

Nutritional Value and Digestibility of Fermented Shrimp Head Waste Meal by African Catfish *Clarias gariepinus*

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Abstract: Feeding trials and digestibility studies were conducted in recirculatory systems to assess the effect of replacing fish meal with 0, 5, 10, 20, 30 and 40% fermented shrimp head waste meal (FSHM) in practical diets for African catfish *Clarias gariepinus*. The different levels of FSHM were mixed with other ingredients to formulate 40% protein diets (Diets 1-6). The diets were fed to fingerlings of *C. gariepinus* (12.0 ± 0.03 g) at 3% body weight per day for 84 days. The effect of the diets on the growth, carcass and mineral compositions of the fishes were evaluated. Results showed no significant variation ($p > 0.05$) in apparent digestibility coefficient (ADC) of nutrients ADC_{protein} and ADC_{energy} , protein efficiency ratio (PER), food conversion ratio (FCR) and hepasomatic index of the fishes fed all the diets. However, the fishes fed diets (1-5) had similar ($p > 0.05$) mean weight gain (MWG) and specific growth rate (SGR), which differed significantly ($p < 0.05$) from the MWG and SGR of the group of fishes fed diet 6. Carcass yield and mineral depositions differed marginally in the fishes fed the various diets. Comparative costs analyses indicated that the best profit margin would be realized by replacing fish meal with 30% FSHM in the diet of the fish.

Key words: Shrimp waste, fish meal, African catfish

Introduction

The development of aquaculture is hampered by inadequate supply of feedstuffs particularly fish meal which is scarce and expensive. This has stimulated the evaluation of a variety of alternative dietary protein sources with the objectives of partially or totally replacing fish meal protein in aquafeeds. A possibility is the use of shrimp head (waste) meal, which contains high levels of protein with excellent amino acid profile comparable to that of fish meal (Meyers, 1986). But the utilization of available protein in shrimp head meal by fishes is limited by the presence of substantial quantity of exoskeletal chitin and ash (Bhuiyan, 1989). The need for improvement in the quality of shrimp head waste protein has attracted the application of different processing methods (Fox *et al.*, 1994). Cooking requires excessive use of firewood or other scarce fuels and degrades the lipids, vitamins and pigments content of the meal (Fox *et al.*, 1994) while sun-drying is frequently carried out under unhygienic conditions leading to meals with high microbial loading (Wood, 1982). Although formic acid insolation can improve the nutritional quality and feedstuffs value of shrimp heads, the cost of organic acids is high and mineral acid silage needs to be neutralized before use in animal feeding (Raa and Gilberg, 1982). However, prompt preservation through lactic acid bacterial fermentation which has been used successfully in fish insolation (Hall and De Silva, 1994) could be desirable as alternative to cooking, sun-drying and acid insolation.

According to (Balogun and Akegbejo Samsons, 1992)

about 1.6×10^4 MT of shrimp head waste (*Penaeus spp*) are generated annually in Nigeria and discarded as wastes and close to 2.8×10^5 MT from shrimp companies around the world (Fox *et al.*, 1994). Continued production of the shrimp head waste without corresponding development of technology utilizing the wastes has resulted in waste collection, disposal and pollution problems (Nwanna *et al.*, 2003). Harnessing of these wastes into fish feed production apart from minimizing the costs of fish production would serve as an excellent means of sanitizing the environment.

This project was conducted to evaluate the effect of fermented (150g/kg cane molasses + 50m L/kg *Lactobacillus plantarum*) shrimp head waste silage meal on the production of Catfish, *Clarias gariepinus*. Specific objectives include; to, evaluate, the chemical quality of shrimp head silage meal; the use of shrimp head silage meal as dietary protein replacement for fish meal in the production of *C. gariepinus* and to estimate the costs and benefits of using shrimp head silage meal compared with fish meal.

Materials and Methods

Sample Collection: Fresh shrimp waste (comprising mainly heads of *Penaeus notialis*, *Penaeus duorarum*, *Parapenaeus longirostris* and *Penaeus kerathurus*) were collected from International Fishing Company (ICF), Lagos and transported in frozen blocks to the Federal University of Technology, Akure, Fisheries Laboratory and stored at -20°C prior to processing.

