

## Assessment of the Growth Performance and Feed Utilization of Fingerling *Heterobranchus longifilis* Fed Raw and Boiled Jackbean (*Canavalia ensiformis*) Seed Meal as Fishmeal Substitute

<sup>1</sup>D.I. Osuigwe and <sup>2</sup>A.I. Obiekezie

<sup>1</sup>Department of Biotechnology, Federal University of Technology Owerri, Nigeria

<sup>2</sup>Institute Of Oceanography, University of Calabar, Nigeria

**Abstract:** Fingerlings of *Heterobranchus longifilis* were fed thirteen isonitrogenous (CP30%) and isocaloric (ME 2900 Kcal kg<sup>-1</sup>) diets formulated by substituting fishmeal with raw or 60 min. boiled Jack Bean Seed Meal (JBSM). After 56 days of feeding at 3% body weight, the specific growth rate SGR and apparent protein efficiency ratio APER values at 10% raw JBSM substitution and up to 40% boiled JBSM substitution were not significantly different from the controlled diet. The apparent feed conversion ratio AFCR for all the diets except 100% JBSM substituted diets were statistically similar. The fish carcass protein significantly decreased with increasing JBSM substitution. Similarly the carcass fat values for fish fed boiled JBSM substituted diets decreased significantly with increasing substitution while those fed raw JBSM substituted diets showed no trend. It is therefore concluded that raw and boiled JBSM could be successfully used to substitute fishmeal at 10 and 40% levels respectively in diets for *Heterobranchus longifilis*

**Key words:** Fishmeal substitute, *Heterobranchus longifilis*, jackbean (*Canavalia ensiformis*)

### INTRODUCTION

Aquaculture has been the world's fastest growing food production system with global production increasing from 10.1 million metric tons (mt) in 1984 to 27.8 million mt in 1995 Kureshy *et al.*, 2000. This corresponds to an average annual growth rate of 9.6% since 1984, compared with a growth rate of 3.1% for terrestrial livestock meat production and 1.6% for capture fisheries production over the same period Tacon and Barg, 1998. Currently, aquaculture feeds use more than 20% of the world's supply of fishmeal put at 6 million mt per year Hardy, 1999. To reduce long-term dependence upon fishery resources, Tacon and Barg, 1998. recommended that effort be placed on use of products arising from the terrestrial agricultural production sector.

Jackbean (*Canavalia ensiformis*) an indigenous legume has shown promise as energy and protein source for animal production in view of its high seed yield (2.5-30t ha<sup>-1</sup>) Okonkwo and Udedibie, 1999. and up to 30% crude protein. However, jackbean contains toxic antinutritional factors which limit its use as feed for monogastrics D' Mello *et al.*, 1985. Attempts by earlier workers have shown that the nutritive value of jackbean could be significantly improved by heat treatment Udedibie and Madubuike, 1988. This study investigated the use of milled raw and 60 min. boiled JBSM as a substitute for fishmeal in fish diets.

### MATERIALS AND METHODS

Two types of JBSM were obtained by milling the raw seed with hammer mill and subjecting a portion of the milled bean to boiling for 60 min. The boiled meal was thereafter dried in an oven at 60°C.

Samples of the meals were assayed for proximate composition using the A.O.A.C., 1990. procedures. Micro-Kjeldahl method was employed for Crude Protein (CP) and soxhlet extraction method for Ether Extract (EE). The gross energy was determined using adiabatic oxygen bomb calorimetric technique. The milled raw seeds was subjected to wet digestion with perchloric and nitric acids by the Johnson and Ulrich, 1959. method. Following the digestion, the mineral content was determined by atomic absorption spectrophotometry. The phosphorus content was determined on a spectronic 20 spectrophotometer following the development of colour with ammonium molybdate. Table 1 shows the composition of jackbean seed meal.

Thirteen isonitrogenous (CP30%) and isocaloric (ME 2900Kcal kg<sup>-1</sup>) diets were formulated using raw and 60min. boiled JBSM (Table 2). Diet I without JBSM served as the control while diets 2,3,4,5,6 and 7 had the fishmeal replaced progressively by raw JBSM at 10, 20, 40, 60 and 100% respectively. Diets 8, 9, 10, 11, 12 and 13 had the fishmeal replaced by 60 min. boiled JBSM at 10, 20, 40 60, 80 and 100, respectively.

