Nutritional Evaluation of Termite (*Macrotermes subhyalinus*) Meal as Animal Protein Supplements in the Diets of *Heterobranchus longifilis* (Valenciennes, 1840) Fingerlings

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Received 28 August 2007
Accepted 17 March 2008

Abstract

250 fingerlings of *Heterobranchus longifilis* had an average weight of 2.04±0.21 g were fed five crude protein 42.5% isonitrogenous experimental diets coded Tm1 – Tm5 were tested on the fingerlings. Termite meal was used to replace fish meal in the diets at 0% (Diet Tm1- control diet), 25% (Diet Tm2), 50% (Diet Tm3), 75% (Diet Tm4) and 100% termite meal inclusion levels (Diet Tm5). The experiment was in triplicates and the fingerlings were fed 5% body weight twice a day for 12 weeks. Termite meal had a crude protein of 46.3% and ash content of 3.6% while fish meal used has 71.5% crude protein and 18.2% ash and these differed significantly ($P<0.05$). The lipid content of 11.3% and 8.0% respectively for termite meal and fishmeal also differed significantly ($P<0.05$). The water stability of the experimental diets ranged between72.3%-76.9%. The highest mean weight gain of 9.6 g/fish, relative growth rate of 488.0% and specific growth rate of 0.9%/day were recorded in fish fed 50% termite meal inclusion diet. The feed striking time ranged between 5.0-6.0 second. The lowest feed conversion ratio of 2.9 and highest protein efficiency ratio of 0.8 were also recorded in fish fed 50% termite meal inclusion diet. The lowest incidence of cost (2.1), highest profit index (1.6) and best benefit cost ratio (1.2) were also from 50% termite meal diet. Based on the broken-line analysis, 50% inclusion levels of termite meal will yield the best result in a practical diet for *H. longifilis* fingerlings for a profitable and sustainable aquaculture venture.

Key words: termite meal, fishmeal, nutrient, growth, cost, *H. longifilis*.

Introduction

In fish farming, sufficient consumption of feed is essential for increased yield and profitability. Fish meal is the conventional source of animal protein in fish diet and it has been valued for its balanced amino acids, vitamin content, palatability and growth factors (Tacon, 1993). Because of the increasing cost of high quality fish meal required for aquafeed and due to declining stocks of fish from capture fishery and competition for feed in animal husbandry, there is now need to search for alternative sources of animal protein for fish feeds especially in developing countries like Nigeria (Sales and Janssens, 2003). These alternatives must be able to supply adequate indispensable and dispensable amino acid requirements of the fish or sufficient amino nitrogen to enable their synthesis (Macartney, 1996) along with dietary energy requirements because its excessive intake may restrict protein consumption and subsequent growth of the fish fed (NRC, 1983).

Many scientists have reported the possible use of some alternative animal protein feedstuffs to fish meal such as Tacon, (1985) - Earthworm meal; Sogbesan and Ugwumba, (2006a) – Earthworm meal; Annune, (1990) -Toad meal; Ayinla *et al*. (1994) - Tadpole meal; Fagbenro and Jauncey, (1995) - Fermented fish silage; Ugwumba *et al*. (2001)- Maggot meal; Sogbesan *et al*. (2005) - Maggot meal; Fasakin *et al*. (2000) -Poultry dung meal; Sogbesan and Ugwumba, (2006b) - Garden snail meal.

Termites are social insects that swarm seasonally especially at the onset of rainy season or after heavy rainfall. The long winged reproductive termite is edible and highly sorted after as a delicacy. During swarming, a lot of these termites are wasted and could be utilized for fish feed production since fish had been reported to consume them live when they fall into fish pond (Madu *et al*., 2003). *Macrotermes subhyalinus* (Rambur) used for this study has been reported as the most commen termite in New-Bussa, Nigeria (Malaka, 1996). The nutritive potential and utilization of this insect as fish feed ingredient have not been adequately documented.

Heterobranchus longifilis is one of the major mud catfish species in Nigeria that inhabits freshwater bodies (Reed *et al*., 1967), feeds on any available food, including plankton, insects, fish, benthic invertebrates (annelids), tadpoles and detritus (Olufeagba, 1999). The optimum protein requirement for the fingerling stage as reported by Fagbenro *et al.* (1992) is 42.5%. *H. longifilis* is a highly priced fish in Nigeria along with other African catfish species due to their good taste and flavour. The Nigerian fish farmers have not been able to meet the populace demand for this species due to high cost of feeding. Hence, there is a need to boost the production of this highly demanded cultured fish with high growth rate for aquaculture sustainability and food security in Nigeria using least-cost feeds.