Fish feedstuffs, fish meal, soybean, corn starch, fish and

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vegetable oil, corn flour, vitamin - mineral premix, were purchased from Boar farms Limited, Lagos.

Also hatchery bred *Clarias gariepinus* fingerlings (12.04 ± 0.03g) were bought from Femi Fish Farms Limited, Akure and transported in oxygenated polythene bags to the Fisheries Laboratory of Federal University of Technology, Akure.

Preparation of silage meal: Twenty (20) kilograms of the sample was weighed and thoroughly rinsed in fresh water before blended into paste. 1000ml (at 50ml/kg) of *Lactobacillus plantarum* and 3000g (at 150g/kg) of cane molasses were added to the paste and allowed to ferment for 14 days in an air tight plastic containers. The liquid product was then co-dried with 15% hydrolyzed feather meal (3.0kg) (filler) and oven dried at 60 °C for 48 h. The pH of the silage dropped from the initial value of 7.10 to 4.39 on the 14th day. The dried product was ground into fine powder to form the silage meal and stored at -20 °C prior to further processing.

Formulation of Experimental Diets: Six (6) isonitrogenous diets (40% crude protein) were formulated and contained increasing levels of the shrimp head waste silage meal at 0% (control), 5, 10, 20, 30 and 40% making up diets (1-6). These were mixed thoroughly with other ingredients, (Table 3) in a Hobart A-200T pelleting and mixing machine to obtain a homogeneous mass. Corn starch and hot water were added and mixed further to obtain a dough-like paste. The diets mixtures were then extruded through a 2-mm die mixer (Hobart A-200T) pelleting machine to form model-like strands which were mechanically broken into pellets of suitable size for *Clarias gariepinus* fingerlings. The pelleted diets were sun-dried at 31-32 °C and stored at -20 °C in air-tight polyethylene bags prior to use.

Digestibility Experiment: Six (6) diets were formulated for the digestibility experiment as in Table 3. The differences between the digestibility test diets and growth trial diets (Table 3) are, digestibility test diets contained 1% chromic oxide (marker) each and 1% starch. *Clarias gariepinus* fingerlings (12.04 ± 0.03) were acclimated in recirculating systems under laboratory conditions for 7 days before the experiment. After acclimation, groups of 20 fingerlings/tank were distributed into triplicates into the recirculating tanks (70 x 45 x 45 cm) (flow rate 2.5-3.0 L/minute). Water parameters were constant at temperature 27 - 30 °C; dissolved oxygen 6.5-8.3 mg/L and pH 6.0 - 8.5. The fishes were fed to satiation twice daily (9.00 - 9.30 h and 16.30 - 17.0 h) for 14 days. Faeces were collected from each tank daily 8h after feeding by siphoning with plastic tubes. On the last day, faeces were collected from each groups of fishes 8h after feeding by the rectal dissection

method (Henken *et al.*, 1985; Fagbenro, 1996) from terminal 2.5 cm of the intestine after anaesthetizing the fishes in quinaldine (2.5ml) and pooled for each treatment. Dry matter and crude protein were analyzed in triplicate samples of diets and faeces according to AOAC (1990) methods. Gross energy contents were determined by bomb calorimetry. Chromic oxide content of the diets and faeces was determined using the methods of Furukawa and Tsukahara (1966) and Fagbenro (1996). ADC of dry matter crude protein and gross energy in the test and reference diets were calculated as follows: ADC nutrient = $10^2 - [10^2 \times (1d/1f \times Nf/Nd)]$, where Nd = nutrient in diet, Nf = nutrient in faeces, 1d = Cr₂O₃ in diet, 1f = Cr₂O₃ in faeces.

