INCREASING PRODUCTIVITY OF NILE TILAPIA (*OREOCHROMIS NILOTICUS*) THROUGH ENHANCED FEEDS AND FEEDING PRACTICES

Sustainable Feed Technology and Nutrient Input Systems/Experiment/16SFT03PU

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ABSTRACT

In Tanzania fish productivity in aquaculture is low mainly due to poor feeds and feeding practices. Fish feeding depends on natural food in the ponds produced by irregular application of inadequate manure and supplementation of low quality feeds such as maize bran, kitchen leftovers and green vegetables/weeds. Small-scale fish farmers cannot afford the price of fishmeal and soybean meal that are used as protein sources in fish diets. This study was conducted to determine the appropriate inclusion levels of substituting fishmeal and soybean meal with a combination of Moringa leaf meal and housefly maggot meal as sources of protein in Nile tilapia diets. In addition, the study aimed at determining the most suitable substrate for production of housefly (*Musca domestica*) maggots. A total of five substrates (cow dung, chicken manure, pig manure, cattle offal and kitchen leftovers) were tested for production of housefly maggots. Also the effects of quantity of manure and the age at which housefly maggots are harvested on maggot yields were assessed. A feeding trial was carried out to evaluate the effect of substituting fishmeal and soybean meal with a mixture of Moringa leaf meal and housefly maggot meal on growth performance of sex reversed Nile tilapia (*Oreochromis niloticus*). Eight diets were formulated and each diet contained about 30% crude protein. Diet one (D_1) was a control diet and contained only fishmeal as the source of protein. Diet D_2 was another control diet, but based on soybean meal as the main source of protein. Diets D_3, D_4, D_5, D_6 and D_7 contained various combinations of housefly maggot meal and Moringa leaf meal while diet D_8 contained only housefly maggot meal as sources of protein. Diets D_2 , D_3, D_4, D_5, D_6 and D_7 contained 5% fishmeal as an additional protein source. The feeding experiment was conducted using 24 plastic tanks, each with capacity of 30 litre, in an indoor semi-recirculation system. Each tank was stocked with 10 Nile tilapia fingerlings with mean initial weight of 1.17 ± 0.04 g. The fish were fed to apparent satiation, but not exceeding 5% of their biomass. Water temperature, pH and dissolved oxygen (DO) were measured weekly. Body weight was measured once per week during the experimental period. The experiment took 56 days.

Results show that the type of substrate influenced the yield of maggots ($p \leq 0.05$). The use of cattle offal resulted in significantly higher maggot yield ($p \leq 0.05$) compared to the other substrates. The quantity of maggots produced from chicken manure (40.83 ± 0.67 g/kg) was higher ($p \leq 0.05$) than that obtained from pig manure (27.25 ± 1.29 g/kg), cattle manure (21.57 ± 0.21 g/kg) and kitchen leftovers (27.24 ± 0.33 g/kg). Increasing the quantity of manure from 6 to 12 kg increased the yield of maggots from 54.49 ± 1.43 to 74.72 ± 1.43 g/kg of manure. Maggots harvested five days after hatching showed significantly higher yield (72.23 g/kg of manure) than those harvested four and three days after hatching. Fishmeal had the highest crude protein content (60.59%), followed by maggot meal (46.96%). The type of diet had significant effect ($p \leq 0.05$) on body weight gain, average daily weight gain and specific growth rate. Fish fed diet D_1 had the highest body weight gain (3.32 ± 0.25 g), average daily weight gain (0.059 ± 002 g/day) and specific growth rate (2.91%/day), followed by those on D_8 and D_6. Fish fed diet D_5 had the lowest body weight gain (2.07 ± 0.23 g) and average daily weight gain (0.037 g/day). Feed conversion ratio (FCR) was lower on fish fed diet D_1 (2.34 ± 0.06) and D_6 (2.46 ± 0.06), but was higher on those fed diet D_7 (2.84 ± 0.06) and D_4 ($2.83 \pm 0,06$).

The type of diet had no significant effect ($p > 0.05$) on protein efficiency ratio. Fish fed diet D_4, D_6, D_7, D_1 and D_8 had significantly higher survival rate compared to those on diet D_2 and D_5. It is concluded that chicken manure is a better substrate than cattle manure and pig manure for production of maggots. Housefly maggot meal can be used to replace fish meal in the diets without affecting the growth performance of Nile tilapia. Furthermore, Housefly maggot meal has higher protein content and promotes better growth performance than soybean meal.

INTRODUCTION

Aquaculture is one of the world's fastest growing animal producing sector with an average growth rate of 8.8%, outpacing capture fisheries (1.2%) and terrestrial farmed meat production (2.8%) (FAO, 2014). Aquaculture accounts for almost half of the world's fish food supply (FAO, 2014). Therefore, aquaculture offers a great potential for food security, poverty alleviation and enhanced trade and economic benefits (ADB, 2005). Aquaculture expansion in Asian countries such as Bangladesh and Thailand has led to enhanced food security among adopters and the population at large (Pant *et al*., 2004; De Silva and Davy, 2010; Jahan *et al*., 2010; Lazard *et al*., 2010). Furthermore, fish are a good source of animal-protein containing essential nutrients of high bioavailability which are found in limiting amounts in most human diets. These nutrients include essential amino acids, essential fatty acids, minerals and vitamins. Fish is a good source of long-chain omega-3 fatty acid docosahexaenoic acid (DHA) that is important for optimal brain and neurodevelopment in children and eicosapentaenoic acid (EPA) that improves cardio-vascular health. Thus, improving fish production from aquaculture will increase the intake of these important nutrients required in a healthy diet and thus reduce the problem of malnutrition.

