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Full Length Research Paper

Nutritive potential and utilization of super worm (*Zophobas morio*) meal in the diet of Nile tilapia (*Oreochromis niloticus*) juvenile

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Super worm meal (SWM) was evaluated to investigate the effect of partial or total replacement of fish meal (FM) in diets for tilapia juvenile, *Oreochromis niloticus*. Triplicate groups of fish with average initial body weight (5.57 ± 0.15 g) were fed each with 5 isonitrogeneous (32% crude protein) diets formulated to include 0, 25, 50, 75 and 100% (diets 1 – 5, respectively) of FM substituted with SWM. After eight weeks of feeding trials, fish fed with diet 2 and 3 revealed the highest values for live weight gain, specific growth rates, better feed conversion ratio as well as protein efficiency ratio compared to the others. Survival range was 100% in all the treatments. However, fish fed to diet 5 exhibited lower growth than those fed others diets. There were no significant differences (P > 0.05) in the moisture, protein, lipid and ash content in the whole body composition. These results clearly indicate that up to 25% of FM protein in fish diet can be replaced by SWM without any adverse effect on feed utilization and body composition. A decrease in weight gain and other growth associated parameters was observed with higher replacement.

Key words: Feed utilization, growth performance, insect based diet, *Oreochromis niloticus*, super worm meal, *Zophobas morio*.

INTRODUCTION

In fish farming, nutrition is the most crucial factor to take into account due to its contribution of up to 40 to 50% of the production costs. In formulating nutritive diet for cultured fish, fish meal (FM) is used as the main dietary protein source because of its nutritional quality and palatability properties (Hardy and Tacon, 2002). The increased demand in FM especially in commercial fish diet industry has resulted in a supply shortage with concomitant price increase. It is crucial to reduce the use of FM in fish diet by replacing it with alternative protein sources because total dependence can affect the whole operation of aquaculture system and consequently reduce the production. Factors of concern are nutritional availability and costs of production (Dong et al., 1993). Competition from livestock industry for FM has resulted in a drastic decline of fish production and shortage of protein supply.

Therefore, fish nutritionists seek alternatives for FM. Insect nowadays has become more promising alternatives protein source due to the low success in fish meal replacement by animal or plant origin. Ogunji et al. (2008) showed some of the factors that may contribute to the variation in the results obtained, such as protein composition and amino acid profile of alternative feeds, phosphorus content and palatability of alternative feeds.

These alternatives must supply sufficient amino acids to the fish to enable their growth coupled with adequate dietary energy because an excessive or imbalance of dietary energy may restrict protein consumption and produce fatty fish (NRC, 1993; Macartney, 1996). Recent research interest include identifying and utilizing alternative locally available feed resources such as insects in formulating fish diets. Unconventional protein sources such as maggot meal (Atteh and Ologbenla, 1993), termite meal

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Table 1. Proximate analysis of fish meal and super worm meal used in the trial diets.

Component %)	Fish meal (%)	Super worm meal (%)
Dry matter	89.24	92.49
Crude protein	57.53	47.43
Crude fat	4.75	40.01
Crude ash	12.75	3.54

(Fadiyimu et al., 2003) and grasshopper meal (Ojewola et al., 2005) have been used to replace FM. These studies indicate a reduction in feed cost and increased profitability, without compromising performance. Due to the known as best protein animal feeding stuff, super worm (*Zophobas morio*) meal is widely used as a feed supplement for birds and fish (Ebeling, 1975). This insect is widely found in the part of world including Canada and in the province of British (Cotton, 1963). It is also found locally available in Malaysia for its well adaptation with tropical climate (Ghaly and Alkoaik, 2009). Since insect has been identified to be an alternative to FM in the future recently, *Z. morio* based diet is the most promising project to evaluate whether it can give similar growth performances of fish as FM based diet did before. Tilapia production is rapidly increasing in Malaysia and other parts of the world (FAO, 1997). This is due to its high growth rate, resistance to parasites and other pathogens as well as their suitability in a wide range of farming systems (Shiau, 2002). This species is omnivorous because it can consume on variety of feed materials including both plant and animal sources and increase in demand (Popma and Masser, 1999).

The aim of this study was to evaluate the growth performance and feed utilization efficiency in juvenile of the Nile tilapia (*Oreochromis niloticus*) when FM was replaced with SWM.

