Nutritional Values of Some Non-Conventional Animal Protein Feedstuffs Used as Fishmeal Supplement in Aquaculture Practices in Nigeria

A.O. Sogbesan1,*, A.A.A. Ugwumba2
1 Federal University of Technology, Department of Fisheries, Yola, Adamawa state, Nigeria.
2 University of Ibadan, Department of Zoology, Ibadan, Nigeria.

Abstract

Four animal protein sources were cultured, processed and analysed for their basic nutrient values in comparison with the conventional clupeids fishmeal.

The result of study showed that the clupeid fishmeal had the highest crude protein, 71.64% and unskinned-dried tadpole meal, 43.50% had the lowest value. There was a significant difference (P<0.05) between the crude protein composition of these animal protein sources. Termite had the highest crude lipid, 30.50% and garden snail the lowest value, 7.85%. Termite meal recorded the highest gross energy, 2,457.61 kJ/100 g while the lowest 1,639.63 kJ/100 g was from unskinned-dried tadpole meal. The highest sodium and potassium, 2.32 g/100 g and 2.23 g/100 g respectively were from garden snail meal while termite meal had the lowest sodium, 0.20 g/100 g and unskinned-dried and skinned tadpole meal had the lowest potassium, 0.21 g/100 g. There were significant differences (P<0.05) between the highest and lowest minerals for the animals studied. The highest total essential amino acids, 51.33 g/16 N g were from fishmeal and the lowest 19.84 g/16 N g from termite meal.

Based on the results from this study, any of the understudied animal proteins have the tendency to supplement fishmeal in fish feed since they all have competitive nutrient values.

Key words: non-conventional animal, proteins, essential amino acids indices, proximate, fishmeal.

Introduction

Essential or indispensable amino acids (EAAs) cannot be synthesised by fish and often remain inadequate but are needed for growth and tissue development (Fagbenro et al., 2000; Wilson, 1989). Fishmeal is known to contain complete EAA profile that is needed to meet the protein requirement of most fish species. Since fishmeal is expensive as a feed ingredient, the use of non-conventional feedstuffs has been reported with good growth and better cost-benefit values.

The utilization of non-conventional feedstuffs of plant origin had been limited as a result of the presence of alkaloids, glycosides, oxalic acids, phytates, protease inhibitors, haematoglutinin, saponegin, monosos, cyanoglycosides, linamarin to mention a few despite their nutrient values and low cost implications (New, 1987; Sogbesan et al., 2006). These anti-nutritional factors negate growth and other physiological activities at higher inclusion levels (Oresegun and Alegbeleye, 2001).

Non-conventional feed resources (NCFRs) are feeds that are not usually common in the markets and are not the traditional ingredients used for commercial fish feed production (Devendra, 1988; Madu et al., 2003). NCFRs are credited for being non competitive in terms of human consumption, very cheap to purchase, by-products or waste products from agriculture, farm made feeds and processing industries and are able to serve as a form of waste management in enhancing good sanitation.

These include all types of feedstuffs from animal (silkworm, maggot, termite, grub, earthworm, snail, tadpoles etc.), plant wastes (jack bean, cottonseed meal, soybean meal, cajanus, chaya, duckweed, maize bran, rice bran, palm kernel cake, groundnut cake, brewers waste etc.) and wastes from animal sources and processing of food for human consumption such as animal dung, offal, visceral, feathers, fish silage, bone, blood) (Devendra, 1988; Oyelese et al., 1999; Fasakin et al., 2000; Omitoyin and Faturoti, 2000). All these can be recycled to improve their value if there are economically justifiable and technological means for converting them into useable products.

The nutrient quality of feed ingredient is one of the major prerequisite apart from availability (which sometimes is a function of cost and season) for production of good quality feeds. The basic nutrient that cannot be compromised in the choice of ingredients for feed formulation and preparation is protein (Zeitler et al., 1984). Hence it becomes imperative to research into the nutrient composition of some of the easily culturable animal protein sources.

The aim of this experiment is to analyse chemical composition of earthworm, garden snail, termite and tadpole meals so as to provide information which will help in incorporating any of these non-conventional animals into fish feed ingredients during the feed formulation by fish
nutritionist and fish farmers who may want to use them as on-feed ingredients.