Despite its potential for improving livelihoods, aquaculture has never developed to a significant extent in Tanzania. Chenyambuga *et al.* (2014) reported tilapia productivity of 5,312 kg ha^{-1} yr^{-1}. This low productivity is mostly attributed to poor feeds and feeding practices. Feeding of fish cultured in ponds of small-scale farmers depends on natural food in the ponds produced by irregular application of inadequate manure. In addition, fish farmers in rural areas provide maize bran, kitchen leftovers and green vegetables/weeds as supplementary feeds. These feeds are of poor quality and when fed as sole diets results into slow growth and low yield of fish at harvest. Elsewhere, it has been shown that with proper feeds and feeding practices, it is possible to attain yields of up to 19,000 kg ha^{-1} yr^{-1} (Hasan and New, 2013). To achieve this high level of production, it is important to develop good quality supplemental diets for use in hatcheries and nursery and grow-out ponds. For many decades, fishmeal and soybean have been used as the main sources of protein in fish feeds (El-Sayed, 1999; El-Saidy and Gaber, 2002). However, fish farmers in Tanzania cannot afford the price of good quality protein sources such as fishmeal and soybean meal that can meet protein requirement required for fast growth of fish. Thus, there is a need to identify cheaper alternatives sources of proteins. Plant protein sources such as *Moringa oleifera* leaf meal can replace fishmeal, either partially or totally, in practical Nile tilapia diets (Afuang *et al*., 2003). Our previous study showed that a diet containing a mixture of Moringa leaf meal and sunflower seed cake in equal proportions can promote higher growth rate of Nile tilapia, even better than soybean meal (Shigulu, 2012; Kitojo, 2013). Morover, insects and other invertebrates have been shown to be cheaper sources of animal protein in tilapia diets (Omoyinmi and Olaoye, 2012). These invertebrates are abundantly available because of their short life cycle and ability to produce large numbers and high biomass within a short time. Our previous study showed that diets containing housefly maggot meal as source of protein promote higher growth rate of Nile tilapia than cotton seed cake based diets (Ally, 2015). Thus, the diets based on Moringa leaf meal and maggot meal can be used as alternative to fishmeal and soybean meal as sources of protein since they have high crude protein content and are abundantly available and affordable to small-scale farmers. However, the inclusion levels of a combination of Moringa leaf meal and maggot meal in Nile tilapia diets have not been established. The overall objective of this study was to develop good quality and cheap diet for Nile tilapia based on Moringa leaf meal and housefly maggot meal. Specifically, the study aimed at determining the appropriate inclusion levels of a combination of Moringa leaf meal and housefly maggot meal in Nile tilapia diets. In addition, the study aimed at determining the most suitable substrate for production of housefly maggots.

METHODOLOGY

Study location and Sampling procedure

The experiment was conducted at Magadu fish farm, Sokoine University of Agriculture (SUA), Morogoro. Sokoine University of Agriculture is located between latitude 6 - 7^{o}S and longitude 37 - 38^{o}E at an altitude of about 500 - 600 m above sea level. The area receives an average annual rainfall of between 600 and 1000 mm. The climate is characterized by bimodal rainfall patterns, with short rains starting in November and ending in December and long rains starting in March and ending in May. The temperature ranges from 25^0 to 30^0C.

Data collection procedure

Two experiments were conducted. The first experiment involved designing an appropriate method and determining the most suitable substrate for production of housefly maggots. The second experiment involved determination of the appropriate levels of substituting fishmeal and soybean meal with a mixture of Moringa leaf meal and maggot meal.

Designing of method for production of housefly maggot

Fifteen plastic containers were designed and used for production of maggots. Each had 40 cm diameter and 21.5 cm height (Plate 1). The container consisted of two chambers: the top and the bottom chambers. The top chamber is the culture chamber in which substrates were placed. This chamber was separated from the bottom chamber using a 2 mm plastic mesh to allow dropping of maggots into the harvesting chamber. The dimensions of the culture chamber were 7 cm height and 40 cm diameter. The bottom chamber was the harvesting chamber from which the maggots were collected. The dimensions were 40 cm diameter and 14.5 cm height. The base of this chamber was covered by a lid which can easily be opened during collection of maggots.

