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Production and utilization of *Musca domestica* maggots in the diet of *Oreochromis niloticus* (Linnaeus, 1758) fingerlings

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Musca domestica **maggots were produced from poultry dung for five weeks, and its meal utilized as a replacement for fishmeal in the diet of the fingerlings of Nile tilapia, *Oreochromis niloticus*. The maggots were cultured in four different enclosures: aluminium mobile maggotry, aluminium, plastic and wooden boxes. They were harvested at the end of the culture period, processed by oven-drying, and grinding into powdery form as maggot meal. The produced maggot meal was used to replace fishmeal in eight compounded isonitrogenous diets at levels of 0% (Control diet), 20, 30, 40, 50, 60, 70 and 80%. The diets were fed to *O. niloticus* fingerlings to determine the effects of maggot meal in comparison with fishmeal on the growth, nutrient utilization and survival of the fingerlings. The feeding experiment was carried out in 40 L plastic tank in triplicates, with 20 Nile tilapia fingerlings per tank. The fingerlings were fed 5% of their body weight on a daily ration for 10 weeks. Aluminium culture box was best for maggot production with the highest weight, and the most cost-effective. Highest mean weight gain, relative growth rate and specific growth rate was in fingerlings fed 50% maggot meal diet, and lowest in the control diet. Food conversion ratio was lowest in fish fed 60% maggot meal diet, and highest in fish fed the control diet. The protein efficiency ratio was highest in fish fed 60% maggot meal diet, and lowest in fish fed the control diet. Survival was higher, 100% in fish fed maggot meal-based diets, and lower, 95% in fish fed the control diet. These results indicate that replacement of fishmeal with maggot meal at 50 to 60% inclusion level is suitable for optimal growth performance, nutrient utilization and survival in *O. niloticus* fingerlings.**

Key words: Maggot meal, feeding trial, cost-effectiveness, nutrient utilization, growth rate.

INTRODUCTION

Aquaculture has the same target as agriculture, namely, to increase the production of food above the level that would be produced naturally. This brings about competition in the use of fish as food for direct human consumption and in animal husbandry for feed production. Shortages of major feedstuff has been on the increase in recent times in Nigeria (FDF, 2008), and with poultry and farm animals industry expanding at the rate of 10% annually, the aquaculture industry is finding it more difficult to source for critical feed ingredients (Gao and

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Lee, 2012; Nzeka, 2013).

The future growth of the aquaculture industry depends upon the availability of suitable and economical feeds. The cost of feeding is a major factor affecting the development of aquaculture in Nigeria (FAO, 2007). Fagbenro et al. (2003) reported that the use of commercial pellets and supplementary fish feeds accounts for about 60 and 40% respectively of the cost of fish farming venture in Nigeria, because fishmeal, a major protein source for many commercial feeds is expensive and scarce. In 2015, the cost of imported fishmeal in Nigeria ranged from US$2800–3050 per tonne, while the cost of locally produced fishmeal was US$1270–1550 per tonne. At present, around 10% of global fish production goes to fishmeal (either whole fish or fish remains resulting from processing) and is used mainly in aquaculture (FAO, 2012). Recent high demand and consequent high prices for fishmeal, together with increasing production pressure on aquaculture, has led to the research on non-conventional animal proteins for aquaculture and livestock (which could eventually supplement or replace fishmeal).Meanwhile, aquaculture is growing and fishmeal production is declining rapidly as a source of feed because of decreased supplies of caught fish (FAO, 2012). The search for alternative and sustainable proteins is an issue of major importance that needs viable solutions in the short term, making insects an increasingly attractive feed option.

Musca domestica maggots have potentially supplemented fishmeal in the diet of fish including *Oreochromis niloticus* and mud catfish fingerlings (Ugwumba and Abumoye, 1998; Ugwumba et al., 2001; Ajani et al., 2004; Sogbesanet al., 2005; Ogunji et al., 2006, 2008). Culture of maggots is used in converting wastes (of low economic value) e.g. animal dung into valuable animal protein (Calvert, 1976; Ugwumba et al., 2001; Omoyinmi et al., 2005). The major problem with maggot production is harvesting/collection of the maggots from dung, hence, the need for Aluminium mobile maggotry which makes harvesting/collection easier. This study was carried out to investigate the suitability of different culture enclosure for the production of maggots and to determine the effect of replacement of fishmeal with maggot meal in the diet of *O. niloticus*, which is popularly cultured in Nigeria.

MATERIALS AND METHODS

Production of maggots

Maggots were produced from poultry dung (which was collected from Oluwalonse Farm, Lanniba Village, Ajibode, Ibadan, Oyo State from March to May, 2013) using four culture enclosures namely: Aluminium Mobile Maggotry, aluminium, wooden and plastic boxes.

Aluminiummobile maggotry

The mobile maggotry (1.2×0.8×0.5 m) was made with aluminum sheets and consisted of three chambers: the top, middle and bottom chambers. The top chamber of the maggotry was the culture chamber and it had a lid at the top and at the front for easy introduction of the culture substrate. The lids were left open for access to *M. domestica* adult for egg-laying on the exposed dung. The base of the culture chamber was screened with 3mm wire mesh net to allow dropping of the maggots. Mosquito netting of 1.8mm mesh size was placed on the wire mesh to overcome the problem of dung dropping with the maggots. The middle chamber was the cleaning chamber for maggots emerging from the culture chamber. The base of this chamber was also screened with 3mm wire mesh for cleaning of maggots from the remains of the culture substrate. The bottom chamber was the collection chamber where the maggots were collected.

