Potentials of Fresh Housefly Maggot in the Diet of Oreochromis niloticus Fingerlings

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ABSTRACT: The study was designed to investigate the value of fresh housefly maggot diet as protein source and the level of inclusion for optimum growth in the diet of Nile Tilapia (Oreochromis niloticus) fingerlings. Five experimental diets, four fresh maggot substituted diets containing 25%, 50%, 75% and 100% fresh maggot meal and a control (0% maggot inclusion) were prepared and tested on triplicate groups of O. niloticus fingerlings (mean weight of 0.52g) for twelve weeks. The fish were fed twice daily at 3% of their body weight. The optimum water quality parameters were 27°C, 7.63 and 7.55 for Temperature, pH and Dissolved Oxygen respectively and the maggot did not pollute the water media. The best growth rate was recorded among the fish fed control diet and 100% fresh maggot inclusion as the only protein source and the least growth rate was showed by fingerlings fed 25% fresh maggot inclusion. Optimum Specific Growth Rate, Feed Conversion Ratio and Protein Efficiency Ratio of 1.8702, 159.92 and 1.8759 respectively showed that there was no significant difference in weight gained by the fish fed with the five diets except 25% fresh maggot substituted diet. The study indicated that fresh maggot meal can be successfully used to replace fishmeal partially or completely from 50% up to 100% in the diet of O. niloticus fingerlings for optimal growth and nutrient utilization. Based on these results, maggot meal is suggested as an effective and sustainable protein source to replace fishmeal in the diet of farmed tilapia.

DOI: https://dx.doi.org/10.4314/jasem.v23i4.17

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Dates: Received: 02 March 2019; Revised: 10 April 2019; Accepted 19 April 2019

Keywords: Fishmeal, Housefly maggot, Optimum growth, Diet.

Fish production has a special role in enhancing food security and in alleviation poverty as fish is highly nutritious food that forms the essential part of the diet of a large proportion of the people in developing countries (FAO, 2000). The predicted shortage of animal protein in Nigeria necessitates the evaluation of all means of multiple water use and unconventional method of animal production. Scarcity and high cost of fishmeal are one of the several factors that contribute to the shortage of fish supply. The global supply of fishmeal has dwindled due to overexploitation of the natural fishery stock. With the predicted continuous growth of the aquaculture industry, Brugère and Ridler (2004) observed that, the demand for fishmeal will continue to increase, causing its price to soar. Various studies have been conducted with sustainable alternative protein sources to determine their effects on fish growth (Emilie et al., 2017; Cabral et al., 2011; Silva et al., 2010) and these have shown contradicting results. The major constraint to rapid development of aquaculture in Nigeria is the inadequate supply of feedstuff at economic prices. There are many less expensive by-products and waste products of good quality protein that can eventually lead to reduced cost of production. Fish cultivators have tried such products like rap seed meal, sunflower meal, cottonseed meal, parkia seed and blood meal as ingredients of fish feed. These products are locally available, inexpensive and readily easy to obtain.

