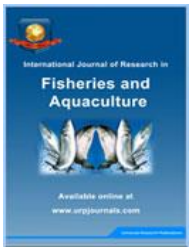
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Original Article

Performance of *Clarias gariepinus* (Burchell, 1822) Fed Dietary Levels of Black Soldier Fly, *Hermetia illucens* (Linnaeus, 1758) Prepupae Meal as a Protein Supplement

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Abstract

One hundred and fifty *Clarias gariepinus* fingerlings were used to evaluate the effect of Black Soldier Fly (BSF) prepupae meal as a protein supplement to replace fish meal on performance and economic efficiency. BSF prepupae meal was incorporated at 0, 25, 50, 75 and 100% to replace fish meal. Triplicate groups of *C. gariepinus* fingerlings (3.93 ± 0.01g) were fed the test diets at 5% body weight twice per day for 12 weeks. Parameters measured were Mean Weight Gain (MWG), Feed Conversion Ratio (FCR), Protein Efficiency Ratio (PER), Specific Growth Rate (SGR) and economic indices.

Results showed that the MWG was significantly ($p<0.05$) reduced with more than 75% level of BSF prepupae meal. Increasing BSF prepupae meal level in the diets had no significant effect ($p<0.05$) on PER and SGR while FCR (2.00) value of 100% level was the highest and significantly different from the control diet. However, feed and protein intakes were decreased ($p<0.05$) with increasing level of BSF prepupae meal. 100% BSF prepupae meal was least expensive. 50% BSF prepupae dietary level had the highest percentage profit margin (27.73%) and this replacement level is recommended in the production of *C. gariepinus* for optimum performance and profitability.

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Key words: performance, fish meal, BSF prepupae meal, *Clarias gariepinus*.

Introduction

Intensification of aquaculture has resulted to global rapid growth of the sector. About 86 percent of total fisheries production was used for direct human consumption while the remaining 14 percent was destined for non-food products, mainly for the manufacture of fishmeal and fish oil (FAO, 2010, 2012). Production of fish below the demand for fish, results to importation of frozen fish into the African countries, especially in Nigeria. Aquaculture is also an important income-generating sector of many economies with considerable prospects for job creation, poverty alleviation, community development, and food security. The exponential growth of the aquaculture sector during the past two decades is a result of the progressive intensification of the production systems.

Production of quality fish feed is a major contributor to the intensive production to meet the nutritional requirements of the targeted fish species. Feeds account for up to 70 % of the variable cost of a commercial aquaculture operation (Webster *et al.*, 1999) for many fish species. Feed production costs are driven by the cost of fishmeal, an important protein source in fish feeds. The price of fishmeal has increased more than two fold in recent years, It rose from about US$600 per metric ton in 2005 to about US$2000 per metric ton in the first quarter of 2010 (International Monetary Fund, 2010). Furthermore, the provisions of fishmeal are not adequate to sustain the current rate of growth of aquaculture in addition to the demand from other animal feed industries.

The potential of insects (housefly maggot and termites) in fish production has been explored by some researchers (Achionye-Nzeh and Ngwudo, 2003: Sogbesan and Ugwumba, 2008; Omoruwu and Edema, 2011). Black soldier fly, *Hermetia illucens*, is native from the tropical, subtropical and warm temperate zones of America. *Hermetia illucens* is a fly (Diptera) of the *Stratiomyidae*

family. The adult fly is black, wasp-like and 15-20 mm long (Hardouin *et al*., 2003). The larvae are voracious consumer of decaying organic matter, from 25 to 500 mg of fresh matter per larva and per day, and with minimal nuisances. They can grow on a wide range of decaying organic materials, such as rotting fruits and vegetables, kitchen waste, coffee bean pulp, distillers' grains, fish offal, and particularly animal manure and human excreta (Hardouin *et al*., 2003; Diener e*t al*., 2009; van Huis *et al*., 2013). Black soldier fly larvae are a high-value feed source, rich in protein and fat. They contain about 40-44% DM protein (Newton *et al*., 2005; Diener *et al*., 2009). The potential of BSF prepupae meal as alternative to fishmeal has been examined for the production of *Oncorrhynchus mykiss* and *Ictalurus punctatus* (Newton *et al*., 2005, Sealy *et al*., 2011; Stamer *et al*. (2014)), but not for *Clarias gariepinus*. Therefore, the aim of this study was to evaluate the performance of African catfish, *C. gariepinus* fed varying inclusion levels of Black Soldier Fly (BSF) prepupae meal as dietary animal protein.