Plate 1: *The culturing containers*

Determination of the most suitable substrate for maggot production

A total of five substrates (cow dung, chicken manure, pig manure, cattle offal and kitchen leftovers) were tested for production of housefly maggots. The experiment was conducted for a period of 21 days. The treatments were cow dung (treatment one - $\mathbf{T_1}$), chicken manure (treatment two - $\mathbf{T_2}$), pig manure (treatment three - $\mathbf{T_3}$), cattle offal (treatment four - $\mathbf{T_4}$) and kitchen leftovers (treatment five - $\mathbf{T_5}$). The treatments were allocated randomly to 15 culture containers shown above and replicated three times. The substrates were put in an air-tight plastic bucket with capacity of ten (10) liters for 24 hours so as to kill fly eggs or maggots if any. A total of 2.5 kg of each substrate (cattle, pig and chicken manures; cattle offal and kitchen leftovers) was put in the culture chamber of the container. Then, 250 g of mixture of blood, small pieces of meat debris and rotten eggs (as housefly attractant) was spread over substrate in each culture chamber. Each culture containers was half covered with polythene sheet and a lid, leaving space for houseflies to get in for laying eggs. Substrates were exposed to flies to oviposit for 7 hrs (11:30 am to 05:30 pm). Few perforations were made through the nylon and lids in order to allow aeration. Hatched larva were seen the second day after oviposition.

Maggots were dropping from the culture chamber into the harvesting chamber. Harvesting of maggots was done once on the fourth day after oviposition. Prior to harvesting, temperature in each substrate was measured. Collection of maggots, from each harvesting chamber was done by opening the base (lid) of the bottom chamber of the culture container. Collected maggots were thoroughly washed with water to clean them. The maggots were killed by boiling in hot water at 70 ^oC for 10 seconds and weighed using digital weighing balance. Then they were dried in the oven at 60^{o}C for 48 hours for determination dry matter content.

Another study was conducted to evaluate the effects of quantity of manure and the age at which housefly maggots are harvested on maggot yields. Chicken manure was used as the substrate for culturing the housefly maggots and two levels of manure were used (6 kg and 12 kg), each replicated three times. The manure were spread onto culture chamber and exposed to flies to lay eggs which hatched into maggots. The maggots were harvested at three different ages after hatching i.e. on day three, day four and day five. The harvested maggots were cleaned with water, boiled in hot water at 70^{o}C for 10 sec, weighed and then dried in the oven at 60^{o}C for 48 hours, ground and then subjected to proximate analysis.

Determination of the appropriate levels of substituting fishmeal and soybean meal with Moringa leaf meal and housefly maggot meal

A feeding trial was carried out to evaluate the effect of substituting fishmeal and soybean meal with a mixture of Moringa leaf meal and housefly maggot meal on growth performance of sex reversed Nile tilapia (*Oreochromis niloticus*). Housefly maggots were produced from wet chicken manure as described in experiment 1 above. Harvesting of maggots was done from day 3, through day 4 to day 5 after oviposition. Harvested maggots were cleaned, blanched with hot water, oven dried at 60^{o}C for 48 hrs and ground into powder using a hammer mill to form maggot meal. Moringa leaves were harvested from *Moringa oleifera* tree plots at Sokoine University of Agriculture. Harvested leaves were soaked in tap water overnight and then boiled at 80^{o}C for 15 minutes to remove water soluble anti-nutritional factors and deactivate trypsin inhibitor. The boiled leaves were oven dried at 60^{o}C for 48 hrs, and then ground into powder using a hammer mill to form Moringa leaf meal. The processed maggot meal and Moringa leaf meal were mixed together with other ingredients to form tilapia diets and in total, eight diets were formulated as shown in Table 1. Fishmeal, soybean meal, maggot meal, Moringa leaf meal and all formulated diets were analyzed using the proximate analysis scheme according to the standard procedures of AOAC (2000) to determine dry matter (DM), ash, crude protein (CP) and ether extract (EE) contents. All diets were formulated to contain about 30% crude protein (Table 2). Diet one (D_1) was a control diet and contained only fishmeal as the source of protein. Diet D_2 was another control diet, but based on soybean plus 5% fishmeal as the sources of protein. For the rest of the diets the percentage of fishmeal was fixed at 5%, except diet 3 (D_3) which contained 10% fishmeal. Diets D_3, D_4, D_5, D_6 and D_7 contained various combinations of housefly maggot meal and Moringa leaf meal (Table 1) while diet D_8 contained only housefly maggot meal as sources of protein, addition to 5% fishmeal.

The feeding experiment was conducted using 24 plastic tanks, each with capacity of 30 litre, in an indoor semi-recirculation system. Each tank was stocked with 10 Nile tilapia fingerlings with mean initial weight of 1.17 ± 0.04 g. The diets were randomly allocated to the plastic tanks and each diet was replicated three times (i.e each diet was randomly allocate to three plastic tanks). The fish were manually fed to apparent satiation, but not exceeding 5% of their biomass and they were fed twice per day at 1000 and 1700 hours. The amount of feed provided was adjusted weekly in accordance with the change in fish's body weight. Water temperature, pH and dissolved oxygen (DO) were measured weekly. Body weight was measured before the start of the experiment and then once per week during the experimental period. The experiment took 56 days. After the experiment the following growth performance parameters were computed:- weight gain, growth rate, specific growth rate, feed intake, feed conversion ratio and protein efficiency ratio.