MATERIALS AND METHODS

Experimental set-up

This study was carried out at the Freshwater Aquarium Laboratory of the Institute of Biological Sciences. 15 aquaria units (45 x 30 x 25 cm, 33.75 L each) were fitted with oxygen inlets for aeration. The aquarium was cleaned, disinfected and then filled with dechlorinated water. The water from the aquarium was changed periodically at a frequency of three days. For each aquarium, water was changed once, while the quarter portion of the water was left before new water was installed. Each aquarium contained a bottom filter (Code No. 139, Guppy Plastic) system with aeration by air pump (EK-8000, Eiko President).

Super worm meal preparation

Super worm meal (SWM) was prepared at the workshop of the Freshwater Fisheries Research Glami Lemi, Titi, Malaysia. Fresh super worms (*Z. morio*) were obtained from a local aquarium shop. They were freezed for 1 h, packed in plastic bags, sealed and then, placed on oven tray before oven-dried at 70°C overnight to remove moisture. The dried super worm were milled and stored at 8°C for further use. The results are shown in Table 1.

Experimental diets

Five isonitrogenous (32% crude protein) and isocaloric (range of 470 kcal/g) diets were formulated using WinFeed version 2.8 Software (Least Cost Feed Formulation). SWM was used to replace FM at various inclusion levels; 0% (control), 25, 50, 75 and 100%, as shown in Table 2. All ingredients were ground in a hammer mill (Disk Mill, FFC-454) thoroughly mixed to ensure the homogeneity of the ingredients. 10% water was added to the mixed ingredients. The resulting mixture was pelleted wet, using the mini pelleting plant machine (KCM, Y132M-4) with a 2 mm mesh sieve. The pellets were dried in an oven at 70°C for 24 h. They were packed in plastic bags, labeled and kept at room temperature in the laboratory until used for feeding.

Rearing conditions of fish

Juvenile Nile tilapias were obtained from the Freshwater Hatchery Center, Bukit Tinggi, Pahang, Malaysia. Prior to the experiment, all fish were acclimated to the laboratory condition for one week in a 250 L fiber tank and fed with a commercial diet (Takara Sakana-II) twice daily. The feeding trial was conducted over 56 days. 15 aquarium tanks contained ten juveniles each with an average weight of 5.57 ± 0.15 g. The aquaria were monitored daily and any mortality was recorded.

The feeding rate consisted of 10% of the biomass and the ratio was adjusted biweekly after the fry were weighed on an electronic top pan balance (AND EW-I Series). Feeding was carried out twice daily throughout the experimental period.

At the start of the experiment, 10 juvenile fish were sacrificed and kept frozen. At the end of the experimental period, fish were randomly removed from the aquaria, sacrificed and frozen for carcass composition analysis.

Analysis of experimental data

From the experimental data obtained, growth was expressed as weight gain (WG), specific growth rate (SGR), and survival rate. Nutrient utilization indices were expressed as feed conversion ratio (FCR), and protein efficiency ratio (PER) as follows:

WG = W2 – W1, where W2 = mean final weight, W1 = mean initial weight.

FCR = Feed offered / live weight gain.

SGR = (ln W2 – ln W1 /T) x 100; where W2 = final weight of fish, W1 = initial weight of fish, T = experimental period (day).

PER = Live weight gain (g) / protein fed (g).

Survival (%) = F2 / F1 x 100; F1 = number of fish at the beginning of experiment, and F2 = number of fish at the end of the experiment. All calculations were based on the triplicate tank treatment.

Monitoring of water quality

Parameters of water quality were measured using the method mentioned by APHA (1992). Ammonia and nitrate was determined bi weekly using Spectroquant Pharo 300 (Merck, USA). Water temperature and pH were recorded daily using pH meter. Dissolved

Table 2. Formulation and chemical composition of the experimental diets (%).