Maggots have only been associated with waste product, decay and worthlessness in Nigeria. Insect-based diets have been recognized and studied in recent times as one of the cheaper alternatives to fishmeal. Insects such as the black soldier fly (Hermetia illucens), the meal worm beetle (Tenebrio molitor) and the house fly (Musca domestica) have been studied as alternative protein sources and as substitute for fish meal in fish diets with promising results (Emilie et al., 2017; Ogunjiet al., 2008; Zuidhof et al., 2003; Ng et al., 2001). Interestingly maggot supplemented meal have been used successfully to feed Oreochromis niloticus fingerlings (Emilie et al., 2017; Ezewudo et al., 2015; Ajani et al., 2004; Idowu et al., 2003; Fasakin et al., 2003; Akinwande et al., 2002; Adesulu and Mustapha, 2000; Faturutiet al., 1995).Housefly (Musca domestica) maggot meal was reported to contain 39-65% protein (Awoniyi et al., 2003; Atteh and Ologbenla, 1993), while the protein content of Chrysomya megacephala maggot meal...
ranged from 52-56% depending on the age of maggots at harvesting. Such variations in protein content could be attributed to the processing, drying, storage and protein estimation methods employed, or the substrate used for the production of housefly maggots (Ogunji et al., 2008; Awoniyi et al., 2003). Maggots has come to be known not only as safe food for fishes, but also as rich protein source for them. Maggots are produced from the semitransparent larval stage of the housefly, Musca domestica and are used to process magmeal. Studies have shown that magmeal is of high biological value. The percentage of crude protein of housefly maggot ranges from 39–61.4%, lipid 12.5–21%, and crude fiber 5.8–8.2%. Examination of the comparative minerals and amino acid contents of fishmeal and maggot meal showed that no essential amino acid was limiting (Adesulu and Mustapha, 2000). Spinelli et al., (1978) used magmeal protein in the diets of rainbow trout. The protein provided growth and feed conversion levels equivalent to fish meal at harvesting. Such variations in protein content could be attributed to the processing, drying, storage and protein estimation methods employed, or the substrate used for the production of housefly maggots (Ogunji et al., 2008; Awoniyi et al., 2003). Maggot has come to be known not only as safe food for fishes, but also as rich protein source for them. Maggots are produced from the semitransparent larval stage of the housefly, Musca domestica and are used to process magmeal. Studies have shown that magmeal is of high biological value. The percentage of crude protein of housefly maggot ranges from 39–61.4%, lipid 12.5–21%, and crude fiber 5.8–8.2%. Examination of the comparative minerals and amino acid contents of fishmeal and maggot meal showed that no essential amino acid was limiting (Adesulu and Mustapha, 2000). Spinelli et al., (1978) used magmeal protein in the diets of rainbow trout. The protein provided growth and feed conversion levels equivalent to fish meal at substitution levels ranging from 25-100%.

Feedstuff Preparation: The fresh maggot and sun-dried yellow maize were milled separately using a grinding machine, packed separately and stored for use. The fish after being degutted and descaled was boiled for ten minutes and then pressed to remove the water and oil. It was then oven dried at 95°C for 12 hours, milled and packaged for use. The various ingredients were weighed and thoroughly mixed together and kept in the refrigerator for dispensation as required.

Feed Formulation: Pearson Square Method described by Pearson (1976) was used to formulate a 35% crude protein diet for the fingerlings. Prior to formulation of the experimental diets, the proximate nutrient composition of fishmeal and maggot meal was determined using (AOAC, 2012) method. Five diets with increasing levels of substitution of fishmeal by maggot meal D1 (25%), D2 (50%), D3 (75%), D4 (100%) and D5 (0%) maggot meal in the protein fraction were prepared. The diet containing fishmeal as the only protein source (0% maggot inclusion) was taken as control. Proximate analysis was carried out to determine the moisture content, ash and crude protein of the five diets (AOAC, 2012). Growth indices were determined to properly evaluate the performance of the fingerlings in the experimental diets.

Experimental Set-up: The experiments were carried out in 15 plastic bowls (240 litre each) in the aquaculture centre laboratory at Obafemi Awolowo University, Ile-Ife. Each bowl was filled with filtered water from Opa dam up to three-quarter of the volume. 300 fingerlings of Oreochromis niloticus with a mean weight of 0.52 ± 0.062 were acclimatized in the laboratory for one week. The survivors after one week were weighed and randomly assigned to the bowls at a stocking density of 20 fingerlings per bowl. Feeding commenced 48 hours after stocking, so as to ensure that all the stocked fish empty their gastro-intestinal tract. Each diet treatment was given in triplicates. Fish were kept in a natural photoperiod regime and the water temperature was 25±1.8°C. The fish were fed for 12 weeks at 3% body weight with their respective test diet twice daily. The entire population of each bowl was weighed bi-weekly and the feeding rate adjusted according to the mean fish weight in each tank. The bowls were monitored daily and dead fish number in each bowl was recorded and percentage survival was estimated. Water quality is controlled by replacing the water loss by evaporation, daily cleaning, changing the water weekly and removal of uneaten food. Water temperature, pH and dissolved oxygen were measured daily.