Materials and Methods

Experimental Set-up

The experiment was carried out in the Fish Nutrition Laboratory of Aquaculture and Biotechnology Department of the National Institute for Freshwater Fisheries Research (NIFFR), New-Bussa, Nigeria.

Five experiment sets in triplicates were used for this experiment. A total of fifteen (15) indoor mini-flow through system, 0.25 m depth and 0.55 m diameter circular plastic tanks of 50 litres capacity each were used for the trials. Water was supplied to each tank from 30,000 litres head tanks. Each unit had a control for comparison. 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 a net of 3 mm mesh size to protect the fish from jumping out of the tanks. A constant photoperiod of 12 hours light and 12 hours dark was maintained.

Termite Meal Preparation

Reproductive termites were collected during swarm activity from a termitarium in the hatchery complex of NIFFR. They were weighed fresh and oven-dried at 80°C for 3 hours. The wings were blown off. The dried termites were weighed, milled, weighed again, packed in plastic containers and stored at 8°C in a refrigerator till when needed.

Experimental Diets

A completely randomized design was used with each treatment. Five experimental diets which were isonitrogenous at about 43% crude protein were formulated using algebraic method along with least cost formulae (LCF) of Falayi (2003). In the diets, termite meal was used to replace clupeid fishmeal as animal protein source at various inclusion levels namely 0% (control), 25%, 50%, 75% and 100%. The diets were coded Tm1 (control) to Tm5. The percentage composition of the ingredients and production costs in the diets is shown on Table 1. After formulation, the ingredients were measured using electric sensitive weighing balance (OHAUS-LS 2000 Model), milled into fine particles (<0.25 mm) and mixed thoroughly in a bowl for 30 minutes to ensure homogeneity of the ingredients. Starch was prepared with hot water into a paste and mixed with the other ingredients as binder. The dough was pelleted wet using hand pelleting machine (Kitchen hand Cranker Pelletizer). The pelleted dough was collected in flat trays and sun-dried to constant weight after which the feeds were crushed into crumbs with pestle and mortar (for easy ingestion by the fish). They were packed in jute bags, labelled and stored at room temperature in the laboratory.

Proximate composition of processed termite meal and fish meal diets, fish carcasses before and after the experiments were analysed for crude protein, crude fibre, crude lipid, ash, Nitrogen free extracts and gross energy according to Association of Analytical Chemist Methods (A.O.A.C., 2000). The

Table 1. Percentage composition of ingredients (g/100g of ingredients) and cost of production of termite meal-based diets for the feeding trial

Ingredients	Tm1 (Control)	Tm2	Tm3	Tm4	Tm5
Fish meal	30.0	22.5	15.0	7.5	0.0
Termite meal	0.0	7.5	15.0	22.5	30.0
Yellow maize	28.7	23.2	17.7	12.2	6.7
Groundnut cake	11.7	14.4	17.2	19.9	22.7
Soy bean meal	12.6	15.4	18.1	20.9	23.6
Blood meal	10.0	10.0	10.0	10.0	10.0
Chromic Oxide	0.5	0.5	0.5	0.5	0.5
*Vitamin/mineral premix	2.0	2.0	2.0	2.0	2.0
Palm oil	2.0	2.0	2.0	2.0	2.0
Common salt	0.5	0.5	0.5	0.5	0.5
Bone meal	1.0	1.0	1.0	1.0	1.0
Cassava starch binder	1.0	1.0	1.0	1.0	1.0
Total	100.0	100.0	100.0	100.0	100.0
Calculated Crude protein (%)	42.5	42.5	42.5	42.5	42.5
Calculated Gross Energy kJ/100g	1900	1900	1900	1900	1900
P :GE mg of Protein /kJ of GE	22.4	22.4	22.4	22.4	22.4
Inclusion levels of Termite meal (%)	0.0	25.0	50.0	75.0	100.0
**Cost of production (₦/100g)	82.29^{a}	78.10^{a}	73.74^{a}	69.40^{ab}	65.04^{b}

Tm: Termite meal.