Materials and Methods

The culture of the non-conventional animals took place in the hatchery premises of National Institute for Freshwater Fisheries Research (NIFFR), New-Bussa, Niger-State from May to August, 2005. Earthworm, *Hyperodrilus euryaulos* was cultured according to the method of Sogbesan and Ugwumba (2006). Garden snail, *Limicolaria aurora* was cultured according to Sogbesan et al. (2007). Termite, *Macrotermes subhyalinus* meal were collected during nuptial flight as reported by Sogbesan (2006) and tadpole, *Bufo maculata* were cultured in outdoor concrete tanks using the method reported in Sogbesan and Ugwumba (2007).

Processing of the Non-Conventional Animal Feed Ingredients

Earthworm Meal: At the end of the culture period, the harvested worms were thoroughly rinsed in water and kept in a bowl for 30 minutes to evacuate the residual undigested contents in their guts (Akpodiete and Okagbare, 1999). The worms were then weighed, blanched in hot water, re-weighed and oven-dried at 80°C for 3 hours. After drying, the worms were weighed, then milled with Hammer milling machine into powdered form, packed as dried earthworm meal in an airtight plastic bowl and stored in a refrigerator till used.

Snail Meat Meal: The snails harvested were boiled for 30 minutes for easy removal of the foot and viscera from the shell. The shells were removed manually using knife. The snail meat was weighed and steamed for 10 minutes. They were oven dried at 80°C for 9 hours then weighed and milled into powdered form. The snail meal was packed in an airtight plastic bowl and stored in a refrigerator till used.

Termite Meal: Reproductive termites were collected during swarm activity from a termitarium outside the Hatchery Complex of NIFFR. They were weighed and then oven-dried at 80°C for 3 hours. The wings were blown off. The dried termites were weighed, milled, packed in plastic bowl and stored in a refrigerator till used.

Tadpole Meal: The harvested tadpoles were weighed and divided into three equal halves. First halve was oven dried at 80°C for 6 hours while the second was boiled before oven dried and the third halve was skinned before oven dried. They were separately weighed, milled into powdered form, packed in three airtight plastic bowls and coded as dry-unskinneated, boiled-dry unskinned and skinned tadpole meals then stored in a refrigerator till used.

Proximate Composition and Mineral Salts Analysis of the Non-Conventional Animal Samples

The proximate composition, mineral salts and amino acids profile of the processed animal meals were carried out at NIFFR Chemical Laboratory and National Institute for Veterinary Research, Vom, Plateau State. The earthworm, garden snail meat, termites, tadpole and fish (clupeid) meals were analysed for moisture content, dry matter content, crude protein, crude lipid, nitrogen free extracts, crude fibre, ash, mineral salts, gross energy, digestible energy, and metabolizable energy according to Association of Official Analytical Chemist Methods (A.O.A.C. 2000). A mean of three samples for each nutrient was recorded.

Essential Amino Acid Indices

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). The essential amino acids indices determined were:

(a) Chemical score (%) = [Essential amino acid of the sample / Essential amino acid of the whole hen egg] x 100

(b) Chemical score to protein score ratio (CSPS) (%) = [Total essential amino acid of the sample / Total essential amino acid of whole hen egg] x 100

(c) Total essential amino acid to crude protein content ratio (EAA: CP) (%) = [Total essential amino acid / (Crude protein of the animal meal /100 g of diet)] x 100

Statistical Analysis

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 multiple tests and Dunnet test. Standard deviation and standard error were calculated to identify the range of means and error respectively. Least significance differences (LSD) were used to determine the level of significance among treatments.

Results

Proximate Compositions of the Cultured Animal Meals and Fishmeal

Table 1 shows the proximate, gross energy and mineral composition of the cultured animal and fishmeal. Fishmeal had the highest crude protein.
followed by garden snail meat meal while unskinned- dry tadpole meal had the lowest and these were significantly different (P<0.05). Termite had the highest crude lipid and garden snail the lowest value. Termite meal recorded the highest gross energy followed by fishmeal while the lowest was from tadpole meal. The highest sodium and potassium were from garden snail meal while termite meal had the lowest sodium and unskinned-dried and skinned tadpole meal the lowest potassium. There were significant differences (P<0.05) between the highest and the lowest minerals for the animals studied.