MATERIALS AND METHODS

Collection of Maggot: Maggot used was those of housefly (Musca domestica). The main method adopted in the collection was the modified form of floating method (Atteh et al., 1990). The poultry droppings were collected from the part where maggots were highly concentrated into a 50 litres bowl until it was filled up. The bowl was left for some times to allow the maggots to move and congregated at the bottom of the container. The method gives room for collection of life and active maggot. Further separation was done by sieving and freeing them from waste particles. The maggots were thoroughly washed until they showed their characteristics whitish colour. They were killed by subjecting them to low temperature at 0°C and were kept in the refrigerator for further use.

Source of other feedstuff: Starch, minerals and vitamin premix were obtained from a livestock feed store and yellow maize were obtained from the local market.
Reproductive investigations were monitored weekly using standard method (APHA, 1985). At the end of the feeding trial, fish were fasted for 24h before the final body weight was recorded. Specific Growth Rate (SGR), Feed Conversion Ratio (FCR) and Protein Efficiency Ratio (PER) were calculated according to the method of Olvera-Novoa et al. (1990), Eyo (2005), Olaniyi and Salau (2013) as follows:

\[
SGR = \frac{W_f - W_i}{T} \times 100
\]

Where \( W_f = \) Final Weight, \( W_i = \) Initial Weight, \( T = \) Time in Days.

\[
FCR = \frac{\text{Total feed given}}{\text{Weight gained}}
\]

\[
PER = \frac{\text{Weight gained}}{\text{Protein fed}}
\]

Where protein fed = \( \frac{\% PD \times \text{TDC}}{100} \)

Where PD = protein in diet and TDC = total protein consumed

Data analysis: Growth performance and nutrients utilization were evaluated from data on weight gain, SGR, FCR, PER and Carcass composition. The data were analyzed using One-way analysis of Variance (ANOVA) test followed by the least significant (LSD) test for comparison among treatment mean of 5% probability (\( P = 0.05 \)).

RESULTS AND DISCUSSION

The physicochemical parameters of the culture media were found suitable for fish. The water temperature range of 26.01 to 27.52°C was within the range described by Okayi (2003) for river Benue and, Komolafe and Arawomo (2008) for Osinmo reservoir. The pH range of 7.40 to 7.60 were within the range of 7 – 7.69 recommended for Tilapia (El-Sayed, 2006; Beveridge and McAndrew, 2000). High survival of fish was consequent of water quality parameter being within the optimum range for the fish. Oreochromis niloticus like other cichlids is highly adaptable and can tolerate adverse condition within their habitat. The mortality, though very insignificant was attributed to stress encountered during frequent sampling and faeces collection (Bolivar et al., 2004; MacNiven and Little, 2001).

Oxygen concentration were found to reduce with time in the culture medium with the value ranging from 4.10ml/g to 5.50mg/l. Dissolved oxygen range of 1 ml/g to 4.99 mg/l make fish survive, but slows the growth on prolonged exposure of the fish to the condition and the value is within tolerance limits for tilapia (El-Sayed, 2006; Beveridge and McAndrew, 2000). High survival of fish was consequent of water quality parameter being within the optimum range for the fish. Oreochromis niloticus like other cichlids is highly adaptable and can tolerate adverse condition within their habitat. The mortality, though very insignificant was attributed to stress encountered during frequent sampling and faeces collection (Bolivar et al., 2004; MacNiven and Little, 2001).