*Vitamin and Minerals: Vitamin A –10,000,000 I.U.; D3- 2,000,000 I.U.; E –23,000mg; K3 – 2,000 mg; B1 – 3,000 mg; B2- 6,000 mg; Nacin – 50,000 mg; Calcium Pathonate – 10,000 mg; B6 – 5,000 mg; B12- 25.0 mg; Folic acid 1,000 mg; Biotin- 50.0 mg; Choline chloride – 400,000 mg; Manganese – 120,000 mg; Iron- 100,000 mg; Copper– 8,500 mg; Iodine – 1,500 mg; Cobalt-300 mg; Selenium-120 mg; Anti-oxidant 120,000 mg.

** Ingredient cost was based on current market value in feed ingredient stores in New-Bussa, Nigeria.

minerals in the ash of each diet was brought into solution by wet digestion using conc. HNO_3 (63%), perchloric acid (60%) and sulphuric acid (98%) in the ratio of 4:1:1 (Harris, 1974). Potassium and sodium were determined using flame photometer (Allen, 1974). Phosphorus was determined using spectronic 20E, while Magnesium by Perkin Elmer Atomic Absorption Spectrophotometer Model 2900. Amino acids analysis was determined for the experimental diets according to Association of Analytical Chemist Methods (A.O.A.C. 2000). The essential amino acids indices were calculated according to Abdullah (2001) and the whole egg amino acids composition in FAO/WHO (1973) was used as the reference diet. The essential amino acids indices were calculated according to Abdullahi (2001) and Wilson (2002), using whole hen egg crude protein and essential amino acids composition documented in FAO/WHO (1973) and Cudderfold (1983) as references. The essential amino acids indices determined were chemical score value (%), Chemical score to Protein score ratio (C. S: P. S) (%) and Total essential amino acids to protein value computation.

Water Stability of the Feeds

The purpose of this experiment was to determine the nutrient retaining capacity of the experiment feeds. This was carried out before the feeding trials following the method described by Falayi *et al*. (2004). Triplicate 2.5 g of pellets from each experiment was placed in Muslin cloth of 250 µm mesh size made of rayon material. This was suspended with string on retort stand and slowly immersed in a 250 ml beaker filled with 150 ml of water and left for 30 minutes. The beakers were labelled with the feed codes accordingly and aerated with electric aerator (Cosmos Air Pump 1000 Model). At the end of the set time, the feeds were removed and allowed to drain for 5 minutes and then oven dried at 105°C for 3 hours, cooled and re-weighed. The new weights represented the leftover from the original weight. The water stability was calculated after Murai *et al.* (1981) and Fagbenro and Jauncey (1995) as follow:

Water stability (%) = [Final (wet weight x % dry weight) / Initial (wet weight x % dry weight)] x 100

Water Quality

Temperature was taken daily with thermometer while dissolved oxygen and pH were measured weekly using Winkler's solution (Boyd, 1990) and pH metre (E251), respectively.

Experimental Fish

A total number of 250 fingerlings of *H. longifilis* of weight range 1.69 g -2.45 g (mean, 1.98$\pm$0.083 g and total length range of 6.2 cm -7.2 cm (mean, 6.5$\pm$0.08 cm) were purchased from the Hatchery Unit of NIFFR. They were acclimatized for one week in plastic holding tanks of 2.0 m x 0.5 m x 0.4 m, aerated with Erckman Electric Aerator and fed a compounded NIFFR feed of 35% crude protein in the Laboratory.

Fingerlings were sorted, weighed, randomly stocked into the experimental tanks at the rate of fifteen (15) fingerlings per tank. They were starved overnight before the commencement of the feeding trials. Fish were offered 5% of their body weight meal per day administered in two equal portions between 8.00-9.00 h and 18.00-19.00 h. The quantity of feed was adjusted based on the weight of fish for previous week throughout the 12 weeks duration of the feeding trials. The fish were daily monitored for mortality. Dead fish were removed, counted and recorded.

The length and weight of each fingerling in each tank were measured at the commencement of the experiment. Subsequently, 5 fingerlings were taken randomly from each tank once a week and weighed with beam balance to access the growth rates. At the end of the experiment, all fingerlings in each tank were measured. Survival rate was determined from the number left at the end of the experiment relative to the number stocked.

Feed Striking Time and Acceptability

Striking time was taken as the time it takes the first fish to strike the first particle of the feed (Sogbesan and Ugwumba, 2006b) and it was is monitored immediately when the feed was dropped into the tanks using stop watch and recorded in seconds. The feed acceptability was estimated as the reciprocal of striking time following the method described by Eyo and Ezechie (2004) as follows:

Feed acceptability = 1/ feed striking time (sec).