Materials and Methods

Preparation of Ingredients and Diets Formulation

Black soldier fly prepupae were sourced from a poultry house in Ilorin, Kwara State in Nigeria; the prepupae were thoroughly washed and oven dried. Other feed ingredients were purchased in Ilorin. Feed ingredients (Table 1) were ground into fine particles and the required quantities weighed, using an electronic digital weighing scale (Ohaus®). Five isonitrogenous diets (40% crude protein) were formulated using trial and error method. Black Soldier Fly (BSF) prepupae meal was used to replace fish meal at 0, 25, 50, 75 and 100% inclusion levels. All ingredients were thoroughly mixed to ensure homogeneity. Cassava starch was prepared with hot water and added as binder. The resultant dough was pelleted using pelleting machine with 2mm die size. The sinking pellets were sundried, hand crumbled into smaller sizes, after which they were packed in separate airtight polythene bags, labelled and stored in dry environment at room temperature. Proximate compositions of experimental diets were analysed using AOAC (2005) method.

Feeding and Experimental Set up

The experiment was carried out in the Teaching and Research Farm of College of Agriculture, Kwara State University (KWASU), Malete, Nigeria. Two hundred and fifty (250) *Clarias gariepinus* fingerlings of average size 1.98±0.083 g, were purchased from a hatchery in Ilorin. The fingerlings were acclimatized for two weeks in plastic tanks in a static renewal system, during which they were fed with commercial floating feeds. Thereafter, one hundred and fifty (150) fingerlings (3.93± 0.011g) were sorted from the acclimatised fish and were distributed into 15 rectangular plastic tanks of 50cm x 35cm x 28 cm dimension in a completely randomized design, in triplicate groups. They were starved for 24 hours before the commencement of the feeding trials. The Fish were offered 5% of their body weight meal per day administered in two equal portions between 8.00-9.00 am and 5.00-6.00 p.m. The quantity of feed was adjusted weekly throughout the 12 weeks duration of the feeding trials. The fish were daily monitored for mortality. Dead fish were removed, counted and recorded. Four (4) fish were taken randomly from each tank before feeding once a week and weighed to assess the growth rates for 12 weeks. Water quality parameters were determined weekly. Dissolved Oxygen (DO) was measured using dissolved oxygen meter; temperature was measured using mercury-in-glass thermometer while pH was determined by using pH meter.

Determination of Growth and Feed Utilization

The following parameters were calculated from the data obtained from each treatment during the experiments:

Feed intake = Sum of feed fed during the experiment

Protein Intake = Feed intake x Crude protein in diet/100

Mean Weight Gain = Initial mean weight – Final mean weight

$$\text{Relative growth rate (RGR)} = \frac{\text{Mean Weight of fish}}{\text{Mean initial Weight of fish}} \times 100$$

$$\text{Specific Growth Rate (SGR)} = \frac{\text{Log (mean final weight)} - \text{Log (mean initial weight) (g)}}{\text{Time (days)}} \times 100$$

$$\text{Feed Conversion Ratio (FCR)} = \frac{\text{Weight of feed fed}}{\text{Weight gain of fish}}$$

$$\text{Protein Efficiency Ratio (PER)} = \frac{\text{Weight gain of fish}}{\text{Protein fed}}$$

Economic Indices and Analyses

The following parameters were calculated from the data obtained from each treatment:

$$\text{Survival rate} = \frac{\text{Final number of fish at the end of the experiment}}{\text{Initial number of fish stocked}} \times 100$$

Investment Cost = Cost of feeding + Cost of fingerling stocked

Gross profit = Weight gained × Cost of fish/kg

Net profit = Gross profit – Investment cost

Feed cost/ kg Fish weight gain = FCR x Feed cost/kg

Statistical Analysis

Data were analysed using one way Analysis of Variance (ANOVA) while Least Significance Differences (LSD) was used to determine the level of significance among treatments at $p<0.05$, using SAS Windows 2010.

Results and discussion

Analysis of experimental diets and water

Percentage composition of experimental ingredients and nutritional composition of experimental diets are shown in Table 1. The proximate compositions of experimental diets were similar. Water temperature was between 25-27^{o}C, dissolved oxygen ranged from 3.8-5.0mg/l while the pH was between 7.6-7.8. These values are within the ranges required for *C. gariepinus*. The value of crude protein of experimental diets and the water quality parameters for this study were within the recommended value for *Clarias gariepinus* (Fagbenro *et al*., 2003 and FAO, 2014).