Aluminium, plastic and wooden culture boxes

The Aluminium boxes (0.2×0.33×0.5m), plastic boxes (0.5×0.35×0.22m), and the wooden boxes (0.6×0.5×0.3m) were perforated at the sides to allow adequate aeration and the perforations were screened on the inside with mosquito mesh net (1.8mm mesh size) to prevent escape of maggots. The upper part of each box was open while the bottom which was also perforated to allow dropping of maggots and was placed on an aluminium tray to serve as collection platform for the dropping maggots. The inner sides of the collection trays were painted black as maggots are known to be negatively photo-tactic (Ugwumba et al., 2001). All the culture boxes were placed on a constructed long wooden table.

Experimental set-up for maggot production

The culture enclosures were set-up in quadruplicates for the experiment. A shed was constructed over the enclosures to avoid direct effect of rainfall and sunlight. Freshly collected dung was tied in air tight sacks for two days in order to kill any maggots before loading into the culture enclosures. Twenty kilogrammes of dung was placed in the culture chamber of each maggotry, wooden, plastic and aluminium boxes and exposed to flies for egg-laying. The dungs were moistened with half a litre of water every day to prevent them from drying up. The set-up was checked every day for collection of maggots. The dung was collected weekly for a period of five weeks, from March to May 2013. The production was done in the Animal House of the Department of Zoology, University of Ibadan, Ibadan, Nigeria.

Harvesting and processing of maggots

Maggots were harvested daily once they emerge from the dung. Harvesting of maggots from the mobile maggotry was done by collecting the maggots from the outlet of the maggotry, while in the boxes, it was done by lifting each box and collecting the maggots from the collection tray that was placed beneath each box. Harvested maggots were rinsed with water to remove any dung on them and then weighed. The maggots were then blanched with hot water and re-weighed. The maggots were oven-dried at 60°C for 24 h, cooled, processed into powdery form as maggot meal using pestle and mortar. The maggot meal was packed in an air-tight plastic container and stored at 4°C till when needed.

Feeding trial with *O. niloticus*

Experimental diet

Eight dry isonitrogenous feeds were formulated based on the

Table 1. Percentage composition (% dry weight) of experimental diets.

Ingredients	Experimental diets							
	Diet A	Diet B	Diet C	Diet D	Diet E	Diet F	Diet G	Diet H
Fishmeal (g)	28.71	25.20	22.86	20.53	17.97	15.14	11.99	8.47
Maggot meal (g)	-	6.30	9.79	13.69	17.97	22.71	27.98	33.87
Corn meal (g)	61.29	58.50	57.34	55.78	54.06	52.16	50.03	47.66
*Vitamin & Mineral Premix (g)	0.05	0.50	0.50	0.50	0.50	0.50	0.50	0.50
Soybean oil (g)	1.50	1.50	1.50	1.50	1.50	1.50	1.50	1.50
Cassava starch binder (g)	8.0	8.0	8.0	8.0	8.0	8.0	8.0	8.0
Total (g)	100	100	100	100	100	100	100	100
Calculated crude protein (%)	30	30	30	30	30	30	30	30
Inclusion levels of maggot meal (%)	0	20	30	40	50	60	70	80

*Vitamins and Minerals Premix: 2.5kg of premix contained: Vitamin A- 12,500,000.00 I.U, Vitamin D_3- 2,500,000.00 I.U, Vitamin E – 40,000.00 mg, Vitamin K3 - 2,000.00 mg, Vitamin B1 - 3,000.00 mg, Vitamin B2 - 5,500.00 mg, Niacin - 55,000.00 mg, Calcium pantothenate - 11,500.00 mg, Vitamin B6 - 5,000.00 mg, Vitamin B12 - 25.00 mg, Folic acid - 1,000 mg, Choline chloride - 500,000.00 mg, Biotin - 80.0 mg, Manganese - 120,000.00 mg, Iron - 100,000.00 mg, Zinc - 80,000.00 mg, Copper- 8,500.00 mg, Iodine - 1,500.00 mg, Cobalt - 300.00 mg, Selenium - 120.00 mg, Anti-oxidant - 120,000.00 mg.

protein content of the major feed ingredients namely fishmeal, maggot meal and corn meal using the Pearson Square Method described by Pearson (1976). Fishmeal was replaced in the diets with increasing levels of inclusion of maggot meal at 0% (Diet A, Control Diet), 20% (Diet B), 30% (Diet C), 40% (Diet D), 50% (Diet E), 60% (Diet F), 70% (Diet G), 80% (Diet H). Table 1 shows the percentage composition of experimental diets.

Fishmeal, corn meal, mineral and vitamin premix were purchased from Kesmac Feeds, Orogun, Ibadan, Nigeria; while starch (binder) and soybean oil were purchased from Bodija Market, Ibadan, Nigeria. Appropriate quantities of ingredients in each diet were weighed and mixed thoroughly in a bowl before adding gelatinized starch. The feeds were sun-dried for five days, after which, they were packed in air-tight plastic bags and stored at 4°C in the laboratory. Proximate analyses of maggot meal, fishmeal, corn meal and the compounded diets were carried out using the methods of AOAC (2012).