Table 1: Chemical composition of JBSM (g kg<sup>-1</sup> DM)

	Raw	Boiled (60 min)
Crude protein N x 6.25	282.50	254.00
Ether extract	29.00	28.00
Crude fibre	67.30	62.10
Ash	34.40	29.20
NFE <sup>1</sup>	586.80	626.70
Phosphorus	6.20	-
Calcium	0.90	-
Magnesium	0.80	-
Gross energy (Kcal 100 g <sup>-1</sup> )	459.32	456.52

<sup>1</sup>NFE = nitrogen free extract (100-[(%protein+% ether extract+% crude fibre+% ash)])

Table 2: Composition of experimental diets

	Diet No. /% fishmeal substituted with JBSM												
	1 Control	2 10%	3 20%	4 40%	5 60%	6 80%	7 100%	8 10%	9 20%	10 40%	11 60%	12 80%	13 100%
Fishmeal	22.00	19.80	17.60	13.20	8.80	4.40	0.00	19.80	17.60	13.20	8.80	4.40	0.00
JBSM*	0.00	4.36	8.72	17.44	26.17	38.89	43.61	4.93	9.86	19.71	29.57	39.42	49.28
Maize	35.00	32.84	30.68	26.36	22.03	15.21	12.39	32.27	29.54	24.09	17.63	12.18	6.72
Groundnut Meal	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00	20.00
Soybean meal	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00	15.00
Wheat bran	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00	5.00
Palm oil	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Bone	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00
Salt	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
Premix**	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25	0.25
% crude Protein	30.27	30.15	29.93	29.50	29.07	28.39	28.11	30.10	29.83	29.28	28.63	28.09	27.54
ME (Kcal kg) <sup>-1</sup>	2986	2975	2964	2943	2920	2903	2933	2973	2916	2937	2967	2943	2918

\*JBSM: diets 2-7 = raw JBSM; 8-13 = 60min. boiled JBSM ; \*\* Vitamin and mineral premix ; \*\*\* ME calculated

The fingerlings of *Heterobranchus longifilis* used for the experiment were procured from Green Lake Farms Mgbahiri near Owerri. Individuals of fairly uniform size of initial average body weight 1.89g that had been acclimated in 20 L square plastic aquaria for seven days were used.

The test diets were assigned randomly to duplicate groups of ten fingerlings in the aquaria. The experimental fish were fed the assigned diets once daily for fifty-six days at 3% body weight per day in order to stimulate food consumption (Cruz and Laudencia, 1977). After the initial weight records the fish in each aquarium was batch-weighed fortnightly and from the data, the quantity of feed to be dispensed was adjusted to reflect the new weight. During this period, water was replaced from each aquarium every 3 days by siphoning. The water temperature, PH and dissolved oxygen were also monitored daily.

Four fish were sacrificed at the commencement of the study and two fish from each aquarium at the end of the experiment for fish proximate body composition analysis.

From the data collected, the following growth indices and nutrient utilization parameter were calculated for each treatment. Specific Growth Rate (SGR), Apparent Feed Conversion Ratio (APER), Crude Protein (CP) and ether extract (fat) of fish carcass.

The indices were calculated using the following formulae:

$$\text{specific growth rate} = \frac{\log e W_2 - \log e W_1}{T} \times 100 \quad (1)$$

W<sub>2</sub> = Final body weight; W<sub>1</sub> = Initial body weight; T = Duration of study in days.

$$\text{Apparent feed conversion ratio AFCR} = \frac{\text{WY of dry feed dispensed}}{\text{live weight gain}} \quad (2)$$

$$\text{Apparent protein efficiency ratio APER} = \frac{\text{WT gain (g)}}{\text{Apparent protein intake}} \quad (3)$$

**Statistical analyses:** One-way Analysis of Variance (ANOVA) was used in determining any statistical variation among the treatment groups. The Duncan's multiple range test was used in separating the means.