Feed Response Calculations and Statistical Analysis

For this study, growth was expressed as weight gain, relative weight gain, specific growth rate, condition factors (Bagenal, 1978) and survival rate (Fasakin *et al*., 2001). Nutrient utilization indices were expressed as voluntary feed intake, feed conversion ratio, protein efficiency ratio (Wilson, 1989), gross protein value (Devendra, 1989), apparent net protein and lipid utilization (Ali, 2001) as follows:

Mean weight gain = $W_f – W_i$ / n.

Relative Growth Rate = (Weight gain / Initial body weight) x 100

Specific Growth Rate = (Log w – Log w_I / t) x 100.

Metabolic growth rate (MGR) = [Live body weight gain/{(W_i+W_f)/2000}$^{0.8}$] / Experimental period (days

Voluntary feed intake (VFI)(%)= (100 x FI)/[(W_i + W_f) x t]

Food conversion ratio = Feed intake (g) / Fish weight gain (g).

Protein efficiency rate = Weight gain /Protein intake

Gross protein Value (GPV) = A / Ao

A = Weight gain of the fish fed test diet (g) / Protein intake of test diet (mg/100 g of diet).

A_0 = Weight gain of the fish fed control diet (g) / Protein intake of control diet (mg/100 g of diet).

Apparent net protein utilization (ANPU%) = [(P_2 - P_1) / Total protein intake] x 100

Apparent net lipid utilization (ANLU)(%) = [(L_2 - L_L) / Lipid intake] x 100

Economic evaluations in terms of gross profit (GP), net profit value (NPV), investment cost analysis, profit Index (PI), incidence of cost (IC), and benefit cost ratio of substituting fish meal with termite meal in the culture of *Heterobranchus longfilis* were determined according to New (1989), Faturoti and Lawal (1986) and Mazid *et al.* (1997).

Gross profit = Net profit value (₦) - Investment cost analysis (₦)

Net profit value = Mean weight gain of fish cropped (g) x Total no of the survival (n) x cost per kg.

Investment cost analysis = Cost of feeding (₦) + Cost of fingerlings stocked (₦).

Profit Index=Value of fish (₦)/cost of feed (₦)

Incidence of cost=Cost of feed (₦)/mean weight gain of fish produced (g)

Benefit: cost ratio (BCR) = Total cost of fish cropped (₦) / Total expenditure (₦)

All data collected were subjected to analysis of variance (ANOVA). Comparisons among treatment means were carried out by one way analysis of variance followed by Tukey's test (P=0.05). Standard deviation (SD) was calculated to identify the range of means. Least Significance differences (LSD) was used to determine the level of significance among treatments. Correlation and regression analysis was carried out to determine the relationship between the treatments and some of the parameters using SPSS 7.5 Windows 2000 and Graph pad instat packages. The broken line model (Robbins *et al*., 1986) was used to estimate the optimal termite meal inclusion levels based on the mean weight gain and specific growth rate of the fish fed with the graded levels of the termite meal based diets.

Results

Fish meal was significantly (p<0.05) higher in crude protein, 71.5% than termite meal, 46.3% while termite meal had higher lipid content of 30.1% than fish meal, 8.0% as shown in Table 2. Termite meal recorded higher gross energy, 2457.6 kJ/100 g than fish meal, 2074.7 kJ/100 g. The crude protein ranged between 43.2%-43.5% and was not significantly different (P>0.05). The highest lipid content 22.2% was in 100% termite meal inclusion diet while the lowest value of 10.6% was in the control diet. The lipid content significantly differed (P<0.05) in all the experimental diets. The highest gross energy value of 1882 kJ/100 g was recorded in 100% termite meal inclusion diet while the lowest value of 1,776 kJ/100

Table 2. Proximate and energy composition (% dry matter) of the termite meal diets

Composition	Major animal protein sources	
	Fish meal (Clupeids)	Termite meal
Crude Protein (%)	71.5^{a}	46.3^{b}
Crude Lipid (%)	8.0^{b}	30.1^{a}
Crude Fibre (%)	1.2^{b}	7.3^{a}
Ash (%)	18.2^{a}	3.6^{b}
Nitrogen free Extract (%)	3.2^{fb}	9.0^{a}
Dry matter (%)	90.2	96.4
Sodium (g)/100g)	0.91	0.20
Calcium (g/100g)	3.53^{a}	0.23^{e}
Potassium (g/100g)	0.96^{a}	0.38^{c}
Phosphorus (g/100g)	2.4^{a}	0.38^{d}
Magnesium (g/100g)	0.08	0.15
Gross Energy (kJ/100g)	2074.00^{b}	2457.61^{a}
Metabolizable Energy (kJ/100g)	1556.05^{b}	1843.21^{a}
Digestible Energy (kJ/100g)	3150^{a}	3040^{a}

All values on the same row with the different superscripts are significantly difference (P<0.05).

g was recorded in the control diet. Gross energy content of all the experimental diets were significantly different (P<0.05).