Experimental procedure

Fingerlings of *Oreochromis niloticus* with mean weight of 0.95±0.03g, and mean length of 3.63±0.160cm were acclimatized in the laboratory for one week, during which they were fed with fishmeal. They were then starved for 24 h before the commencement of the experiment, after which, the standard length and weight of each fingerling was measured and randomly assigned to plastic culture tanks at a stocking density of 20 fingerlings per tank, giving a total of 60 fingerlings per experimental diet. Total and average lengths and weights of fish for each tank were calculated and recorded as initial lengths and weights. The length and weight of five randomly selected fingerlings from each tank were measured weekly to access growth rate and to calculate feed rations from estimated total fingerling weight in each tank. The fish were fed diet corresponding to 5% of their body weight daily for ten weeks, from June to September 2013; half of the ration was fed at 09.00 h and the other half at 18.00 h. Feeding was done manually at a particular point in each tank and visual observations of the fingerlings were made during this process. The tanks were monitored daily for mortality; dead fish were removed, and counted. At the end of the experiment, final lengths and weights of all *O. niloticus* fingerlings left in each tank were measured, and total and average final lengths and weights were calculated.

Economic evaluations of diets formulated

The economic evaluations of the diets formulated were calculated using the formulae reported in Sogbesan et al. (2006).

Estimated investment cost analysis= Cost of feed ($) + Cost of fingerlings stocked ($)

$$\text{Profit Index} = \frac{\text{Value of fish (\$)}}{\text{Cost of feed (\$)}}$$

$$\text{Incident of cost} = \frac{\text{Cost of feed (\$)}}{\text{Mean weight gain of fish produced (g)}}$$

Net profit = Total cost of fish cropped ($) - Total Expenditure ($)

$$\text{Cost: Benefit ratio (C: Br)} = \frac{\text{Total cost of fish cropped (\$)}}{\text{Total Expenditure (\$)}}$$

Monitoring of water quality

Temperature was taken daily between 07.00 to 08.00h with Mercury-in-glass thermometer. Dissolved oxygen was determined using the Winkler's Method described by Boyd (1990) and pH with a pH meter (JENWAY 3510) weekly. During the experimental period, water temperature ranged from 26.1 to 26.5°C, dissolved oxygen 5.0 to 5.9 mg/L and pH 8.01 to 8.10.

Evaluation of growth and nutrient utilization of fish

The following growth, nutrient utilization and survival of fish were computed for fingerlings on each diet using the following formulae reported in Monebi and Ugwumba (2013).

Mean weight gain = FMW– IMW

Where FMW = final mean weight (g/fish), IMW = initial mean weight (g/fish)

$$\text{Relative growth rate (RGR) \%} = \frac{W_f - W_i}{W_i} \times 100$$

Where W_i = initial weight of fish (g), W_f = final weight of fish (g).

$$\text{Specific Growth Rate (SGR) \%} = \frac{\log_e W_f - \log_e W_i}{t} \times 100$$

Where Log_e = the natural logarithm, t = duration of experiment in days.

$$\text{Food conversion ratio (FCR) \%} = \frac{\text{Total food supplied to fish (g)}}{\text{Total weight gain by fish (g)}}$$

Protein Intake = Food supplied (g) × % crude protein of feed.

$$\text{Protein efficiency ratio (PER) \%} = \frac{\text{Mean weight gain by fish (g)}}{\text{Mean protein intake (g)}}$$

$$\text{Protein productive value (PPV) \%} = \frac{B - B_0}{PI} \times 100$$

Where B= Final body protein (at the end of experiment), B_0 = Initial body protein (at the beginning of experiment), and PI= Protein Intake.

$$\text{Survival (S)} = \frac{N_f}{N_i} \times 100$$

Where N_i = Number of fish at the beginning of the experiment, and N_f = Number of cultured fish at the end of the experiment.

Economic evaluation of maggot production

Economic evaluation of maggot production was calculated using the formula reported in Sogbesan et al. (2006) as:

$$\text{Cost of production} = \frac{\text{Cost of constructing culture enclosure (\$)}}{\text{Quantity of maggot produced (g)}}$$

Statistical analysis

All data collected were subjected to descriptive statistics, student's t-test and one-way analysis of variance (ANOVA).

RESULTS

Production of maggots

There was a gradual increase in the weight of maggots followed by a drop in the third week after which production is increased in the third and fifth weeks for maggots cultured in aluminium and wooden boxes. Production from plastic box decrease steadily from the first to the fourth week, followed by an increase in the fifth week.

Production from the aluminium mobile maggotry was relatively the same throughout the culture period. (Figure 1).

Maggots produced fom aluminium box had the highest total quantity of 1.603 kg maggot/5 weeks while the lowest value, 0.230 kg maggot/5 week was recorded in aluminium mobile maggotry (Table 2). There was significant difference ($p < 0.05$) between the mean weight of maggots produced in all the four culture enclosures. Also, aluminium box was found to be the most cost-effective, 0.002$/kg maggot, while the least cost-effective, 0.081$/kg was recorded in aluminium mobile maggotry (Table 2). There was significant difference ($p < 0.05$) in the cost-effectiveness of the four culture enclosures. The result of the production from proximate composition of maggots produced showed that crude protein content was 45.5%, crude lipid, 9.0%; crude fibre, 3.0% and ash content, 12.0%.