Pellet water stability: Triplicate samples of each experimental diet, 2g weight, were placed in flasks containing 1000 ml of water fetched from the experimental water tanks. The flasks were aerated for 10 minutes. After which excess water plus dissolved feed were drained off and the remaining feed (floats) filtered through pre-weighted What-man No. 1 filter papers. The papers were oven-dried at 48 °C for 24h and reweighed. The mass of dried diet residue was expressed as a percentage of the initial diet introduced into the flask (Fox *et al.*, 1994).

Growth Experiment/Trials: *Clarias gariepinus* fingerlings (12.04 ± 0.03) used for the feeding trials were starved for 72h and acclimated to experimental diets for 72h before starting the feeding trials. The experiments were conducted in recirculating glass tanks (70 x 45 x 45 cm) with water flow of 2.5 - 3.0 L/minute. The fingerlings were randomly distributed into the tanks at 20 fish/tank and fed twice daily at 3% body weight between (9.00 - 9.30h and 16.30 - 17.0h) for 84 days. Each experiment was replicated thrice. At the start and end of the experiment, five fishes per treatment were randomly selected and processed and used for carcass evaluation/proximate composition analyses. Weighing of the fishes during the trials was done weekly and the mean weight data were used to assess the growth performance as follows: after Castell and Tiews (1980). Mean weight gain (MWG) = Final body weight - initial body weight

Specific growth rate (SGR) = $10^2 (\ln wt - \ln wo)/t$
where wt is the weight of fish at time t, wo is the weight of fish at time 0, t is the culture period in days.

Food Conversion Ratio (FCR) = Total dry feed fed/total wet weight gain.

Protein Efficiency Ratio (PER) = Wet weight gain/protein fed.

Water Quality Measurement: Water temperature (°C) and dissolved oxygen were measured daily with a combined digital YSI meter (YSI Model 57, VWR

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Table 1: Proximate/Mineral Composition of the Shrimp Head Silage Meal(FSHM)

Parameters	% Composition
Crude Protein	58.96
Moisture	10.58
Ash	21.87
Fibre	3.35
Lipid	3.61
Nitrogen free extract	1.63
Calcium (g/kg)	8.72
Phosphorus (g/kg)	1.68

Company New Jersey USA), while pH was monitored weekly using an electric pH meter (Metler Toledo - 320 model, serial No. M5970, United Kingdom. Conductivity was determined using WPACM 35 conductivity.

Biochemical Analyses: The proximate composition of the shrimp head waste silage meal, the experimental fishes and the diets were analyzed according to the methods of AOAC (1990). A factor of 6.25 was used to convert nitrogen to protein. While the amino acid profile of the shrimp head waste silage meal and the diets were analyzed at Federal Institute of Industrial Research Oshodi (FIIRO), Lagos - Nigeria using thin layer chromatography (TLC) method described by Williams (1988). Carcass minerals were determined by atomic absorption spectrophotometer (AOAC, 1990), while (P) phosphorus was determined by the calorimetric method (Fiske and Subbarow, 1925).

Hepatosomatic Index (HSI): At the end of the feeding trials, 5 fishes were randomly selected from each of the experimental tanks per treatments and weighed individually. After which they were dissected and the livers removed and weighed individually too. HSI was calculated as $HSI = 10^2$ (wet weight of liver/wet weight of fish).

Statistical Analyses: Data resulting from the experiment were subjected to one way of analysis of variance using the SPSS (Statistical Package Computer, Software 1988 version Chicago Illinois, USA). Duncan's multiple range test and fisher least significant difference were used to compare differences among individual means at ($P = 0.05$), Duncan (1955).

Costs analyses: Economic analyses were carried out to estimate the cost of feed to raise a kilogram of fish using the various diets. Cost of feed was used as a single economic criterium on the assumption that all other operating costs for commercial fish production will remain the same for all diets. The costs of the diets was based on the current prices of the feed ingredients purchased from Boar Farms Limited, Lagos. The cost of the shrimp head waste was put at US\$600/ton, as

transportation and processing costs. The economic performance of the diets were calculated from the method of (Vincke, 1969) as: Profit index (PI) = value of fish/cost of feed (US\$)

Incidence of Cost = Cost of feed (US\$)/Mean weight gain of fish produced.