All ten essential amino acids present in fish meal were also present in termite meal. The highest total essential amino acids, chemical score and percentage ratio of essential amino acids to crude protein content of 37.5 g/100 g diet, 70.6% and 86.1% were recorded respectively in the control diet while the least values of 28.2 g/100 g diet, 53.1% and 65% were recorded in 100% termite meal inclusion diet as shown in Table 3. Chemical score and essential amino acid to protein ratio percentage showed significant difference (P<0.05) between all the diets.

The highest and lowest mean weight gain, 9.58 g/fish and 6.97 g/fish were recorded from 50% and 100% termite meal diets respectively. There was significant difference (P<0.05) between the mean wet weight gain at the 50%, 75% and 100% termite meal diets (Table 4). The highest relative growth rate of 488.8% was recorded from 50% termite meal diet while the lowest value of 344.7% was recorded in 75% termite meal diet. The specific growth rate ranged between 0.7715% - 0.9167%, the highest value was recorded in 50% termite meal while the lowest value was in 75% termite meal diet. There was significant difference (P<0.05) between the relative and specific growth rate of fish fed with all the diets, except between the control and 50% termite meal diet. The metabolic growth rate ranged from 24.64 to 28.43. There was a significant difference (P<0.05) between metabolic growth rate of fish fed with termite meal based diet. The highest metabolic growth rate of 28.43 was recorded in 50% termite meal while lowest metabolic growth rate of 24.64 was recorded in 75% termite meal inclusion diet.

Table 3. Proximate and energy composition (% dry matter) of the termite meal diets (TM1-TM5)

Composition	TM1 (Control)	TM2	TM3	TM4	TM5
Inclusion levels of termite meal (%)	0	25	50	75	100
Crude Protein (%)	43.5^{a}	43.5^{a}	43.4^{a}	43.3^{a}	43.2^{a}
Crude Lipid (%)	10.6^{e}	12.2^{d}	15.0^{c}	18.6^{b}	22.2^{a}
Crude Fibre (%)	3.4^{c}	4.1^{bc}	4.9^{b}	5.1^{b}	5.2^{b}
Ash (%)	8.4^{b}	8.3^{b}	6.6^{bc}	5.2^{c}	4.1^{c}
Nitrogen free Extract (%)	18.3^{a}	16.6^{b}	15.4^{c}	13.7^{d}	10.7^{e}
Dry matter (%)	84.3	84.7	85.2	85.9	85.9
Sodium (g)/100g)	0.53	0.47	0.42	0.36	0.30
Calcium (g/100g)	1.47^{b}	1.23^{b}	0.99^{bc}	0.76^{c}	0.52^{d}
Potassium (g/100g)	0.72^{b}	0.73^{b}	0.73^{b}	0.74^{b}	0.75^{b}
Phosphorus (g/100g)	0.95^{b}	0.82^{b}	0.69^{c}	0.55^{c}	0.42^{cd}
Magnesium (g/100g)	0.10	0.12	0.13	0.14	0.15
Gross Energy (kJ/100g)	1776^{d}	1798^{cd}	1819^{c}	1841^{c}	1882^{c}
Metabolizable Energy (kJ/100g)	1332.0^{d}	1348.0^{cd}	1364.0^{c}	1381.0^{c}	1411.0^{c}
Digestible Energy (kJ/100g)	2400^{b}	2420^{b}	2490^{b}	2580^{b}	2640^{bc}

All values on the same row with the different superscripts are significantly difference (P<0.05).