Fish growth and nutrient utilization

Table 2 shows the growth performance and nutrients utilization of *C gariepinus* fed with the experimental diets for this study. The MWG of 78.41, 66.49, 62.59, 59.40 and 42.16 were obtained for *Clarias gariepinus* fed experimental Diet 1, 2, 3, 4 and 5 respectively. Results showed numerical reduction in Mean Weight Gain (MWG) of *C. gariepinus* with increase in inclusion level of BSF prepupae meal without significant differences up to 75% while MWG was significantly ($p<0.05$) reduced with more

Table 1: Composition of ingredients (%) and Nutritional Composition (%) of Experimental Diets

	DIETS				
Ingredients	**D_1 0%**	**D_2 25%**	**D_3 50%**	**D_4 75%**	**D_5 100%**
Fish meal (65% CP)	24.20	18.15	12.10	6.05	---
BSF prepupae meal (42% CP)	---	6.05	12.10	18.15	24.20
Groundnut cake (48% CP)	24.30	26.10	28.1	29.80	31.90
Soya bean (45% CP)	24.00	26.00	27.7	29.8	31.40
Yellow maize (9.5% CP)	19.00	15.20	11.5	7.7	4.00
Vegetable oil	2	2	2	2	2
Starch	4.5	4.5	4.5	4.5	4.5
Vitamin/mineral premix	2.0	2.0	2.0	2.0	2.0
Total	100	100	100	100	100
Calculated CP	40.00	40.01	39.99	40.00	39.99
Proximate composition					
Moisture	5.36	5.43	6.26	5.71	6.29
Crude protein	40.63	41.32	41.43	41.12	41.61
Crude lipid	3.70	3.63	3.59	3.73	3.68
Crude fibre	2.53	2.62	2.58	2.64	2.60
Ash	9.24	8.91	9.38	8.97	9.30
NFE	38.54	38.09	36.78	37.83	36.52

*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; Niacin– 50,000 mg; Calcium Pathonate – 10,000 mg; B6 – 5,000 mg; B12- 25.0 mg; Folic acid 1,000 mg; Biotin- 50.0mg; 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; Antioxidant 120,000 mg.
Keys: D1= Diet 1, D2 = Diet 2, D3 = Diet 3, D4 = Diet 4, D5 = Diet 5 BSF = Black Soldier Fly

than 75% inclusion level of BSF prepupae meal. Feed intake significantly ($p<0.05$) decreases from Diet 1 to Diet 5. Increasing BSF prepupae meal level in the diets had no significant differences in Specific Growth Rate (SGR) and Protein Efficiency Ratio (PER). Feed Conversion Ratio (FCR) value of 2.00 was obtained for 100% BSF prepupae meal level and was significantly ($p<0.05$) different from 1.67 FCR value obtained for the control diet.

The mean weight gain and relative growth rate obtained for all the treatments is an indication that the fish were able to convert the feed to flesh. The numerical reduction in growth rate obtained in this study could be attributed to the deficiency of methionine and cystine in BSF prepupae meal (Newton *et al*., 1977 in Newton *et al*., 2005; Sealy *et al*., 2011) as well as nutrient digestibility of the meal due to high chitin, insect exoskeleton, which is indigestible to many fish species because they lack chitinase activity (Rust, 2002). This agrees with Newton *et al*. (2005) who reported that higher numerical value in the weight gain of channel catfish, *Ictalurus punctatus,* fed 7.5% BSF prepupae meal after which there was reduction. Sealy *et al.* (2011) also observed reduction in weight gain of rainbow trout, *Oncorrhynchus mykiss,* fed 25% and 50% BSF prepupae meal as replacement of fish meal compare to the control diet. The author emphasized the possibility of replacement of fish meal with BSF prepupae meal up to 50%. A similar result was also obtained for rainbow trout fed BSF prepupae meal (Stamer *et al*., 2014). The reduction in feed intake with increasing levels of BSF prepupae meal is not voluntary but rather as a result of the new weekly ration resulting from growth response and calculated based on the 5% body weight across the treatments.

The non-significant FCR values obtained for Diet 1, 2, 3 and 4 in this study show that the feed were well utilized by fish fed with these diets. Better FCR was obtained in this study than for Channel catfish reported by Newton *et al*. (2005). However, the significant difference above 75% fish meal replacement indicated that the Diet was poorly utilized by *C. gariepinus*. St Hilaire *et al.* (2007) also reported that replacement of fish meal at 25% BSF prepupae meal had no effect on feed conversion ratio. Similarly, Sealey *et al*. (2011) and Stamer *et a.l* (2014) observed no significant difference in the FCR of rainbow trout fed 25% and/or 50% BSF meal. The non-significant differences in SGR and PER obtained in this study is similar to report of Omoruwu and Edema (2011) on Heteroclarias and *Heterobranchus* fed with 0% and 50% housefly maggot meal. Similarly, Sogbesan and Ugwumba (2008) reported no significant difference in SGR and PER in *Heterobranchus longifilis* fed termite meal up to 50% inclusion level.