Calculation was based on the exchange rate of N50 : US\$1.0

Results and Discussion

Shrimp head silage meal (FSHM): The pH of the fermented shrimp head silage dropped from 7.10 to 4.39 on the 14th day. The rapid and sharp drop in the pH values indicated good fermentation of the silage. This pH value is within the recommended value for successful silage fermentation (Yeoh, 1979). The value of the pH obtained also support the drop in pH of 7 to 4.5 in 14 days reported by (Kompiang *et al.*, 1979); and a drop in pH to (<4.5) (Fagbenro, 1996) for fermented African river prawn, *Macrobrachium vollehovenii*. The proximate and mineral composition of the shrimp head silage meal (FSHM) is presented in Table 1. It has crude protein (CP) of 58.69% , fibre content of 3.35%, Lipid content of 3.61% and nitrogen free extract (NFE) of 1.63%, calcium content of 8.72g/kg and P content of 1.68g/kg. The high protein and low fibre contents are indications that the meal may be highly digestible. The table also shows that the meal could be a good source of calcium and P. The CP of 58.96 obtained showed that the meal is rich in protein and compares favourably with other conventional dietary protein sources such as fish meal, 65.5%, soybean meal 44.5% and groundnut cake meal 48.5%. The CP of 58.96 got from the present study is higher but compares favourably with the CP of 51.2% obtained from formic acid ensiled shrimp head silage meal (Fox *et al.*, 1994). The discrepancy in the values is attributable to the effects of biological and chemical insolation (Raa and Gilberg, 1982). The amino acid (AA) profile of the FSHM, experimental diets and AA requirements for *Clarias gariepinus* are presented in Table 2. The amino acid content of the FSHM are relatively high (>1) except for Histidine and Tryptophan which are below 1%. This amino acid profile are similar to the values of AA got from unfermented oven dried and formic acid ensiled shrimp head meal (Fox *et al.*, 1994). The values are also comparable to the commercial fish meals available in many developing countries (Tacon, 1993). The amino acid contents of the experimental diets are marginally higher than AA requirements of *C. gariepinus* reported by Uys (1989). The values are also comparable with the AA values reported by Fagbenro and Jauncey (1995) from co-dried Lactic-acid fermented fish silage diets.

Experimental Diets: The gross and proximate composition of the experimental diets are presented in

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Table 2: Essential amino acid composition (EAA, g/100g/protein) of shrimp head silage meal (FSHM), experimental diets and EAA requirements of *C. gariepinus*

	FSHM	Diet1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6	EAA requirements ^a
Arginine	2.25	5.4	5.3	5.3	5.3	5.2	5.1	4.3
Histidine	0.56	1.7	1.7	1.6	1.6	1.5	1.3	1.5
Isoleucine	1.50	2.9	2.9	2.9	2.8	2.7	2.7	2.6
Leucine	2.42	6.6	6.6	6.5	6.5	6.4	6.4	3.5
Lysine	2.39	5.8	5.0	5.1	5.2	5.0	4.8	5.0
Methionine ^b	1.13	3.0	2.8	2.8	2.7	2.7	2.6	2.3
Phenylalanine	5.82	6.2	6.2	6.1	6.0	6.0	5.8	5.0
Threonine	2.42	3.8	3.8	3.6	3.6	3.5	3.4	2.0
Tryptophan	0.50	1.0	0.80	0.8	0.7	0.7	0.7	0.5
Valine	1.82	5.9	5.9	5.8	5.7	5.6	5.5	0.5