Proximate and amino acid analyses of the maggot meal and test diets were carried out. Minerals and amino acids contents of Maggot and Fish meal are shown in Tables 1, and 2 respectively. The composition of the experimental diets and the proximate analysis of the diets including calorimetric energy termination are shown in Table 3 and 4 respectively. Bi-weekly weight gain by the fish fingerlings fed the experimental diets is shown in Fig 1. Table 5, 6 and 7 show the growth performance parameters, initial and final carcass composition of the fish and records of water quality parameters respectively. The best growth rate was recorded among fish fingerling fed with fishmeal as the only protein source (D5) while diet D4 (100% maggot meal) produced the second best growth response and nutrient utilization. Diet D3 (75% maggot inclusion) was the third best growth rate, the forth D2 (50% maggot inclusion) and the least growth was shown by fingerling fed diet (D1) containing 25% fresh maggot meal as protein source.

| Table 1: Minerals contents of Maggot and Fish meal |
|----------------|----------------|----------------|
| Minerals | Fishmeal | Maggot |
| Ca(%) | 0.40 | 0.36 |
| Mg(%) | 0.02 | 0.21 |
| Na (%) | 0.55 | 0.31 |
| K(%) | 0.08 | 0.45 |
| Fe(ppm) | 162 | 1129 |
| Zn(ppm) | 173 | 49.63 |
| Cu(ppm) | - | 21.47 |
| Mn(ppm) | 86 | 15.41 |
| Pb(ppm) | - | 1.08 |

| Table 2: Amino acid contents of Maggot and Fish meal |
|----------------|----------------|----------------|
| Amino Acid | Fishmeal | Maggot |
| Alanine | 6.34 | 6.15 |
| Arginine | 5.82 | 5.42 |
| Asparagine | 9.32 | 10.80 |
| Cysteine | 0.70 | 0.80 |
| Glutamine | 13.30 | 12.20 |
| Glycine | 5.90 | 5.40 |
| Histidine | 2.22 | 3.50 |
| Isoleucine | 4.36 | 4.13 |
| Leucine | 7.35 | 6.95 |
| Lysine | 7.85 | 7.37 |
| Methionine | 2.84 | 2.24 |
| Pheny-lalanine | 4.35 | 6.95 |
| Proline | 4.35 | 3.66 |
| Serine | 4.55 | 4.51 |
| Threonine | 4.55 | 4.53 |
| Trypto-phan | 1.33 | 1.45 |
| Tyrosine | 3.45 | 8.10 |
| Valine | 5.65 | 5.60 |
Weight gain were not significantly different between treatments (P < 0.05). Specific growth rate increases up to 100% maggot inclusion level. The FCR decrease with increasing maggot level from 25% to 100% and Protein Efficiency Ratio (PER) decreased as the dietary maggot inclusion level increased. SGR and FCR were not significantly different between the five treatments except those fed Dt1.

**Table 3:** Percentage Composition of Experimental Diets (% dry weight)

| Diets             | Dt1 | Dt2 | Dt3 | Dt4 | Dt5 |
|-------------------|-----|-----|-----|-----|-----|
| Dietary maggot inclusion | 25% | 50% | 75% | 100% | 0%  |
| Fish              | 35.90 | 35.50 | 34.90 | 36.50 | 36.67 |
| Yellow maize      | 56.83 | 56.83 | 56.83 | 56.83 | 34.95 |
| Vitamin Premix    | 2.00  | 2.00  | 2.00  | 2.00  | 2.00  |
| Palm oil          | 0.50  | 0.50  | 0.50  | 0.50  | 0.50  |
| Salt (NaCl)       | 0.50  | 0.50  | 0.50  | 0.50  | 0.50  |
| Starch (Binder)   | 2.00  | 2.00  | 2.00  | 2.00  | 2.00  |
| Total             | 100  | 100  | 100  | 100  | 100  |

**Table 4:** Proximate Composition of the Experimental Diets (% weight)

| Diets             | Dt1 | Dt2 | Dt3 | Dt4 | Dt5 |
|-------------------|-----|-----|-----|-----|-----|
| Moisture          | 36.05 | 40.43 | 43.01 | 20.40 | 8.90 |
| Protein           | 35.90 | 35.50 | 34.90 | 36.50 | 36.67 |
| Ether extract     | 4.32  | 4.98  | 5.60  | 18.20 | 21.04 |
| Crude fibre       | 1.02  | 1.16  | 1.32  | 7.40  | 7.34  |
| Ash               | 4.99  | 5.21  | 5.89  | 16.30 | 7.87  |
| Energy Kcal/Kg    | 5272.5 | 5259.3 | 5243.4 | 4563.5 | 4563.5 |