Table 2: Growth Performance and Feed Utilization for *C. gariepinus* fingerlings Fed Diets Containing Varying Inclusions of Black Soldier Fly (BSF) Prepupae or 12 Weeks

Parameters	BSF levels (%)				
	0	25	50	75	100
	D_1	D_2	D_3	D_4	D_5
Mean Initial weight (g)	3.94^{a}	3.93^{a}	3.93^{a}	3.93^{a}	3.92^{a}
Mean Final weight (g)	82.42^{a}	70.42^{ab}	66.50^{ab}	63.33^{ab}	46.08^{b}
Mean Weight gain (g)	78.41^{a}	66.49^{ab}	62.59^{ab}	59.40^{ab}	42.16^{b}
Relative Growth Rate (%)	1992.09^{a}	1691.30^{ab}	1598.70^{ab}	1511.10^{ab}	1073.10^{b}
Feed Intake/fish (g)	131.38^{a}	117.51^{b}	107.38^{c}	102.36^{d}	84.44^{e}
Protein Intake/fish (g)	52.54^{a}	49.40^{b}	42.95^{c}	40.94^{d}	33.78^{e}
SGR (%/day)	1.55^{a}	1.49^{a}	1.46^{a}	1.43^{a}	0.92^{a}
Feed Conversion Ratio	1.67^{b}	1.76^{ab}	1.72^{ab}	1.72^{ab}	2.00^{a}
Protein Efficiency Ratio	1.49^{a}	1.46^{a}	1.45^{a}	1.35^{a}	1.25^{a}

Means having the same letter in the same row is not significantly different at $P < 0.05$.

Table 3: Cost Benefit Analyses of experimental diets with varying inclusions of BSF Prepupae meal.

Parameters	Prices of Feed Ingredients (₦) *				
	D_1 (0%)	D_2 (25%)	D_3 (50%)	D_4 (75%)	D_5 (100%)
Cost of feed/ kg	224.88	198.01	170.94	144.15	117.14
Economic Analyses					
Total number stocked	30	30	30	30	30
Survival number	25	26	29	25	23
Survival rate (%)	83.33	86.67	96.67	83.33	76.67
Total mean final weight (kg)	2.06	1.97	1.93	1.58	1.06
Total mean weight gain (kg)	1.96	1.87	1.81	1.48	0.97
Gross profit value (₦)**	1236.00	1182.00	1158.00	948.00	636.00
Total feed intake (kg)	3.28	3.06	3.11	2.56	1.94
Total Cost of feeding (₦)	737.61	605.91	531.62	369.02	227.47
Total Cost of fingerlings (₦)	375.00	375.00	375.00	375.00	375.00
Total Investment Cost (₦)	1112.61	980.91	906.62	744.02	602.25
Net Profit value (₦)	123.39	201.09	251.38	203.98	33.75
Profit margin (%)	11.09	20.50	27.73	27.42	5.60
Feed Cost/kg weight gain (₦)	375.55	348.50	294.02	247.94	234.28

*Prices of feed ingredients at the prevailing market price in Nigeria (January, 2014)
**Value of 1kg fish = ₦600, 1US S = ₦164.50

Economic analyses

The economic analyses of the five diets used for this study is shown on Table 3. Increasing levels BSF prepupae meal decreases the cost of experimental Diet per kg with ₦224.88 for Diet 1 to ₦117.44 (47.96% reduction) for Diet 5. Consequently, Diet 1 has the highest total cost of feeding (₦737.61), which doubled that of Diet 4 (₦369.02) and tripled total cost of feeding for Diet 5 (₦227.47). Diet 2, 3 and 4 had better Net Profit Value (NPV) than the controlled Diet (1). The highest NPV (₦251.38) and highest profit margin (27.73%) obtained from Diet 3 doubled that of Diet 1 while the least NPV was obtained for Diet 5 (₦33.75). Feed cost/kg fish weight gain decreases with increasing levels of BSF prepupae meal in the experimental diets. Increasing level of BSF prepupae meal up to 75% gave profit margin above 20%. The results indicate that from the economic point of view diets 2, 3 and 4 (25% - 75% BSF prepupae inclusions) is more profitable than Diet 1 (0% BSF prepupae i.e. 100% fish meal) in the production of African catfish, *Clarias gariepinus*. Sogbesan and Ugwumba (2008) similarly reported the economic benefit of termite meal at 50% inclusion levels in the production of *Heterobranchus longifilis.*

Conclusion

In the present study, all the fish had increased growth rate up to 12 weeks. The performance of the experimental fish up to 75% inclusion levels of has no significant difference the growth rate, feed conversion ratio and protein efficiency ratio compared to the control. Inclusion of black soldier fly prepupae meal at 50% has the best economic value. There would be economic benefits to farmer from using BSF prepupae meal up to 75% inclusion levels.

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