Table 1: Proportion of different ingredients in the experimental diets

Ingredient	D_1	D_2	D_3	D_4	D_5	D_6	D_7	D_8
FM (%)	35.00	5.00	10.00	5.00	5.00	5.00	5.00	5.00
HMM (%)	**0.00**	**0.00**	**15.00**	**25.00**	**30.00**	**35.00**	**40.00**	**45.00**
MLM (%)	**0.00**	**0.00**	**50.00**	**45.00**	**30.00**	**20.00**	**10.00**	**0.00**
SBM (%)	0.00	40.00	0.00	0.00	0.00	0.00	0.00	0.00
MM (%)	57.11	44.21	18.92	19.95	30.56	36.00	41.00	46.00
WM (%)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
SFO (%)	3.89	6.79	2.08	1.05	0.44	0.00	0.00	0.00
Vit/Min (%)	2.00	2.00	2.00	2.00	2.00	2.00	2.00	2.00
Total (%)	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00

Note: D_1 = control diet 1 with only fishmeal, D_2 = control diet 2 with 40% soybean meal, D_3 = test diet 3 with 15% HMM and 50% MLM, D_4 = test diet 4 with 25% HMM and 45% MLM, D_5 = test diet 5 with 30% HMM and 30% HMM, D_6 = test diet 6 with 35% HMM and 20% MLM, D_7 = test diet 7 with 40% HMM and 10% MLM, D_8 = test diet 8 with 45%HMM and 0% MLM.
FM = Fishmeal, HMM = Housefly maggot meal, MLM = Moringa leaf meal, SBM = Soybean meal, MM = Maize meal, WM = Wheat meal, SFO = Sunflower oil, Vit/Min = Vitamin/Mineral mix.

Statistical analysis

Data generated on yield and chemical composition of maggots in experiment 1 and on growth performance (final weight, weight gain, growth rate, specific growth rate) and feed utilization parameters (FI, FCR, and PER) in experiment 2 were analysed using GLM procedure of SAS (2003) in a completely randomized design. In experiment 1 analysis of variance was carried to assess the effects of substrate, chicken manure quantity, age of maggots at harvest and interaction of chicken manure quantity and maggot age at harvest on maggot yield. In experiment 2 the analysis of variance was conducted to assess the effects of diet on growth performance and feed utilization of Nile tilapia. Tukey's test was used to determine the significance of the differences between a pair of treatment means.

RESULTS

Experiment 1 - Determination of the most suitable substrate for maggot production

Five substrates were tested for their suitability as media for production of housefly maggots. The yield of maggots obtained from the different substrates are shown in Table 2. The results show that the type of substrate significantly influenced the yield of maggots ($p \leq 0.05$) (Table 2). The use of cattle offal resulted in significantly higher maggot yield ($p \leq 0.05$) compared to other substrates. The quantity of maggots produced from chicken manure was higher ($p \leq 0.05$) than that obtained from pig manure, cattle manure and kitchen leftovers. The lowest yield of maggots was obtained from cattle manure.

Temperature was significantly higher in chicken manure ($p<0.05$) than in other types of substrates. The temperatures observed in cattle manure, pig manure, cattle offal and kitchen leftovers did not differ significantly and ranged from $32.66 \pm 3.50\,^{o}C$ in cattle manure to $34.86 \pm 4.45^{o}C$ in kitchen leftovers. The results for correlation analysis indicate that there was a weak relationship between temperature and maggot yield ($r = 0.191$).

Table 2: Maggot yield and temperature from different types of substrates

No	Substrate	Yield (g/kg of substrate)	Temperature (°C)
1	Cattle manure	21.57 ± 0.21^{d}	32.66 ± 3.50^{b}
2	Poultry manure	40.83 ± 0.67^{b}	41.60 ± 3.45^{a}
3	Pig manure	27.25 ± 1.29^{c}	34.66 ± 3.25^{b}
4	Cattle offal	50.47 ± 0.43^{a}	33.46 ± 5.05^{b}
5	Kitchen leftovers	27.24 ± 0.33^{c}	34.86 ± 4.45^{b}

The study carried out to evaluate the effect of quantity of chicken manure on maggot yield indicate that the amount of manure used as substrate significantly influenced ($p \leq 0.001$) the yield of maggots (Table 3). On average the increase of the quantity manure from 6 to 12 kg increased the yield of maggots from 54.49 ± 1.43 to 74.72 ± 1.43 g/kg of manure. Also the results shown in Table 3 indicate that the age of maggots at harvest had significant effect on maggot yield. Maggots harvested five days after hatching showed significantly higher yield (72.23 g/kg of manure) than those harvested four days after hatching (65.27 g/kg of manure), which, in turn, had higher yield than those harvested three days after hatching (56.33 g/kg of manure).

Table 3: Effects of manure quantity and age at harvest on yield of housefly maggots (mean ± se) (g/kg of manure)

	Age of maggots at harvest			
Manure mass	**3-days old**	**4-days old**	**5-days old**	**P-Value**
6 kg	47.47 ± 1.41^{c}	55.12 ± 1.38^{b}	60.87 ± 1.41^{a}	0.0001
12 kg	65.18 ± 1.73^{c}	75.41 ± 1.68^{b}	83.58 ± 1.73^{a}	0.0001

^{abc}Means with different superscripts within the same row are significantly different at $p \leq 0.001$.