Table 4. Essential amino acids composition (% dry matter) of experimental diets

Essential Amino Acids (%)	Major animal protein sources		Experimental diets				
	Fish meal (Clupeids)	Termite meal	TM1	TM2	TM3	TM4	TM5
Inclusion levels of termite meal (%)			0	25	50	75	100
Arginine	5.34	3.63	4.72^{a}	4.56^{a}	4.40ab	4.24^{b}	4.08^{b}
Histidine	4.19	2.65	3.42^{a}	3.23^{a}	3.01^{b}	2.85^{b}	2.65^{b}
Isoleucine	2.62	2.32	2.06	2.02	1.98	1.95	1.91
Leucine	8.31	3.26	6.88^{b}	6.38^{b}	5.89^{b}	5.39^{b}	4.89^{bc}
Lysine	10.96	6.97	6.10^{b}	5.52^{b}	4.95^{bc}	4.37^{bc}	3.79^{c}
Methionine	2.26	2.08	1.61	1.54	1.47	1.40	1.33
Phenylalanine	5.52	3.98	4.49	4.30	4.12	3.93	3.74
Threonine	5.28	3.73	3.62^{b}	3.35^{b}	3.07^{b}	2.79^{b}	2.51^{b}
Valine	5.88	3.86	3.94^{b}	3.55^{b}	3.30^{b}	2.97^{b}	2.65^{b}
Tryptophan	0.97	0.78	0.62	0.62	0.63	0.63	0.64
Total EAA	51.33	33.26	37.46^{b}	35.07^{a}	32.82^{b}	30.52^{b}	28.19^{bc}
Chemical Score	96.7	37.5	70.55^{a}	66.05^{b}	61.81^{c}	57.48^{d}	53.09^{e}
EAA/ CP	0.72	0.43	0.86^{a}	0.81^{b}	0.76^{c}	0.71^{d}	0.65^{e}

All values on the same row with the different superscripts are significantly different (P<0.05).
Key: EAA/CP: Essential amino acids ratio to that of crude protein.

The highest survival rate of 93.3% was recorded in control while the lowest of 80% was recorded in 75% and 100% termite meal diets. There was significant difference (P<0.05) between survival rate of fish fed termite meal based diets and the control. There was no significant difference (P>0.05) between the condition factor of the fish fed termite meal inclusion diets.

There was significant difference (P<0.05) between the voluntary feed intake and feed conversion ratio of fish fed termite meal diets. Highest voluntary feed intake of 5.53 was recorded from in 75% termite meal diet while the lowest of 4.69 was recorded in 25% termite meal-based diet. The feed conversion ratio ranged from 2.88 to 3.67. Highest feed conversion ratio, 3.67 recorded 75% termite meal diet while lowest feed conversion ratio, 2.88 was recorded in 50% termite meal diet (Table 5).

There was no significant difference (P<0.05) between the protein efficiency rate of fish fed with lower substitution levels of termite meal-based diet. The highest apparent net protein utilization of 35.76% was recorded from 50% termite meal diet while the lowest value of 23.07% was recorded from 100% termite meal diet. There was a significant difference (P<0.05) between the apparent net protein utilization of the fish fed with termite meal diets.

The highest net profit value of ₦424.13 k/kg was reported in the control diet while the lowest of ₦273.55 k/kg was reported in the 100% termite meal inclusion levels. The highest and the lowest profit index of 1.63 and 1.37 were reported in 50% and 75% termite meal inclusion levels respectively. The best benefit: cost ratio 1.1810 was reported in 50% termite meal diet. The broken line-analysis shows maximum weight gain, 9.59 g/fish, maximum specific growth rate and termite meal inclusion levels of 50% as the required quantity needed to produce the best weight gain and specific growth rate as specified in Figure1. This will also be the most economical one for *H. longifilis* development.

Discussion

The crude protein of termite meal in this work is higher than 37% and 44.12% reported by Aduku (1993) for *Macrotermes* spp Oyarzum *et al.* (1996) for *Nasutitermes spp* but lower than 48.80% reported by Fadiyimu *et al.* (2003) for *Macrotermes* spp. The lipid content analysis of this animal confirms the work of Oyarzum *et al.* (1996) and Aduku (1993) that termites have high composition of lipid. Termite meal is poor in mineral composition. This result is in accordance with the report of Barker *et al.* (1998) that

Table 5. Growth, nutrient utilization and economic indices of *Heterobranchus longifilis* fingerlings fed termite meal diets for 84 days