Ingredients of SWM inclusion level	Diet 1 (0%)	Diet 2 (25%)	Diet 3 (50%)	Diet 4 (75%)	Diet 5 (100%)
Fish meal	30	22.5	15	7.5	0
Soybean meal	22.06	24.35	26.65	28.94	31.23
Rice Bran	31.44	29.15	26.85	24.56	22.27
SWM	0	7.5	15	22.5	30
Corn starch	15	15	15	15	15
Vitamin premix	0.2	0.2	0.2	0.2	0.2
Mineral premix	0.3	0.3	0.3	0.3	0.3
DCP	1	1	1	1	1
Total	100	100	100	100	100
Cost of feed (RM/kg)	2.59	3.83	5.15	6.43	7.71
Nutrient levels determined by analysis (as basis)					
Dry matter (%)	92.27	92.29	93.12	92.62	92.16
Crude protein (%)	34.18	31.31	32.62	31.88	30.85
Crude fat (%)	7.05	7.41	11.21	13.05	15.93
Crude ash (%)	12.81	11.27	9.51	8.06	6.45
Crude fiber (%)	2.95	2.82	4.24	4.21	4.18
NFE[1]	43.01	47.19	42.42	42.80	42.59
Gross energy[2] (kcal/g)	436.08	440.41	464.16	478.92	473.11
P/E ratio (mg protein Kj^{-1})	19.83	17.90	17.68	16.69	15.44

[1] NFE = 100 – (% protein + % fat + % ash + % fiber), [2] Gross energy (GE) was calculated as 5.65, 9.45, 4.1 kcal/g for protein, fat and NFE respectively (NRC, 1993).

oxygen was recorded daily using DO meter (YSI Model 58, Yellow Springs, OH). Water quality parameters including dissolved oxygen, pH, nitrate and ammonia were monitored biweekly (Table 6).

Chemical analysis

All proximate analysis composition and chemical composition of fish fillet and diets were analyzed in the Fish Nutrition Laboratory of Freshwater Fisheries Research Glami Lemi, Jelebu, Negeri Sembilan, Malaysia based on the procedure of AOAC protocols (1995). The analysis consisted of dry matter; drying in an oven (Carbolite) at 105°C for 24 h, crude protein was determined (as g N x 6.25) by the Kjeldahl method (FOSS Tecator Digestor Auto), fat by the Soxhlet method (FOSS Soxtec 2055), ash by combustion at 550°C in a muffle furnace (Naberthem) for 24 h, crude fiber after an alkali and acid digestion and nitrogen-free extract (NFE) by the difference [NFE = 100 – (% protein + % fat + % ash + % fiber)] according to AOAC (1995). Gross energy was calculated using the following factors: crude protein = 5.65 kcal/g, crude lipid = 9.45 kcal/g and NFE = 4.1 kcal/g (NRC, 1993). Amino acid profiles were conducted using the HPLC (Jasco, CO-2065 Plus, Intelligent Column Oven) using column (Purospher STAR RP-18 encapped, 5 µm). The amino acids were determined by comparing peak retention times to a known standard. Protein to energy ration were calculated over each diet and expressed in unit of mg protein Kj^{-1}.

Statistical analysis

Data analysis was performed by one-way analysis of variance (ANOVA) using SPSS version 12.0. Differences among the means were compared using Duncan's post hoc test at 5% probability level.

RESULTS

As reported in Table 1, crude protein, crude lipid and ash of FM and SWM were obtained as followed: 57.53, 4.75 and 12.75%; 47.43, 40.01 and 3.54%, respectively. Table 3 show the essential amino acid (EAA) content in all the experimental diets. Table 2 shows the inclusion level of ingredients and proximate analysis of the experimental diets. The growth response and performance data of Nile tilapia fed diets containing various inclusion of SWM are shown in Table 4. The study shows that there was no significant difference ($P > 0.05$) in the initial weight of the fish fed with diet 1 until diet 3. The mean final weight, WG and SGR of fish fed with the diets containing 25 and 50% SWM were significantly higher ($P < 0.05$) than those fed with 0, 75 and 100% SWM based diets. Growth response was higher in groups fed with diets 2 and 3 compared to all the other diets in terms of final weight, weight gain and specific growth rate. The growth performance worsened in fish fed with diets containing even much lower SWM level (75%) and continued to worsen as the level of SWM increased. The highest weight gain and SGR were clearly recorded in tilapia fed diet 2, followed by diet 3 which did not significantly differ ($P > 0.05$). Diets 2 and 3 gave the

Table 3. Essential amino acid composition of diets used in this study (mg/g crude protein).