Table 1. Proximate, mineral composition (% dry matter) and energy content (kJ/100g) of the cultured animal protein sources and fishmeal

<table>
<thead>
<tr>
<th>Animal Proteins</th>
<th>Earthworm meal</th>
<th>Garden snail meal</th>
<th>Termite meal</th>
<th>Unskinned-dried tadpole meal</th>
<th>Unskinned-boiled tadpole meal</th>
<th>Skinned tadpole meal</th>
<th>Fishmeal (clupeids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crude protein (%)</td>
<td>63.0±4.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66.8±3.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.3±3.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>43.5±3.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>45.9±2.5&lt;sup&gt;c&lt;/sup&gt;</td>
<td>47.8±4.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>71.5±4.6&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude lipid (%)</td>
<td>5.9±1.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>7.9±2.3&lt;sup&gt;e&lt;/sup&gt;</td>
<td>30.1±5.1&lt;sup&gt;e&lt;/sup&gt;</td>
<td>11.3±2.4&lt;sup&gt;b&lt;/sup&gt;</td>
<td>10.7±2.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>11.6±1.8&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.0±1.4&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Ash (%)</td>
<td>1.9±0.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.1±0.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>7.3±1.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.8±2.1&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.8±1.8&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.0±1.9&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.2±0.8&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Sodium (g/100g)</td>
<td>0.43±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.32±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.20±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>0.61±0.006&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.59±0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.63±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.91±0.006&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Calcium (g/100g)</td>
<td>0.53±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.13±0.08&lt;sup&gt;c&lt;/sup&gt;</td>
<td>0.23±0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.51±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.43±0.03&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.59±0.02&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.53±0.15&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Gross energy(kJ/100g)</td>
<td>1943.0±1.15&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2006.0±3.46&lt;sup&gt;c&lt;/sup&gt;</td>
<td>2458.0±60.1&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1640.0±17.32&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1640.0±23.1&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1661.0±&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2075.0&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values on the same row with the different superscripts are significantly different (P<0.05).

Table 2. Essential amino acids composition (g/16gN) of the tested animal protein sources