Indices	Experimental diets					±SD
	TM1 Control	TM2	TM3	TM4	TM5	
Inclusion levels (%)	0	25	50	75	100	
Number stocked	15	15	15	15	15	±0.0
Mean initial weight (g/fish)	1.92±0.11	2.35±0.06	1.96±0.06	2.15±0.06	1.84±0.03	±0.21
Mean Initial total length (cm/fish)	6.3^{b}	6.7^{b}	7.2^{a}	7.4^{a}	6.6^{b}	±0.45
Mean final weight (g/fish)	10.71^{a}	10.60^{a}	11.54^{a}	9.56^{ab}	8.81^{b}	±1.70
Mean weight gain (g/fish)	8.79^{a}	8.25^{ab}	9.58^{a}	7.41^{c}	6.97^{c}	±1.05
Relative growth rate (%/fish)	457.8^{a}	351.1^{bc}	488.8^{a}	344.7^{c}	378.8^{b}	±65.26
Specific growth rate (%/day)	0.89^{a}	0.78^{b}	0.92^{a}	0.77^{b}	0.81^{ab}	±0.07
Metabolic growth rate	27.52^{a}	25.32^{ab}	28.43^{a}	24.64^{b}	25.01^{ab}	±1.68
Initial Condition factor (K_1)	0.7524^{a}	0.7910^{a}	0.5308^{c}	0.5273^{c}	0.6439^{b}	±0.12
Final Condition factor (K_2)	1.17^{a}	1.17^{a}	1.19^{a}	1.12^{b}	1.13^{b}	±0.03
Survival (%)	93.3^{a}	86.7^{b}	86.7^{b}	80.0^{c}	80.0^{c}	±5.57
Voluntary feed Intake (g/fish)	4.91^{b}	4.69^{bc}	4.87^{b}	5.53^{a}	5.36^{a}	±0.36
Feed striking time (sec)	6.0	6.0	5.0	6.0	6.0	± 0.45
Feed acceptability index (sec^{-1})	0.17	0.17	0.20	0.17	0.17	±0.013
Water stability (%)	74.17	75.68	72.32	74.11	76.88	±1.73
Feed conversion ratio	2.96^{a}	3.09^{a}	2.88^{a}	3.67^{b}	3.44^{b}	±0.34
Protein efficiency ratio	0.78	0.75	0.80	0.63	0.67	±0.07
Apparent Net Protein Utilization (%)	34.07^{a}	30.60^{a}	35.76^{a}	23.62^{b}	23.07^{b}	±5.86
Apparent Net Lipid utilization (%)	18.18^{c}	32.40^{a}	32.17^{a}	30.32^{a}	26.98^{b}	±5.91
Gross protein value	1.0	0.94	1.09	0.85	0.80	±0.16
Net profit value (₦/kg)	424.13^{a}	359.07^{b}	422.03^{a}	288.79^{c}	273.55^{c}	±71.23
Investment cost analysis (₦)	395.63^{a}	347.42^{ab}	357.77^{a}	310.14^{b}	274.83^{c}	±46.27
Gross profit/loss (₦)	28.50^{b}	11.65^{c}	64.26^{a}	-21.35^{e}	-1.28^{d}	±32.39
Profit index	1.43^{b}	1.45^{b}	1.63^{a}	1.37^{bc}	1.56^{a}	±0.105
Incidence of cost	2.44^{a}	2.41^{a}	2.13^{c}	2.55^{a}	2.24^{b}	±0.169
Benefit: Cost ratio (r)	1.07^{a}	1.03^{a}	1.18^{a}	0.93^{ab}	1.00^{ab}	±0.092

All values on the same row with the different superscripts are significantly difference (P<0.05).

insects are low in major mineral compositions most, especially in calcium and phosphorus.

The protein values reported for each of the termite meal diets were in accordance with the report of Fagbenro *et al.* (1992) that optimum dietary protein requirements for *Heterobranchus* sp. is 42.5% and this will favour high growth. The result of the essential amino acids indicated that this animal supplement could be a replacement for fish meal. Abdullahi (2000) reported that each of the dietary indispensable (essential) amino acid must be available at levels equal to or higher than dispensable amino acid body levels of fish. Eyo (1999) and Fagbenro *et al.* (2000) have reported the essential amino acid composition of *H. longifilis.* This indicates that the animal protein supplements are capable of supplying the fish with the required essential amino acids. The nutritive value of protein which depends on the capacity to produce nitrogen and amino acids in adequate amounts to meet the requirements of culture fish (Wilson, 1989; Eyo and Olatunde, 2001) and the value of the amino acid have been scored using amino acid composition of hen egg as reported by National Research Council (NRC) (1983).