Amino acid	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Histidine	5.23 ± 0.45^{a}	5.52 ± 0.13^{a}	6.80 ± 0.19^{b}	7.16 ± 0.01^{b}	8.22 ± 0.68^{c}
Arginine	22.96 ± 0.01^{c}	21.48 ± 0.41^{b}	21.29 ± 0.15^{b}	19.66 ± 0.12^{a}	19.08 ± 0.11^{a}
Threonine	23.15 ± 0.11^{e}	13.14 ± 0.08^{a}	14.76 ± 0.11^{d}	13.60 ± 0.05^{b}	14.12 ± 0.15^{c}
Valine	13.19 ± 0.14^{a}	15.86 ± 0.05^{b}	17.17 ± 0.05^{d}	16.16 ± 0.05^{c}	16.23 ± 0.06^{c}
Methionine	26.29 ± 2.79^{b}	3.75 ± 0.01^{a}	3.63 ± 0.04^{a}	3.08 ± 0.07^{a}	3.52 ± 0.06^{a}
Isoleucine	14.32 ± 0.06^{e}	13.12 ± 0.04^{b}	13.90 ± 0.02^{d}	13.38 ± 0.04^{c}	12.83 ± 0.07^{a}
Leucine	24.43 ± 0.25^{d}	22.49 ± 0.01^{b}	23.66 ± 0.13^{c}	22.62 ± 0.03^{b}	19.37 ± 0.01^{a}
Phenylalanine	16.49 ± 0.35^{a}	15.79 ± 0.25^{a}	15.92 ± 0.02^{a}	15.74 ± 0.25^{a}	15.94 ± 0.02^{a}
Lysine	13.74 ± 0.12^{b}	13.25 ± 0.03^{a}	15.83 ± 0.02^{c}	15.65 ± 0.06^{c}	18.82 ± 0.02^{d}

* All values are means ± SE for triplicate feeding groups and values in the same row with different superscripts are significantly different ($P < 0.05$). Essential amino acid requirements of Nile tilapia (%) according to NRC (1993) are: tryptophan 1.00, lysine 5.12, histidine 1.72, arginine 4.20, threonine 3.75, valine 2.80, methionine 2.68, isoleucine 3.11, leucine 3.39, phenylalanine + tyrosine 3.75.

Table 4. Growth performance of *O.niloticus* fingerlings fed with the experimental diets*.

Parameter	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Initial weight, g	5.57 ± 0.15^{a}	5.71 ± 0.24^{a}	5.81 ± 0.04^{a}	5.53 ± 0.27^{a}	5.59 ± 0.11^{a}
Final weight, g	9.18 ± 0.42^{ab}	10.11 ± 0.26^{c}	10.24 ± 0.15^{c}	9.17 ± 0.43^{ab}	8.49 ± 0.18^{a}
Weight gain, g	3.61 ± 0.27^{ab}	4.39 ± 0.11^{b}	4.43 ± 0.15^{b}	3.64 ± 0.41^{ab}	2.87 ± 0.26^{a}
SGR[1]	0.88 ± 0.04^{ab}	1.02 ± 0.41^{b}	1.01 ± 0.29^{b}	0.90 ± 0.08^{ab}	0.75 ± 0.06^{a}
FCR[2]	1.47 ± 0.05^{bc}	1.25 ± 0.02^{a}	1.36 ± 0.03^{b}	1.42 ± 0.02^{bc}	1.50 ± 0.03^{c}
PER[3]	1.34 ± 0.12^{a}	1.97 ± 0.15^{b}	1.92 ± 0.12^{b}	1.39 ± 0.15^{a}	1.10 ± 0.04^{a}
Survival, %	100.00 ± 0.0^{a}	100.00 ± 0.0^{a}	100.00 ± 0.0^{a}	100.00 ± 0.0^{a}	100.00 ± 0.0^{a}

* All values are means ± SE for triplicate feeding groups and values in the same row with different superscripts are significantly different ($P < 0.05$). [1]SGR = (ln W2 – ln W1 /T) x 100; [2] FCR = food fed / live weight gain; [3] PER = live weight gain (g) / protein fed (g).

Table 5. Initial and final composition of tilapia fingerlings fed on the experimental diets (%)*.

Component	Initial	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Dry matter	21.10	22.81±0.41	22.91±1.50	21.30±1.46	23.11±0.56	22.14±0.64
Protein	54.08	66.52±0.00	73.40±1.16	73.11±0.05	69.71±0.97	69.18±0.59
Fat	3.85	14.02±0.09	8.81±0.22	9.94±0.17	12.29±0.12	13.86±0.12
Ash	17.46	14.94±3.19	14.47±2.15	13.06±0.95	14.38±0.24	13.69±1.91

* All the values are means ±SE for triplicate feeding groups.

highest weight gain and were better utilized by the fish as it gave the following biological parameter: SGR of 1.02 and 1.01% day^{-1}; FCR of 1.25 and 1.36; PER, of 1.97 and 1.92, respectively.