a: Uys (1989), b: Methionine + cystine, c: Phenylalanine + lysosine

Table 3. The proximate composition of the diets are marginally ($P > 0.05$) different. Crude protein levels of the diets varied from 40.12 to 40.42 and the lipid content from 13.89 to 14.49, while nitrogen free extract and crude fibre ranged between 26.17 and 27.39 and 4.37 and 4.72 respectively. Gross energy (Kcal/g/DM) of the diets ranged between 436.42 and 438.25 and the protein-energy ratio (P/E) (mg/protein/GE) varied from 90.15 to 92.50. The water stability (Table 3) ranged between 12.5 (control diet) and 13.06 (diet 6). The mean crude fibre of 4.59 and gross energy (GE) of 437.06 obtained from the present study are marginally identical to the values of 4.5 and 431.3 for crude fibre and GE respectively, reported for fish silage blended with hydrolyzed feather meal (Fagbenro and Jauncey, 1995). The values are also comparable to the values of 4.6 and 441.3 for crude fibre and GE reported for commercial trout diet (Fagbenro and Jauncey, 1995). Li *et al.* (1991) reported that protein energy ratio (P/E) of diets influences nutrient utilization and growth; and optimum balanced P/E ratio increases the protein sparing ability and profitability of diets (Xiqin *et al.*, 1994). Though there is a dearth of information on the P/E requirements of *C. gariepinus*, the mean P/E ratio of 91.93 obtained from the experimental diets compares well with the P/E ratio of 87.91 reported for good production of *C. gariepinus* (Fagbenro *et al.*, 1994). There was no significant differences ($P > 0.05$) in the stability of the diets in water. The highest percentage stability (13.06%) was recorded in diet 6, while the reference diet (diet 1) had the least (12.5%). This observation agrees with the findings of Fagbenro *et al.* (1994) and Fagbenro and Jauncey (1995) who reported non-significant differences in pellet water stability of fermented fish silage and soybean blend diets and fermented fish silage with hydrolyzed feather meal blend.

Digestibility Experiment: Digestibility of individual ingredients in the compounded diet is considered as one of the important factors affecting the growth of fish

(Cho *et al.*, 1985; De Silva *et al.*, 1996). Uys (1988) and Fagbenro (1996) observed that other than looking at growth responses, the digestibility of nutrients and energy contents in feedstuffs could be used to assess the suitability and nutritive value of feedstuffs/diets in fishes. The apparent digestibility coefficient $ADC_{protein}$ and ADC_{energy} (Table 4) obtained from the present study are high (80.6 - 84.04) and (78.7 - 80.5) respectively. The $ADC_{protein}$ increased progressively from diet 6 to diet 1 (Table 4) but without any significant differences ($P > 0.05$) in the values. Also ADC_{energy} varied marginally and increased progressively from diet 6 to diet 1. The values of $ADC_{protein}$ and ADC_{energy} obtained from the study compare favourably with the mean values of $ADC_{protein}$ (85%) and ADC_{energy} (78%) reported by Fagbenro (1996) for *Clarias isheriensis* fed hydrolyzed feather meal. The value of the ADC_{energy} is also similar to the ADC_{energy} values for Channel catfish reported by Wilson *et al.* (1985).

Growth and Nutrient Utilization: Water quality parameters monitored were similar in all treatments and the values (Temperature 27.03 - 32.13 °C) (pH 6.2 - 6.62), dissolved oxygen (6.2 - 7.0 mg/L), conductivity (0.60 - 0.85 x 10⁻⁴) conform to the recommendation of Boyd (1982) for warm water fish culture. *Clarias gariepinus* fingerlings fed the various diets (Table 4) had similar ($P > 0.05$) mortality (%). Fishes fed the control diet had the highest mean weight gain (MWG) and specific growth rate (SGR) which did not vary significantly ($P > 0.05$) from the MWG and SGR of fishes fed diets 2, 3, 4 and 5 but differed remarkably ($P < 0.05$) from the MWG and SGR of fishes fed diet 6. However, there was no noticeable changes ($P > 0.05$) in protein efficiency ratio (PER) and food conversion ratio (FCR) of the fishes fed the various diets. The Hepatosomatic index (HSI) was unaffected by the shrimp head silage diets. From the present study, the steady decrease in MWG and SGR of the fishes fed diets 1-6, corresponded to similar decrease in the $ADC_{protein}$ and ADC_{energy} of the fishes.

