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Effects of sesame seed meal and bambaranut meal on growth, feed utilization and body composition of juvenile African catfish *Clarias gariepinus*

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Abstract

Plant proteins are plausible fishmeal substitutes but are deficient in some essential amino acids (EAA) like lysine and methionine. Combination of different plant proteins with complimentary EAA could be useful alternative. Bambaranut (*Voandzeia subterranea*) contains high amount of lysine while methionine is in sesame seed (*Sesamum indicum*). This experiment tested effects of combining sesame seed meal (SSM) and bambaranut meal (BNM), on juvenile African catfish *Clarias gariepinus*. Inclusion levels (%) of SSM: BNM in four novel diets were, feed 1 (F1) 0:35, feed 2 (F2) 11.7:23.3, feed 3 (F3) 23.3:11.7, feed 4 (F4) 35:0. Catfish (initial weight ± SD 11.7 ± 0.56 g) were stocked in four replicate 15L glass aquaria at 20 fish tank^{-1}. Final weight and specific growth rate (SGR) were significantly higher for catfish fed F2, F3 and F4 (SGR treatment means varying between 8.34 - 8.67 % day^{-1}) than for F1 (7.60 ± 0.27 % day^{-1} and feed conversion ratio (FCR) significantly lower for F2, F3 and F4 (0.71-0.73) than for F1 (0.8 ± 0.04). Catfish fed F1 had higher body water and lower lipid and protein content than fish in the other treatments. Protein efficiency ratio was similarly higher for catfish fed F2, F3, F4 than F2 and F1. The cost kg^{-1} of diet production increased with inclusion of SSM justifying reduction of SSM in the mixture. Results indicate that SSM and BNM alone or in combination are good plant proteins. Diets of SSM-BNM-FM were similar to SSM-FM. Inclusions of SSM increased body lipid than BNM.

Keywords: Sesame, Bambaranut, Fishmeal, Catfish, Growth.

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Introduction

Plant proteins are alternative ingredients to fishmeal but deficient in some essential amino acids (EAA) like lysine and methionine. Plant protein substitutes of fish meal must be nutritionally balanced, environmentally friendly and beneficial for human health (Gatlin *et al*., 2007). Deficiencies of some essential amino acids are problematic in using plant proteins (Tacon, 1997). Inclusion of plant ingredients with high fiber content elevates food conversion ratio and increases fecal material (Cruz, 1997; Bureau and Hua, 2010). Plant proteins with potential for application in fish feed production must be easily available and cost efficient (Gatlin *et al*., 2007). Inclusion of plant ingredients like soybean, corn, wheat middling's and cotton seed meal in fish feed have been reported to reduce fish growth rate in comparison to fish meal (Imorou-Toko *et al*., 2008; Li *et al*., 2010). The reduced growth rate of fish fed with plant proteins is due to several factors such as poor digestibility (Lech and Reigh, 2012), imbalanced amino acid composition (Xie *et al.*, 2001) and inherent anti nutritional factors (ANFs) in most plant ingredients (Francis *et al*., 2001).

Soybean has been the major plant ingredient used in fish feeds (Shipton and Hecht, 2005), but it has become less economical in recent times due to increased price (Hardy, 2010). Price increase in soybean is due to multi usages and increased demand from consumer countries like China and other developing economies (Hardy, 2010). This underscores the need for alternative plant proteins. The search for alternatives to soybean is important for sustenance of aquaculture industry and its profitability.

Bambaranut (*V. subterranea*) and sesame (*S. indicum*) are two promising legume and oil seed plants, respectively, with untapped potentials in fish feed industry. Bambaranut is known to contain high amount of essential amino acids lysine, cystine and methionine (Dakora and Muofhe, 1995). The incorporation and replacement of soybean meal with 20% bambaranut offal in diets of broilers (*Gallus* sp.) improved growth and profitability (Ekenyem and Onyeagoro, 2006). Also sesame seeds are the source of essential amino acids and sulphur amino acids (Lee *et al*., 2003; Hahm *et al*., 2009) Sesame seeds are also a good source of C_{18} group essential fatty acids (linoleic and linolenic acids) (Nzikou *et al*., 2009). Sesame seed meal has been shown to replace up to 16% of soybean meal in diets of Nile tilapia (*Oreochromis niloticus*) without negative growth effects (Guo *et al*., 2011). Unprocessed raw sesame seeds have about 52.24% oil (Elleuch *et al*., 2007), 18% protein and 17% carbohydrate while the respective values for bambaranut are 6% and 21% (Yusuf *et al*., 2008) and 50% carbohydrate (Amadi *et al*., 1999; Sirivongpaisal, 2008).