Table 4 shows the proximate chemical composition of maggots harvested at different ages. On average, maggot meal had crude protein, fat, crude fiber and ash contents of 46.69, 25.92, 6.58 and 9.10%, respectively. The results show that maggot age at harvest had significant effect ($p \leq 0.05$) on crude protein, ether extract (fat), crude fiber and ash contents. Crude protein content significantly decreased ($p \leq 0.001$) with increase in maggot age at harvest. Fat, crude fiber and ash contents were found to significantly increase ($p \leq 0.05$) with advancement of maggot age at harvest. For increased biomass yield and relatively high protein content it is worth harvesting housefly maggots when they are five days old.

Table 4: Effect of maggot age at harvest on chemical composition of housefly maggot meal

	Age of maggots			
Chemical composition parameter	**3-days**	**4-days**	**5-days**	**P-Value**
Crude protein (%)	48.67 ± 0.31^{a}	46.78 ± 0.31^{b}	44.62 ± 0.31^{c}	0.0003
Ether extract (%)	23.06 ± 0.21^{c}	25.39 ± 0.21^{b}	29.30 ± 0.21^{a}	0.0001
Crude fibre (%)	6.24 ± 0.01^{c}	6.35 ± 0.01^{b}	7.15 ± 0.01^{a}	0.0001
Ash (%)	8.88 ± 0.01^{b}	8.90 ± 0.01^{b}	9.52 ± 0.01^{a}	0.0001

^{abc}Means with different superscripts in the same row are significantly different ($p \leq 0.001$).

Experiment 2 - Determination of the appropriate levels of substituting fishmeal and soybean meal with Moringa leaf meal and housefly maggot meal

Table 5 shows the chemical composition of maggot meal, Moringa leaf meal, fishmeal, soybean meal and formulated diets used in the experiment. Soybean had the highest dry matter content, followed by maggot meal. Fishmeal had the highest crude protein content (60.59%), followed by maggot meal (46.96%) while Moringa leaf meal had the lowest crude protein content. Crude fat content was highest in maggot meal (23.12%) and lowest in Moringa leaf meal (6.40%). Maggot meal had the highest crude fiber content while fishmeal had the lowest crude fiber content. The highest ash content was observed in fishmeal while the lowest value was found in soybean meal. The formulated diets had almost the same crude protein contents and ranged from 30.15% in diet D_7 to 31.20% in diet D_2. Diet D_6 (14.88%) and D_8 (14.80%) had the highest fat contents while diet D_1(9.70%) had the lowest. Diet D_1 had the lowest crude fiber content (2.83%) while diet D_6 had the highest value (7.01%). Ash content was highest in diet D_1 (17.7%) and lowest in diet D_2 (11.23%).

Figure 1 shows the growth performance of Nile tilapia fed different dies during the experimental period. Generally fish fed diet D_1 and D_8 showed the highest growth performance while those on diet D_5 had the lowest growth performance throughout the experimental period. The growth performances of fish fed diets D_2, D_3, D_4, D_6 and D_7 did not differ significantly. The analysis of variance revealed that the type of diet had significant effect ($p \leq 0.05$) on final body weight, weight gain, average daily weight gain and specific growth rate. Fish fed diet D_1 had the highest body weight gain, average weight gain and specific growth rate, followed by those on D_8 and D_6 (Table 6). Fish fed diet D_5 had the lowest body weight gain and average daily weight gain. Table 6 also shows that the type of diet significantly influenced ($p \leq 0.05$) feed utilization efficiency. Fish fed diet D_1 and D_8 had higher feed intake values while those fed diet D_5 had lower value than the rest of the diets. Feed conversion ratio (FCR) was lower on fish fed diet D_1 and D_6, but was higher on those fed diet D_7 and D_4. The type of diet had no significant effect ($p > 0.05$) on protein efficiency ratio. However, diets D_1 and D_3 showed slightly higher protein efficiency ratio compared to the other diets. Results on survival rate are shown in Table 6. The results indicate that survival rate differed significantly among the fish fed different diets. Fish fed diet D_4, D_6, D_7, D_1 and D_8 had significantly higher survival rate compared to those on diet D_2 and D_5.

Table 5: Chemical composition of maggot meal, Moringa leaf meal , fishmeal and formulated diets used in the experiment

	Dry matter (%)	**Crude protein (%)**	**Ether extract (%)**	**Crude fiber (%)**	**Ash (%)**
Maggot meal	94.26	46.96	23.12	10.58	8.51
Moringa leaf meal	93.76	28.60	6.40	9.83	7.14
Fishmeal	93.09	60.59	9.44	0.24	20.74
Soy bean meal	95.12	40.36	14.86	8.42	5.20
D1 (CON 1, FM)	92.46	30.52	9.70	2.83	17.7
D2 (CON 2, SBM)	92.31	31.20	13.32	6.65	11.23
D3 (15%HMM/50%MLM)	92.33	30.83	11.25	6.95	11.72
D4 (25%HMM/45%MLM)	92.68	30.77	12.36	6.75	11.39
D5 (30%HMM/30%MLM)	93.43	30.59	10.32	5.10	12.23
D6 (35%HMM/20%MLM)	92.22	31.13	14.88	7.01	11.93
D7 (40%HMM/10%MLM)	92.60	30.15	11.32	6.83	11.41
D8 (45%HMM/0%MLM)	92.00	30.68	14.80	5.23	11.33

DM = dry matter, FM = fishmeal, SBM = soy bean meal, HMM = housefly maggot meal, MLM = moringa leaf meal, CON 1 = control 1 (FM inclusion), CON 2 = control 2 (SBM inclusion).