Feeding trial with *O. niloticus*

The crude protein content of the eight experimental diets ranged from 37.60 to 37.70% and were not significantly different ($p>0.05$) (Table 3). The weekly changes in weight of the fingerlings fed the different diets are illustrated in Figure 2. There was progressive increase in the weight gain of fish fed all the experimental diets. Results on the growth and nutrient utilization of fingerlings are shown in Table 4. The mean weight gain, relative and specific growth rates were highest, 9.29 g/fish, 967.7 and 1.47%) in fish fed 50% maggot meal diet and lowest, 4.05g/fish, 430.85% and 1.04% respectively in fish fed control diet. Differences in growth rates between the diets were significantly different ($p<0.05$).

The food conversion ratio was highest (3.01) in fish fed the control diet while the lowest (2.37) was in fish fed 60% maggot meal diet and the differences were significant ($p<0.05$). The highest protein intake (8.38g) was obtained in fish fed 50% maggot meal diet while the lowest value (4.59g) was in fish fed the control diet and the differences were significant ($p<0.05$). Protein efficiency ratio was highest (1.12) in fish fed 60% maggot meal diet and lowest (0.88)in fish fed the control diet and the differences were significant ($p<0.05$). There was no mortality, that is, 100% survival in the maggot-based diets unlike the control, where survival was 95%. The difference was significant ($p<0.05$).

The carcass composition before and after the experiment is shown in Table 5. There was significant difference between the crude protein, lipid, fibre and ash

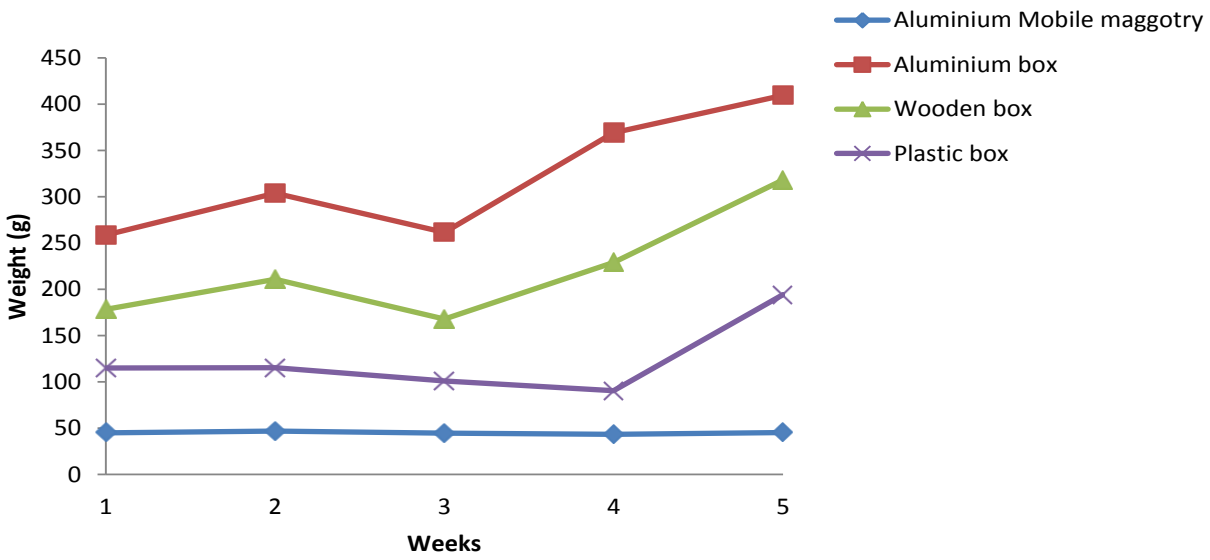

Figure 1. Weekly production of *M. domestica* maggot in different enclosures.

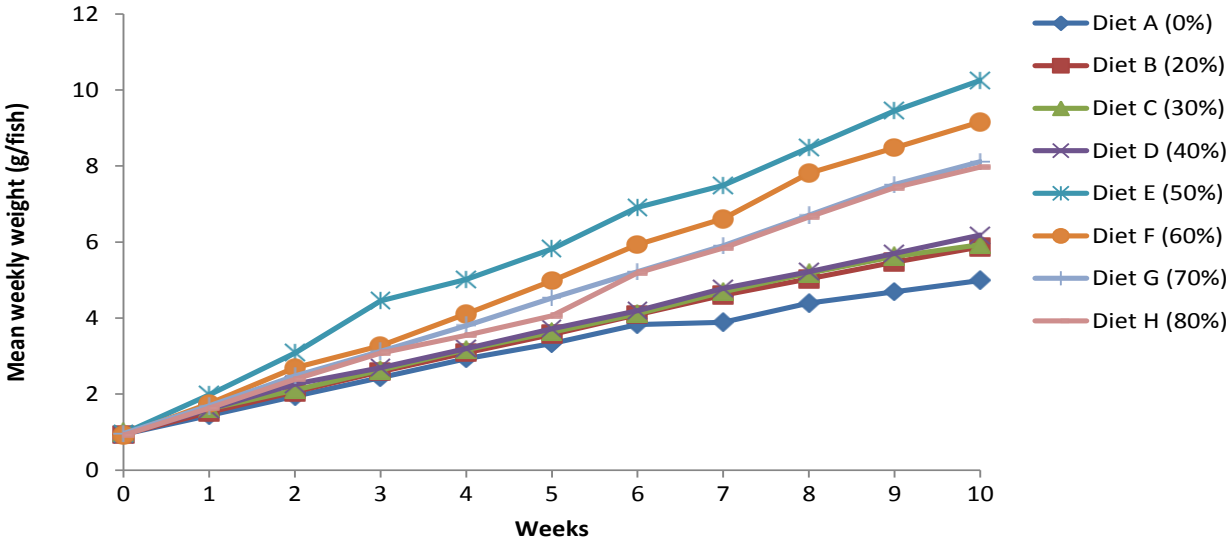

Figure 2. Weekly weight changes of *O. niloticus* fingerlings fed the various experimental diets.