Inclusion of sesame seed meal and/or bambaranut meal into African catfish *C. gariepinus* diets could be a good alternative to soybean meal and also fish meal in terms of cost. As such, this research was designed to examine the effects of SSM, BNM and their combinations on the growth, nutritional performance and body composition of juvenile African catfish.

Materials and methods

Experimental fish and set up

African catfish fingerlings of initial average biomass (± S.D) 11.7 ± 0.6g, n= 320, were stocked at 20 fish tank^{-1} in four replicate 15L flow-through glass aquaria. The aquaria were subjected to D18:6L photoperiod. The light period was divided into two parts, three hours in the morning (08-11) and three hours in the evening (17-20) and corresponded to cleaning and feeding (twice per day) periods. The light intensity was 80 lux at the water surface (HD 9221 lux meter, Delta OHM, Padua, Italy). The aquaria were cleaned every morning prior to feeding. Filtered and aerated water of average temperature (mean + SD, n=22) 29.0 ± 1.5^{o}C was supplied from the university water works. The water total gas pressure was 101 ± 2.07 (P4 Tracker Total Gas Pressure saturometer; Point Four Systems Inc., Richmond, Canada). Dissolved oxygen content was 6.05 ± 1.09 mg L^{-1} (YSI oxygen meter model 550A, YSI Inc. Yellow Springs, Ohio, USA) and pH was 7.35 ± 0.77. Ammonia concentration was 0.7 ± 0.6 mg l^{-1} (Tetra ammonia kit, Malvern, PA, USA).

Experimental feeds

Bambaranut meal (BNM) used in this experiment was imported from Enugu, Nigeria. Sesame seed meal (SSM) was produced by milling unhulled sesame seeds into powder, and stored at -20°C.

Four diets were produced at Laukaa Aquaculture Station of the Finnish Game and Fisheries Research Institute. The diets varied in the percentage inclusion of BNM:SSM as follows; feed 1, (F1), 0:35; feed 2 (F2), 11.7:23.3; feed 3 (F3), 23.3:11.7; feed 4 (F4), (35:0). The amount of basal ingredients and fish meal was constant for all compounded treatment feeds (Table 1).

Table 1. Composition of experimental diets varying different percentages of sesame seed meal and bambaranut meal used in feeding African catfish juveniles.

Ingredients	Feed types				
	F1	F2	F3	F4	F5
BNM	35	23.3	11.7	0	commercial
SSM[a]	0	11.7	23.3	35	
FM[b]	53	53	53	53	
Wheat	5	5	5	5	
Vit. Premix[c]	2	2	2	2	
Fish oil	5	5	5	5	
Total	100	100	100	100	
Proximate composition					
% moisture	7.13	6.22	5.61	5.07	
Crude lipids	23.08	29.58	30.21	33.76	
Crude protein	46.70	45.90	46.10	45.80	
Ash	6.68	8.43	8.45	8.34	

SSM=Sesame seed meal[a], FM= fish meal [b] Icelandic low temperature capelin.meal, crude protein 70% and crude lipid 8% [b] Source Raisio group. Raisio Finland [c] Vitamin and mineral premix added for supplying following mineral and vitamins (mg kg^{-1} diet): zinc,180; manganese. 60, iodine, 4, retinol acetate, 300 IU; menadione sodium bisulfate.10 mg; thiamine-HCl, 20mg, riboflavin, 30mg, calcium d-pantothenate. 90mg; biotin, 0.3mg; folic acid, 6mg; vitamin B12,0.04mg; niacin.120mg; pyridoxine-HCL, 20mg; ascorbic acid, 315mg; inositol, 200mg.