Results for water quality parameters, specifically pH, dissolved oxygen (DO) and temperature, during the experimental period are shown in Table 7. Diet had no significant effects on DO and temperature, but significantly influenced water pH. Plastic tanks subject to diet D_4 had higher pH values than those on diet D_6, but the two did not differ significantly from the plastic tanks subjected to the rest of the diets. Generally the values of DO, temperature and pH observed during the whole experimental period were within the range suitable for growth of *O. niloticus*.

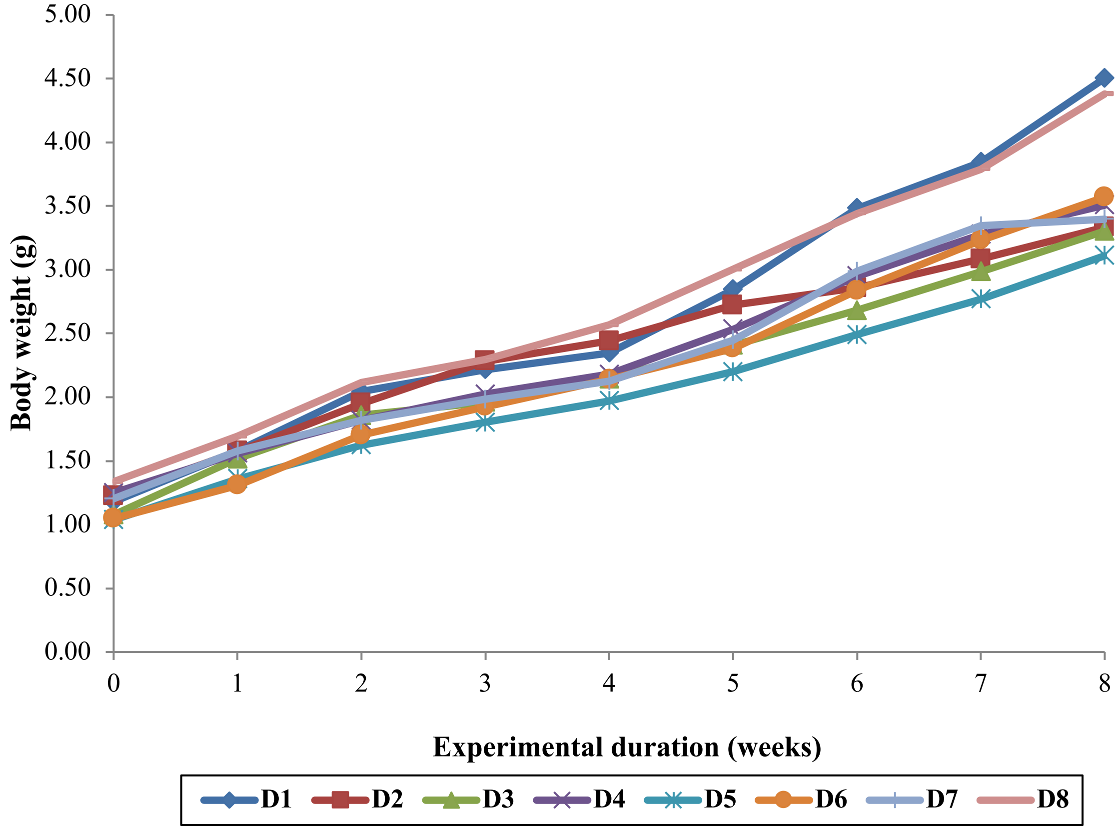

Figure 1: Growth Pattern of Nile Tilapia fed HMM and MLM Diet

Table 6: Growth Performance and Nutrient Utilization of *Oreochromis niloticus* fed diets containing different inclusion levels of housefly maggot meal and Moringa leaf meal