Table 3 clearly indicates that the growth performance and feed utilization of Nile tilapia was affected by the different experimental diets ($P < 0.05$). Final weight, weight gain and SGR values of fish fed with diets 2 and 3 which had 25 and 50% replacement of FM, were higher compared to those fed with other diets. The highest growth performance was obtained from the group fed with diet 2 which indicate that 25% inclusion of SWM can be considered as the most optimal level of inclusion in the diet of *O. niloticus.* Reduced weight gain was observed when SWM content in the diet was higher than 50%, suggesting that high SWM level led to growth reduction.

PER of fish fed with diets 2 and 3 were significantly higher ($P < 0.05$) than those juvenile tilapia fed with other diets. The highest protein efficiency ratio was recorded by diet 2 (25% SWM) with 1.97 while the lowest value of 1.10 was recorded in 100% SWM based diet (Table 4). Survival rate of Nile tilapia fingerlings fed all the treatments was satisfactory with no significant difference among them ($P > 0.05$).

Initial and final body composition of the fish is presented in Table 5. There were no significant differences in body composition among the treatment ($P > 0.05$). In general, body composition of tilapia fed with varying

Table 6. Water quality parameter during experimental period.

Parameter	Diet 1	Diet 2	Diet 3	Diet 4	Diet 5
Dissolved oxygen (mg/l)	5.86±0.19[a]	5.59±0.24[a]	5.33±0.19[a]	5.45±0.19[a]	5.43±0.36[a]
pH	7.26±0.31[a]	7.25±0.24	7.39±0.26	7.36±0.26	7.35±0.27[a]
Temperature (ºC)	25.87±0.58[a]	25.85±0.56[a]	25.63±0.39[a]	25.50±0.28[a]	25.57±0.22[a]
Ammonia (mg/l)	0.52±0.40[a]	0.37±0.27[a]	0.48±0.37[a]	0.52±0.32[a]	0.79±0.44[a]
Nitrate (mg/l)	0.71±0.12[a]	0.73±0.15[a]	1.24±0.51[a]	1.84±0.51[a]	1.13±0.31[a]

* All values are means ± SE for triplicate feeding groups and values in the same row with different superscripts are significantly different (P < 0.05).