contents of the initial and final carcass composition of *O. niloticus.* At the end of the experiment, the highest percentage crude protein (76.75%) was obtained in fish fed 50% maggot meal diet, while the lowest (69.30%) was in fish fed the control diet and the differences were significant ($p < 0.05$).

Economic evaluations of experimental diets

Results on the economic evaluation of experimental diets are shown in Table 6. At the end of the experiment, the best net profit of $12.97 and cost: benefit ratio of 2.90 was obtained in fish fed 50% maggot meal diet while the lowest net profit value of $1.89 and cost: benefit ratio of 1.48 was in fish fed the control diet.

DISCUSSION

The water parameters monitored during the study were within the suitable range for tropical fish indicating that the environmental conditions of the fish during the experimental period were adequate. Recommended temperature range for optimum growth of tilapias is 22 to 29°C (Sarig, 1969; Mires, 1995) while Magid and Babiker

Table 2. Cost effectiveness of maggot production from the different enclosures.

Enclosure	Cost of enclosure ($)	Quantity of maggot produced (kg maggot/ 5 week)	Incidence cost ($/kg maggot)
Aluminium mobile maggotry	18.67	0.230	0.081
Aluminium box	3.55	1.603	0.002
Plastic box	2.54	0.620	0.004
Wooden box	5.08	1.104	0.005

Table 3. Proximate composition of experimental diets (% dry weight).

Nutrients	Diet A (Control, 0%MM)	Diet B (20% MM)	Diet C (30% MM)	Diet D (40% MM)	Diet E (50% MM)	Diet F (60% MM)	Diet G (70% MM)	Diet H (80% MM)
Crude protein	37.70^{a}	37.68^{a}	37.66^{a}	37.64^{a}	37.65^{a}	37.63^{a}	37.62^{a}	37.60^{a}
Crude lipid	8.00^{b}	7.00^{a}	7.00^{a}	7.00^{a}	8.00^{b}	7.00^{a}	7.00^{a}	7.00^{a}
Crude fibre	4.00^{b}	3.00^{a}	4.00^{b}	4.00^{b}	4.00^{b}	3.00^{a}	4.00^{b}	3.00^{a}
Ash	5.00^{a}	12.00^{d}	12.00^{d}	8.00^{c}	12.00^{d}	14.00^{e}	8.00^{c}	7.00^{b}
Dry matter	90.25^{h}	90.16^{g}	89.46^{d}	89.12^{b}	89.38^{c}	88.74^{a}	89.62^{f}	89.55^{e}

MM = Maggot Meal. Values on the same row with different superscript are significantly different ($p < 0.05$).

Table 4. Growth and Nutrient Utilization of *O. niloticus* fed maggot meal diets for 10 weeks.

Parameters	Diet A (Control, 0% MM)	Diet B (20% MM)	Diet C (30% MM)	Diet D (40% MM))	Diet E (50% MM)	Diet F (60% MM)	Diet G (70% MM)	Diet H (80% MM)
Duration (Days)	70	70	70	70	70	70	70	70
No of fish stocked	60	60	60	60	60	60	60	60
No of fish left	57	60	60	60	60	60	60	60
IMW (g/fish)	0.94^{ab}	0.94^{ab}	1.0^{c}	0.94^{ab}	0.96^{b}	0.92^{a}	0.96^{b}	0.92^{a}
FMW (g/fish)	4.99^{a}	5.87^{b}	5.93^{c}	6.18^{d}	10.25^{h}	9.16^{g}	8.11^{f}	7.97^{e}
MWG (g/fish)	4.05^{a}	4.93^{b}	4.93^{b}	5.24^{c}	9.29^{g}	8.24^{f}	7.15^{e}	7.05^{d}
RGR (%)	430.85^{a}	524.47^{c}	493^{b}	557.45^{d}	967.7^{h}	895.65^{g}	744.79^{e}	766.30^{f}
SGR (%)	1.04^{a}	1.14^{c}	1.1^{b}	1.17^{c}	1.47^{f}	1.42^{e}	1.33^{d}	1.34^{d}
FCR	3.01^{f}	2.74^{d}	2.83^{e}	2.71^{d}	2.40^{ab}	2.37^{a}	2.47^{c}	2.42^{b}
PI	4.59^{a}	5.09^{b}	5.25^{bc}	5.38^{c}	8.38^{g}	7.35^{f}	6.64^{e}	6.41^{d}
PER	0.88^{a}	0.97^{b}	0.94^{ab}	0.97^{b}	1.11^{c}	1.12^{c}	1.08^{bc}	1.10^{c}
PPV	46^{a}	75^{b}	86^{c}	115^{e}	114^{e}	116^{e}	108^{d}	106^{d}
Survival (%)	95.0^{a}	100.0^{b}	100.0^{b}	100.0^{b}	100.0^{b}	100.0^{b}	100.0^{b}	100.0^{b}

Values with different superscripts on the same row are significantly different ($p < 0.05$). Key: MM = Maggot meal; IMW = Initial Mean Weight; FMW = Final Mean Weight; MWG = Mean Weight Gain; RGR = Relative Growth Rate; SGR = Specific Growth Rate; FCR = Food Conversion Ratio; PI = Protein Intake; PER = Protein Efficiency Ratio; PPV = Protein Productive Value.