## RESULTS

The crude protein, ether extracts and crude fibre decreased in boiled JBSM (Table 1) while the NFE increased. The mean values of some physico-chemical parameter of the culture water monitored were:

Table 3: Effect of test diets on the SGR, AFCR, APER Carcass Protein and fat of *H. longifilis*

Variable	Proc method	% Fishmeal Substitution (Diet type)						
		0	10	20	40	60	80	100
SGR	1	1.71 <sup>a</sup> (1)	-	-	-	-	-	-
	2	-	1.62 <sup>abc</sup> (2)	1.35 <sup>bcd</sup> (3)	1.11 <sup>def</sup> (4)	0.96 <sup>fg</sup> (5)	0.55 <sup>h</sup> (6)	0.31 <sup>i</sup> (7)
	3	-	1.67 <sup>abc</sup> (8)	1.57 <sup>abc</sup> (9)	1.51 <sup>abc</sup> (10)	1.24 <sup>cdef</sup> (11)	0.91 <sup>fg</sup> (12)	0.39 <sup>i</sup> (13)
AFCR	1	1.69 <sup>a</sup> (1)	-	-	-	-	-	-
	2	-	1.89 <sup>a</sup> (2)	2.23 <sup>a</sup> (3)	2.58 <sup>a</sup> (4)	3.05 <sup>a</sup> (5)	3.05 <sup>a</sup> (6)	10.24 <sup>c</sup> (7)
	3	-	1.72 <sup>a</sup> (8)	1.83 <sup>a</sup> (9)	1.89 <sup>a</sup> (10)	2.35 <sup>a</sup> (11)	3.15 <sup>a</sup> (12)	7.69 <sup>bc</sup> (13)
APER	1	1.95 <sup>a</sup> (1)	-	-	-	-	-	-
	2	-	1.75 <sup>ab</sup> (2)	1.53 <sup>bc</sup> (3)	1.29 <sup>c</sup> (4)	1.12 <sup>d</sup> (5)	0.37 <sup>e</sup> (6)	0.37 <sup>e</sup> (7)
	3	-	1.92 <sup>a</sup> (8)	1.82 <sup>ab</sup> (9)	1.78 <sup>ab</sup> (10)	1.49 <sup>bc</sup> (11)	0.49 <sup>e</sup> (12)	0.49 <sup>e</sup> (13)
Protein	1	62.22 <sup>a</sup> (1)	-	-	-	-	-	-
	2	-	61.48 <sup>cd</sup> (2)	61.43 <sup>cd</sup> (3)	60.82 <sup>d</sup> (4)	60.36 <sup>eh</sup> (5)	59.88 <sup>i</sup> (6)	59.55 <sup>j</sup> (7)
	3	-	61.78 <sup>b</sup> (8)	61.34 <sup>de</sup> (9)	60.85 <sup>d</sup> (10)	60.20 <sup>hi</sup> (11)	60.20 <sup>hi</sup> (12)	59.97 <sup>i</sup> (13)
Fat	1	9.41 <sup>bc</sup> (1)	-	-	-	-	-	-
	2	-	9.30 <sup>d</sup> (2)	9.49 <sup>b</sup> (3)	9.63 <sup>a</sup> (4)	9.31 <sup>cd</sup> (5)	9.45 <sup>b</sup> (6)	9.47 <sup>b</sup> (7)
	3	-	9.28 <sup>d</sup> (8)	9.17 <sup>ef</sup> (9)	8.98 <sup>a</sup> (10)	8.76 <sup>b</sup> (11)	8.44 <sup>d</sup> (12)	8.26 <sup>i</sup> (13)

All means in the same cell with different superscripts are significantly different ( $p < 0.05$ ), \* Processing method: 1 = control; 2 = diets containing raw jackbean seed meal, 3 = diets containing 60min boiled jackbean seed meal

Temperature  $28.5 \pm 1^\circ\text{C}$ ; PH  $6.8 \pm 0.2$  and dissolved oxygen (DO)  $6.4 \pm 0.5 \text{ mg L}^{-1}$ . The water quality during the period is thus considered suitable for fish production.

The performance of *H. longifilis* under the different diet treatments presented in Table 3. The results show significant differences among treatments for SGR. The SGR values recorded for *H. longifilis* fed 10% raw JBSM substituted diet (2) and up to 40% boiled JBSM substituted diets (8,9 and 10) were statically ( $p < 0.05$ ) similar with those fed the central diet (1) but significantly different from diets 4, 5, 6, 7, 12 and 13.

The values recorded for the Apparent Feed Conversion Ratio (AFCR) showed that all the treatments were statistically ( $p < 0.05$ ) similar except for fish fed 100% JBSM substituted diets (7 and 13).