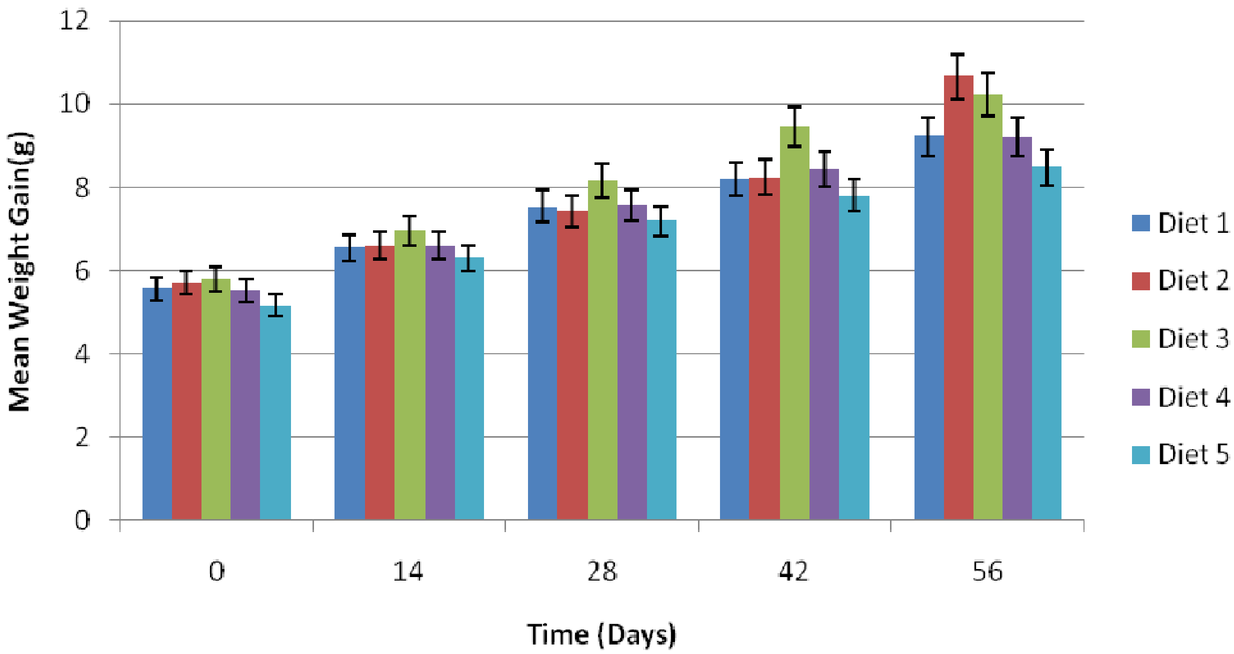

Figure 1. Growth of juvenile tilapia *O. niloticus* fed the experimental diets over a 56-day trial: Diet 1, 0% super worm meal inclusion level based diet; Diet 2, 25% super worm meal inclusion level based diet; Diet 3, 50% super worm meal inclusion level based diet; Diet 4, 75% super worm meal inclusion level based diet; Diet 5, 100% super worm meal inclusion level based diet.

experimental diets resulted in higher protein, lipid and moisture compared with its initial composition. However, crude ash content in the final body composition of experimental fish increased with the increase in dietary SWM. The fish fed diets 2 and 3 showed higher protein but lower lipid content in comparison with those fed with other diets. Partial replacement of SWM in diets did not reduce fish composition of dry matter, protein or fat contents compared to the control treatment. Ash content irregularly fluctuated in fish among treatments at the end of the experiment.

During the experimental period, water temperature ranged from 25.50 to 25.87°C, dissolved oxygen from 5.33 to 5.86 mg/l, pH from 7.25 to 7.36, total ammonia from 0.37 to 0.79 mg/l and total nitrate concentration from 0.71 to 1.84 mg/l (Table 6). There was no significant different in all treatments (P > 0.05) during the whole experimental period indicating that the experimental diets did not affect water quality of the experimental fish.

DISCUSSION

The results of this study clearly indicate that the growth performance and feed utilization of Nile tilapia was affected by different experimental diets. Final weight, weight gain and SGR values of fish fed with diets 2 and 3 with 25 and 50% replacement of fish meal protein improved growth performance when compared with those fish fed the other diets. Highest growth performance was obtained from the group fed with diet 2 which indicate that 25% inclusion of SWM can be considered as the most optimal level of inclusion in the diet of *O. niloticus*. The reduced weight gain as observed when SWM content in the diet was higher than 50%, suggests that high SWM level led to growth reduction. This indicated that 25% inclusion of SWM in this study seems to be favorable in the diet of *O. niloticus*. SWM is similar to meal worm but are slightly different in their nutrient content and size. The nutritive value of insects as feeds for fish, poultry and pigs has been recognized for some time in China where studies have demonstrated that insect-based diets are cheaper alternatives to those based on fish meal.

Numerous studies on use of insects as alternative to fish meal have been described. Adesulu and Mustapha (2000) reported the use of housefly maggot meal as a substitute for fish meal in tilapia and African catfish diets. Bondari and Sheppard (1987) observed that channel catfish and blue tilapia fed on soldier fly larvae for 10 weeks were acceptable as food by consumers. Growth and organoleptic quality were not affected when common carp were fed on nondefatted silkworm pupae, a major byproduct of the sericulture industry in India (Nandeshaa et al., 2000). Ng et al. (2001) demonstrated that *T. molitor* larvae meal was highly palatable to the African catfish (*Clarias gariepinus*) and could replace up to 40% of the fish meal component without reducing growth performance. The fish also seem to show the varying growth performance individually in the replicate tanks.

The growth of fish also is highly variable in especially in size, being greatly dependent upon a variety of interacting environmental factors such water temperature and other factors such as degree of competition, the amount and the quality of feed ingested, the age and the maturity of the fish (Moyle and Cech, 2000). This problem of poor growth and variable in size can be explained by riboflavin deficiency (Murai and Andrews, 1978). This also may be due to limiting amino acid content (Nengas et al., 1999; NRC, 1993). This assumption denies the high level fat content that resulted in reduced growth performance of fingerlings.