(1975) and also Ross (2000) reported dissolved oxygen values >3 mg/L as the standard range for optimum growth of tilapias. Boyd and Lichtkoppler (1979) reported dissolved oxygen concentration of 5.0 mg/L and above as desirable for survival of fish. Ross (2000) recommended pH range of 7-9 as the optimum for the growth of tilapias.

Maggot production

The four enclosures investigated were suitable for the production of maggots. However, aluminium culture box was the best enclosure for the production of maggots and also the most cost-effective. The higher maggot

Table 5. Carcass composition of *O. niloticus* fingerlings fed experimental diets at the beginning and end of feeding trial (% dry weight).

Nutrients	Initial carcass composition	Experimental diets							
		Final carcass composition							
		Diet A (Control, 0% MM)	Diet B (20% MM)	Diet C (30% MM)	Diet D (40% MM)	Diet E (50% MM)	Diet F (60% MM)	Diet G (70% MM)	Diet H (80% MM)
Crude protein	67.20[a]	69.30[b]	71.00[c]	71.74[d]	73.35[e]	76.75[h]	75.70[g]	74.35[g]	74.00[f]
Crude lipid	7.00[a]	7.50[b]	8.00[d]	7.50[b]	7.50[b]	7.70[c]	7.50[b]	8.00[d]	7.50[b]
Crude fibre	2.00[b]	1.50[a]	1.50[a]	1.50[a]	1.50[a]	1.50[a]	1.50[a]	1.50[a]	1.50[a]
Ash	22.00[e]	21.00[d]	18.00[b]	19.00[c]	21.00[d]	18.00[b]	17.50[a]	19.00[c]	18.00[b]

MM= Maggot Meal. Values on the same row with different superscripts are significantly different ($p<0.05$).

Table 6. Economic analysis of experimental diets.

Diets	Parameter determined				
	Estimated investment cost analysis ($)	Profit index ($)	Incident of cost	Net profit ($)	Cost: Benefit ratio (C:Br)
Diet A (Control, 0% MM)	3.90	0.04	0.69	1.89	1.48
Diet B (20% MM)	4.45	0.02	0.93	2.25	1.51
Diet C (30% MM)	4.75	0.02	1.15	1.95	1.41
Diet D (40% MM)	5.09	0.02	1.28	4.04	1.79
Diet E (50% MM)	6.82	0.03	1.33	12.97	2.90
Diet F (60% MM)	6.86	0.02	1.52	11.42	2.67
Diet G (70% MM)	6.99	0.02	1.81	9.76	2.40
Diet H (80% MM)	7.40	0.02	2.03	8.75	2.18

production in aluminium, plastic and wooden boxes compared to aluminium mobile maggotry in this present study could be due to the use of collection trays introduced for harvesting of maggots from the culture boxes, thereby making harvesting easier.

The crude protein of maggots recorded in this study (45.5%) is similar with that reported by Gado et al. (1982) (45.0%), Atteh and Olegbenla (1993) (45.0%), close to those reported by Ugwumba et al. (2001) (41.3%)and Okah and Onwujiariri (2012) (44.44%) but at variance with those of Calvert et al. (1971) (63%), Hwangbo et al. (2009) (63.99%), Awoniyi et al. (2003) (55.1%), Sogbesan et al. (2006) (55.4%). Also, the crude fibre recorded in this study (3.0%) is also slightly similar with that reported by Omoyinmiand Olaoye (2012) (2.41%) but clearly at variance with those of Ugwumba et al. (2001) (9.5%), Sogbesan et al. (2006) (1.56%), and Aniebo et al. (2009) (7.5%). Variations in nutritional components of maggot meal have been reported to be mostly due to differences in age at harvest (Inoaka et al., 1999; Newton et al., 2004; Aniebo et al., 2008; Aniebo and Owen, 2010), method of drying (Fasakin et al., 2003; Aniebo and Owen, 2010) and larval feed substrate (Newton et al., 1977). The age of the maggots in the present study was not known. Poultry dung used for the production of the maggots in the present study has been reported to be the best substrate for maggot production (Omoyinmi et al., 2005; Anene et al., 2013).

Feeding trial with *O. niloticus*

Progressive weight gain of *O. niloticus* recorded in all the dietary treatments throughout the duration of the experiment is an indication that the fish responded positively to all the diets in terms of growth, and that the protein content of the experimental diet was likely adequate for growth of the fish. The results obtained from this present study show that fingerlings fed 50% maggot meal inclusion diet has the best growth performance, an indication that they were able to properly convert their food into body growth than those on all the other diets. This result is in accordance with that recorded by Omoruwou and Edema (2011), and Ajani et al. (2004), who recorded the highest weight gain in 50% maggot meal inclusion in the diet of 'Heteroclarias' and *O. niloticus* fingerlings respectively.