Parameter	D1 (CON 1)	D2 (CON 2)	D3	D4	D5	D6	D7	D8
	0% HMM, 0%MLM	5% FM, 40% SBM	15%HMM, 50%MLM	25%HMM, 45%MLM	30%HMM, 30%MLM	35%HMM, 20%MLM	40%HMM, 10%MLM	45%HMM, 0%MLM
IWT (g)	1.18 ± 0.10	1.22 ± 0.09	1.08 ± 0.10	1.25 ± 0.10	1.04 ± 0.09	1.05±0.09	1.20±0.09	1.34±0.10
FWT (g)	4.50 ± 0.23^{a}	3.3.3 ± 0.22^{bc}	3.30 ± 0.22^{bc}	3.51 ± 0.24^{abc}	3.11 ± 0.21^{c}	3.57 ± 0.21^{abc}	3.40 ± 0.22^{bc}	4.38 ± 0.23^{ab}
WTG (g)	3.32 ± 0.25^{a}	2.11 ± 0.23^{b}	2.23 ± 0.24^{ab}	2.26 ± 0.25^{ab}	2.07 ± 0.23^{b}	2.52±0.23^{ab}	2.19 ± 0.23^{ab}	3.04 ± 0.24^{ab}
ADG (g fish^{-1} day^{-1})	0.059 ± 0.002^{a}	0.037 ± 0.002^{bc}	0.046 ± 0.002^{bc}	0.039 ± 0.002^{c}	0.040 ± 0.002^{c}	0.050 ± 0.002^{c}	0.042 ± 0.002^{c}	0.054 ± 0.002^{ab}
SGR (% day^{-1})	2.91 ± 0.104^{a}	2.54 ± 0.104^{abc}	2.81 ± 0.104^{ab}	2.55 ± 0.104^{c}	2.59 ± 0.104^{abc}	2.69 ± 0.104^{abc}	2.45 ± 0.104^{bc}	2.56 ± 0.104^{abc}
FI (g fish^{-1} day^{-1})	0.12 ± 0.003^{ab}	0.11 ± 0.003^{bc}	0.10 ± 0.003^{cd}	0.11 ± 0.003^{bc}	0.09 ± 0.003^{d}	0.10 ± 0.003^{cd}	0.109 ± 0.003^{bcd}	0.127± 0.003^{a}
FCR	2.34 ± 0.06^{c}	2.73 ± 0.06^{bc}	2.55 ± 0.06^{abc}	2.83 ± 0.06^{a}	2.73 ± 0.06^{bc}	2.46 ± 0.06^{bc}	2.84 ± 0.06^{a}	2.56 ± 0.06^{abc}
PER	1.64 ± 0.08^{a}	1.42 ± 0.08^{a}	1.60 ± 0.08^{a}	1.27 ± 0.08^{a}	1.48 ± 0.08^{a}	1.52 ± 0.08^{a}	1.42 ± 0.08^{a}	1.43 ± 0.08^{a}
Survival (%)	98.33 ± 0.96^{a}	92.08 ± 0.96^{c}	95.41 ± 0.96^{abc}	99.16 ± 0.96^{a}	92.91 ± 0.96^{bc}	98.75 ± 0.96^{a}	98.75 ± 0.96^{ab}	97.91 ± 0.96^{a}

^{abc} Means with different superscript letter in the same row are significantly different at $p<0.05$.
IWT = initial weight, FWT = final weight, ADG = average daily gain, SGR = specific growth rate, FI = fed conversion ratio, FCR = food conversion ratio, PER = protein efficiency ratio. Values represent the mean and standard deviation.

Table 4: Water Environment Parameters During the Feeding Experiment

Diet	Parameter		
	pH	DO (*ppm*)	Temp (°C)
D1 (CON 1, FM)	6.94 ± 0.07[ab]	6.26 ± 0.05[a]	24.00 ± 0.01[a]
D2 (CON 2, SBM)	6.76 ± 0.07[b]	6.27 ± 0.05[a]	24.07 ± 0.01[a]
D3 (15%HMM/50%MLM)	6.83 ± 0.07[ab]	6.24 ± 0.05[a]	24.01 ± 0.01[a]
D4 (25%HMM/45%MLM)	7.15 ± 0.07[a]	6.32 ± 0.05[a]	24.07 ± 0.01[a]
D5 (30%HMM/30%MLM)	6.92 ± 0.07[ab]	6.26 ± 0.05[a]	24.05 ± 0.01[a]
D6 (35%HMM/20%MLM)	6.75 ± 0.07[b]	6.16 ± 0.05[a]	24.03 ± 0.01[a]
D7 (40%HMM/10%MLM)	6.83 ± 0.07[ab]	6.31 ± 0.05[a]	24.07 ± 0.01[a]
D8 (45%HMM/0%MLM)	6.82 ± 0.07[ab]	6.11 ± 0.05[a]	24.02 ± 0.01[a]

[abc] Means with different superscript letter in the same column are significantly different at $p<0.05$.
DO = dissolved oxygen, Temp = temperature, FM = fishmeal, SBM soybean meal, CON1 = control 1, CON 2 = control 2.

DISCUSSION

Determination of the most suitable substrate for maggot production

Maggot, the larvae of the domestic fly (*Musca domestica*) has ability to grow on a large range of substrates. This study assessed the suitability of five substrates for production of maggots. The results indicate that the highest yield of maggots was obtained from cattle offal, followed by chicken manure. Despite the fact that cattle offal produced higher quantity of maggots than chicken manure, chicken manures seem to be the most suitable substrate for culturing housefly maggots because they are readily available and can be obtained at no cost. The findings in this study agree with Odesanya *et al*. (2011) and Ezewudo *et al*. (2015) who reported that chicken droppings are the most suitable substrate for production of housefly maggots. In the present study the use of chicken manure as attractants for houseflies and substrate for culturing the resulting maggots produced significantly large quantity of maggots, almost double, compared to pig manure, cattle manure and kitchen leftovers. This may be due to higher content of nitrogen in chicken manure compared to cattle and pig manure. The observation in the present study is in agreement with Obeng *et al*. (2015) who reported that poultry waste is a better substrate for production of maggots. According to Moreno-Caselles *et al*. (2007) chicken manure is well suited for agricultural purposes compared to other types of manure due to the high content and correct proportion of NPK.