All the experimental diets had the same percentage of binder made of cassava starch. Incorporation of binder to fish feed may be beneficial to the pelleting quality of the diet, retention of the nutrient and fish growth (NRC, 1993; Wilson, 1994). Despite this, there were variations presented in the water stability of the diets which have been reported to affect their nutrient retention capacity (Wood, 1987). The water stability of feed in the present study linearly correlated with the inclusion levels of tested animal protein than the nitrogen free extract (carbohydrate) of the experimental diets. Starch gelatinization, which is a binding factor in feed has been reported to perform better when in contact with protein plasticization which increases the adhesive force within the ingredients (Brigg *et al.,* 1999). Despite the use of binder, the floating ability and particle size of feed ingredients do affect the stability of the feed (Falayi *et al*., 2004)

The low feed striking time recorded with no significant difference indicates the palatability of the diets fed. Termite has been appraised in the diet of chickens to be very palatable and a suitable replacement for soybean, fish meal and vitamin premix without any reduction in growth performance (Men *et al*., 2005). The fact that weight gain was recorded in all experimental diets was an indication that the fish was able to convert the protein fed to muscles. The higher growth performance observed in combined feeding can be explained by the synergetic effect of combining two biological compounds to have a single and superior effect than when applied individually. This observation is in agreement with suggestions by previous authors that combined protein source is better than single protein source for fish diets (Ugwumba *et al*., 2001; Sogbesan *et al*., 2005; Sogbesan and Ugwumba, 2006a; 2006b). Ability of an organism to convert nutrient especially protein will positively influence its growth performance. This is justified by the best protein efficiency ratio and growth performance in 50% termite meal fed fingerings. Lower feed conversion

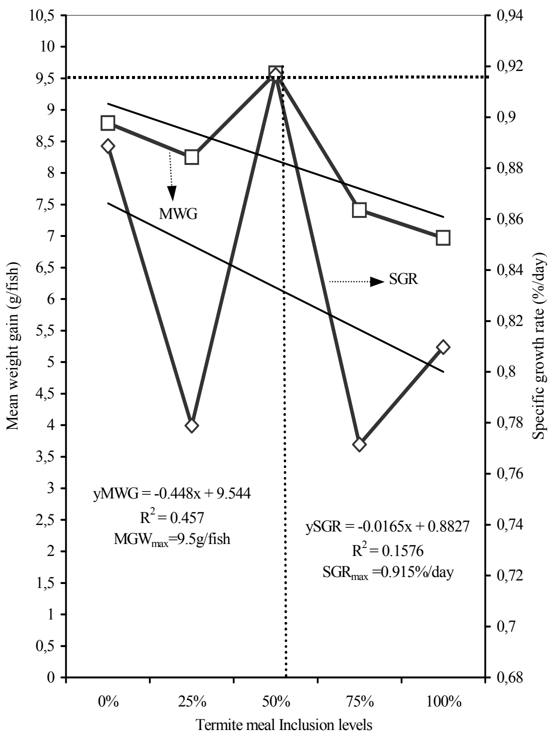

Figure1. Effect of graded termite based diets on mean weight gain and specific growth rate of *Heterobranchus longifilis*.

ratio indicates better utilization of the feed by the fish fed. DeSilva and Anderson (1995) reported that protein efficiency ratio is a measurement of how well the protein sources in a diet could provide the essential amino acids requirement of the fish fed. The authors also reported that this index has also been associated with fat deposition in the fish muscle and that higher protein efficiency ratio is an indication of diet that produces fatty fish, hence the protein efficiency ratio range of 0.63-0.80 recorded in this study did not favour fat deposition in catfish meaning that the crude lipid in the diet might be responsible for a sparing effect on the protein content of the diets which had been utilized by the fish for muscle development. The condition factors at the end of the experiment showed that the feeds were properly utilized for better growth and sound health since all the condition factors were above 1.0 (Lagler, 1956). Condition factor even in the wild is not constant for individuals, species or population but is subject to wide variations. For fish, Wade (1992) gave 1.0 as the best natural condition factor.

The highest cost for the control diet affirmed the report of Faturoti and Lawal (1986), that fish meal prices are very high while the alternatives which have comparative nutritive value were preferably cheaper than conventional protein source. Competition from consumer during the swarm period may likely affect the cost of getting termite, since it is edible by man and has been reported as a seriously competed delicacy by children (Banjo *et al.*, 2004). Other members of this social insect have been tried with appreciable result (Iziko, 2004). In Uganda, the head of soldier termite is a good delicacy (Iziko, 2004) for human consumption. The result of the economic analysis showed that there would be economic benefits to the farmer from using dried termite meal to replace fish meal in the diet of *H. longifilis* at 50% inclusion levels of the meal as also specified by the broken-line analysis.

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