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Table 3: Ingredient and Proximate Composition of Experimental Diets

Ingredient (g/100g/DM)	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5	Diet 6
Fish meal (72% CP)	36.11	34.30	32.50	28.28	25.28	21.67
Soybean meal (45.4 CP)	30.00	30.00	30.00	30.00	30.00	30.00
Shrimp head silage (58.96 CP)	0	2.12	4.43	8.86	13.29	17.72
Cassava Flour (1.6 CP)	23.89	23.58	23.07	22.25	21.43	20.61
Fish + Vegetable oil (1:1)	5	5	5	5	5	5
Starch	2	2	2	2	2	2
Vitamin-Mineral Premix	3	3	3	23	3	3
Proximate Composition (g/10g/DM)						
Crude Protein	40.37	40.12	40.18	40.42	40.20	40.40
Ether extract	13.89	14.37	14.27	14.24	14.42	14.49
Nitrogen free extract	27.39	27.08	27.00	26.60	26.46	26.17
Crude fibre	4.37	4.59	4.56	4.60	4.72	4.70
Ash	13.98	13.84	13.99	14.14	14.20	14.24
Gross Energy (Kcal/g/DM)	436.4	438.25	437.33	436.66	436.62	437.09
Protein Energy (PE) ratio (mg/protein/GE)	92.50	90.15	91.88	92.57	92.07	92.43
Pellet stability (%)	12.5	12.5	13.0	13.01	13.04	13.06

Table 4: Hepatosomatic Index, Growth and Utilization of *C. gariepinus* fed FSHM Diets for 84 days

	Treatments					
	1	2	3	4	5	6
Initial mean weight (g)	12.03±.03 ^a	12.04±.03 ^a	12.11±.03 ^a	12.08±.03 ^a	12.03±.03 ^a	12.03±.03 ^a
Final mean weight (g)	57.98±1.95 ^a	56.12±1.95 ^a	55.12±1.95 ^a	54.90±1.95 ^a	53.98±1.90 ^a	52.20±1.9 ^b
Mean weight gain (g)	45.95±1.9 ^a	44.08±1.9 ^a	43.01±2.0 ^a	42.82±1.95 ^a	41.95±1.95 ^a	40.17±1.95 ^b
Weight gain (%)	382±16.19 ^a	366±16.19 ^a	355±16.19 ^a	354±16.18 ^a	349±16.18 ^a	334±16.17 ^b
Survival (%)	95 ^a	95 ^a	95 ^a	95 ^a	95 ^a	95 ^a
Feed Consumed (g)	102.22	97.02	95.16	93.16	92.18	89.04
SGR	1.87±.04 ^a	1.83±.04 ^a	1.80±.04 ^a	1.80±.03 ^a	1.79±.03 ^a	1.75±.03 ^b
PER	1.11±.01 ^a	1.13±.01 ^a	1.12±.01 ^a	1.14±.02 ^a	1.13±.02 ^a	1.11±.01 ^a
FCR	2.22±.02 ^a	2.20±.02 ^a	2.21±.02 ^a	2.18±.02 ^a	2.20±.02 ^a	2.23±.02 ^a
HSI (%)	1.05± 19.0 ^a	1.26± 19 ^a	1.30±18 ^a	1.40±18 ^a	1.45±19 ^a	1.46±19 ^a
ADC protein	84.04 ^a	82.50 ^a	82.0 ^a	81.50 ^a	81.50 ^a	80.60 ^a
ADC energy	80.50 ^a	80.0 ^a	80.0 ^a	79.7 ^a	79.3 ^a	78.7 ^a

Table 5: Carcass and mineral Composition (g/100g/DM) of *C. gariepinus* fed FSHM Diets for 84 days