Determination of the appropriate levels of substituting fishmeal and soybean meal with Moringa leaf meal and housefly maggot meal

Maggot meal has been reported to be a possible alternative to the expensive protein sources as it has good nutritional value and is cheaper and less tedious to produce than other animal protein sources. The results in this study show that maggot meal had higher crude protein content than soybean meal and Moringa leaf meal, but lower than that of fish meal. This shows that maggot meal is better source of protein than soybean and Moringa leaf meals. The CP content of maggot meal observed in this study is almost similar to the CP values of 47.1 and 48.0% reported by Aniebo *et al*. (2008) and Odesanya *et al*. (2011), respectively, but lower than the CP value of 64.0% reported by Hwangbo *et al*. (2009). The high CP content implies that maggot meal has high nutritive value and can provide the amount of protein required by Nile tilapia for proper growth. The values crude fibre, fat and ash contents obtained in this study are close to that reported by Odesanya *et al*. (2011) and Aniebo *et al*. (2008).

The results of a feeding trail show that fish fed the diet based on maggot meal (D_8) as the main source of protein had body weight gain, growth rate and FCR that were not significantly different from that of fish fed diet based on fishmeal as the source of protein (D_1). This observation is in agreement with the findings of Ogunji *et al*. (2006), who suggested that maggot meal can completely replace fishmeal in the diet of Nile Tilapia (*Oreochromis niloticus*) and can meet the nutrient requirements of this species. Makinde (2015) recommended that the inclusion of maggot meal in fish diets should be limited to 25-30% as performance tends to decrease when higher inclusion levels are used. In the present study the percentage of maggot meal was increased from 0, 15, 25, 30, 35, 40 to 45% of the diet and growth performance and FCR were better at the inclusion level of 45%, almost comparable to the control diet based on fish meal. At inclusion level of 45%, fishmeal was replaced with maggot meal in diet D_8 by about 86% and the growth performance and survival did not differ significantly from that of the diet containing 100% fishmeal. This demonstrates that maggot meal is an ideal protein source and can completely substitute fishmeal. Sogbesan *et al*. (2006) evaluating the use of maggot meal in the diet of *Heterobranchus longifilis* x *Clarias gariepinus* hybrids concluded that 100% replacement of fishmeal with maggot meal is an economically viable option.

Soybean has been identified as most attractive plant protein source, palatable to most fish species and can successfully replace fishmeal up to 75% (El-Sayed, 1999). When comparison is made between maggot meal and soybean meal in the current study, fish fed the diet based on maggot meal (D_8) as the source of protein had higher growth performance and better FCR than those fed the soybean meal based diet (D_2). Maggot meal had higher crude protein content than soybean meal, thus fish fed diets based on maggot meal showed faster growth. This indicates that maggot meal is a better source of protein than soybean meal and can be used to replace fishmeal in fish diets.

Moringa leaf meal has a potential of becoming source of protein in fish diet because of its high nutritional quality. The present study evaluated the effects of including different combination levels of Moringa leaf meal and maggot meal in Nile tilapia diets. The inclusion of Moringa leaf meal in the diet significantly reduced the growth performance of the fish and increased the FCR. The lower growth performance of the fish fed diets containing Moringa leaf meal may be due to the relatively low protein content as the CP content of Moringa leaf meal was significantly lower than that of fishmeal, soybean meal and maggot meal. Moreover, Moringa leaves contain anti-nutritional factors such tannins, trypsin and amylase inhibitors, lectins, cyanogenic glucosides, saponins, phenols and phytic acid that can reduce palatability, intake and nutrient bioavailability from Moringa leaf meal (Makkar and Becker, 1996; Makkar and Becker, 1997; Afuang *et al*., 2003). Richter *et al*. (2003) showed that saponins and tannins can reduce growth in *Oreochromis niloticus*. This indicates that Moringa leaf meal is not an ideal protein source in fish diets as its use results in lower growth performance compared to fishmeal, maggot meal and soybean meal.

CONCLUSIONS

Generally, fish fed fishmeal based diet (D_1) showed the highest growth performance, followed by those fed housefly maggot meal based diet (D_8) while those fed the diet containing 30% housefly maggot meal and 30% Moringa leaf meal had poor performance. The study has demonstrated that housefly maggot meal alone can replace fishmeal as the source of protein in the diets for Nile tilapia. The lack of significant difference in the values for protein efficiency ratio between the diets containing fishmeal and maggot meal implies that maggot meal has biological value almost equivalent to fishmeal. Based on the results from this study, the following conclusions can be made:-

i. Chicken manure as is a better substrate than both cattle manure and pig manure for production of housefly maggots.
ii. Increasing the quantity of chicken manure in the facilities for production of maggots can increase significantly the yield of maggots.
iii. Housefly maggot meal has higher protein content and promotes better growth performance than soybean meal.
iv. Housefly maggot meal alone can be used to replace fish meal in the diets without affecting the growth performance of Nile tilapia.
v. Mixture of housefly maggot meal and Moringa leaf meal gives better growth performance compared to soybean meal, hence, can be used in tilapia diets instead of soybean meal.

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