The ingredients were blended with industrial electric mixer for 10 minutes during which 5% of water and 5% of fish oil was also added to the mixture. The mixed dough was then extruded at 130-140°C with a twin-screw Creusot-Loire cooking extruder using a 1 mm die. The extruded feeds were dried for a day in a drying chamber at 40°C and stored in air tight plastic bags at -20^{o}C. The fish were fed twice daily, at 0800-0900 h and 1700-1800 h. Fish were fed to apparent satiation in the morning, while restricted feeding (3% of estimated body weight) was given in the evening.

Sampling and analyses

The fish were individually weighed on experimental days 1, 11 and 22 and they were fasted for 18 hours before weighing. At the end of the experiment five fish were taken from each aquarium for analyses of proximate composition, hepatosomatic index (HSI) and peritoneal fat somatic index (FSI). The fish were dissected and liver and visceral fat of the fish were removed and weighed (to 0.01 g). These five fish per aquarium were then ground together and freeze dried for calculation of water content, and stored at -80°C to be used in analyzing proximate composition. Moisture content of the feeds was determined by oven drying feed samples at 70°C for two days while freeze dried feed samples were used for lipid and protein analyses.

Ash content was determined by incineration samples in a muffle furnace at 550°C for 24 hrs. The ash % was weight of ash/weight of sample*100.

Total lipids were analyzed using a modified chloroform methanol method. Lipids in the samples were extracted twice with 2:1 chloroform: methanol mixture.

Lipid extraction was after modified methods of Parrish (1999) and Kainz *et al.* (2004). Whole body protein was analyzed by Kjeldahl method, using Tecator Kjeltech model 1002 (Tecator, Kjeltect, Höganäs, Sweden). Protein % was expressed as %N x 6.25.

The essential amino acid (EAA) content of the main protein ingredients, FM, SSM and BNM were analyzed (Table 2), and the essential amino acid content of the experimental feeds was estimated from the analyzed values by using the quantities of the main feed components (Table 3).

Table 2. Essential amino acid (AA) content of fish meal (FM), bambaranut meal (BNM) and sesame seed meal (SSM) used in formulating diets for African catfish.

Amino Acid	FM	BNM	SSM
Arg	45.4	17.0	31.7
His	16.5	6.7	5.7
Ile	31.3	9.4	8.9
Leu	51.9	17.2	15.7
Lys	55.7	13.9	5.3
Met	20.8	3.1	7.4
Cys	7.4	2.0	4.4
Phe	27.1	12.2	10.3
Tyr	22.0	10.5	10.4
Thr	29.0	7.3	8.2
Val	43.0	10.6	10.9

Values represent amino acids concentration as g kg^{-1} as fed.

Table 3. Amino acid content of African catfish diets that varied in sesame seed meal and bambaranut meal content as in Table 1. Values represent amino acids as g kg^{-1} feeds as fed.

	Feeds				
Amino acids	**F1**	**F2**	**F3**	**F4**	**Rec.**
Arginine	30.0	31.8	33.5	35.2	4.3
Histidine	11.1	11.0	10.9	10.8	1.5
Isoleucine	19.7	19.9	19.8	19.7	2.6
Leucine	33.6	33.4	33.2	33.1	3.5
Lysine	34.4	33.4	32.4	31.4	5.1
Methionine	12.1	12.6	13.1	13.6	2.3[a]
Cystine	4.6	4.9	5.2	5.5	
Phenylalanine	18.7	16.1	18.2	18.0	5.0[b]
Tyrosine	15.4	15.3	15.3	15.3	
Threonine	17.9	15.1	18.7	18.3	2
Valine	26.5	26.5	26.6	26.6	3

Amino acids[a] represents methionine and cystine; [b] represents the values of phenylalanine and tyrosine. Feed amino acids were based on dietary proportions and values derived from the ingredient amino acid analyses (Table 2). Recommended values are % of dietary protein (NRC 1993). F1 to F4 represents feeds 1 to feed 4.

Amino acid levels were measured according to the methods of the European Commission (1998). Total peptides (bound and free) were evaluated with Waters Finland Mass Trak UPLC (Water Corporation Milford, USA) and the application was UPLC Amino Acid Analysis Solution®.