Food conversion ratio was lowest in fish fed 60%

maggot meal diet indicating that they were most efficient in converting their food to body growth.Protein efficiency ratio and protein productive value were highest in fish fed 60% maggot meal diet, an indication of good protein digestibility and bioavailability for optimum body protein increase and growth (Pellett, 1989). Survival was high for all diets during the experiment, and was significantly different ($p<0.05$) between fingerlings fed the control diet and all the other maggot meal based diets, 100% survival in the maggot-dependent diets, further indicates the suitability of maggot meal diets for *O. niloticus* fingerlings.

The proximate composition of the fish carcass from all the diets showed an increase in the values of crude protein at the end of the experiment. This may be attributed to the ability of *O. niloticus* to convert and utilize the crude protein in their diets for body growth.The economic evaluation of feeding *O. niloticus* fingerlings on experimental diets shows that 50% maggot meal diet recorded the highest net gain and cost: benefit ratio. The positive net gain and cost: benefit ratio recorded in all the diets indicate that *O. niloticus* can be economically reared on all the diets. However, the replacement of fishmeal with maggot meal from 40-80% in the diets of *O. niloticus* showed better cost: benefit ratio with optimum at 50% maggot meal inclusion. The cost of production and the benefits positively favoured all treatments since the values computed are > 1.0 which shows an increase in the fish value above the amount invested. This is not withstanding, more monetary profits awaits a farmer when 50% of maggot meal is used to replace fishmeal in the diet of *O. niloticus*. This agrees with the findings of Sogbesan et al. (2006) who reported that cost of production and benefits positively favoured (> 1.0) all treatments when maggot meal was partially substituted at 0, 25, 50, 75 and 100% in the diet of 'Heteroclarias' fingerlings.Aluminium culture box is the best and most cost-effective enclosure for the production of maggots. The present study showed that though maggot meal can completely replace fishmeal in the diet of *O. niloticus* fingerlings, replacement of fishmeal with maggot meal is best at 50% for optimum growth and 60% for optimum nutrient utilization. Therefore, replacement of fishmeal with maggot meal at 50 to 60% inclusion level is recommended.

Conflict of Interest

The authors have not declared any conflict of interest.

REFERENCES

Ajani EK, Nwanna LC, Musa BO (2004). Replacement of fishmeal with maggot meal in the diets of Nile Tilapia, *Oreochromis niloticus*. World Aquaculture- Baton Rouge 35(1):52-55.

Anene A, Afam-Anene OC, Ike K, Ekekwe NH (2013). Preliminary investigations on quantity of maggots produced from four different sources of livestock wastes. J. Res. Biol. 3(6):1060-1065.

Aniebo AO, Erondu ES, Owen OJ (2008). Proximate composition of housefly larvae (*Musca domestica*) meal generated from mixture of cattle blood and wheat bran. Livest. Res. Rural Dev. 20(12):1-5.

Aniebo AO, Erondu ES, Owen OJ (2009).Replacement of fish meal with maggot meal in African catfish (*Clarias gariepinus*) diets. Revista UDO Agricola 9(3):666-671.

Aniebo AO, Owen OJ (2010). Effects of age and method of drying on the proximate composition of housefly larvae(*Musca domestica,* Linnaeus) meal (HFLM). Pak. J. Nutr. 9(5):485-487.

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

Atteh JO, Olegbenla FD (1993). Replacement of fishmeal with maggots in broiler diet: Effects on performance and nutrient retention. Nig. J. Anim. Prod. 20:44-49.

Awoniyi TAM, Aletor VA, Aina JM (2003). Performance of broiler chickens fed on maggot meal in place of fishmeal. Int. J. Poult. Sci. 2:271-274.

Boyd CE (1990). Water quality in ponds for Aquaculture. Alabama Agriculture Experiment Station, Auburn University. Alabama. P. 462.

Boyd CE, Lichtkoppler F (1979). Water Quality Management in Fish Ponds. Research and Development Series No. 22 International Centre for Aquaculture (J.C.A.A) Experimental Station Auburn University, Alabama. pp. 45-47.

Calvert CC (1976). Systems for indirect recycling by using animal and municipal wastes as a substrate for protein production. In: New feed resources proceedings of technical consultation held in Rome, 22–24 November 1976. Part IV, Chapter 18.

Calvert CC, Martins RD, Eby HJ (1971). Biodegraded hen manure and adult houseflies: Their nutritional value to the growing chick. In: Livestock Waste Management and Pollution Abatement. Proc. Internat, Symp. Livestock waste, Columbus, Ohio. pp. 319–320.

Fagbenro OA, Adeparusi EO, Fapohunda OO (2003). Feedstuff and dietary substitution for farmed fish in Nigeria. In: Proceedings of the Joint Fisheries Society of Nigeria/National Institute for Freshwater Fisheries Research/FAO- National Special Programme for Food Security National Workshop on Fish feed development and Feeding Practices in Aquaculture (Eyo AA Ed). National Institute for Freshwater Fisheries Research, New- Bussa. pp. 60– 72.

FAO (2007). State of World Fisheries and Aquaculture. Rome. P. 240.

FAO **(**2012).State of the world fisheries. Rome. P. 209.

FDF (2008). Federal Department of Fisheries, Fisheries Statistics of Nigeria Projected human population; fish demand and supply in Nigeria, 2000 – 2015. P. 56.