The data obtained from the Apparent Protein Efficiency Ratio (APER) gave a trend that is similar to that obtained for SGR. Fish fed diets 2,8,9 and 10 were statistically ( $p < 0.05$ ) similar to those fed the control diet (1), but significantly different from those fed 80% and 100% JBSM substituted diets (6, 7, 12 and 13). However, fish fed diets 2, 3, 9, 10 and 11 had statistically similar values.

The fish carcass protein values for the various treatments showed significant statistical ( $p < 0.05$ ) variation. The general trend showed decreasing protein values with increasing JBSM substitution. The values obtained for fish fed the control diet (1) was higher and significantly different from those obtained for other treatments.

The fish carcass fat values for the various treatments also showed significant ( $p < 0.05$ ) statistical variation. Fish

fed diet 4 had fat content that was highest and significantly different from others. The values from diets 3, 6 and 7 were higher than that of the control diet (1), they were statistically ( $p < 0.05$ ) similar. Generally fish fed raw JBSM substituted diets had higher carcass fat than those fed boiled JBSM substituted diets.

## DISCUSSION

The decrease in the protein and ether extract of boiled JBSM may have been caused by some form of leaching. The decrease in the crude fibre is a positive development since high fibre feed ingredients are generally poorly digested by fish. Similar decrease in values of crude protein, ether extract and crude fibre for jackbean seed meal had also been reported earlier by Udedibie *et al.* (1996).

The general decrease in the SGR of *H. longifilis* fed increasing dietary levels of JBSM (Table 3) may be attributed to the presence of antinutritional factors in jackbean seed Belmar and Morris, 1994. which are known to cause growth reduction in fish. Al-Owafeir, 1999. similarly observed significant reduction in growth of fish fed low levels of tannic acid. Dabrowski *et al.*, 1989. reported that replacement of fishmeal with soybean meal by 50% only led to growth reduction while total replacement of fishmeal in the diet by soybean meal resulted in growth arrestment.

In this study, replacement of fishmeal in the diet with raw JBSM beyond 10% led to significant ( $p < 0.05$ ) reduction in SGR. But boiling JBSM improved the quality to the extent that *H. longifilis* fed with up to 40% boiled

JBSM substituted diets had similar SGR to those fed the control diet. Wee and Shu cited in Ogunji, 2004. noted that boiling not only reduced the trypsin inhibitor level in fullfat soybean, it also enhance viability of carbohydrate to Nile tilapia, hence increased the digestibility.

Same reason may have warranted the improvement experienced in this study. Fish fed diets (11,12 and 13) containing boiled JBSM above 40% fishmeal substitution had poor SGR values that are significantly different from the control diet. This reflects the inadequacy of boiling to transform JBSM to the quality of fishmeal. Heat treatment markedly reduces protein digestibility and biological value due to the destruction of amino acids or through the formation of linkages between individual amino acids which are resistant to digestion (Bressani *et al.*, 1987; McCallum and Higgs, 1989; Pike *et al.*, 1990).

Though the Apparent Feed Conversion Ratio (AFCR) values of *H. longifilis* generally increased with increasing dietary JBSM, the very high AFCR values for fish fed diets (7 and 13) with 100% substitution of fishmeal by JBSM relative to other diets caused distortion in the ranking (Table 3) such that only two groups emerged (ie diets similar to the control and diets with 100% substitution). The high AFCR observed at high dietary JBSM level may have been ceased by growth arrestment and even emaciation in some of the fish.

The trend in Apparent Protein Efficiency Ratio (APER) of *H. longifilis* fed the test diets is similar to what obtained in SGR (Table 3). It is obvious that the essential amino acid composition of jackbean seed is not comparable to that of fishmeal. Though jackbean seed is rich in lysine, it is deficient in tryptophan and methionine/cysteine Kessler *et al.*, 1990. The deficiency, coupled with the presence of antinutritional factors may be responsible for the very poor APER values obtained in *H. longifilis* fed diets containing raw JBSM (with the exception of diet 2). Rosenthal and Dalman, 1982. reported that canavanine in jackbean causes reduction of protein and glyco-protein synthesis and inhibition of RNA synthesis by incorporating into proteins in place of arginine resulting in aberrant macromolecules with reduced activity and change of function. Though soluble in water, canavanine is considered thermostable and has been suggested as one of the main causes of poor performance of chicks given diet containing either autoclaved or cooked jackbean D'Mello *et al.*, 1985. Chymotrypsin and amylase inhibitors implicated in reducing protein digestibility were reported by Gomez-sotillo *et al.*, 1993. in jackbean. Though boiling significantly improved JBSM quality such that up to 40% substitution level (diet 10) had similar APER to the control diet (1), the presence of these antinutritional factors even in boiled JBSM may have been partly responsible for the