Diet formulation (Table 1) ensured complimentary combination and proportional increase (based on calculations) of deficient EAAs per feed type.

Calculations and statistical analyses

The following calculations were made for each aquarium, which was the experimental unit in the calculations:

Specific growth rate (SGR, % day^{-1}) was calculated as 100 * (Ln w_2 – Ln w_1) * t^{-1}, where w_1 and w_2 were average weights in g at the start and the end of the experiment, respectively, and t was the length of the experiment in days.

Food conversion ratio (FCR) was calculated as (feed consumed in g) * (change in tank biomass in g)$^{-1}$.

Total feed intake (TFI) (g^{-1} fish on as fed basis) = Cumulative feed intake – rejects/ number of fish.

Protein efficiency ratio (PER) = (w_2-w_1) (g) * protein fed (g)$^{-1}$.

Hepatosomatic index (HSI) = 100 * liver weight (g)* fish weight (g)$^{-1}$

Peritoneal fat somatic index (FSI) = 100 * intraperitoneal fat (g) * fish weight (g)$^{-1}$.

Survival = 100 * final number of individuals * initial number of individuals^{-1}.

Fish meal ratio (FMR) = FCR * % dietary fish meal inclusion* 100^{-1}

Protein retention = 100* (final protein content of fish in g - initial protein content of fish in g)* protein fed (g)$^{-1}$.

Cost (USD kg fish produced^{-1}) = Feed conversion ratio * feed cost (USD kg^{-1}) where bambaranut costs ca. 0.1USD kg^{-1}, sesame seed 0.3USD kg^{-1} and fishmeal 2.2USD kg^{-1} .

Results were analyzed using one way ANOVA and least significant difference (LSD) 0.05 was used in separating possible differences of treatment means. The statistical package used for analyses was SPSS 14.0.

Results

SGR varied from 7.60 ± 0.27 % day^{-1} (F1) to 8.67 ± 0.54 % day^{-1} (F4). There were no significant differences (*$p>0.05$*) in the SGR of catfish fed F2, F3 and F4 but those fed F1 grew significantly slower (Table 4).

Table 4. Growth and nutritional parameters of African catfish fed diets F1 – F4 for 22 varying in sesame seed meal and bambaranut meal content as in Table , values represent Average ± SD (n=4).

	FEEDS			
	F1	F2	F3	F4
IW(g)	11.66 ± 1.00^{ns}	11.31 ± 0.14^{ns}	11.45 ± 0.04^{ns}	11.71 ± 0.33^{ns}
FW(g)	61.94 ± 3.62^{b}	72.11 ± 7.62^{a}	70.66 ± 3.94^{a}	72.51 ± 8.73^{a}
AWG(g)	50.28 ± 3.00^{a}	60.80 ± 7.65^{b}	59.21 ± 3.99^{b}	60.79 ± 8.59^{b}
SGR (%)	7.60 ± 0.27^{b}	8.34 ± 0.51^{a}	8.57 ± 0.27^{a}	8.67 ± 0.54^{a}
FCR	0.80 ± 0.04^{c}	0.73 ± 0.05^{b}	0.71 ± 0.04^{b}	0.72 ± 0.03^{b}
PER	2.76 ± 0.15^{b}	3.00 ± 0.20^{ab}	3.07 ± 0.18^{a}	3.10 ± 0.11^{a}
ECR	1.16 ± 0.06^{ns}	1.13 ± 0.08 ^{ns}	1.13 ± 0.07 ^{ns}	1.17 ± 0.58 ^{ns}
C/Protein	0.023 ± 0.01^{ns}	0.024 ± 0.04^{ns}	0.024 ± 0.10^{ns}	0.024 ± 0.03^{ns}
HS	1.36 ± 0.21^{a}	1.17 ± 0.03^{b}	1.14 ± 0.11^{bc}	0.96 ± 0.18^{c}
FSI	1.14 ± 0.16^{ns}	1.24 ± 0.27^{ns}	1.36 ± 0.44^{ns}	1.34 ± 0.32^{ns}
TFI	38.89 ± 0.83^{a}	43.59 ± 2.91^{a}	41.30 ± 1.58^{a}	43.28 ± 2.7^{a}
Cost(US$)	1.50 ± 0.08^{b}	1.55 ± 0.10^{b}	1.59 ± 0.08^{ab}	1.64 ± 0.04^{a}