**Table 5:** Growth performance of *Oreochromis niloticus* fingerlings fed for 12 weeks

| Diets | Initial mean weight (g) | Final mean weight (g) | Mean weight (g) | Specific growth rate (g/kg/day) | Feed conversion ratio | Protein efficiency ratio (g/g) | % survival |
|-------|-------------------------|-----------------------|-----------------|---------------------------------|----------------------|-------------------------------|-----------|
|       | 0.51±a                   | 1.52±b                | 1.02±a          | 1.0767±a                       | 1.8702±a             | 1.6117±b                      | 95.00±a   |
|       | 0.53±a                   | 1.53±b                | 1.04±a          | 1.1470±a                       | 1.8510±a             | 1.6016±b                      | 96.07±a   |
|       | 0.52±a                   | 1.52±b                | 1.03±a          | 1.1675±a                       | 1.8501±a             | 1.6016±b                      | 96.07±a   |
|       | 0.52±b                   | 1.52±b                | 1.03±a          | 1.1675±a                       | 1.8501±a             | 1.6016±b                      | 96.07±a   |
|       | 0.53±a                   | 1.52±b                | 1.03±a          | 1.1675±a                       | 1.8501±a             | 1.6016±b                      | 96.07±a   |

**Table 6:** Initial and final carcass composition of *Oreochromis niloticus* fed for 12 weeks.

| Diets | Crude Protein (%) | Ether extract (%) | Ash (%) | NFE (%) |
|-------|-------------------|-------------------|---------|---------|
|       | 19.42±a           | 4.92±a            | 2.95±a  | 19.42±a |
|       | 20.34±a           | 4.01±a            | 4.28±a  | 20.34±a |
|       | 22.90±a           | 4.22±a            | 2.67±a  | 22.90±a |
|       | 23.77±a           | 3.67±a            | 2.52±a  | 23.77±a |
|       | 23.05±a           | 3.69±a            | 2.63±a  | 23.05±a |

The improvement in growth and feed efficiency recorded in *Oreochromis niloticus* fed maggot-supplemented diet suggest that maggot contain all the necessary growth promoting factors. Agbede and Faleye (1998) reported that feed ingredient of 20% protein level and above could be regarded as good protein source. Tilapia requires relatively low protein level of about 25 – 30% as compared to the more carnivorous species (Karabeky, 1980). Crucially, the values for maggot meal are similar and can readily substitute locally produced fishmeal (Kolawole and Ugwumba, 2018; Ezewudo et al., 2015; Henry et al., 2015; Barroso et al., 2014). Proximate analysis of fishmeal and housefly maggot meal suggested crude lipid was higher in maggot meal, a finding consistent with a previous study (Ogunji et al., 2008) where the nutrient composition of housefly maggot meal was evaluated.

The result of SGR indicated an increase in the weight gain and food utilization by the fish fingerling. The reason for the superiority of 100% fresh maggot diet over other diets was attributed to the relatively large amount of soft tissue contain in the whole diet.

This is in accordance with Adesulu and Mustapha (2000) who reported that the superiority of maggot over other protein sources in fish was due to tender and easily digested nature of maggot. The protein efficiency ratio, which decreased as the maggot inclusion level increase, was similar to the observance of *Sarotherodon mossambicus* (Jauncey, 1982). The value of FCR and PER becomes better as the protein level increased.

This is favourably compared with those obtained by Faturoti et al., (1995) who found that fish fed 100% life poultry dung maggot had the highest percentage mean weight gain, SGR and lowest FCR than those artificial diets. *O. niloticus* fingerlings are capable of utilizing compounded diet effectively as shown by the low feed conversion ratio.

The best-feed conversion ratio was obtained with 100% fresh maggot diets.