poor protein utilization efficiency at high (> 40% substitution) levels of boiled JBSM. This observation agrees with the report by Kissil *et al.*, 1997. that cyanogenic glycosides in rapeseed protein caused reduction in protein utilization efficiency in gilthead seabream. De la Higuera *et al.*, 1988. equally reported that saponin in lupin seed meal adversely affected dietary protein utilization in rainbow trout.

The general decrease in fish carcass protein with increasing dietary level of JBSM (Table 3) in this study agrees with the findings of Dalorowski and Kozłowska (1981) for carp fed rapeseed meal. This may not be unrelated to the poor nutrient utilization associated with increased level of dietary jackbean seed meal earlier mentioned. On the other hand, the fish carcass fat content showed a decreasing tendency only with increasing dietary boiled JBSM. Fish fed diets containing raw JBSM did not display any marked change. This is contrary to an earlier report by Hossain and Januncey, 1989. for common carp. Phosphorus deficiency is known to cause such effect Sakamoto and Yone, 1980. The presence of antinutritional factors in raw JBSM may have caused unavailability of phosphorus for utilization as a result of complexing with other compounds.

It is believed that compounding feeds with 10% or 40% of the fishmeal substituted with raw JBSM or 60 min-boiled JBSM respectively will ensure optimum growth in semi-intensive production systems for *H. longifilis*. The result of this study is therefore envisaged to have practical applications particularly in terms of ready availability of essential protein feed ingredient (JBSM) that is considerably cheaper than fishmeal.

## REFERENCES

- A.O.A.C., 1990. Official Methods of Analysis (13th Edn). Association of Official analytical Chemists, Washington D.C.
- Al-Owafeir, M., 1999. The effect of dietary saponin and tannin on growth performance and digestion in *Oreochromis niloticus* and *Clarias gariepinus*. Ph. D Thesis, Inst. Aqu. Uni. Stirling, U.K., pp: 220.
- Belmar, R. and T.R. Morris, 1994. Effect of raw and treated jackbeans (*Canavalia ensiformis*) and of canavanine on the short-term feed intake of chicks and pigs. J. Agric. Sci. (Cambridge), 123: 407-414.
- Bressani, R.G., Garcia and L.G. Elias, 1987. Chemical composition, amino acid content and protein quality of *Canavalia* spp seeds. J. Sci. Fd. Agric., 40: 17-23.
- Cruz, R.M. and I.I. Laudencia, 1977. Protein requirements of *Tilapia mossambica* fingerlings, Kalikasan Philip. J. Fish Biol., 692: 177-182.