Although, SWM is poor in mineral composition such as calcium and phosphorus, they have the essential amino acids that were required for optimum fish growth (Ghaly and Alkoaik, 2009). Based on the study by Ghaly and Alkoaik (2009) who focused on meal worm, it was reported that it has been used for human consumption in their dietary nutrition due to the higher protein content and shorter production time before harvesting; were the crucial factor considered as a FM replacement as the supply of FM are uncertain and fluctuating in production (Hardy and Tacon, 2002).

In this study, the growth of fish fed with diets 2 and 3 improved compared with the other diets offered. This indicates that they were able to meet the nutrient requirements of tilapia (Ogunji et al., 2008). When the feeding trial began, fish may not have consumed diets 4 and 5 as rapidly and readily as other diets, thus did not increase the weight as instantly as fish fed with diets 1, 2 and 3. This also may be due to limiting amino acid contents (Nengas et al., 1999) found in the diets. The supplementation of methionine to soy bean meal based diet has been reported to improve the growth of tilapia performances (Polat, 1999). The best FCR will be suitable for the growth gain as the fish could convert each gram of feed consumed to be deposited in body protein of the carcass.

In this study, the FCR ranged from 1.25 to 1.50 and it was within the acceptable range recommended by De Silva and Anderson (1995). The poor conversion ratio reported in diets 4 and 5 may be attributed to the feeding management, culture system, experimental condition, improper balance of amino acids, high carbohydrates and reduction in pellet quality (Ovie, 2007). FCR and PER in terms of feed utilization efficiency were influenced by dietary treatments.

In general, SGR, FCR and PER were negatively influenced with increasing SWM level in the feed. Higher SGR and better FCR were obtained by diet 2. This result was in accordance with the study managed by Gumus (2009). SGR, FCR and PER of Nile tilapia were improved slightly when they were fed the diet containing 25 and 50% SWM inclusion in the experimental diets while as the SWM replacement level increased up to 75%, SGR, FCR and PER decreased. PER and FCR also were generally related to digestibility of nutrients. The higher survival rate recorded indicates that feeding *O. niloticus* juvenile with SWM based diets could enhance the survival of fish. In fact, Holm and Torrisen (1987) reported that living organisms incorporated into animal feed such as zooplankton do enhance the survival and healthy state of fish at early stage. The insect also was classified as living organism in this study.

Partial replacement of FM with SWM affected the whole body composition in terms of protein, fat and moisture in comparison with the initial fish. Fish fed with all experimental diets had higher percentages of protein, lipid and dry matter contents whereas ash was lower in the initial fish. These suggested that Nile tilapia efficiently ingested, digested and assimilated SWM protein as an alternative feedstuff. Body composition of Nile tilapia fry fed with diets containing various levels of SWM did not significantly differ in this study. These findings are in agreement with the values reported by Hassan et al. (1993). Report from Weatherup and McCracken (1999) also supports the result that found the final lipid levels higher and ash lower than the initial composition. In the study, the lipid content was slightly higher and ash was lower in fish fed with diet 4. The findings also are also in agreement with Ogunji and Wirth (2000) who reported that decreased growth and body protein retention were observed in *O. niloticus* fingerlings fed with diets containing extremely low crude protein content of 0.18% dry matter and P/E ration of 0.42. The dietary P/E ratio recommended as optimal growth for tilapia has been established between 16.26 mg kJ^{-1} and 19.43 mg Kj^{-1} (Mazid et al., 1979; De Silva et al., 1989). This study shows the P/E ratio between this range. To avoid fatty fish due to excess energy or excess discharge of ammonia excretion in water, P/E ratio seem to be a practical index in fish feed formulation (Du et al., 2009).

The study indicate that 25 and 50% SMW can be included within a 32% crude protein diet in *O. niloticus* fingerlings and are suitable for growth and feed utilization. However, for higher substitution levels of FM, growth and feed utilization were adversely affected. This situation is attributed to either EAA deficiency or low feed intake. Further study should be done on the super worm as it holds great potential to resolve the constraint of the aqua feed industry especially on diminishing FM availability worldwide by producing it through mass production under controlled condition. Also, if the price of SWM is reduced to be competitive with other alternative protein sources, SWM appeared to be a suitable ingredient to be used in practical diet for tilapia.

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