IW = initial weight (g), FW = final weight (g), AWG = average weight gain (g), SGR = specific growth rate (% day^{-1}), FCR = feed conversion ratio, PER = protein efficiency ratio, ECR=economic conversion ratio, C/Protein= cost per unit protein, HIS= hepatosomatic index, FSI = peritoneal fat somatic index, TFI= total feed intake (g fish^{-1}) =Cumulative feed intakes-rejects / no of fish. Cost of feed as USD per kg of catfish produced. Means not followed by the same superscript are significantly different (P<0.05). ns = no significant difference.

Similarly, final average weight and average weight gain (AWG) of the catfish were significantly higher for those fed with F2, F3 and F4 than for F1 (Table 4). The FCR of the catfish was ≤0.8 for all treatments. The fish fed with F2, F3 and F4 (average FCR 0.72) had significantly lower (P<0.05) FCR than those fed F1 (0.8 ± 0.04).

Protein efficiency ratio was similar for the catfish fed F2, F3 and F4 (3.0 - 3.1) but the lower PER of those fed F1 (2.76 ± 0.15) was not significantly different (*p>0.05*) from F2. The FSI of the catfish was same for all treatments while HSI was significantly higher in the catfish fed F1 than in the other treatments (Table 4). The catfish total feed intake (TFI) was high (38.89 ± 0.83 to 43.59 ± 2.91g fish^{-1}) but not significantly different (P<0.05) for all treatment diets (Table 4). There was no significant difference (*p>0.05*) in cost per kg of fish produced irrespective of treatment diets (Table 4).

The water content of the fish fed with F1 was higher (74.6 ± 0.2%) than in any other treatment (*p*<0.05), and those fed with F4 had the lowest body water content (72.3 ± 0.4%) (Table 5). Body lipid and protein contents were significantly lower for the catfish fed F1 but similar for those fed F2, F3 and F4. Body ash content did not differ between the treatments (Table 5).

Table 5. Average ± SD (n=4) final body composition of African catfish fed diets F1 – F4 varying in sesame seed meal and bambaranut meal content as in Table 1.

Feeds	Parameters of proximate composition			
	% Moisture	% Lipids	% Protein	% Ash
F1	74.56 ± 0.20[a]	3.93 ± 0.21[b]	16.90 ± 0.42[b]	4.85 ± 0.61[ns]
F 2	73.01 ± 0.29[b]	5.40 ± 0.6[a]	17.70 ± 0.38[a]	4.41 ± 0.16[ns]
F 3	73.52 ± 0.64[b]	4.78 ± 0.79[a]	17.67 ± 0.1[a]	4.17 ± 0.36[ns]
F4	72.30 ± 0.36[c]	5.76 ± 0.19[a]	17.54 ± 0.38[a]	4.94 ± 1.36[ns]

Means not followed by same superscript are significantly different (p<0.05), ns = not significant.

The cost of producing the feeds increased from F1 to F4 (Table 5). However there was no significant difference between the production cost of F2 to F4 ($p>0.05$). Production cost of F1 was 0.14 US than reciprocal diet F4 and significantly different from the rest ($p<0.05$). Although production cost of F1 was cheaper than F2 to F4 the cost per unit protein of fish biomass were not significantly different ($p>0.05$). Similarly the economic conversion ratio of the feed (cost of using the feed) was not significantly different ($p>0.05$) irrespective of feed type.