This is in contrast to Kolawole and Ugwumba (2018), Ezewudo et al., (2015), Olaniyi and Salau (2013) and Akinwande et al., (2002), who reported that fingerling performed better when fed with control diet and diet containing 60% and 75% maggot protein inclusion level for fingerling of *Oreochromis niloticus* and *Clarias gariepinus*. 

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In another research conducted by Mustapha (2001), the best growth rate was recorded among fingerling fed with diet containing 75% oven dried maggot meal, followed by 50% maggot inclusion and the least growth was exhibited by fingerlings fed diet containing 100% oven dried maggot meal as the protein source. The concentration of K, Ca, Mg, Na, Fe, Zn analyzed for maggot meal were within the range of the value obtained for each of the element for *Sarotherodon galilaeus* by Olaleye and Akintunde (1991). This further confirms the suitability of maggot as Tilapia fishmeal. Spinelli (1978) had earlier shown that maggot contains the same number of amino acids found in fishmeal (including the ten essential ones for animals). This phenomenon is usually related to a deficiency or absence of one or more essential amino acids in those animal and plant protein sources. Moreover, insufficient amounts of certain essential amino acids in any given diet can cause fish to suffer cataracts (methionine and tryptophan) and scoliosis (tryptophan) (Cowey, 1994).

![Fig 1](image)

**Fig 1:** Bi-weekly records of weight increment (g) of *O. niloticus* fingerlings fed for 12 weeks.

High levels of fishmeal replacement with housefly maggot meal have been associated with low body weight gain in both fish and chickens (Ogunji et al., 2008; Oyelese, 2007). Earlier studies indicated that housefly maggot meal should only partially substitute fishmeal in the diets of omnivorous fish species such as catfish and Nile tilapia (Ogunji et al., 2008; Oyelese, 2007). Some authors reported replacement of fishmeal with housefly maggot meal at 50% or less provided the optimum level in chicken feed (Adeniji, 2007; Awoyiyi et al., 2003). These earlier studies contrast with the present study which showed increased substitution of fishmeal by housefly maggot meal improved the growth, survival and feed efficiency of juvenile tilapia with the total replacement diet giving the optimal results. Although palatability of the maggot meal was not directly tested, these results and the observations in the laboratory indicated that there was no food rejection by the fish.

**Conclusion:** Housefly maggot meal contained all the essential amino acids needed by juvenile tilapia for normal growth and equivalent protein content to fishmeal. It is shown from this study that fresh maggot meal is favorable compared with fish meal in term of protein content and nutrient composition and has growth promoting ability. Low mortality and suitable water quality showed that fresh maggot diet did not pollute the water media. 50% to 100% level of replacement of fishmeal with maggot meal is recommended. Housefly maggot larvae can be produced enmass from agricultural waste. Therefore replacing of fishmeal with housefly maggot meal in *O. niloticus* feed should directly reduce the production costs.

**REFERENCES**

AOAC. (Association of Official Analytical Chemists) International. (2012). *Official Methods of Analysis of AOAC International, 19th Edition*. Gaithersburg, Maryland, USA, AOAC International. 1230 Pp.

Adeniji, AA (2007). Effect of replacing groundnut cake with maggot meal in the diet of broilers. *Int. J Poult. Sci*, 6: 822-825.

Adesulu, EA; Mustapha, AK (2000). Use of housefly maggots as fish meal replacement in Tilapia culture: A recent vogue in Nigeria. In: K. Fitzsimmons, K., Filho, J.C. (Eds). Proceedings of 5th International Symposium on Tilapia in Aquaculture (ISTAV), Rio de Janeiro, Brazil. pp. 138-143.

Ajani, EK; Nwanna, LC; Musa, BO (2004). Replacement of fishmeal with maggot meal in the diets of Nile tilapia, *Oreochromis niloticus*. *World Aquaculture*. 35: 52-54.

Akinwande AA; Ugwumba AAA; Ugwumba OA (2002). Effects of replacement of fish meal with maggot meal in the diet of *Clarias gariepinus* (Burchell, 1822) fingerlings. *The Zoologist* Vol. 1(2):41 – 46.