<table>
<thead>
<tr>
<th>Animal Protein Sources</th>
<th>Earthworm meal</th>
<th>Garden snail meal</th>
<th>Termite meal</th>
<th>Unskinned-dried tadpole meal</th>
<th>Unskinned-boiled tadpole meal</th>
<th>Skinned tadpole meal</th>
<th>Fishmeal (clupeids)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arginine</td>
<td>2.83±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>11.99±0.11&lt;sup&gt;a&lt;/sup&gt;</td>
<td>2.87±0.12&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3.63±0.02&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.79±0.09&lt;sup&gt;c&lt;/sup&gt;</td>
<td>4.01±0.06&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.34±0.17&lt;sup&gt;a&lt;/sup&gt;</td>
</tr>
<tr>
<td>Histidine</td>
<td>1.47±0.23&lt;sup&gt;d&lt;/sup&gt;</td>
<td>1.77±0.12&lt;sup&gt;c&lt;/sup&gt;</td>
<td>1.28±0.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.65±0.03&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.21±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.96±0.05&lt;sup&gt;b&lt;/sup&gt;</td>
<td>4.19±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Isoleucine</td>
<td>2.04±0.01&lt;sup&gt;e&lt;/sup&gt;</td>
<td>6.23±0.32&lt;sup&gt;a&lt;/sup&gt;</td>
<td>1.70±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.32±0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.30±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.74±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>2.62±0.07&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Leucine</td>
<td>4.11±0.11&lt;sup&gt;c&lt;/sup&gt;</td>
<td>6.79±0.12&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.11±0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.26±0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.72±0.08&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.38±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.31±0.09&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Methionine</td>
<td>5.30±0.05&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.13±0.08&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.68±0.02&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.26±0.04&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.72±0.08&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.38±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
<td>8.31±0.09&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
<tr>
<td>Phenylalanine</td>
<td>6.26±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.04±0.005&lt;sup&gt;ab&lt;/sup&gt;</td>
<td>1.97±0.01&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.98±0.09&lt;sup&gt;d&lt;/sup&gt;</td>
<td>4.36±0.08&lt;sup&gt;b&lt;/sup&gt;</td>
<td>3.96±0.03&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.52±0.05&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Threonine</td>
<td>4.43±0.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>5.91±0.2&lt;sup&gt;e&lt;/sup&gt;</td>
<td>1.67±0.06&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.73±0.05&lt;sup&gt;c&lt;/sup&gt;</td>
<td>3.41±0.2&lt;sup&gt;d&lt;/sup&gt;</td>
<td>3.64±0.2&lt;sup&gt;c&lt;/sup&gt;</td>
<td>5.28±0.6&lt;sup&gt;d&lt;/sup&gt;</td>
</tr>
<tr>
<td>Total Essential amino acids</td>
<td>37.11±2.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50.06±2.89&lt;sup&gt;a&lt;/sup&gt;</td>
<td>19.36±0.38&lt;sup&gt;c&lt;/sup&gt;</td>
<td>32.48±1.15&lt;sup&gt;b&lt;/sup&gt;</td>
<td>32.24±1.18&lt;sup&gt;b&lt;/sup&gt;</td>
<td>34.69±2.31&lt;sup&gt;b&lt;/sup&gt;</td>
<td>50.36±2.31&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>Crude Protein %</td>
<td>63.04±4.5&lt;sup&gt;b&lt;/sup&gt;</td>
<td>66.96±3.6&lt;sup&gt;b&lt;/sup&gt;</td>
<td>46.32±3.2&lt;sup&gt;e&lt;/sup&gt;</td>
<td>43.50±3.4&lt;sup&gt;c&lt;/sup&gt;</td>
<td>45.38±2.5&lt;sup&gt;d&lt;/sup&gt;</td>
<td>47.81±4.1&lt;sup&gt;c&lt;/sup&gt;</td>
<td>71.64±4.6&lt;sup&gt;c&lt;/sup&gt;</td>
</tr>
</tbody>
</table>

Values on the same row with the different superscripts are significantly different (P<0.05).

Mean±SE
total essential amino acids than all the other animal meals except garden snail meal.

The overall highest chemical score was from arginine for garden snail meat meal followed by histidine from fishmeal as illustrated in Figure 1. The least chemical scores were from termite meal for all essential amino acids except arginine in earthworm meal and methiohine in garden snail meat meal. The highest chemical score for the ten essential amino acids was recorded for fish meal while the least was recorded for termite meal (Table 3).

Discussion

One of the benefits of earthworm cultured is the production of a valuable protein source (Lieberman, 2002). The crude protein of earthworm reported in this study (Table 1) for *H. euryaulos* is lower than 69.8% for *P. excavatus* (Guerrero, 1983) and 67.68% for *E. foetida* (Reinecke and Alberts, 1987) but higher than 56.4% and 61.8% for *E. foetida* reported by Tacon (1994) and Medina et al. (2003), respectively. The lipid content of *H. euryaulos* analysed from this study is similar to 5.8% by Guerrero (1983) for *P. excavatus* and higher than 5.15% by Reinecke and Alberts (1987) but lower than 7.8% by Tacon (1994) and 9.88% by Dynes (2003) for *E. foetida*. The quantity of sodium, calcium and potassium reported from this study for earthworm meal is within the required level for catfish and all tropical fish (NRC, 1993). The 0.62 g/100 g of phosphorus reported in *H. euryaulos* is lower than the recommended phosphorus, 0.8 g/100 g for natural diets but higher than 0.42 g/100 g for chemically refined diets. Since earthworm meal is a natural diet, feeding it as whole ingredient to catfish may result into poor growth, feed efficiency and bone mineralization (NRC, 1993).