Discussion

The experimental diets produced very high SGR in African catfish. The catfish approximated more than five times their initial weight in 22 days. Growth rate of the fish was more than two times higher than in previously reported experiments with catfish of similar size (Goda *et al*., 2007; Ahmad, 2008; Imorou Toko *et al*., 2008; Davies and Gouveia, 2008; Nyina-Wamwiza *et al*., 2010). The entire reasons for the high growth rate observed in our study is not totally clear, but certainly it relates at least partly to the nutritional quality of the experimental diets. For example, in many of the previous experiments the feed FM content has been much lower than 53% of the present experiment, varying between 13 and 26% (Goda *et al*., 2007; Ahmad, 2008; Nyina-Wamwiza *et al*., 2010). On the other hand, in some other experiments (Davies and Gouveia, 2008; Imorou Toko *et al*., 2008) feed FM content has been over 50% but growth rate has been much less than in our experiment. Consequently, our results suggest that the quality of plant proteins we used together with FM may have increased growth rate. Therefore the fast growth rate of the catfish in our research can be attributed to the nutritional quality of the experimental feeds and also to the environmental factors, e.g. water quality.

Our diets had high content of essential amino acids (EAA) like lysine and methionine, and these may have influenced growth and feed utilization of our catfish. Analyses of our ingredients EAAs (Table 2) showed that BNM has more lysine (13.9g kg^{-1}) than SSM (5.3g kg^{-1}) while SSM contains more methionine (7.4 g kg^{-1}) than BNM (3.1g kg^{-1}). Lysine is the major limiting amino acid in plant diets (Mai *et al*., 2006; Abimorad *et al*., 2009). High dietary lysine has been noted to improve feed intake in African catfish (Ozório *et al*., 2002; Davies and Ezenwa, 2010). Low content of lysine in SSM based diets had been documented in previous studies (Mukhopadhyay and Ray, 1999a, b; Nang Thu *et al*., 2011). However, the high fishmeal content (53%) of our diets has also contributed much to the needed EAAs thereby obliterating any deficiency effect of plant ingredients, thereby enhancing fast growth.

The low FCR (0.71 ± 0.04 to 0.80 ± 0.04) in our experiment indicates good usage of the experimental diets. African catfish utilized BNM and SSM well in our experiment and had better FCR than catfish in another experiment (grown from c. 6 to 34g) where soybean meal was replaced with SSM (Jimoh and Aroyehu, 2011); they reported an increase in FCR (from 1.3 to 1.8) and decrease in SGR (from 3.0 to 2.2% day^{-1}) when soybean meal was replaced with SSM. However, in their experiment maximum SSM content was c. 52% and FM content only 26.6% while the respective values in our experiment were 35% and 53%. Sotolu (2010) recorded FCR of 1.27 and SGR <1 for *C. gariepinus* (average weight 6.26 ± 0.24g and weight gain of 18.97 ± 0.32g in 70 days) juveniles fed diets with sesame seed oil. The diet contained 23% FM and 36 % blood meal as protein sources and was fortified with 2% methionine and lysine.

Low FCR in fish has previously been linked to the low amount of certain dietary amino acids, like lysine in grass carp (Yang *et al*., 2010) and rainbow trout (Cheng *et al*., 2003). The increase in FCR may also be due to higher carbohydrate content of F1. Although we did not analyze dietary carbohydrate, based on literature bambaranut has about 50% carbohydrate (Amadi *et al*., 1999; Sirivongpaisal, 2008) while SSM has about 13.5% to 16% carbohydrate (Elleuch *et al*., 2007; Yusuf *et al*., 2008). High carbohydrate diets have been shown to reduce feed efficiency in southern catfish, *Silurus meridionalis,* (Luo and Xie, 2010).

We noted a high feed acceptance (in terms of feed fed) by the catfish for all treatment diets. This could be due to palatability and or the oil content of SSM. Sesame seeds have about 52.24% oil (Elleuch *et al*., 2007). Bambaranut is estimated to contain about 30% neutral sugars identified as glucose and galactose (Minka and Bruneteau, 2000). Combination of oil and sugars plus FM content of feed may have contributed to the palatability and positive gustatory effect. High lysine content has also been noted to improve feed intake in African catfish (Ozório *et al.*, 2002). On the other hand sesame seed hull contains oxalic acids that impact bitter taste on the meal (Carbonell-Barrachina *et al.*, 2009).