Sample	Ash	Moisture content	Crude protein	Crude Lipid	%Fibre	%CHO	%Pho	%Na	%K	%Ca	%Mg	%Cl
Initial	13.13	13.73	66.75	2.34	ND	4.05	0.42	0.25	0.78	2.35	0.60	0.20
T1 (Treatments)	12.10	12.76	70.23	2.90	ND	5.01	27.96	0.27	0.88	2.28	0.76	0.17
T2	11.71	11.82	69.17	3.87	ND	3.43	27.45	0.26	0.87	2.29	0.72	0.18
T3	11.13	11.38	70.14	3.96	ND	3.39	27.50	0.28	0.84	2.33	0.75	0.15
T4	11.51	11.52	70.10	3.22	ND	3.65	27.45	0.26	0.86	2.34	0.82	0.13
T5	11.88	11.31	69.27	3.85	ND	3.69	27.82	0.28	0.85	2.32	0.76	0.16
T6	11.43	12.17	69.08	3.83	ND	3.49	27.58	0.27	0.82	2.34	0.73	0.21

ND - Not Detected

This observation supports the work of Fagbenro and Jauncey (1995) who reported that low amounts of available amino acids would cause a lower protein utilization and digestibility, resulting in less fish growth. The mean SGR of 1.81 obtained is lower than the SGR of 2.28 reported by Fagbenro and Jauncey (1995) from *C. gariepinus* juveniles fed fish silage blended with hydrolyzed feather meal. This discrepancy is attributable to other factors (intrinsic) other than nutritional, as the ADC_{protein} and ADC_{energy} reported by Fagbenro and Jauncey (1995) compared favourably with the ADC_{protein}

and ADC_{energy} values reported from the present study. However, the non-significant (P > 0.05) values of PER and FCR reported from the study is in line with the observations of Fagbenro and Jauncey (1995) and Fagbenro *et al.* (1997). Unremarkable changes (P > 0.05) in the carcass ash, moisture and fat obtained from the present study validates the findings of Fox *et al.* (1994) and Fagbenro and Jauncey (1995). Similarity in the values of HSI obtained from the experiment are in consonant with the reports of (Xiqin *et al.* 1994; Keshavanath and Jagadeesh, 1994; Fagbenro

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Table 6: Costs Evaluation

	Diets/Treatment					
	1	2	3	4	5	6
Feed consumed (g)	102.22	97.02	95.16	93.16	92.18	89.54
Weight gain (Kg)	0.8731	0.8375	0.8172	0.8136	0.7971	0.763
Cost of feed (US\$) ^a	0.23	0.23	0.23	0.22	0.21	0.21
Value of fish (US\$)	4.36	4.19	4.09	4.07	3.99	3.82
Incidence of Cost ^b	0.26	0.27	0.28	0.27	0.26	0.28
Profit Index ^c	18.96	18.22	17.78	18.5	19.0	18.19

a: Exchange rate is put at N50: US\$1.0, b: Incidence of cost = cost of feed/Kg fish produced, c: Profit index = value of fish/cost of feed

and Jauncey 1995; Fagbenro 1996). The carcass and mineral composition of the fishes (Table 5) explain that the ash and moisture contents of the fishes decreased after the feeding trials, while the crude protein and lipid contents increased. Also the phosphorus, potassium and magnesium contents of the fishes increased marginally after the feeding trials. The marginal differences in the carcass yield and mineral depositions in the fishes fed all the diets support the work of Nwanna *et al.* (2003) who reported non-significance differences in the carcass composition and mineral depositions of *C. gariepinus* fingerlings fed chemically preserved shrimp head waste silage diets.

Economic evaluation revealed that the cost of producing the fishes (Incidence of cost, IC) were marginally similar (Table 6). However, the trend indicates possibility of disparity ($p < 0.05$) in the costs of using diet without FSHM; and more profits ($p < 0.05$) by using diets that contain FSHM. This will be remarkable in commercial aquaculture when much more feed is consumed over a long period of time. The profit (profit index, PI) obtained by using the diets was highest in diet 5. Comparatively, the analyses indicate that the best profit margin would be achieved by using 30% of fermented shrimp head silage meal in the production of *Clarias gariepinus* fingerlings.

In conclusion, based on the estimated economic benefits and nutrient utilization indices, biologically ensiled shrimp head silage meal can effectively replace fish meal up to 30% in the diet of African catfish *Clarias gariepinus* fingerlings.

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