The crude protein for garden snail meat meal from this study is higher than crude protein of 62% for golden snail and 60-70% for African giant snails.
as reported by Seira (1998) and Odaibo (1997) respectively. The lipid content presented in this study is lower than 8.3% reported by Seira (1998). High level of sodium reported from this ingredient could have been positively influenced by the table salt used during processing of the meal. Higher level of sodium has been reported to adversely affect growth and feed efficiency (Shiau and Hseih, 2001).

The crude protein of termite meal in this work is higher than 37% reported by Aduku (1993) for Macrotermes spp and corroborate to 48.80% reported by Fadiyimu et al. (2003) also for Macrotermes spp. and 44.12% reported by Oyarzum et al. (1996) for Nasutitermes spp. The lipid content analysis of this animal is aligned with the work of Oyarzum et al. (1996) and Aduku (1993) that termites have high lipid content. Feeding catfish with this type of high lipid diet exposes them to a risk of fat deposition in the organs (Tacon, 1987) though dietary lipids that have been reported to be well digested by fish and serve as better energy source for protein sparing than carbohydrate (Okoye et al., 2001). Termite meal is poor in mineral composition. This result is in accordance with the report of Barker et al. (1998) that insects are low in major mineral compositions, especially calcium and phosphorus.

The crude protein and lipid composition of the unskinned-dried tadpole in this present study is similar to 43.50% crude protein and 11.30% crude lipid of dry weight reported by Ayinla et al. (1994) (for Bufo sp.). This simply implies that there may not be variation in tadpoles of bufonidae family. The sodium, 0.61 g/100 g, calcium, 2.51 g/100 g, and magnesium, 0.58 g/100 g were within the required amount for catfish (NRC, 1993). The low phosphorus, 0.57 g/100 g may need to be supplemented with other higher sources if needed by H. longifilis because this fish along with other catfish has been reported to utilize 60% of phosphorus in its diet since it has enough gastric juices to digest this mineral (Lovell, 1978).

The fact that the crude protein content of the earthworm meal and garden snail meal were close to that of fishmeal and those of termite and that they tadpole still fall within range of the protein required by the culturable tropical fish (Eyo and Olatunde, 2001) indicated that feeding any of these fish with any of these animal protein supplements will not pose the problem of malnutrition to the fish. Eyo (2003) reported that the value of animal products used in aquaculture diets will be high if the protein content is high and ash is low and results of the proximate compositions of the animals’ protein in this study corroborate this. Allan et al (2000) reported that aquaculture diet is expected to contain higher protein-to-energy ratios than diets for pig and poultry. Since protein content is usually between 35-50% for aquaculture diets compared with 15-22% for poultry and pig diet.

The result of the essential amino acids indicated that these animal supplements could substitute fishmeal in fish feed (Table 2) since they all contain the required essential amino acids needed by fish for protein metabolism (DeSilva and Anderson, 1995). This result showed that earthworm meal is richer in methionine (Figure 1) than other animal protein sources studied which agreed with the observation of Finke (2003) when he compared the nutrient values in some invertebrates. Methionine has been credited as growth promoting essential amino acid, which is highly needed by cultured fish and limited in most plant and many animal supplements (Wilson, 2002).

The nutritive value of protein depends on its capacity to produce nitrogen and amino acids in adequate amounts to meet the requirements of culture fish (Wilson, 1989; Eyo and Olatunde, 2001). The lowest total essential amino acids and highest crude fibre from termite meal could have resulted from the fact that high proportions of fibre has been associated with reduction in total essential amino acid since it is a non-protein nutrient and has nothing to do with sparing of protein like lipids and nitrogen-free extract (Van der Meer and Verdegem, 1996).

The essential amino acid, protein and lipid value of the animal supplements from this study could satisfy the requirement of catfish at all ages for both somatic and reproductive development. These nutrients were comparable to the quality and quantity of what are obtained in the conventional fishmeal used in this study (Table 2) and similar reports were generated by Van der Meer et al. (1995), Dynes (2003) and Okoye (2003).

References


Devendra, C. 1988. General approaches to Animal Nutrition research and their relevance to fish production in the Asian region. In: S.S. DeSilva (Ed.), Finfish Nutrition...