The reason why there was no difference in PER of all SSM containing diets (F2 –F4) or in PR of all diets is not quite clear since BNM has more protein than SSM. It can be due to the lipid content of the sesame seed meal diets and also higher carbohydrate content of BNM than SSM. Based on our proximate composition analyses of the diets lipids increased with increasing sesame seed meal. High dietary carbohydrate has been noted to lead to lowered PER in southern catfish (Luo and Xie, 2010). BNM has higher protein content than SSM which may have resulted in significant differences in catfish PER of F1 (35% BNM) and F4 (35% SSM). Kim and Lee (2005) noted that PER decreased with increasing dietary protein in bagrid catfish (*Chrysichthys nigrodigitatus*).

The higher HSI of the catfish fed with high BNM diets could have been affected by its carbohydrate or oligosaccharide content. In previous experiments higher HSI was been noted in African catfish fed with diets containing high carbohydrate: lipid ratios (Ali and Jauncey, 2004). Similarly HSI was higher in southern catfish fed diets with high carbohydrate (Luo and Xie, 2010), while in the diets of juvenile flounder *Platichthys stellatus* HSI also increased with increasing starch (Lee and Lee, 2004). However Amadi *et al* (1999) and Yusuf *et al* (2008) noted that sesame seeds have less carbohydrate and more oil than bambaranut meal. Consequently, the HSI of the catfish fed with F1 was significantly higher than those fed with F2, F3 and F4.

Total body lipids and protein of catfish fed with sesame seed meal was higher than those fed with bambaranut meal based diets (Table 5). The elevated body lipid of catfish fed with high SSM maybe a consequence of higher fat content of sesame seed meal than bambaranut meal. Dietary lipid content has been shown to directly affect body lipid content (Salhi *et al.*, 2004; Lee and Lee, 2005). The high lipid contents of fish fed with SSM diet as against BNM could also partially be result of lower lysine in SM even though all experimental feeds contained lysine much above the recommended minimum level. Low levels of lysine have been noted to result in increased body lipid in tissues of African catfish

(Ozório *et al.*, 2002). However this is subject of further research to proof the mode of action.

The cost of producing the diets was increasing with inclusion of SSM. However the production cost of 1kg of F1 was 0.14US$ cheaper than F4. Although this difference is small it could have some economic implication and high volume production. This underscores the need to combine the SSM with BNM especially since there are no differences in SGR, FCR, ECR or cost per unit protein compared with using SSM-FM alone. The cheaper cost of making F1 was because comparatively, BNM is cheaper than SSM. The current cost of bambaranut has not appreciated from the price we assumed for cost calculations and analyses. This is generally because bambaranut is not in high demand by humans and the sales need promotions (Hillocks *et al.*, 2012).

The price difference between the production costs could not significantly reflect in the cost per unit protein of producing neither the catfish nor the economic conversion ratio (ECR). This was majorly because of the differences in higher FCR of the catfish fed the SSM diets than BNM. It will therefore take approximately 0.09% more BNM diet than based than SSM to raise 1 kg. Therefore although feed production cost significantly differs when BNM and SSM are used alone with FM, the growth improvement of the fish fed with mixed diets eases off the price increase. This cost estimation suggests that the combination of the ingredients is cost effective given the high SGR of the fish. The low cost of producing our diets is cheap compared to items like soybean that is costly and in high demand (Shipton and Hecth, 2005; Hardy, 2010). Bambaranut from which the meal (BNM) is made is produced abundantly in tropical Africa and beyond (Hillocks *et al.*, 2012). Similarly sesame seed is very abundantly produced in Nigeria and several African countries and China (Wara, 2011). The abundance of bambaranut and sesame especially as sesame is produced in China makes them very plausible for use in fish feed. It is noteworthy that the high demand of soybean from China is one of the reasons for increased soybean price (Hardy, 2010).

In conclusion the combination of SSM and BNM, or SSM alone with fish meal produced fast growth in African catfish. The amount of SSM in the diets can be reduced since combination SSM-BNM-FM produced similar growth effects as SSM-FM. Equal inclusion of SSM and BNM produced similar growth response with 35% SSM justifying reduction in amount of SSM due to cost. Feed production cost all increased with increasing SSM. However body lipids increased with highest SSM and conversely diminished with inclusion of BNM.

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