APHA – AWWA - WPCF (1985). *Standard Method for the examination of water and waste water 16th Edition*. Prepared jointly by the American Public Health Association, American water works association and water pollution control federation 1113 pp.

**MUSTAPHA, AK; KOLAWOLE, AA**
Atteh, JO; Ologbenla, S (1993). Replacement of fish meal with maggotin broiler diets: Effects on performance and nutrition. *Niger J. Anim Prod*, 20: 44-49.

Awoniyi, T; Aletor, V; Aina, J (2003). Performance of broiler chickens fed on maggot meal in place of fishmeal. *Int J PoultSci*, 2: 271-274.

Barroso, FG; de Haro, C; Sanchez-Muros, MJ; Venegas, E; Martinez-Sanchez, A; Perez-Banon, C (2014). The potential of various insects species use as food for fish. *Aquaculture*, 422-423, 193-201.

Beveridge, MCM; McAndrew, BJ (2000). Tilapias: Biology and Exploitation. Kluwer Academic Publishers.

Boyd, CE (1979). *Water quality in warm water fish ponds*. Agricultural Experiment station, Auburn University, Alabama, pp 358.

Brugère, C; Ridler, N (2004). Global aquaculture outlook in the next decades: an analysis of national aquaculture production forecasts to 2030. FAO Fisheries Circular No. 1001, Rome, FAO, 47p.

Cabrál, EM; Bacelar, M; Batista, S; Castro-Cunha, M; Ozório, ROA; Valente, LMP (2011). Replacement of fishmeal by increasing levels of plant protein blends in diets for Senegalese sole (*Solea senegalensis*) juveniles. *Aquaculture*, 322-323: 74-81.

Cowey, CB (1994). Amino acid requirements of fish: a critical appraisal of present values. *Aquaculture*, 124: 1-11.

El-Sayed, AFM (2006). *Tilapia Culture*. Wallingford, UK: CABI Publishing.

Emilie, S; Will, L; Francis, JM; David, CL (2017). Growth performance, feed utilization and body composition of advanced nursing Nile tilapia (*Oreochromis niloticus*) fed diets containing Black Soldier Fly (*Hermetia illucens*) laevae meal. *J. Aqua Nutr*, 1-8.

Eyo, JE (2005). Effects of substituting soya bean meal for maggot meal on acceptability of diets, Growth Performance and Cost benefits of diet fed to hybrid Catfish-Heterobranchus bidorsalis and *Clariasgariepinus*. *J. of Sci Tech Res*, 4: 37-43.

Ezewudo, BI; Monebi, CO; Ugwumba, AAA (2015). Production and utilization of *Muscadomestica* maggots in the diet of *Oreochromis niloticus* (Linnaeus, 1758) fingerlings. *Afr. J. Agri res.* 10(23): 2363- 2371.

FAO (2000). *Aquaculture development beyond 2000: The Bangkok ration and strategy – Conference on Aquaculture Development in the third millennium, 20 – 25 Feb. Bangkok, Thailand* FAO Aquaculture newsletter no. 25.

FAO (2011). *Tilapia - February 2011*. Available: http://www.globefish.org/tilapia-february-2011.html, Accessed 22 July 2012.

Fasakin, EA; Balogun, AM; Ajayi, OO (2003). Evaluation of full fat and defatted maggot meals in the feeding of Clarid catfish *Clarias gariepinus*. *Aquaculture Research*. 34(9): 733-738.

Fashina-Bombata, HA; Balogun, O (1997). The effect of partial or total replacement of fish meal with maggot meal in the diet of tilapia (*Oreochromis niloticus*) fry. *J. Prosp in Sci*, 1: 178–181.