Fasakin EA, BalogunAM, Ajayi OO (2003). Evaluation of full-fat and defatted maggot meals in the feeding of clariid catfish, *Clarias gariepinus* fingerlings. Aquaculture Res. 34(9):733-738.

Gado MS, El-Aggory SM, Elgawaad AA, Mahmoud AK (1982). The possibility of applying insect protein in broiler rations. Nutr. Abstracts Rev. 53:76.

Gao Y, Lee JY (2012). Compensatory responses of Nile tilapia *Oreochromis niloticus* under different feed deprivation regimes. Fish. Aquat. Sci. 15(4):305-311.

Hwangbo J, Hong EC, Jang A, Kang HK, Oh JS, Kim BW, Park BS (2009).Utilization of house fly-maggots, a feed supplement in the production of broilerchickens. J. Environ. Biol. 30(4):609–614.

Inoaka T, Okubo G, Yokota M, Takemasa M (1999). Nutritive value of house fly larvae and pupae fed on chicken faeces as food source for poultry. J. Poultry Sci. 3(3):174-180.

Magid A, Babiker MM (1975). Oxygen consumption and respiratory behaviour of three Nile fishes. Hydrobiologia 46:359–367.

Mires D (1995). The tilapias.In: Production of Aquatic Animals: Fishes (eds. Nash CE and Novotony AJ) Elsevier, New York. pp. 133–152.

Monebi CO, Ugwumba AAA (2013). Utilization of the Earthworm (*Eudrilus eugeniae*) in the diet of Heteroclarias Fingerlings. Int. J. Fish. Aquacult. 5(2):19-25.

Newton GL, Booram CV, Barker RW, Hale OM (1977).Dried *Hermetia illucens* larvae meal as a supplement for swine. J. Animal Sci. 44(3):395-400.

Newton L, Sheppard C, Watson D, Burtle G, Dove R (2004).Using the black soldier fly, Hermetia illucens, as a value-added tool for the management of swine manure. University of Georgia, College

of Agriculture & Environmental Science. Department of Animal & Dairy Science Annual Report. P. 17.
Nzeka UM (2013).Nigeria Food Processing Ingredients Market.A report from Global Agricultural Information Network (GAIN).United States Department of Agriculture (USDA) Foreign Agricultural Service. P. 34.
Ogunji JO, Kloas W, Wirth M, Schulz C, Rennert B (2006). Housefly maggot meal: An emerging substitute of fishmeal in Tilapia Diets, Conference on International Agricultural Research for Development. DeuscherTropentag, Stuggart-Hoheheim, Oct 11-13, 2006. pp. 1-7.
Ogunji JO, Toor RS, Schulz C, Kloas W (2008). Growth performance, nutrient utilization of Nile Tilapia, *Oreochromis niloticus* fed Housefly Maggot Meal (Magmeal) Diets. Turk. J. Fish. Aquatic Sci. 8:141-147.
Okah U, Onwujiariri EB (2012). Performance of finisher broiler chickens fed maggot meal as a replacement for fish meal. J. Agric. Technol. 8(2):471-477.
Omoruwou PE, Edema CU (2011). Growth response of *Heteroclarias* hybrid fingerlings fed on maggot based diet. Nig. J. Agric. Food Environ. 7(1):58-62.
Omoyinmi GAK, Olaoye OJ (2012). Growth Performance of Nile Tilapia-*Oreochromis niloticus* fed diets containing different sources of animal protein. Libyan Agric. Res. Center J. Int. 3(1):18-23.
Omoyinmi GAK, Fagade SO, Adebisi AA (2005).Assessment of different organic substrates in the laboratory culture of some live food organisms. Zoologist 3:105-111.
Pearson D (1976). The chemical analysis of foods. 7th Edition, Churchill Livingstone, London.
Pellett P (1989). Report of a joint FAO/WHO expert consultation on protein quality evaluation, Bethesda, M.D., U.S.A, 4-8 December, 1989. FAO and Food Nutrition Paper 51:7.
Ross LG (2000). Environmental physiology and energetics. In: Beveridge MCM, McAndrew BJ (Eds.) Tilapias: Biology and Exploitation, Kluwer Academic Publishers, Dordrecht, The Netherlands. Fish Fish. Series 25:89–128,
Sarig S (1969). Winter storage of Tilapia. FAO Fish Culture Bulletin 2:8–9.
Sogbesan OA, Ajuonu ND, Ugwumba AAA, Madu CT (2005). Cost benefits and growth performances of catfish hybrid fed maggot meal diets. J. Sci. Ind. Res. 3(2):51-56.
Sogbesan AO, Ajuonu N, Musa BO, Adewole AM (2006). Harvesting techniques and evaluation of maggot meal as animal protein source for 'Heterobranchus' in outdoor concrete tanks. World J. Agric. Sci. 2(4):394-402.
Ugwumba AAA, Abumoye OO (1998). Growth response of Clarias gariepinus fingerlings fed live maggot from poultry droppings. In: Sustainable Utilization of Aquatic/Wetland Resources. Selected papers from 9th Annual Conference of the Nigerian Association for Aquatic Sciences, Abeokuta, Nigeria, 30thNov.-2nd Dec. 1995, pp. 60-68.
Ugwumba AAA, Ugwumba AO, Okunola AO (2001). Utilization of live maggot as supplementary feed on the growth of *Clarias gariepinus* (Burchell) fingerlings. Niger. J. Sci. 35(1):1-7.