- Dabrowski, K. and H. Kozłowska, 1981. Rapeseed Meal in the Diet of Common Carp in Heated Waters: 1. Growth of Fish and Utilization of Diet In: K. Tiews (Ed.) Proceedings of World Symposium on Aquaculture System, Heinemann, Berlin, 2: 263-274.
- Dabrowski, K., P. Poczyczynski, G. Kock and B. Berger, 1989. Effect of partially or totally replacing fishmeal protein by soybean meal protein on growth, food utilization and proteolytic enzyme activities in rainbow trout (*Salmo gairdneri*). New in vivo test for exocrine pancreatic secretion. *Aquaculture*, 23N-32N.
- De la Higuera, M., M. Garcia-Galego, A. Sanz, G. Cardenete, M.D. Suarez and F.J. Moyano, 1988. Evaluation of lupin seed as an alternative protein source in feeding of rainbow trout (*Salmo gairdneri*). *Aqu.*, 71: 37-50.
- D'Mello, J.P.F., T. Acamovic and A.G. Walker, 1985. Nutritive value of jackbean (*Canavalia ensiformis*) for young broiler chicks. *Trop. Agric. (Trinidad)*, 62: 145-150.
- Gomez-sotillo, A., A. Carmona and S. Seidi, 1993. Fractionation of (*Canavalia ensiformis*) protein. Distribution of the Proteic Anti-Nutritional Factors. In: Recent Advances of Research in Anti-nutritional factors in Legume seeds. Proceedings of the second International Workshop on Antinutritional Factors (ANFs) in Legum Seeds (van der Poel A.F.B. and H.S. Saini, Eds.) EAAP Publication No 70 Wageningen, the Netherlands pp: 235-239.
- Hardy, R.W., 1999. Aquacultures rapid growth: Requirement for alternate protein sources. *Feed Manag.*, 50: 25-28.
- Hossain, M.A. and K. Jauncey, 1989. Studies on the protein, energy and amino acid digestibility of fishmeal, mustard oilcake, linseed and sesame meal for common carp (*Cyprinus carpio* L.) *Aqu.*, 83: 59-72.
- Johnson, C.M. and A. Ulrich, 1959. II: Analytical methods for use in plant analysis. Bulletin 766 California Agricultural Experimental Station, Bekerley.
- Kessler, M., R. Belmar and N. Ellis, 1990. Effects of autoclaving on the nutritive value of the seeds of (*Canavalia ensiformis*) (jackbean) for chicks. *Trop. Agric. (Trinidad)*, 67: 16-20.
- Kissil, G., I. Lupatsch, D.A. Higgs and R.W. Hardy, 1997. Preliminary evaluation of rapeseed protein concentrate as an alternative to fishmeal in diets for gilthead seabream, *Sparus aurata*. *Bamidgeh*, 49: 135-145.
- Kureshy, N., D.A. Davis and C.R. Arnold, 2000. Partial replacement of fish-and bone-meal, flash-dried poultry by-product meal and enzyme-digested poultry by-product meal in practical diets for juvenile red drum. *North Am. J. Aquacul.*, 62: 266-272.
- McCallum, I.M. and D.A. Higgs, 1989. An assessment of processing effects on the nutritive value of marine protein sources for juvenile Chinook salmon (*Onchorhynchus tshawytscha*). *Aqu.*, 77: 1818-200.
- Pike, I.H., G. Anderdotti and H. Mundheim, 1990. The role of fishmeal in diets for salmonids. International Association for Fish Meal Manufacturers Technical Bulletin N0 24, March 1990, London, pp: 35.
- Ogunji, J.O. 2004. Alternative protein sources in diets for famed tilapia. *Nutrition Abstracts and Rev: Series B*. 7415.
- Okonkwo, J.C. and A.B.I. Udedibie, 1999. Preliminary Observation on the Yield Performance of Jackbeans (*Canavalia ensiformis*) in the Guinea Savannah of Nigeria In: Proceedings of the 27th Annual Confer. Agric. soc. Nigeria, pp: 10-11.
- Osuigwe, D.I., 2003. Nutritional and pathological effects of incorporating jackbean (*Canavalia ensiformis*) seed meal in the diets of three clariid catfishes. Ph. D thesis of Michael Okpara University of Agriculture Umudike, Nigeria.
- Rosenthal, G.A. and D.C. Dahlman, 1982. A cautionary note on pentacyanoaminoferrate use for determining L-canavanine in biological materials. *Experientia*, 38: 1034-1035.
- Sakamoto, S. and Y. Yone, 1980. A principal source of deposited lipid in phosphorus deficient red sea bream. *Bull. Jap. Soc. Sci. Fish.*, 46: 1227-1230.
- Tacon, A.G.J. and U.C. Barg, 1998. Major Challenges to Feed Development for Marine and Diadromous Finfish and Crustacean species, In: de Silver, S. (Eds.) *Tropical Mariculture: Academic Press, San Diego, California*, pp: 171-204.
- Udedibie, A.B.I., B.O. Esonu, C. Unachukwu and N.C. Iwuoha, 1996. Two-stage cooking as a method of improving the nutritive value of jackbean (*Canavalia ensiformis*) for broilers. *Nigerian J. Animal produc.*, 23: 107-110.
- Udedibie, A.B.I. and F.N. Madubuike, 1988. Effect of dietary raw and cooked jackbeans (*Canavalia ensiformis*) on the performance of laying hens. *J. Arid, Agric.*, 1: 47-54.