Fatuoroti, EO; Obasa, S; Bakare, AL (1995). Growth performance and nutrient utilization of *Clariasgariepinus* (Burchell 1822) fed live maggots Nigerian Association for Aquacultic Sciences. 9th /10th Annual Conference Programme and Book of Abstract. Pp 14 – 15

Henry, M; Gasco, L; Piccolo, G; Fountoulaki, E  (2015). Review on the use of insects in the diet of farmed fish: Past and future. *Anim. feed tech*, 203, 1-22.

Idowu, AAS; Amusan, AG (2003). The Response of *Clariasgariepinus* fingerlings (Burchell 1822) to the diet containing housefly maggot (*Muscadomestica*) (L) *Nig. J. Anim. Prod.* 30(1):139 – 144.

Jauncey, K (1982). A guide to Tilapia feeds and feeding, institute of Aquaculture, University of Syerling.

Kolawole, AA; Ugwumba, AAA (2018). Economic Evaluation of Different Culture Enclosures for *Muscadomestica* Larval Production and Their Utilization for *Clariasgariepinus* Fingerlings Diets. *Not SciBiol*, 2018, 10(4):466-474.

Komolafe, OO; Arawomo; GAO (2008). Preliminary observations on fish Species in a newly impounded reservoir, Osinmo. *Tur. J of Fisheries and Aquatic Sciences* 8: 289-292.
Mustapha, AK (2001). An Investigation into the Value of Oven-dried Maggot as Protein Source in the Diet of Oreochromis niloticus Fingerlings. *J. Pure Appl. Sci.* 3(1 and 2): 63 – 74.

Ng, WK; Liew, FL; Ang, LP; Wong, KW (2001). Potential of meal worm (*Tenebriomolitor*) as an alternative protein source in practical diets for African catfish, *Clarias gariepinus*. *Aquaculture Res.*, 32: 273-280.

Ogunji, J; Trua, S; Schulz, C; Kloas, W (2008). Growth performance, nutrient utilization of nile tilapia *Oreochromis niloticus*. *Pak Vet J*, 2014, 34(3): 288-292.

Okayi, RG (2003). Effect of effluent discharge on water quality, distribution and abundance of plankton and fish species of River Benue. PhD Thesis. University of Ibadan.

Olaleye, VF; Akintunde, E (1991). Concentration and distribution of some mineral elements in the fillet of *Sarotherodon galilaeus* (Artedi) in a Nigerian freshwater. 8th Annual Conference of Fisheries Society of Nigeria (FISON) at Federal University of Technology, Akure

Olaniyi, CO; Salau, BR (2013). Utilization of maggot meal in the nutrition of African cat fish. *Afr. J. Agr. Res.* Vol. 8(37), pp. 4604-4607

Pearson, D (1976). The chemical analysis of foods. 7th Edition, Churchill Livingstone, London.

Silva, JMG; Espe, M; Conceição, LEC; Dias, J; Costas, B; Valente, LM P (2010). Feed intake and growth performance of Senegalese sole (*Solea senegalensis* Kaup) fed diets with partial replacement of fishmeal with plant proteins. *Aquaculture Res.*, 41: e20-e30.

Sing, KW; Kamarudin, MS; Wilson, JJ; Azirun, MS (2014). Evaluation of blowfly (*Chrysomya megacephala*) maggot meal as an effective, sustainable replacement for fishmeal in the diet of farmed juvenile red tilapia (*Oreochromis* spp.). *Pak Vet J*, 34(3): 288-292.

Spinelli, J (1978). Unconventional feed ingredients for fish feeds. In Fish Feed Technology Aquaculture Development and Co-ordination Programme UNDF/FAO, 395 pp

Watanabe, WO; Losordo, TM; Fitzsimmons, K; Hanley, P (2002). Tilapia production systems in the Americas: Technological advances, trends, and challenges. *Rev Fish Sci*, 103: 465-498.

Zuidhof, MJ; Molnar, CL; Morley, FM; Wray, TL; Robinson, FE; Khan, BA; Al-Ani, L; Goonewardene ,LA (2003). Nutritive value of house fly (*Musca domestica*) larvae as a feed supplement for turkey poults. *Anim Feed Sci Tech*, 105: 225-230