protein (CP) up to 60.9% after the harvest of mushrooms from the residual substrate.

Furthermore, the increase in crude protein may be due to the addition of fungal protein or the bioconversion of carbohydrates in the colonized substrates into mycelia proteins or single cell protein (SCP) by the growing fungus during the fermentation process (Iyayi, 2004). It may also be partly due to the secretion of some extracellular enzymes such as cellulases and amylases by the fungus in an attempt to use cellulose and starch as sources of carbon (Raimbault, 1998; Oboh *et al*., 2002).

It was found that the presence of potash at fermentation time 12, 24 and 48 hours gave significant reduction in crude fibre. This decrease in fibre contents might be due to the action of fungi and increased activities of the fibrolytic enzymes during fermentation which hydrolyses fibrous components of the groundnut shells. This is similar to the work of Sogbesan *et al*. (2012) on the effect of solid state fermentation on the maize cob as co-energy in the diet of carp (*Cyprino Carpio*). Lateef *et al.* (2008) studied the effect of the fungal strain *Rhizopus stolonifer* LAU 07 on cocoa pod husk (CPH), cassava peel (CP), and palm kernel cake (PKC) and observed that the crude fibre contents decreased by 7.2%, 8.6% and 44.5% in CPH, CP, and PKC, respectively after the fermentation. Yang *et al*. (1986) also reported that after the 2nd, 3rd and 4th harvests of mushrooms, crude fibre content reduced by 42.4%, 48.1% and 50.4% respectively. In this research, the crude fibre (CF) content of the fermented groundnut shells (S12, SA12, SA24, and SA48) decreased significantly ($p < 0.05$) from 47.06% to 41.18% for S12, 47.06% to 5.56% for SA12; 47.06% to 5.75% for SA24 and SA48 (5.48%) respectively at the end of the optimum fermentation period.

The decline in crude fibre levels is supported by Kutlu *et al.* (2000) and Alemawor *et al*. (2009) who reported a reduction in crude fibre levels in the substrates they fermented with *P. ostreatus*. The reduction in the crude fibre content could probably be due to the action of the enzymes secreted by the fungus, as suggested by Miszkiewics *et al*. (2004). During the solid state fermentation process and activities, the enzymes from the fungus break down polysaccharides into less complex structures (Aderemi and Nworgu, 2007). Therefore the treatment of the groundnut shells with solid state fermentation has improved their nutritional value of the experimental diets, suggesting that they can be useful fish feedstuffs since their complex components have been broken down by the fungus and the presence of potash.

The mean water qualities in all the treatment diets were within the tolerable ranges for catfish culture (Chuapoehuk, 1999). In this study, there was a general increase in weight gain in all treatments which indicated that the fish were able to convert feed protein in extra muscles. Weight gain and growth rate are usually considered as the most important measurement of productivity of diets (Hossain *et al*., 1995; Omitoyin and Faturoti, 2000). In Table 4, the increase in weight gain recorded in all the treatments also indicated that the fish responded positively to all the diets and that the protein content of the fermented groundnut shell diet enhanced the growth of the fish. This observation is in agreement with the report of Fagbenro and Arowosoge (1991) as well as Eyo and Olatunde (2003).

Specific growth rate values obtained from diet 2 to diet 5 were not statistically different but differed significantly from the values obtained for diet 1 (Table 3). The best feed conversion ratio (FCR), 0.43±0.01 recorded for diet 5 which is an indication of an optimum level of utilization of the groundnut shell diet by the *Clarias gariepinus* fingerlings. This corresponds with Adikwu (2003) who stated that the lower the FCR, the better the feed utilization by the fish. In this study, the lowest FCR value is an indication of better feed utilization by the fish and this account for the better growth performance of *C. gariepinus* fed diet 5 among other diets. This corresponds to observations made by Shabbir *et al*. (2003) and Jabeen *et al*. (2004) in related studies on feeding trials.

Protein efficiency ratio (PER) is known to be regulated by the non-protein energy input of the diet and is a good measure of protein-sparing effect of lipid and/or carbohydrate (Li *et al*., 1989; Tibbets *et al*., 2005). Protein efficiency ratio observed in this study exhibited significant differences in all treatments. The significantly higher PER value obtained from diet 5 indicated maximum utilization of inherent nutrients in the diet at this level which was not in other diets.

The general well-being of the fish fed fermented groundnut shell diets are expressed by the condition factor (K) which is significantly different from the control (diet 1) (Table 4). Survival rate was high in all treatments. The mortality occurred in this study might be due to the antinutrients present in the diets and any other extraneous factors which agreed with Alegbeleye (2005) who reported that mortality might not be due to the antinutrients in the diets alone but also to any other extraneous factors such as stress resulting from handling.

The cost benefit analysis in this study did not take into consideration the cost of both semi-flow through system and water because they are considered as constant. As it was shown in Table 5, there were positive returns for all the diets, diet 5 was the most profitable compared with the diet 1 (control) and other fermented dietary treatments with the profit index value of 9.36±0.03. The lowest profit in diet 4 (₦ 973.56±0.03) was as a result of the low utilization of the feed by the fish, hence lower weight gain compared to diet 5 which has a net profit of ₦ 1,309.76±0.03. The use of diet 5 in the fish feed formulation indicated higher returns than use of diet 1 and other fermented diets (diet 2, diet 3, and diet 4).

Diets 2, 3, 4 and 5 have reduced cost of feed compared with the control diet. This is an indication of a cheaper and cost-effective non-conventional feed ingredient called groundnut shells relative to maize meal. Although diets 2, 3 and 4 also have the same cost of feed as diet 5, the total cost of producing a fermented groundnut shell meal and purchasing other ingredients progressively reduced from ₦266.20 to ₦242.20. Value of fish was significantly higher in diet 5 compared to other fermented diets (diet 2, diet 3 and diet 4) and the diet 1 (control). This observation could be as a result of the fermented groundnut shell diet, which was better utilized by fingerlings at diet 5 than other fermented diets including the control; also it may be due to the highest mean weight gain obtained by diet 5. Diet 1 (Control) had the highest incidence of cost (₦ 81.45±0.04) while diet 5 had the least (₦ 64.10±0.06). Profit index recorded was highest (9.36±0.03) in diet 5 and least (7.26±0.03) in diet 4. The possibility of getting a significantly higher value of profit index in diet 5 above those of the controls and other experimental diets, clearly signifies that more profit would be generated from *Clarias gariepinus* produced from diet 5. There were negative correlations between the FCR and other indices considered except incidence cost (IC), while with SGR, the IC and PI were negatively correlated. Considering the availability of groundnut shells as agro-wastes products in Yola, Adamawa State, and the results from the present study, it can be concluded that diet 5 is profitable and can be used efficiently for the production of *C. gariepinus*. Consequently, fish farmers will benefit economically through the utilization of the cheaper ingredient in Diet 5.

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